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Food, nature & wellness: Dueling epistemologies

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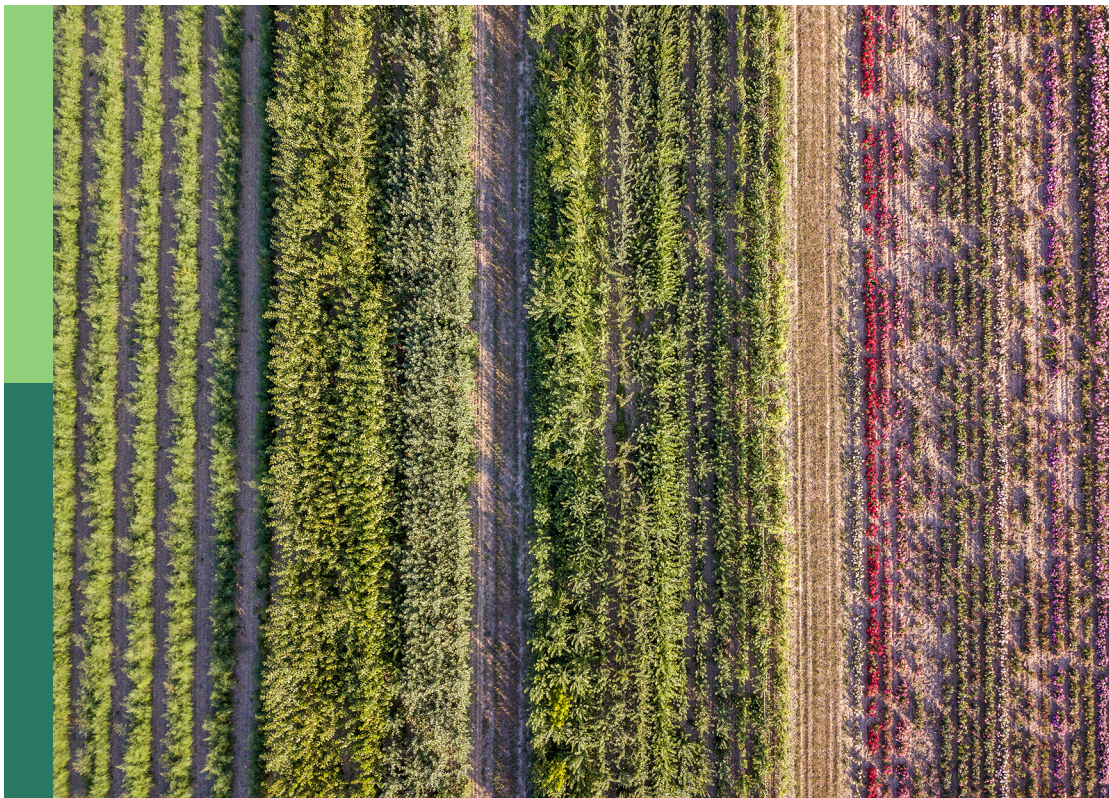

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Food, nature & wellness: Dueling epistemologies

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Editorial: Food, nature & wellness: dueling epistemologies

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Editorial on the Research Topic
Food, nature & wellness: dueling epistemologies

Introduction

Who is responsible for the health of the food system? In today's globally interconnected world, the wellbeing of land, labor, water, and air are generally invisible to most consumers. Industrialized food systems negatively impact natural resources and human health, causing diet-related diseases, foodborne diseases, and long-term, cumulative effects of pesticide residues.

Producing and distributing food that sustains ecosystem fertility and nourishes consumer health requires attention to a breadth of issues, covering many disciplines and communities of practice. While interdisciplinary research in this area is increasing, addressing the full complexity of food system wellbeing requires prioritizing vital and robust life at every stage, and stressing the interconnectedness between the health of humans and that of the planet.

In this Research Topic, we bring together articles addressing different dimensions of food, nature, and wellness, including knowledge frameworks (de Garine-Wichatitsky et al.; Timotijevic et al.; Spring et al.; Ramenzoni), limits of current methodologies in assessing these domains (Hemsworth et al.; Saxena et al.), policy approaches to strengthening human and ecosystem wellness in the food system (Canfield et al.; Valencia et al.; Roothaert et al.; Queenan et al.), and the importance of connection with the natural world for human mental health (Lengieza and Swim; Thiermann et al.; Venkatasubramanian). Together these articles emphasize the importance of mindfulness and interdisciplinary research to advance science and knowledge at the food systems-ecology-human wellbeing nexus.

Mindfulness practices for wellness and sustainability

Connectedness with nature (CWN) is an important construct for appreciating the intricate and complex interdependence of people and the planet. CWN is fundamental to discussions on Climate Change/ Planetary Health/ Sustainable Development Goals. Three articles in this Research Topic discuss practices that promote mindfulness and pro-environmental activities (Lengieza and Swim; Thiermann et al.; Venkatasubramanian).

Lengieza and Swim review indicates that self-awareness and mindfulness are associated with CWN, which is influenced by age, openness to experience, worldviews toward nature, and self-transcendence. Through a study of 300 individuals, Thiermann et al. have shown that advanced meditators reported significantly more pro-environmental activities and the lowest greenhouse gas emissions related to their non-animal protein diet when compared to non-meditators. The authors suggest that CWN is an innate human quality that is affected by modern-day pressures (Thiermann et al.). Venkatasubramanian delineates a novel pedagogical approach in a University Wellness Program (UWP) that nudges students' behavior toward wellness and campus sustainability. Experiential learning of academic modules and evaluation systems are leveraged for students to design and implement projects that are relevant to campus. These authors suggest CWN is an innate human quality that strengthens individual interest and attention to ecosystem and food system health.

Potential role of different knowledge frameworks

Four articles address frameworks for thinking about how and what we know, including conceptualizing responsibility in the food system (Timotijevic et al.), integrating human and ecosystem considerations in addressing socio-ecological system health and resilience (de Garine-Wichatitsky et al.), listening more deeply to cultural reasons for food avoidance to better inform nutritional interventions (Ramenzoni), and using the insights from different ways of knowing to strengthen community food security (Spring et al.). Timotijevic et al. utilize in-depth interviews with individuals working in research, civil society, policy, and industry on cutting-edge approaches in the food system that may impact health and identify four overlapping conceptualizations of responsibility: accountability, impact, reflexivity, and responsiveness. de Garine-Wichatitsky et al. develope a participatory five-step approach to framing and taking action to strengthen socio-ecological system resilience that includes human health, animal health, plant health, and environmental health, and then pilot the framework and approach with an agro-ecological systems project in Vietnam (de Garine-Wichatitsky et al.). Ramenzoni utilizes a mixed-methods approach to study food avoidances among the Coastal Endenese ethnic group, observing that certain types of foods are avoided out of concern for upsetting cosmological relationships, and urging a more community-based and collaborative approach to nutrition interventions. In Spring et al. community-partnered research on food security in the Tsá Tué Biosphere Reserve (Northwest Territories, Canada), the authors examine the interaction between traditional food systems and climate change using a community capitals framework, underscoring the potential of traditional foodways to buffer risks. Taken together these articles highlight the value of conceptual frameworks for addressing complex issues with greater cultural awareness and sensitivity and emphasize the need to include non-Western frameworks.

Methodologies for assessing components of the agricultural system

Two articles highlight methodological challenges in studying food, nature, and wellness, whether in assessing population-level perspectives on animal welfare (Hemsworth et al.) or in exploring the role of traditional foods in food security and nutritional status (Saxena et al.). Hemsworth et al. explore current methodologies for generating representative perspectives of populations by comparing perspectives on animal welfare from a computer-assisted telephone interview of >500 respondents and a probability internet panel of >500 respondents, identifying important differences in respondent attitudes and experiences across the two methods. Saxena et al. explore methodological approaches for assessing connections between agrobiodiversity and food security, demonstrating that standard dietary intake methodologies may underestimate the impacts and importance of traditional foods. Both studies draw attention to the importance of careful conceptualization of conclusions to ensure they are fully supported by the data and the need for innovative methods and analytical approaches to better capture complex systems.

Importance of policy in enhancing food system sustainability

Another key theme in these articles is the importance of public policy (and public funding) for food system sustainability. Based on data from Brazil, Valencia et al. argue that integrating sustainability into public food procurement systems can help to support other sustainable development goals, including poverty reduction, zero hunger, and gender equity. Examining the potential for the uptake of a model similar to Brazil's, Roothaert et al. explore the feasibility of expanding Home-Grown School Feeding programs in Tanzania and conclude such expansion might address some systemic issues, but will not fully substitute for a larger policy framework and resource investment in school meals. Systemic challenges are also the subject of Queenan et al. research, which identifies issues such as an unlevel playing field for importers and local producers, and a small number of large-scale producers with a large market share, that inhibit the potential of the commercial broiler system in South Africa to contribute to the sustainable development goals. Turning to the international scene, Canfield et al. document how the organization of the 2021 UN Food Systems Summit sidestepped existing forums for accountable multilateral food system governance, demonstrating the corporate capture of the international public system's governance of agriculture. Each of these articles highlights the potential of particular policies to enhance wellness.

Conclusions: avoiding pitfalls in new ways forward

Both frameworks and methodologies offer the potential of clear research approaches that are consistent across research studies allowing for better comparison of results. They can

also be applied to different contexts and disciplines which may highlight strengths and weaknesses. However, adopting specific knowledge frameworks /methodologies could lead to an overemphasis on the frameworks/methodologies rather than on empirical observations. This can lead researchers to disregard findings that do not fit their pre-determined categories of analysis. Recommendations include being explicit about frameworks and methods, with clear definitions of constructs, moving beyond past biases by incorporating and adapting multiple frameworks and multidisciplinary methods wherever possible, and using mixed methods and participatory approaches with due consideration of local knowledge, that are better able to honor and characterize complex local systems. Key limitations include the absence of mechanisms to encourage the adoption of specific frameworks and the emphasis on innovation in academic institutions that rewards individual researchers for developing their own frameworks, rather than using and testing the frameworks of others.

The articles on policy and practices illuminate both the opportunities and limitations. There are opportunities for increased use of intersectoral and intersectional policy frameworks and processes. Mindfulness and CWN may provide ways to get beyond business as usual, as a tool for transformative individual, research, and systems change. In addition, similar to the challenges with frameworks and methodologies, there are only limited levers to encourage and reward multidimensional approaches. Taken together, these articles break ground toward reconceptualizing food system health, and locating responsibility for food system outcomes—but they also highlight that much remains to be done to achieve holistic food system health for people and planet. To promote such multidimensional approaches will require flexibility and re-invention not only of research questions and methods, but also of the institutions and funding structures that bring such research into being.

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Practice Matters: Pro-environmental Motivations and Diet-Related Impact Vary With Meditation Experience

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Mindfulness has emerged as a potential motivator for sustainable lifestyles, yet few studies provide insight into the relationship between mindfulness practice levels and individual engagement in pro-environmental behaviors. We also lack information about the significance of meditators' behavioral differences in terms of their measurable environmental impact and the motivational processes underlying these differences in pro-environmental performance. We classified 300 individuals in three groups with varying meditation experience and compared their pro-environmental motivations and levels of animal protein consumption. Exceeding prior attempts to compare high-impact behaviors of mindfulness practitioners and non-practitioners, we created the most detailed classification of practice engagement by assessing frequency, experience and type of meditation practice. This nuanced view on mindfulness practice reveals that advanced meditators, who reported high levels of connectedness with nature (CWN), subjective happiness and dispositional mindfulness showed significantly more concern for the environment. They also demonstrated the lowest levels of greenhouse gas emissions, land occupation and water use related to their animal-protein consumption. This study is the first to follow a self-determination theory perspective to deepen our understanding of the motivational differences between meditator groups. We revealed that advanced meditators reported significantly more integrated motivation toward the environment than non-meditators. We also provided preliminary evidence for a new theoretical framework suggesting that experiential strategies such as mindfulness practices could strengthen the relational pathway of pro-environmental behaviors. Using sequential mediation analysis, we confirmed that the negative effect of mindful compassion practice on greenhouse gas emissions from animal-protein consumption is partially mediated by CWN and integrated motivation toward the environment. While our study does not support assumptions of causality, it shows that much can be learned by studying the motivations of advanced meditators for maintaining high levels of pro-environmental behavior.

Keywords: mindfulness, compassion, connectedness with nature, sustainability, pro-environmental behavior, animal-protein consumption, motivation, self-determination theory

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INTRODUCTION

The environmental crisis is accelerating, with climate change being one of the main drivers for environmental change and biodiversity loss. This creates negative impacts on ecosystem services and human well-being (Costello et al., 2009; IPCC, 2014; Díaz et al., 2019). Paradoxically, even though climate change has become increasingly tangible to the lay person, public opinions on climate change have changed little over the last decade (Egan and Mullin, 2017; Steentjes et al., 2017). The lack of individuals' recognition of the gravity of the crisis stands in stark contrast with the need for individual level contributions to environmental conservation (Creutzig et al., 2016). Oftentimes neglected in the discussion on mitigation strategies, consumption levels must be reduced by a factor of five to attain the 2-degree target of global warming (Girod et al., 2013). This implies structural behavior change in areas like transport and diets, particularly the reduction of animal-protein consumption (Hedenus et al., 2014). A sustainable food transformation is indispensable not only to reach the targets agreed in the Paris Agreement, but also the sustainable development goals (Lucas and Horton, 2019). Changing people's dietary preferences is a challenge that amounts to a socio-cultural revolution (O'Riordan and Stoll-Kleemann, 2015; Macdiarmid et al., 2016) and potential strategies to increase the willingness to adopting sustainable diets continue underexplored (Hartmann and Siegrist, 2017).

In the search for ways to promote sustainable lifestyles in Western populations, mindfulness is receiving growing attention (Ericson et al., 2014; Fischer et al., 2017). Thirty years of pioneer research showed that mindfulness is associated with environmental awareness and pro-environmental behaviors (PEB) (Thiermann and Sheate, 2020b). Some argue that "the promotion of mindfulness and loving-kindness meditation in schools, workplaces, and elsewhere could be construed as a policy that pays a 'double dividend' in that it could contribute both to more sustainable ways of life and to greater well-being" (Ericson et al., 2014, p. 78). Yet to date, causality has not been proven and there is limited information on *measurable* environmental savings related to mindfulness *practice*. With data obtained from an online survey of 300 adults in the United Kingdom, we investigated how different levels of meditation experience are related to animal-protein intake. We also tested core assumptions of the theoretical framework for this study, the two-pathway model of PEB (Thiermann and Sheate, 2020a).

Background

Research Gaps in Mindfulness and Sustainability

The role of mindfulness in sustainability is a novel line of scientific inquiry and several research gaps are yet to be addressed. Mindfulness is a universal human capacity defined as "the awareness that arises when we intentionally pay attention in a kind, open discerning way" (Shapiro et al., 2018, p. 1694). While cross-sectional studies support the association between mindfulness and sustainable behavior, the existence of a causal relationship between the two concepts is still debated and will require a considerable amount of time and financial resources for longitudinal studies (Geiger et al., 2019b; Thiermann and Sheate, 2020b). This study focuses on two other crucial research gaps highlighted in Thiermann and Sheate (2020b).

First, from the several ways of conceptualizing and measuring mindfulness, most researchers rely on dispositional (also: trait) mindfulness to study correlations. Dispositional mindfulness is an individual's capacity to bring mindful awareness to everyday life and increases over time with the practice of meditation (Kiken et al., 2015; Shapiro et al., 2018). Several researchers found a weak to moderate association between dispositional mindfulness and PEB (Geiger et al., 2019b), however, a dominant critique of this research is that only a few studies included meditation practitioners in their samples or even assessed practice parameters (Fischer et al., 2017; Thiermann and Sheate, 2020b). In order to determine if the implementation of mindfulness programs could promote sustainable lifestyles, it is imperative to understand the association between practice experience and PEB. Only a few studies have examined differences in PEB outcomes as predicted by the existence of an active mindfulness practice (Jacob et al., 2009; Panno et al., 2018; Loy and Reese, 2019). Also, it is important to clarify and distinguish between different mindfulness practices, because of their great variation in the underlying neuro-cognitive mechanisms and transformational potential. A recent empirical investigation by Matko and Sedlmeier (2019) identified a total of 309 commonly practiced meditation techniques. They clustered the most popular 20 into seven types, which differ in their degree of body orientation and how much physical movement they involve. Regarding the cognitive mechanisms of different meditation types, most meditations can be classified as belonging to three families: attentional, constructive and deconstructive meditations (Dahl et al., 2015). Most secular mindfulness-based interventions are primarily situated in the attentional family of practices that range somewhere along the continuum between developing focused attention and open monitoring skills (Vago and Silbersweig, 2012; Chiesa, 2013). Another type of practices that is gaining increasing attention in mindfulness research are meditations from the constructive family, particularly those with a relation and affect orientation such as loving-kindness and compassion meditations, also known as ethical enhancement practices (Vago and Silbersweig, 2012; Dahl et al., 2015). In a rigorous large-scale trial that studied the effect of three groups of practices in a "presence," "affect" and "perspective" module, researchers found that affect-oriented practices such as loving-kindness and compassion meditation were most effective in promoting pro-social behaviors and altruistic tendencies (Böckler et al., 2018; Singer and Engert, 2019).

The second research gap is the lack of insight in measurable environmental impact. The measurement of PEB, defined as "behavior that harms the environment as little as possible, or even benefits the environment" (Steg and Vlek, 2009, p. 309), is a challenging task (Gatersleben et al., 2002; Kormos and Gifford, 2014; Gatersleben, 2018; Lange and Dewitte, 2019). Most mindfulness studies revert to behavioral antecedents and unvalidated self-report scales to determine strength of PEB. The Mindful Climate Action program is the only program designed to evaluate behavioral effects via environmental impact

indicators such as greenhouse gas (GHG) emissions from diet, transportation and household energy (Grabow et al., 2018). However, results are limited to a pilot and feasibility study, and the effects from mindfulness practice would be difficult to extricate as the intervention combines mindfulness with environmental education modules (Barrett et al., 2016).

Can Mindfulness Promote Sustainable Diets?

Regarding individual behaviors, our diets are considered under the most impactful. Data from the Global Calculator show that if by 2050 everyone globally ate a healthy diet as recommended by the World Health, the world could save up to 15 gigatons of CO_2 equivalents provided that the newly available land becomes reforested or used to grow bioenergy crops. These savings in GHG emissions amount to approximately one third of the world's emissions in 2011 (Department of Energy and Cimate Change, 2015). This is reflected by a growing number of publications studying the relation between mindfulness and sustainable eating (Jacob et al., 2009; Fung et al., 2016; Böhme et al., 2018; Geiger et al., 2019a; Hunecke and Richter, 2019; Stanszus et al., 2019; Werner et al., 2020).

Fung et al. (2016) proposed a theoretical model where mindful eating is expected to improve the "awareness of the relationships between food and body, feelings, mind and interconnectedness between humans and the environment" (Fung et al., 2016, p. 1084), postulating that mindfulness should help maintaining both personal and planetary health. Stanszus et al. (2019) suggest a theoretical link between mindfulness and sustainable eating based on the potential of mindfulness to disrupt routines, promote physical and psychological well-being, strengthen values, pro-sociality and compassion as well as to improve the congruence between attitudes and behavior. Their research is based on an 8-weeks program combining mindfulness and environmental education (Fritzsche et al., 2018). The training proved effective in promoting mindful eating and changing antecedents of sustainable behavior, such as environmental attitudes and subjective well-being, but none of the intervention brought significant changes in sustainable eating behavior (Böhme et al., 2018; Geiger et al., 2019a; Stanszus et al., 2019).

Four correlational studies shed a more positive light on the relationship between mindfulness and sustainable eating. In a study with more than 800 mindfulness practitioners, Jacob et al. (2009) found a small but significant correlation between the frequency of mindfulness meditation and sustainable diets. Other studies showed that increased levels of dispositional mindfulness, particularly the ability to observe inner and outer experiences, correlated positively with more sustainable food consumption patterns (Hunecke and Richter, 2019; Richter and Hunecke, 2020). A study combining dispositional mindfulness and spirituality found that a supportive mindset marked by self-compassion and an earthly sense of spirituality were positively associated with increased PEB and more sustainable food choices (Werner et al., 2020).

In summary, these studies suggest that changes in sustainable eating and other PEB potentially develop with mindfulness practice over time (Mason et al., 2016; Geiger et al., 2019b). Furthermore, the relationship between mindfulness and sustainable behaviors seems to be indirect and mediated by a variety of factors such as sustainability values and beliefs, connectedness with nature (CWN), spirituality, subjective well-being, health awareness and emotional self-control (Jacob et al., 2009; Barbaro and Pickett, 2016; Aspy and Proeve, 2017; Park and Dhandra, 2017; Geiger et al., 2018, 2019b; Hunecke and Richter, 2019; Werner et al., 2020).

Theoretical Framework

Theoretical studies establish six major arguments for the relationship between mindfulness and PEB: (1) increased awareness, (2) enhanced subjective well-being, (3) higher levels of CWN, (4) improved pro-social tendencies, (5) recognition of intrinsic values, and (6) openness to new experiences (Thiermann and Sheate, 2020b). Because these theoretical connections are not linkable to any of the prominent models explaining PEB (Steg and Nordlund, 2018), we proposed a 2-pathway model of PEB (see **Figure 1**) as an attempt to expand mainstream models of PEB and include mechanisms relevant to mindfulness (Thiermann and Sheate, 2020a). The greatest innovation provided by the model is the addition of the "relational pathway" of PEB, based on CWN, empathy and compassion as the driver of behavioral intention. This model suggests that with increased activation of the relational pathway through experiential strategies such as mindfulness, the motivation to act in favor of the environment becomes more internalized and self-determined, which ultimately improves behavioral outcomes and contributes to personal well-being.

The 2-pathway model of PEB is embedded in the wider framework of the self-determination theory and aims to overcome the widespread dichotomous understanding of environmental motivation as either extrinsic or intrinsic (Ryan and Deci, 2017; Thiermann and Sheate, 2020a). Kasser (2017) argues that self-determination theory, which gained reputation as the most well-researched theory on human motivation and well-being, might be best suited to explore the connection between PEB and individual well-being. Self-determination researchers found that both well-being and high-quality motivation for behaviors arise when an individual experiences satisfaction of inherent psychological needs for autonomy, competence, and relatedness. In application of the self-determination theory to the ecological context, Pelletier et al. (1998) describe six types of motivation toward the environment along a continuum: intrinsic, integrated and identified motivation are based on higher levels of need satisfaction and are therefore seen as the more self-determined motivation types and encourage higher quality and maintenance levels of PEB. Introjected, external and amotivation are the more controlled and less self-determined motivations which tend to collapse when a behavior involves effort, because the individual does not feel their inherent needs satisfied (Pelletier et al., 1998, 2011).

The 2-pathway model of PEB supports the assumption that experiential interventions such as mindfulness practice help to internalize environmental motivation because they help to intensify an individual's relationship with nature and promote their needs for autonomy and competence. This might

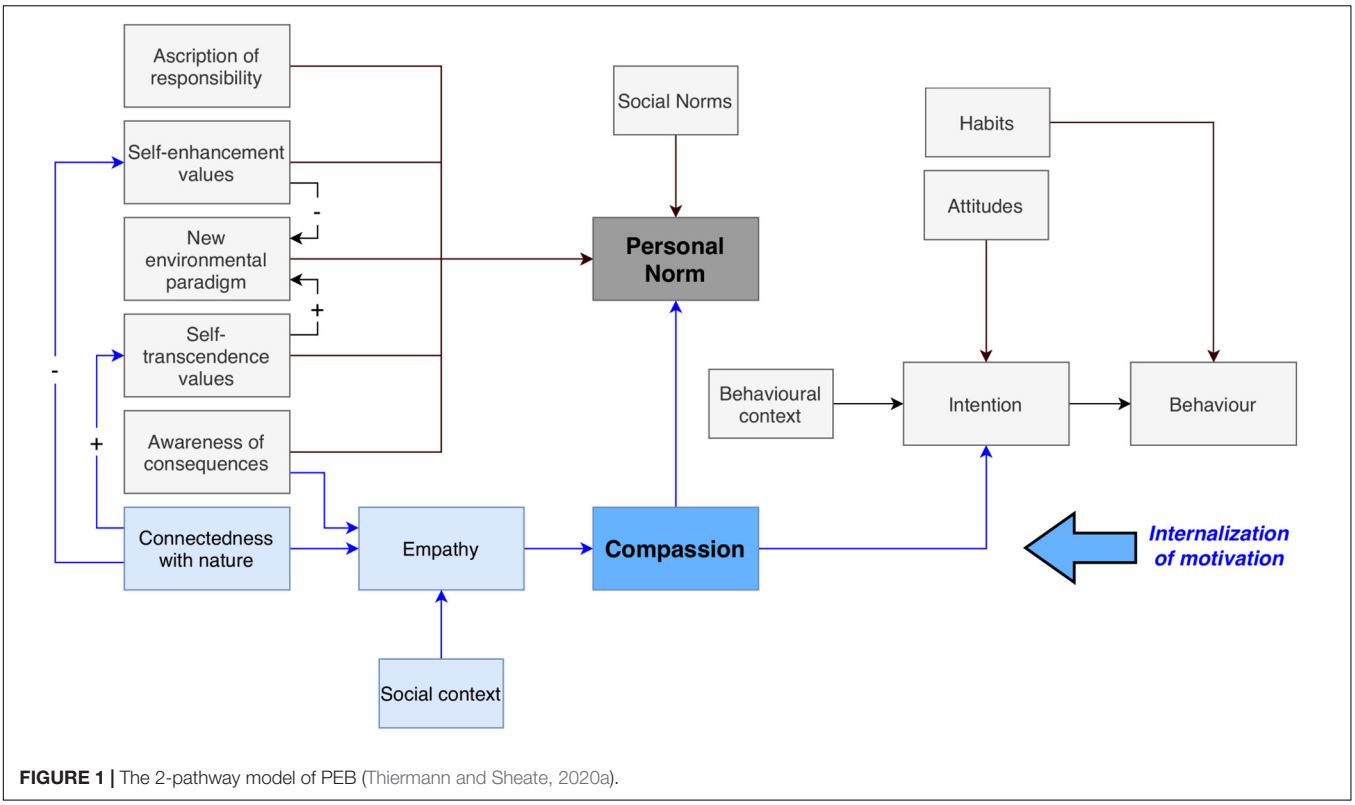

FIGURE 1 | The 2-pathway model of PEB (Thiermann and Sheate, 2020a).

be particularly valid for meditators who formally cultivate compassion as part of their mindfulness practice (Thiermann and Sheate, 2020a). This shift toward more self-determined types of environmental motivation might further contribute to closing the attitude-behavior gap which hinders individuals from expressing their environmental ideals in action (Steg et al., 2015; Fischer et al., 2017; Kasser, 2017).

Study Aim and Hypotheses

The aim of this study was twofold. First, we sought to address gaps in the mindfulness and sustainability literature by examining whether mindfulness practice (rather than dispositional mindfulness) relates to common predictors and measurable indicators of PEB, specifically the environmental impact generated by animal-protein consumption. The second goal was to provide preliminary evidence that mindfulness contributes to a shift in motivation toward the environment by activating the relational pathway of PEB. We focused on comparing the attitudes and behaviors of three groups with varying degrees of meditation experience. More specifically, we outline the following hypotheses:

H1: Dispositional mindfulness, subjective happiness and CWN progressively increase with the degree of meditation experience.

H2: Mindfulness practice is associated with a shift in the quality of motivation toward the environment which becomes more integrated and less amotivated.

H3: The level of self-reported environmental behaviors differs between practitioner groups, with advanced meditators showing the lowest environmental impact.

H4: CWN and integrated motivation toward the environment mediate the relationship between mindfulness practice and PEB.

MATERIALS AND METHODS

Questionnaire Development

The survey was composed of psychometric scales, closed and open-ended questions. We used existing Likert-type scales with established psychometric properties to measure mindfulness, subjective happiness, motivation toward the environment and CWN. Additional items queried the presence and frequency of different forms of mindfulness practice and respondents' dietary habits. We also obtained demographic details and invited general comments.

Psychometric Scales

Mindfulness was measured with the Comprehensive Inventory of Mindfulness Experiences (CHIME), currently the most comprehensive scale assessing mindfulness as a quasi-trait (Bergomi et al., 2013, p. 21). The authors recently revised the 37-item scale and provided an ordinal-to-interval conversion table, improving its validity and making it suitable for samples containing meditators and non-meditators (Medvedev et al., 2018).

We used the 4-item Subjective Happiness Scale (SHS) to assess self-reported wellbeing. The SHS does not specify the characteristics of happiness, thereby not forcing respondents to conform to either an eudaimonic or hedonic concept. The SHS has high internal consistency and excellent reliability (Lyubomirsky and Lepper, 1999; Lyubomirsky, 2020).

To capture motivations for PEB we used the Motivation Toward the Environment Scale (MTES; Pelletier et al., 1998). To distinguish an individual's level of self-determination in PEB, the 24-item questionnaire rates the strength of their intrinsic, integrated, identified, introjected, external and amotivation toward the environment. Only respondents who had previously answered "Yes" to the question "Do you do things for the environment?" (93% of respondents) completed the MTES.

We used the Connectedness to Nature Scale (Mayer and Frantz, 2004) to measure trait levels of feeling connected with nature. The scale measures cognitive beliefs about one's CWN (Perrin and Benassi, 2009), which has been demonstrated to be an important predictor of pro-environmental attitudes and behaviors (Pereira and Forster, 2015; Mackay and Schmitt, 2019; Whitburn et al., 2019).

Details of the psychometric scales are provided in **Table 1**.

Mindfulness Practice

Taking an inclusive approach in targeting mindfulness practitioners, we first asked respondents whether they practiced any form of mindfulness (yes/no). Those answering affirmatively were asked subsequent questions about years of experience in years and weekly practice frequency, regarding both moving meditation (e. g. yoga postures, tai chi, qui gong, other martial art formations) and non-moving meditation (e. g. focused attention to one or more elements, such as to one's body, breath, conscious awareness, or to a particular word, thought or emotive state) separately. We distinguished between moving and non-moving meditations based on observations that in the West, many people practice yoga asanas and martial arts as a fitness discipline without cultivating a mindful orientation, and the degree of mindfulness applied to the practice varies greatly dependent on the discipline and teacher. Those who practice forms of moving meditation such as yoga with the specific intention to cultivate mindfulness typically include a form of non-moving meditation in their practice, e. g. at the end of a yoga class. As such, we strictly allocated respondents to meditator groups based on their experience in non-moving meditation to increase the likelihood that those classed as (advanced) meditators had indeed benefitted from the neurocognitive mechanisms of an on-going *intentional mindfulness* practice. **Advanced meditators** are those who had been practicing non-moving meditation for at least a year and who practiced at least 3–4 times a week. **Novice/infrequent practitioners** are those who had been practicing for less than 1e year and who practice just once or twice per week or less. In addition, because affect-oriented practices have been shown to support pro-sociality more effectively, we also asked respondents to indicate if they

TABLE 1 | Overview of the psychometric scales included in the survey.

Scale	Subscales	Response format	Example items	Cronbach's α
CHIME	Awareness toward internal experiences	6-point Likert scale	When my mood changes, I notice it right away	0.781
	Awareness toward external experiences		I notice details in nature, such as colors, shapes, and textures.	0.832
	Acting with awareness		I break or spill things because I am not paying attention or I am thinking of something else.	0.637
	Accepting and non-judgmental orientation		During both ups and downs of life, I am kind to myself.	0.859
	Decentering and non-reactivity		When I have distressing thoughts or images, I am able to feel calm soon afterward.	0.875
	Openness to experiences		I try to stay busy to avoid specific thoughts or feelings from coming to mind.	0.752
	Relativity of thoughts		It is clear to me that my evaluations of situations and people can easily change.	0.602
	Insightful understanding		In everyday life, I notice when my negative attitudes toward a situation make things worse.	0.771
MTES	Intrinsic motivation	7-point Likert scale	For the pleasure I experience while I am mastering new ways of helping the environment.	0.945
	Integrated motivation		Because taking care of the environment is an integral part of my life.	0.943
	Identified motivation		Because it is a reasonable thing to do to help the environment.	0.961
	Introjected motivation		I think I'd regret not doing something for the environment.	0.905
	External motivation		Because other people will be upset if I don't.	0.887
	Amotivation		Honestly, I don't know; I truly have the impression that I'm wasting my time doing things for the environment.	0.888
SHS	None	7-point Likert scale	Some people are generally very happy. They enjoy life regardless of what is going on, getting the most out of everything. To what extent does this characterization describe you?	0.918
CNS	None	5-point Likert scale	I often feel a sense of oneness with the natural world around me	0.890

TABLE 2 | Distribution and percentages of diet types per meditator group and gender.

	Non-meditator				Infrequent/novice meditator				Advanced meditator			
	Female		Male		Female		Male		Female		Male	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Meat eater	25	13.6	60	32.6	25	13.6	22	12	33	17.9	17	9.2
Pescatarian	2	9.1	1	4.5	5	22.7	0	0	11	50	3	13.6
Vegetarian	7	25.9	0	0	4	14.8	0	0	14	51.9	2	7.4
Vegan	23	35.9	2	3.1	25	39.1	1	1.6	9	14.1	3	4.7

Percentages are attributed per row; unknown diet type and other gender are not listed.

practiced "compassion" as part of their mindfulness practice or as a separate practice (yes/no).

Diet-Related Environmental Impact: GHG, Land Occupation, Water Use

Following previous studies, we measured animal-protein consumption by asking how often respondents ate meat, fish, eggs, and dairy (Scarborough et al., 2014). For each of the animal-proteins, respondents indicated weekly frequency. They also stated whether they were actively trying to reduce their consumption of animal-proteins. Those who answered "yes" stated their reasons by distributing 100 percentage points between the five categories "personal health," "animal welfare," "environment and climate change," "weight control," and "other."

We modeled three environmental impact measures associated with respondents' weekly animal-protein consumption: **GHG emissions, land occupation** and **water use.** The model is based on data from the UK-specific report *Eating For Two Degrees* (WWF, 2017). The report uses country averages of GHG emissions, water use and land occupation associated with 100g of the most common food products, considering national proportions of imported (vs.) local produce, conventional (vs.) organic origin and other variations in production. The impact values were generated in a life-cycle perspective from cradle-to-mouth, including raw materials, agriculture, transport, retail, packaging, waste and preparation of the food in the household. For a detailed explanation of the environmental impact indicator (see **Supplementary Appendix A**).

Questionnaire Distribution

Ethics approval was granted by the Imperial College Research Ethics Committee (21st May 2018). We distributed the survey online via the Qualtrics platform between June and September 2018 and targeted a range of audiences in the United Kingdom to sample across a range of characteristics of interest. Mindfulness practitioners were invited in Facebook groups and via newsletters of London-based mindfulness networks. Respondents of different diet types were approached via Facebook groups such as Vegans United Kingdom, Vegans London, Vegetarians, BBQ and Grilling, CountryWoodSmoke United Kingdom, London Foodies, and health and fitness themes. To incentivize respondents, they could win one of 20 Amazon vouchers to the value of 10 GBP. Additionally, to cover more general population features, we acquired 99 responses from Mechanical Turk[1]; 9 were removed because the responses failed to meet basic quality criteria.

General Data Analysis Strategy

We conducted an *a priori* power analysis using G*Power 3.0.10 (Faul et al., 2007) to determine the desired sample size for detecting a medium sized difference between the practitioner groups regarding performance in PEB. This was based on previous findings by Panno et al. (2018) who compared PEB of two practitioner groups and reported an η^2 effect size of 0.01 at $p < 0.05$ with 95% test power. The medium effect size was later confirmed in another study by Loy and Reese (2019). Our estimated sample size was $N = 252$.

The preliminary dataset of 430 registered responses was cleaned for subsequent data analysis using MATLAB software. We excluded respondents who failed to provide information on their dietary habits or their mindfulness experience (even if they completed other parts of the questionnaire). For any given psychometric scale with more than 10% of datapoints missing, respondents were excluded from further analysis on that scale. When less than 10% were missing, missing data points were substituted with the average of all response values for the respective scale or subscale. The final sample includes 300 respondents. The data analysis was executed in IBM SPSS Statistics version 26. Whenever possible, we controlled for gender effects or separated outcomes by gender, because different patterns in pro-environmental attitudes have been observed between men and women (Vicente-Molina et al., 2018).

For all MANCOVAs, we used Fisher's LSD *post-hoc* tests for pairwise comparisons of practitioner groups. We tested for equality of covariance matrices using Box's M test and we tested for equality of error variances using Levene's test. Due to the assumption that MANCOVA is robust to violations for sample sizes over 30 we proceeded with the analysis even when Box's M was significant ($p < 0.001$) (Allen and Bennett, 2008). When equality of error variances could not be assumed for all variables, we used the Games-Howell *post-hoc* test to identify differences between the groups. For the MANCOVAs where gender was included as a covariate, we used Sidak's adjustment for multiple pairwise comparisons.

[1]A crowdsourcing network: https://www.mturk.com/

Detailed descriptive statistics and correlations between the key dependent variables are reported in **Supplementary Appendix B**. Apart from the GHG, land and water use variables, which are highly correlated and therefore assessed in separate ANOVAs, other variables included in MANOVA analyses were moderately correlated.

RESULTS

Sample Description

Descriptive statistics for gender, education, age, income and faith groups are provided in **Figure 2**.

In total, 186 (61.7%) respondents stated that they practice mindfulness (moving or non-moving), while 115 (38.3%) do not practice. In total, we classified 123 respondents (41%) as non-practitioners, 85 (28.3%) as infrequent/novice practitioners and 92 (30.7%) as advanced meditators.

Gender was unevenly distributed across the three groups, with males dominant in the non-practitioner group (63 men, 58 women) compared to the female-dominated infrequent/novice (23 men, 60 women) and advanced (25 men, 67 women) practitioner groups. 2 respondents chose "other" and 2 did not state gender.

With increasing meditation experience, respondents more frequently practiced compassion. In the non-meditator group, only 3 (1%) practiced compassion vs. 120 (40%) who did not practice. Of the infrequent/novice meditators, 47 (15.7%) practiced compassion whereas 38 (12.7%) did not. In the advanced group, 83 (27.7%) reported practicing compassion while 9 (3%) stated they did not.

Four diet types were represented in the sample of all practitioner groups, totaling 184 (61.3%) meat eaters, 22 (7.3%) pescatarians, 27 (9%) vegetarians and 64 (21.3%) vegans; 3 (1%) remained unknown. **Table 2** summarizes the distribution of diet types per meditator group and gender.

H1: The Three Practitioner Levels Show Differences in Their Levels of Mindfulness, Subjective Happiness and Connectedness With Nature

We employed a multivariate general linear model (MANCOVA) on the mindfulness, happiness and CWN scale scores, using practice level as the independent variable and gender as a covariate. Dependent values were total scale scores on the CHIME, SHS and CWN. The scales and subscales were found to be internally consistent and alpha values are presented in **Table 1**.

The practitioner groups showed moderate differences on the three dependents, $F(6, 574) = 16.793$, $p < 0.001$); Wilk's $\Lambda = 0.724$, $\eta_p^2 = 0.149$. Gender had a relatively small, but statistically significant effect on the dependents, $F(3, 287) = 6.372$, $p < 0.001$; Wilk's $\Lambda = 0.983$, $\eta_p^2 = 0.062$. In follow-up univariate ANCOVAS we found medium-sized differences between practice levels regarding subjective happiness [$F(2, 289) = 15.94$, $p < 0.001$; $\eta_p^2 = 0.099$], small to medium differences on CWN [$F(2, 289) = 11.80$, $p < 0.001$; $\eta_p^2 = 0.076$] and large differences in dispositional mindfulness [$F(2, 289) = 47.04$, $p < 0.001$; $\eta_p^2 = 0.246$]. Women were more connected with nature than men, although the effect was relatively small [$F(3, 289) = 12.91$, $p < 0.001$; $\eta_p^2 = 0.043$], but did not significantly differ on subjective happiness [$F(1, 289) = 0.16$, $p = 0.694$; $\eta_p^2 = 0.001$] or dispositional mindfulness [$F(1, 289) = 1.196$, $p = 0.275$; $\eta_p^2 = 0.004$]. See pairwise comparisons between groups in **Table 3**.

H2: Group Differences Manifest as a Shift in the Quality of Motivation Toward the Environment Which Becomes More Integrated and Less Amotivated

We conducted a multivariate analysis of variance (MANOVA) with practice level as the independent variable and all six motivation types (intrinsic, integrated, identified, introjected, external and amotivation) as outcome variables.

Of the 300 respondents, 279 people confirmed engagement in PEB and completed the MTES scale. Of those who declared no PEB, 61.9% are non-meditators, 28.6% are infrequent/novice meditators, and 9.5% are advanced meditators.

The groups differences between the motivations were medium-sized, $F(12, 504) = 4.57$, $p < 0.001$; Wilk's $\Lambda = 0.813$, $\eta_p^2 = 0.098$. Follow-up univariate tests revealed that the groups showed small but significant differences in integrated motivation $F(2, 257) = 6.49$, $p = 0.002$; $\eta_p^2 = 0.048$, introjected motivation $F(2, 257) = 3.06$, $p = 0.049$; $\eta_p^2 = 0.023$ and amotivation $F(2, 257) = 9.24$, $p > 0.001$; $\eta_p^2 = 0.067$. They did not differ on the other motivational types intrinsic motivation $F(2, 257) = 0.15$, $p = 0.863$; $\eta_p^2 = 0.001$, identified motivation $F(2, 257) = 0.10$, $p = 0.909$; $\eta_p^2 = 0.001$ and external motivation $F(2, 257) = 2.02$, $p = 0.135$; $\eta_p^2 = 0.015$.

Figure 3 shows the mean scores for the different motivations by practice group.

Significant pairwise differences are shown in **Figure 3** and **Table 4**. Pairwise differences for the four motivation types without significant differences can be observed in **Supplementary Appendix C**.

H3: The Level of Self-Reported Environmental Behaviors Differs Between the Groups, With Advanced Meditators Showing the Lowest Environmental Impact

We tested intentions to reduce or limit consumption of animal protein (yes/no) using binary logistic regression. Because dietary habits and intentions differed by gender, we repeated the analysis for men and women separately (**Supplementary Appendix D**). Within the subsample of "reducers," we employed MANCOVA with the reported relative importance (scores) of four diet motivations (i.e., "personal health," "animal welfare," "environmental concerns," and "weight control") as outcome variables, practice level as the independent variable and gender as a covariate. To compare mean environmental impact metrics (GHG emission, land occupation and water use) of

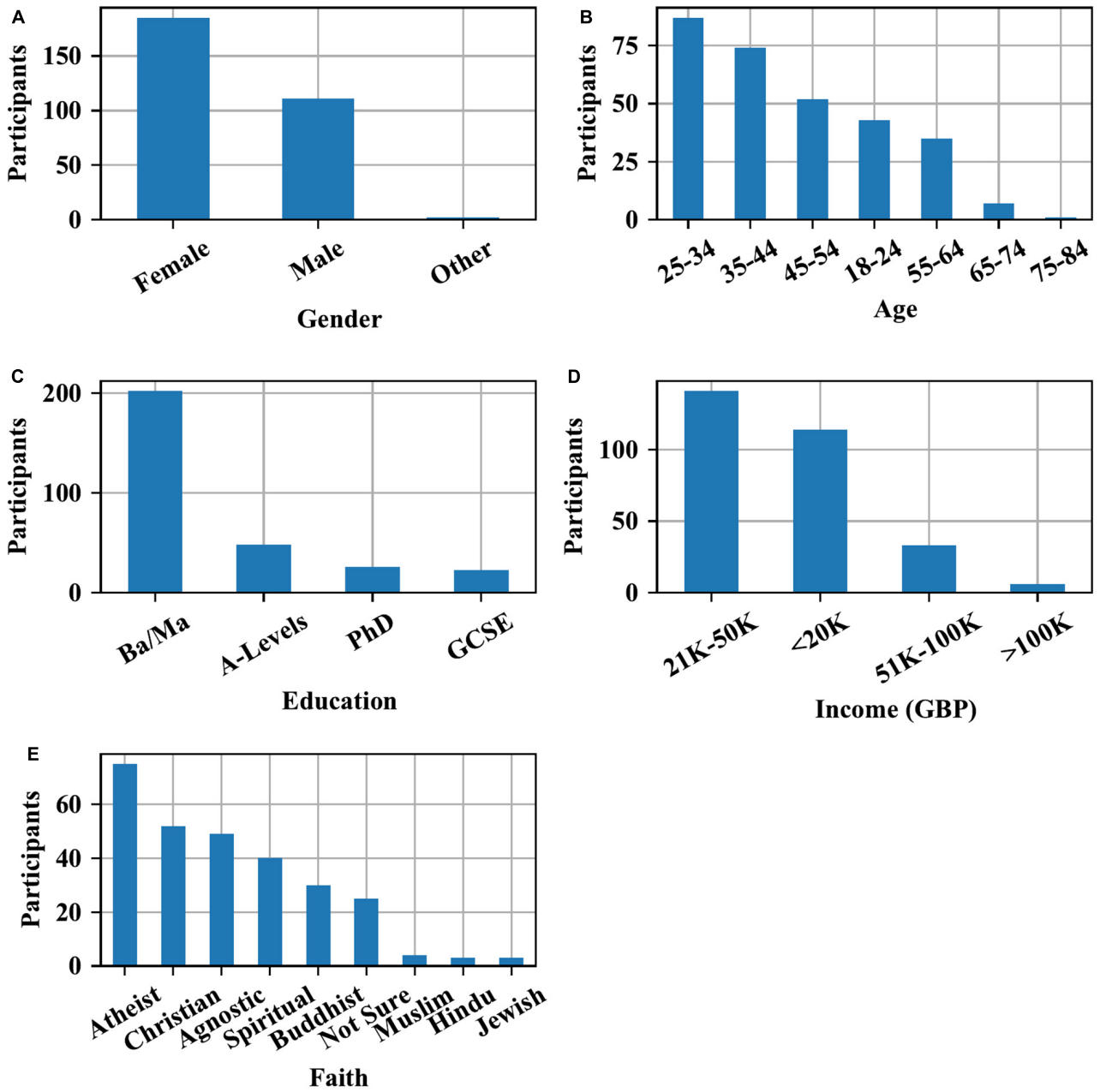

FIGURE 2 | Distribution of sample characteristics in the sample of 300 respondents. **(A)** shows self-identified gender, **(B)** shows age at time of responding, **(C)** shows highest degree attained, **(D)** shows average income per year, **(E)** shows religious affiliation.

the three groups we used three separate univariate general linear models (ANCOVA), including gender as a covariate and following up the main effects with pairwise comparisons. Because of the high participation of vegans in the survey, disproportionally increasing their share in the less experienced practitioner groups, we repeated the analysis excluding all vegans (**Supplementary Appendix D**).

Of non-meditators, 61 (49.6%) stated their intention to reduce animal-protein consumption and 62 (50.4%) stated no such intention. The proportion of reducers increased for both infrequent/novice (60 reducers, 70.6%; 24 non-reducers, 28.2%; 1 unknown) and for advanced meditators (65 reducers, 70.7%; 27 non-reducers, 29.3%). The differences in proportions between the groups were statistically significant, $\chi^2(4, N = 300) = 16.70$, $p = 0.002$. Results from binary logistic regression showed that non-meditators were significantly less likely to reduce their animal-protein consumption in comparison to advanced meditators (Wald (1) = 9.43; $p = 0.002$; CI [0.231, 0.724]). The model predicts that the odds of not reducing animal-protein consumption were less than half [Exp(B) = 0.409] for advanced

TABLE 3 | *Post-hoc* comparison of practitioner group differences on subjective happiness, CWN and dispositional mindfulness.

Dispositional mindfulness

				Sidak comparisons:*p*-value [CI for the difference]		
Meditation practice	***n***	**Mean**	***SD***	**1**	**2**	**3**
1. Non-practitioner	119	3.66	0.46			
2. Infrequent/novice meditator	82	3.80	0.52	0.121 [−0.027, 0.337]	–	
3. Advanced meditator	92	4.33	0.58	<0.001 [0.512, 0.865]	<0.001 [0.346, 0.722]	–

Subjective happiness

				Fisher's LSD (*p*-value) [CI for the difference]		
Meditation practice	***n***	**Mean**	***SD***	**1**	**2**	**3**
1. Non-practitioner	119	3.71	1.49	–		
2. Infrequent/novice meditator	82	4.39	1.25	0.001 [0.274, 1.081]	–	
3. Advanced meditator	92	4.82	1.39	<0.001 [0.715, 1.496]	0.044 [0.011, 0.845]	–

Connectedness with nature (CWN)

				Fisher's LSD (*p*-value) [CI for the difference]		
Meditation practice	***n***	**Mean**	***SD***	**1**	**2**	**3**
1. Non-practitioner	119	3.57	0.71	–		
2. Infrequent/novice meditator	82	3.91	0.70	0.011 [0.058, 0.444]	–	
3. Advanced meditator	92	4.11	0.61	<0.001 [0.273, 0.646]	0.041 [0.009, 0.408]	–

meditators than for non-meditators. In an additional analysis of the reduction effect by gender, we observed that the trend was mostly determined by the men in the sample, while women showed a generally high willingness to reduce animal-proteins across all practitioner groups (**Supplementary Appendix D**).

One hundred and eighty five respondents who reported intentions to reduce animal-protein consumption also indicated their reasons for the reduction. **Figure 4** shows the mean percentage points each of the practitioner group attributed to the different reasons for their reduction behavior.

Both practice level [$F(8, 358) = 2.65$, $p = 0.008$, $\eta_p^2 = 0.056$) and gender [$F(4, 178) = 3.38$, $p = 0.011$; $\eta_p^2 = 0.071$] had a significant small and small to medium sized effect on motivations for reducing meat consumption. Follow-up tests identified that small significant differences between practitioner levels were observed on the relative importance ascribed to environment and climate reasons [$F(2, 181) = 3.566$, $p = 0.030$; $\eta_p^2 = 0.038$], but not with respect to personal health [$F(2, 181) = 1.71$, $p = 0.184$; $\eta_p^2 = 0.019$], animal welfare [$F(2, 181) = 1.472$, $p = 0.232$; $\eta_p^2 = 0.016$] and weight control [$F(2, 181) = 2.677$, $p = 0.072$; $\eta_p^2 = 0.029$]. Men and women showed a small difference in terms of the relative importance ascribed to health reasons [$F(1, 181) = 5.067$, $p = 0.026$; $\eta_p^2 = 0.027$] and animal welfare [$F(1, 181) = 5.510$, $p = 0.020$; $\eta_p^2 = 0.03$], but not for environment/climate [$F(1, 181) = 0.44$, $p = 0.438$; $\eta_p^2 = 0.002$] or weight control $F(1, 181) = 0.24$, $p = 0.628$; $\eta_p^2 = 0.001$]. Pairwise comparisons between the practitioner groups are provided in **Table 5**. Compared to non-meditators, both novice/infrequent and advanced meditators assigned greater importance to the environment as a reason for reducing meat consumption, but the difference reached statistical significance only for advanced meditators.

We compared the mean environmental impact factors (GHG emissions, land occupation and water use) based on the groups' reported consumption of animal-proteins for the duration of 1 month. We found small statistically significant differences between groups on GHG emissions, $F(2, 290) = 4.051$, $p = 0.018$; $\eta_p^2 = 0.027$. The covariate gender had a medium-sized impact on GHG, $F(1, 290) = 44.48$; $p < 0.001$; $\eta_p^2 = 0.133$. Similarly, there was a small significant main effect of practice level on land use impacts $F(2, 290) = 3.860$, $p = 0.022$; $\eta_p^2 = 0.026$ and a medium-sized effect of gender on land use impacts $F(1, 290) = 42.963$, $p < 0.001$; $\eta_p^2 = 0.129$. Finally, the groups showed a small significant difference in water use, $F(2, 290) = 4.032$, $p = 0.019$; $\eta_p^2 = 0.027$ and gender had a medium-sized effect on water use $F(1, 290) = 44.589$, $p < 0.001$; $\eta_p^2 = 0.13$. **Table 6** compares the total mean values of all three environmental impact factors of the three groups for 1 month of eating animal-proteins. This includes pairwise comparisons of practitioner groups. The estimated marginal mean for the environmental impact indicators was significantly higher for non-practitioners over advanced meditators, and for non-practitioners over novice/infrequent meditators. The environmental impact indicators do not differ significantly between novice/infrequent and advanced meditators except when vegans were excluded from the analysis (**Supplementary Appendix E**).

In **Table 6** we also estimated the environmental impact of each group associated with eating animal-proteins for 1 year,

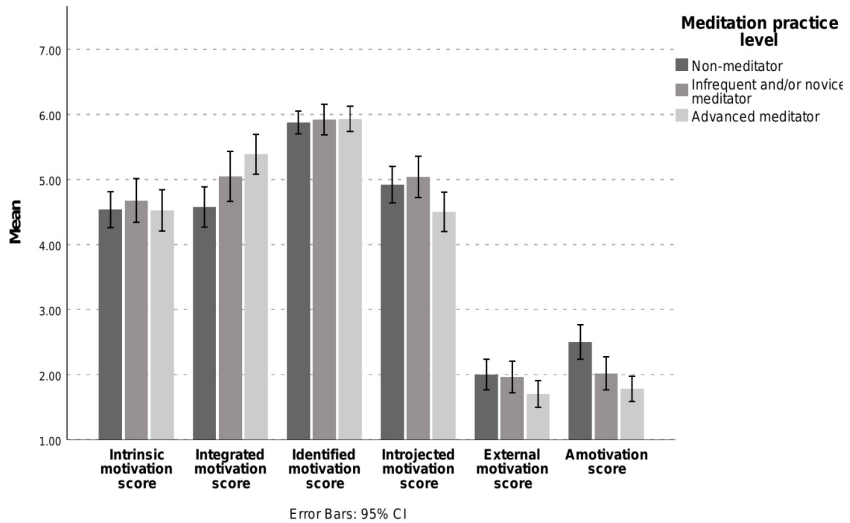

FIGURE 3 | Comparison of the mean scores per meditation practitioner group for all six different motivation types. Note that only integrated motivation significantly differs between advanced meditators and non-meditators ($p < 0.01$). Amotivation significantly differs between advanced meditators and non-meditators ($p < 0.001$) and infrequent/novice meditators and non-meditators ($p < 0.05$).

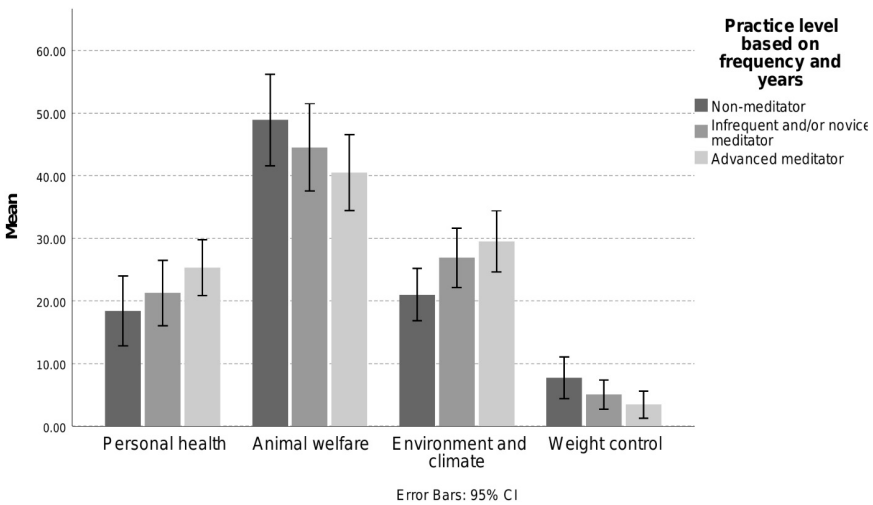

FIGURE 4 | Comparison of the mean percentage points for the reasons for reducing animal-protein consumption, per meditator group. Note that only the scores for environmental and climate concern differ significantly between advanced meditators and non-meditators ($p < 0.05$).

comparing the savings of advanced meditator vs. non-meditators with an every-day example.

H4: CWN and Integrated Motivation Toward the Environment Mediate the Relationship Between Mindful Compassion Practice and Environmental Behavior

We ran a sequential mediation analysis (model 6) using the PROCESS tool v3.4 by Andrew F. Hayes, with 10,000 bootstrap samples and a confidence interval of 95. We applied a binary predictor based on the existence of compassion practice (X), because affect-oriented mindfulness practices have been shown to provide the strongest impact on prosocial tendencies (see section "Research gaps in mindfulness and sustainability"). We assume that the relational pathway for PEB established by the 2-pathway model becomes stronger with the existence of such affect-oriented practices as part of respondents' general mindfulness practice. Almost all the advanced practitioners in our sample reported practicing some form of compassion meditation, as well as a small group of infrequent/novice practitioners. Regarding the outcome variable to test our assumption, we chose to use GHG emissions (Y) as the representative for PEB performance. Repeating the analysis with the other two environmental impact variables would make these additional

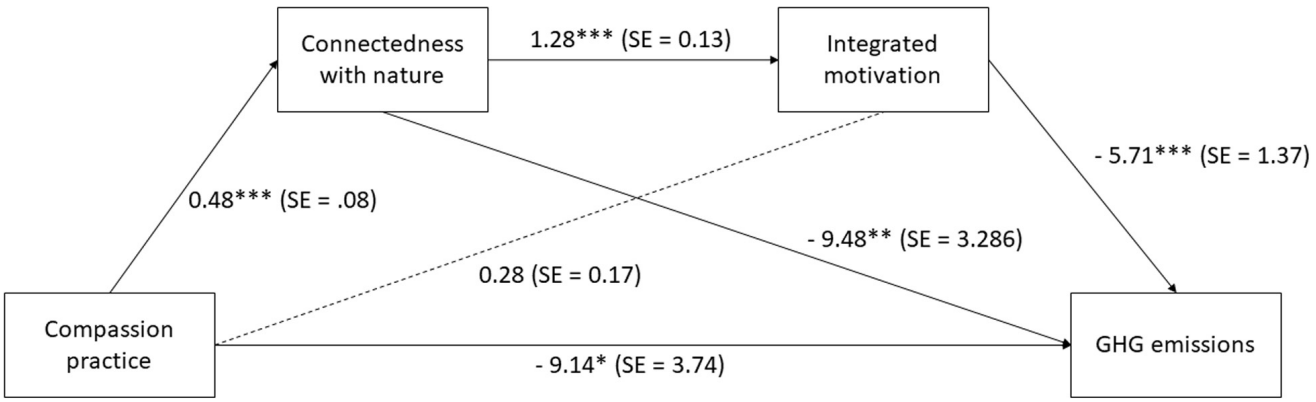

FIGURE 5 | The sequential mediation effect of CWN and integrated motivation in the relationship between compassion practice and GHG emissions. ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; all presented effects are unstandardized; standard errors are indicated in parenthesis; compassion practitioners coded as 2 and non-practitioners coded as 1.

TABLE 4 | *Post-hoc* comparison of practitioner group differences on six different motivation type.

				Games-Howell comparisons (*p*-value)		
Meditation practice	***n***	**Mean**	***SD***	**1**	**2**	**3**
Integrated motivation						
1. Non-practitioner	102	4.56	1.59	–		
2. Infrequent/Novice practitioner	73	4.99	1.67	0.200 [−0.159, 1.014]	–	
3. Advanced meditator	81	5.39	1.39	0.001 [0.3089, 1.3439]	0.242 [−0.984, 0.186]	–
Amotivation						
1. Non-practitioner	102	2.49	1.35	–		
2. Infrequent/Novice practitioner	73	2.04	1.08	0.035 [0.026, 0.886]	–	
3. Advanced meditator	81	1.78	0.87	<0.001 [0.322, 1.096]	0.249 [−0.1213, 0.627]	–

analyses redundant because the three variables are highly correlated (see **Supplementary Appendix B**). We analyzed CWN as the first mediator (M1) and integrated motivation as the second mediator (M2), as shown in **Figure 5**.

The total effect of the model was statistically significant, $B = -18.78$, $SE = 3.8$, $t = -4.94$, $p < 0.001$, 95% CI [−26.26, −11.3]. Compassion practice showed a significant positive effect on CWN, $B = 0.48$, $SE = 0.08$, $t = 6.25$, $p < 0.001$, 95% CI [0.33, 0.63], while its effect on integrated motivation was not significant, $B = 0.28$, $SE = 0.17$, $t = 1.66$, $p = 0.09$, 95% CI [−0.05, −0.6055]. This indicates that those who practice affect-oriented meditation practices such as compassion do show higher levels of CWN than non-practitioners. The practice of compassion also showed to be significantly negatively associated with GHG emissions, $B = -9.14$, $SE = 3.74$, $t = -2.44$, $p = 0.02$, 95% CI [−16.51, −1.7726], meaning that those who practice compassion meditation tend to emit less carbon from their animal-protein consumption than those who don't. The direct effect of CWN on integrated motivation was significant and positive, $B = 1.28$, $SE = 0.13$, $t = 10.28$, $p < 0.001$, 95% CI [1.04, 1.53] and its effect on GHG significant and negative $B = -9.49$, $SE = 3.29$, $t = -2.89$, $p = 0.004$, 95% CI [−15.95, −3.02]. This means that those with higher levels of CWN do show higher integrated motivation toward the environment, and reduced carbon emissions from diet. Also, integrated motivation is negatively associated with GHG emissions: $B = -5.71$, $SE = 1.37$, $t = -4.17$, $p < 0.001$, 95% CI [−8.40, −3.01]. Regarding the indirect effects, we found that compassion practice was negatively associated with GHG emissions while partially mediated by CWN, $B = -0.1307$, $SE = 0.06$, 95% CI [−0.2647, −0.0387]. In comparison, the indirect effect of compassion practice on GHG through integrated motivation was not significant: $B = -0.0488$, $SE = 0.03$, 95% CI = [−0.12, 0.01]. In combination of both mediators, the indirect effect of compassion practice on GHG emissions through CWN and integrated motivation was significant and negative: $B = -0.1084$, $SE = 0.3$, 95% CI = [−1.79, −0.05]. This shows that the relational component of CWN plays a positive role in explaining the reduced GHG emissions of compassion meditators. However, the R-squared of the total effect was 0.084 indicating that our model only explained an estimated 8.4% of the variance in GHG emissions.

DISCUSSION

Mindfulness and its benefits develop through practice and accrue over time (Carmody and Baer, 2008; Bergomi et al., 2015; Franquesa et al., 2017). To gauge the potential of mindfulness

TABLE 5 | Multiple comparisons of practitioner group mean percentages of different reasons for reducing animal-proteins.

Personal health

				Sidak comparisons (*p*-value) [CI for differences]		
Meditation Practice	***n***	**Mean**	***SD***	**1**	**2**	**3**
1. Non-practitioner	61	18.41	21.74	–		
2. Infrequent/novice meditator	59	21.22	20.43	0.655 [−12.597, 4.993]	–	
3. Advanced meditator	65	25.3	17.97	0.187 [−2.004, 15.059]	0.836 [−11.443, 5.992]	–

Animal welfare

				Fisher's LSD (*p*-value) [CI for differences]		
Meditation Practice	***n***	**Mean**	***SD***	**1**	**2**	**3**
1. Non-practitioner	61	48.92	28.54	–		
2. Infrequent/novice meditator	59	44.88	26.96	0.266 [−4.153, 14.972]	–	
3. Advanced meditator	65	40.51	24.47	0.094 [−1.358, 17.195]	0.602 [−6.970, 11.987]	–

Environment and climate

				Fisher's LSD (*p*-value) [CI for differences]		
Meditation Practice	***n***	**Mean**	***SD***	**1**	**2**	**3**
1. Non-practitioner	61	21.02	16.26	–		
2. Infrequent/novice meditator	59	26.95	18.49	0.094 [−0.968, 12.296]	–	
3. Advanced meditator	65	29.51	19.73	0.009 [2.154, 15.021]	0.381 [−3.651, 9.497]	–

Weight control

				Sidak comparisons (*p*-value) [CI for differences]		
Meditation Practice	***n***	**Mean**	***SD***	**1**	**2**	**3**
1. Non-practitioner	61	7.72	13.02	–		
2. Infrequent/novice meditator	59	5.12	9.08	0.498 [−2.187, 7.066]	–	
3. Advanced meditator	65	3.46	8.66	0.065 [−0.188, 8.789]	0.699 [−2.726, 6.447]	–

interventions as a tool for promoting more sustainable lifestyles, we need a deeper understanding of how different levels of engagement with the practice translate into PEB and environmental impacts. The aim was to examine how one high-impact behavior, animal-protein consumption, is associated with mindfulness practice.

Corresponding with our hypotheses, we found that diet-related environmental impacts were lower for meditators compared to non-meditators, regardless of experience. Only advanced meditators showed the expected shift toward a more self-determined and strongly internalized motivation, where PEB become an integral part of a person's self-concept. Advanced meditators also showed significantly more concern for the environment than non-practitioners. In line with the 2-pathway model of PEB, we confirmed that much of the mitigating effect of mindful compassion practice on PEB was mediated by relational aspects.

Regarding hypothesis I, meditators showed progressively higher subjective happiness and CWN compared to non-meditators, but only advanced meditators showed significantly elevated dispositional mindfulness. The latter observation is in line with previous research showing that continued meditation practice is crucial for developing and maintaining mindfulness (Bergomi et al., 2015). Yet in our sample, happiness and CWN showed to be greater even for those with limited mindfulness practice, somewhat moderating the assumption that the development of greater psychological well-being depends on the extent of engagement with the practice (Carmody and Baer, 2008). Our results also reflect experimental research by Aspy and Proeve (2017) who showed that even after a short meditation exercise, CWN increased significantly. Overall, our results indicate that mindfulness, subjective happiness and CWN might be interrelated and practice dependent (Howell et al., 2011).

For hypothesis II, we confirmed significantly higher levels of integrated motivation in the advanced meditator group compared to non-practitioners, and lower levels of amotivation in both the advanced and the infrequent/novice meditator group. All groups reported similar levels of intrinsic motivation toward the environment which might seem contradictory to research showing that mindfulness helps clarify intrinsic values (Ericson et al., 2014; Franquesa et al., 2017; Wamsler et al., 2017) and dampens the pursuit of extrinsic goals such as financial gain (Brown et al., 2009). Yet, we advocate an interpretation of our results that leaves behind the dichotomous understanding of

TABLE 6 | Comparison of total mean environmental impact (GHG emissions, land occupation, water use) per practitioner group for 1 month of eating animal-proteins, with gender as a covariate.

				Fisher's LSD (*p*-value) [CI for difference]				Yearly savings NP vs. AM	
Meditation practice	***n***	**Mean Month**	**SD**	**1**	**2**	**3**	**Mean Year**		**Compares to**
GHG EMISSIONS (KG CO_2-EQ)									
1. NP	120	47.31	36.42	–			567.7	215.52	Return flight from London to Frankfurt
2. IM	82	31.9	32.21	0.044 [0.222, 17.68]	–		382.8		
3. AM	92	29.35	26.41	0.007 [3.14, 20.04]	0.566 [−6.40, 11.67]	–	352.2		
LAND OCCUPATION (M^2*A)									
1. NP	120	48.88	37.66	–			586.5	216.12	Area needed to keep 4 free-range hens on grass pasture, or 293 hens in a Sykes henyard (excluding production of 6t of straw per year for henyard)
2. IM	82	32.95	33.29	0.042 [0.34, 18.40]	–		395.4		
3. AM	92	30.87	27.05	0.010 [2.80, 20.28]	0.648 [−7.17, 11.51]	–	370.4		
WATER USE (M^3)									
1. NP	120	0.39	0.30	–			4.68	1.8	12 days of UK average household water use for one individual
2. IM	82	0.26	0.27	0.041 [0.003, 0.147]	–		3.12		
3. AM	92	0.24	0.22	0.008 [0.025, 0.164]	0.607 [−0.055, 0.094	–	2.88		

The three columns on the right compare the mean consumption per year and exemplify the reduction of environmental impact by the advanced meditators vs. non-practitioners.

NP, non-practitioners; IM, Infrequent/novice meditators; AM, Advanced meditators (Department for Business Energy and Industrial Strategy, 2017; EnergySavingTrust, 2013; Plamondon, 2016).

environmental motivation that has been gaining attraction in mainstream environmental psychology (Thiermann and Sheate, 2020a). Self-determination theorists distinguish between *intrinsic motivation* and *self-determined extrinsic motivation* (such as integrated and identified motivation). Intrinsic motivation is "the innate tendency to engage in an activity for the sole pleasure and satisfaction derived from its practice. [. . .] The behavior is an end in itself." (Pelletier et al., 1998, p. 441). However, for behaviors that "do not occur spontaneously but are rather required by the social world" (Pelletier et al., 1998, p. 462), such as PEB, the aim is their successful internalization which occurs "when an instrumental behavior has been valorized to an extent such that it becomes part of the person's self-definition" (Pelletier et al., 1998, p. 441). Even though PEB might emerge from external sources at the start, they can become fully self-determined (*as if* intrinsic) and an expression of how a person creates meaning. Hunecke and Richter (2019) showed that the relationship between mindfulness and sustainable diets is influenced by personal meaning-making processes. While mindfulness can be practiced with individually varying degrees of spirituality, most often it is directed at inner growth and human development as well as contemplating one's intrinsic values and purpose in life (Garland et al., 2015). Werner et al. (2020) reported that natural spirituality, a concept connected to mindfulness practice, encourages greater responsibility for one's actions and higher levels of intrinsic (to be understood as internalized) motivation. This trend also is reflected in the study of worldviews which found that individuals with more intrinsically oriented worldviews, especially those interested in inner growth, engage more frequently in pro-social behaviors and sustainable lifestyles (Hedlund-de Witt et al., 2014). It is therefore not surprising that the advanced meditators showed the highest levels of self-determined extrinsic motivation for PEB.

For hypothesis III, we did not only assess intentions and reasons for animal-protein reduction, but also compared the average environmental impacts from 1 month of eating animal-based products. Instead of employing dispositional mindfulness as the main predictor variable as in most studies of mindfulness and PEB, we built an indicator based on mindfulness practice frequency and years of experience. Only three other studies in the field used such practice indicators. Panno et al. (2018) and Loy and Reese (2019) applied a broad filter by determining the existence (yes/no) of any mindfulness practices. Our approach resembles Brown et al. (2009) who assessed at least the frequency of non-moving meditation practice. Our results mirror all three studies affirming that self-reported PEB (both the behavioral intention to reduce animal-proteins and the mean environmental impact) are enhanced for meditators compared to non-meditators, independent of the level of meditation experience. However, their underlying reasons differed: only advanced meditators demonstrated greater concern for the environment and climate as the reason for reducing consumption of animal protein, compared to non-meditators.

Hunecke and Richter (2019) found that mindfulness predicted more sustainable food consumption but not vegetarianism, opening questions about the importance of ecological vs. moral norms. Our results identify animal welfare as the leading reason for reducing meat consumption in all groups. Yet, advanced meditators cultivate a more holistic perspective on personal health, animal welfare and the environment. A possible explanation might be that a consistent meditation practice promotes a sense of interconnectedness with all beings and

nature, allowing meditators to balance their individual needs with those of other beings and the environment (Hanley et al., 2017; Vieten et al., 2018). The relative prominence of personal health reasons in the advanced meditator group, even if not to a significant level, may explain some of their environmental savings because healthier diets also tend to be more sustainable (Van Dooren et al., 2014). This aligns with Geiger et al. (2018) who highlighted an indirect path from mindfulness to ecological behavior through health behaviors. Nevertheless, our results reinforce that environmental motivations play a significant role in the dietary decisions of advanced meditators.

Instead of assessing diet type as a binary indicator (Wamsler and Brink, 2018; Hunecke and Richter, 2019) or via Likert-scales (Stanszus et al., 2019; Werner et al., 2020), this study provides a more nuanced picture on diet-related environmental impact. As a result, we recorded several meat eaters with lower self-reported environmental impact than some vegetarians or pescatarians, because they generally ate animal-proteins with moderation. Our analysis further showed that the groups with at least some mindfulness experience had a significantly lower environmental impact than those without. To determine if the environmental savings are meaningful in practical terms, we compared the impact from a year worth of animal-protein consumption to daily-life examples of one United Kingdom citizen. To provide a sense of scale, such a saving extrapolated to every individual in the United Kingdom economy with 66.4 million inhabitants (Office for National Statistics, 2019) and a yearly GHG emission rate of 364.1 million tons (BEIS, 2019) results in a reduction of 14,319,148.8 tons[2] of GHG emissions. This compares to a 3.8% reduction in the UK's yearly emissions rate. Our study is the first to compare the environmental impact from the diets of different meditator groups which common Likert-type PEB scales fail to provide.

For hypothesis IV, the low R-squared value showed that several factors beyond mindfulness practice affect diet-related environmental impact. Yet, we could show that the weak relationship between mindful compassion practice and GHG emission reductions was partially mediated by relational factors, particularly by CWN but also a more internalized motivation for PEB. While previous studies have shown a reciprocal relationship between dispositional mindfulness and CWN (Schutte and Malouff, 2018), little evidence exists regarding the impact of the practice of mindfulness on CWN (Aspy and Proeve, 2017). Furthermore, our mediation analysis indicates that mindful compassion practice could be effective as an experiential strategy that strengthens the relational pathway of PEB and therefore deepens the motivation toward the environment (Thiermann and Sheate, 2020a). The importance of a compassionate mindset for sustainable diets also was discussed by Werner et al. (2020).

Limitations

Creating and comparing three different groups of meditators based on practice frequency and experience is one of the most important innovations of this study, though it involves several limitations. There is no established guidance on how to distinguish advanced from infrequent/novice meditators. While we based our groupings on clear criteria, they represent artificial demarcations. For instance, the experience of advanced meditators varied greatly from 2 to over 15 years of practice. Many additional criteria could be used to classify advanced meditators, such as the total days spent on silent retreats, whether meditators use audio-guidance or meditate in silence, the average duration of meditation sessions, and whether the meditators seek out mindfulness teachings. Also, because of the large variability of moving meditation without scientific evaluation of their effect on trait mindfulness (such as vinyasa-style yoga, walking, or surfing), we refrained from integrating moving meditation as part of our categorization. This potentially disadvantaged some individuals who attain high levels of mindfulness through practices such as classical hatha yoga or qui gong.

Regarding the dietary impact indicator, the high-level focus on four types of animal products excludes other relevant factors of a sustainable nutrition such as the purchase of products from regional, seasonal, organic, fair-trade, and small-scale agriculture origin. Furthermore, within the animal-protein groups, we applied averages of several products which can largely differ in impact, e. g. beef steak and processed sausages. Because we generally attributed an impact of zero to vegans, there is no variation of the impact within this diet group.

Even though we asked detailed questions about the frequency of practice and consumption of animal-proteins, we expect that some social desirability response bias and recall bias is still represented in our data (Subar et al., 2015). The same applies to the psychometric scales, known to attract social desirability biases (Latkin et al., 2017). Respondents also might have been primed by the order of the questions and favored pro-environmental responses after engaging in the environmental scales. However, the effects would have affected all meditation groups equally and are therefore unlikely to have confounded the group effects.

We did not recruit a random or representative sample and as a result of our recruitment strategy, focusing on specific social groups and self-selection, the sample represents a disproportionally high percentage of vegans, particularly in the non-practitioner and infrequent/novice meditator groups which might have played in favor of the average environmental impact of these groups. The sample also includes a high proportion of university graduates and female respondents. Generally, because the survey was advertised as related to the topic of diets, well-being, environment and mindfulness, this likely attracted those who are altruistically inclined. The sampling bias therefore might also contribute to the small effect sizes in the analyses.

Finally, women were overrepresented in our sample and typically show stronger pro-environmental attitudes and behaviors (Lee et al., 2013; Kennedy and Kmec, 2018; Di Fabio and Rosen, 2019). While we have accounted for gender influences in our analysis and the general effect of practice remains significant, we suggest that future research on mindfulness and sustainable lifestyles should take an explicitly gendered approach. For example, our results suggest that at least for some behaviors (e.g., intention to reduce animal-proteins) women are engaging regardless of whether they meditate or not, while men are more likely to do so if they are also engaged in mindfulness practice.

[2]Kg CO_2eq value extracted from **Table 6**, converted to tonnes: 0.216. Then multiplied by 66,440,000 inhabitants.

CONCLUSION

Our exploratory study showed that advanced meditators are happier, more deeply motivated toward the environment and they generate less environmental impact from animal-proteins. This makes mindfulness practitioners a prime target to learn more about individual ways to combine greater personal and planetary well-being. Yet the proof for causality remains an unresolved research gap in the area: is it the practice of mindfulness that renders people more interested in inner growth and sets them on a path to sustainability? Or are those who seek for meaning and self-improvement the ones drawn to mindfulness and therefore more likely to maintain a regular practice? Because our study showed that environmental motivations and ecological concern only significantly improved for advanced meditators with more than a year of practice (many meditate for more than 10 years) we suggest that future studies regarding causality accompany new meditators for a period of *at least* 1 year to detect changes in worldviews and lifestyles. At the same time, the longer the period of measurement, the more essential it is to account for other factors such as changes in social context or the engagement in Buddhist teachings. Qualitative research could greatly enhance this process.

With this study we strove to overcome the narrow research focus on dispositional mindfulness commonly applied in the field. This pioneer work did not only examine how mindfulness practices relate to different antecedent factors for PEB. It also is the first to quantify their effect on real world measures of environmental impact which provided tentative insights into the environmental benefits a widespread adoption of mindfulness practices could potentially entail. With this approach, we hope to spark future research ideas that focus on testing and operationalizing mindfulness programs as a policy tool for sustainable development.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation. To receive the data, please contact the corresponding author: ute.thiermann15@imperial.ac.uk.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Imperial College Research Ethics Committee https://www.imperial.ac.uk/research-ethics-committee/committees/icrec/. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

UT designed and executed this research as part of her doctoral thesis, including writing of this manuscript. AV supported the project as an advisor and particularly supported data analysis, and presentation and discussion of the results. WS was overseeing the work in his function as Ph.D. supervisor, and supported preparation of the manuscript and major discussion points. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.584353/full#supplementary-material

REFERENCES

Allen, P. J., and Bennett, K. (2008). *SPSS for the Health and Behavioural Sciences*, 1 Edn. South Melbourne, VIC: Thomson.

Aspy, D. J., and Proeve, M. (2017). Mindfulness and loving-kindness meditation: effects on connectedness to humanity and to the natural world. *Psychol. Rep.* 120, 102–117. doi: 10.1177/0033294116685867

Barbaro, N., and Pickett, S. M. (2016). Mindfully green: examining the effect of connectedness to nature on the relationship between mindfulness and engagement in pro-environmental behavior. *Pers. Indiv. Differ.* 93, 137–142. doi: 10.1016/j.paid.2015.05.026

Barrett, B., Grabow, M., Middlecamp, C., Mooney, M., Checovich, M. M., Converse, A. K., et al. (2016). Mindful climate action: health and environmental co-benefits from mindfulness-based behavioral training. *Sustainability* 8, 1–20. doi: 10.3390/su8101040

BEIS (2019). *2018 UK Greenhouse Gas Emissions, Provisional Figures. National Statistics*. Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/790626/2018-provisional-emissions-statistics-report.pdf (accessed March, 2019).

Bergomi, C., Tschacher, W., and Kupper, Z. (2013). Measuring mindfulness: first steps towards the development of a comprehensive mindfulness scale. *Mindfulness* 4, 18–32. doi: 10.1007/s12671-012-0102-9

Bergomi, C., Tschacher, W., and Kupper, Z. (2015). Meditation practice and self-reported mindfulness: a cross-sectional investigation of meditators and non-meditators using the comprehensive inventory of mindfulness experiences (CHIME). *Mindfulness* 6, 1411–1421. doi: 10.1007/s12671-015-0415-6

Böckler, A., Tusche, A., Schmidt, P., and Singer, T. (2018). Distinct mental trainings differentially affect altruistically motivated, norm motivated, and self-reported prosocial behaviour. *Sci. Rep.* 8, 1–14. doi: 10.1038/s41598-018-31813-8

Böhme, T., Stanszus, L. S., Geiger, S. M., Fischer, D., and Schrader, U. (2018). Mindfulness training at school: away to engage adolescents with sustainable consumption? *Sustainability* 10, 1–22. doi: 10.3390/su10103557

Brown, K. W., Kasser, T., Ryan, R. M., Alex Linley, P., and Orzech, K. (2009). When what one has is enough: mindfulness, financial desire discrepancy, and subjective well-being. *J. Res. Pers.* 43, 727–736. doi: 10.1016/j.jrp.2009.07.002

Carmody, J., and Baer, R. A. (2008). Relationships between mindfulness practice and levels of mindfulness, medical and psychological symptoms and well-being in a mindfulness-based stress reduction program. *J. Behav. Med.* 31, 23–33. doi: 10.1007/s10865-007-9130-7

Chiesa, A. (2013). The difficulty of defining mindfulness: current thought and critical issues. *Mindfulness* 4, 255–268. doi: 10.1007/s12671-012-0123-4

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., et al. (2009). Managing the health effects of climate change. Lancet and University College London Institute for Global Health Commission. *Lancet* 373, 1693–1733. doi: 10.1016/S0140-6736(09)60935-1

Creutzig, F., Fernandez, B., Haberl, H., Khosla, R., Mulugetta, Y., and Seto, K. C. (2016). Beyond technology: demand-side solutions for climate change mitigation. *Annu. Rev. Environ. Resour.* 41, 173–198. doi: 10.1146/annurev-environ-110615-085428

Dahl, C. J., Lutz, A., and Davidson, R. J. (2015). Reconstructing and deconstructing the self: cognitive mechanisms in meditation practice. *Trends Cogn. Sci.* 19, 515–523. doi: 10.1016/j.tics.2015.07.001

Department for Business Energy and Industrial Strategy (2017). *Greenhouse Gas Reporting: Conversion Factors 2017*. Available online at: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2017 (accessed February 4, 2020)

Department of Energy and Cimate Change (2015). *Prosperous Living for the World in 2050: Insights from the Global Calculator*. London: Department of Energy and Cimate Change.

Di Fabio, A., and Rosen, M. A. (2019). Accounting for individual differences in connectedness to nature: personality and gender differences. *Sustainability* 11:1693. doi: 10.3390/su11061693

Díaz, S., Settele, J., Brondízio, E., Ngo, H. T., Guèze, M., Agard Trinidad, J., et al. (2019). *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services-ADVANCE UNEDITED VERSION-Members of the Management Committee Who Provid*. Availble online at: https://www.ipbes.net/system/tdf/spm_unedited_advance_for_posting_htn.pdf?file=1andtype=nodeandid=35275 (accessed May, 2019)

Egan, P. J., and Mullin, M. (2017). Climate change: US public opinion. *Annu. Rev. Polit. Sci.* 20, 209–227. doi: 10.1146/annurev-polisci-051215-022857

EnergySavingTrust (2013). *At Home With Water*. London: EnergySavingTrust.

Ericson, T., Kjnstad, B. G., and Barstad, A. (2014). Mindfulness and sustainability. *Ecol. Econ.* 104, 73–79. doi: 10.1016/j.ecolecon.2014.04.007

Faul, F., Erdfelder, E., Lang, A.-G., and Buchner, A. (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* 39, 175–191. doi: 10.3758/BF03193146

Fischer, D., Stanszus, L. S., Geiger, S., Grossman, P., and Schrader, U. (2017). Mindfulness and sustainable consumption: a systematic literature review of research approaches and findings. *J. Cleaner Prod.* 162, 544–558. doi: 10.1016/j.jclepro.2017.06.007

Franquesa, A., Cebolla, A., García-Campayo, J., Demarzo, M., Elices, M., Pascual, J. C., et al. (2017). Meditation practice is associated with a values-oriented life: the mediating role of decentering and mindfulness. *Mindfulness* 8, 1259–1268. doi: 10.1007/s12671-017-0702-5

Fritzsche, J., Fischer, D., Böhme, T., Grossman, P. (2018). *Education for Sustainable Consumption Through Mindfulness; Active Methodology Toolkit 9*. Elverum, Norway: PERL - Partnership for Education and Research About Responsible Living. Available online at: http://achtsamkeit-und-konsum.de/wp-content/uploads/2018/06/Toolkit_EN_online-1.pdf (accessed June 18).

Fung, T. T., Long, M. W., Hung, P., and Cheung, L. W. Y. (2016). An expanded model for mindful eating for health promotion and sustainability: issues and challenges for dietetics practice. *J. Acad. Nutr. Diet.* 116, 1081–1086. doi: 10.1016/j.jand.2016.03.013

Garland, E. L., Farb, N. A., Goldin, R. P., and Fredrickson, B. L. (2015). Mindfulness broadens awareness and builds eudaimonic meaning: a process model of mindful positive emotion regulation. *Psychol. Inquiry* 26, 293–314. doi: 10.1080/1047840X.2015.1064294

Gatersleben, B. (2018). "Measuring environmental behaviour," in *Environmental Psychology*, eds L. Steg, A. van de Berg, and J. I. M. de Groot (Berlin: Wiley), 155–166. doi: 10.1002/9781119241072.ch16

Gatersleben, B., Steg, L., and Vlek, C. (2002). Measurement and determinants of environmentally significant consumer behavior. *Environ. Behav.* 34, 335–362. doi: 10.1177/0013916502034003004

Geiger, S. M., Fischer, D., Schrader, U., and Grossman, P. (2019a). Meditating for the planet: effects of a mindfulness-based intervention on sustainable consumption behaviors. *Environ. Behav.* 52, 1012–1042. doi: 10.1177/0013916519880897

Geiger, S. M., Grossman, P., and Schrader, U. (2019b). Mindfulness and sustainability: correlation or causation? *Curr. Opin. Psychol.* 28, 23–27. doi: 10.1016/j.copsyc.2018.09.010

Geiger, S. M., Otto, S., and Schrader, U. (2018). Mindfully green and healthy: an indirect path from mindfulness to ecological behavior. *Front. Psychol.* 8:2306. doi: 10.3389/fpsyg.2017.02306

Girod, B., Van Vuuren, D. P., and Hertwich, E. G. (2013). Global climate targets and future consumption level: an evaluation of the required GHG intensity. *Environ. Res. Lett.* 8:014016. doi: 10.1088/1748-9326/8/2/029501

Grabow, M., Bryan, T., Checovich, M. M., Converse, A. K., Middlecamp, C., Mooney, M., et al. (2018). Mindfulness and climate change action: a feasibility study. *Sustainability* 10, 1–24. doi: 10.3390/su10051508

Hanley, A. W., Baker, A. K., and Garland, E. L. (2017). Self-interest may not be entirely in the interest of the self: association between selflessness, dispositional mindfulness and psychological well-being. *Pers. Indiv. Differ.* 117, 166–171. doi: 10.1016/j.paid.2017.05.045

Hartmann, C., and Siegrist, M. (2017). Consumer perception and behaviour regarding sustainable protein consumption: a systematic review. *Trends Food Sci. Technol.* 61, 11–25. doi: 10.1016/j.tifs.2016.12.006

Hedenus, F., Wirsenius, S., and Johansson, D. J. A. (2014). The importance of reduced meat and dairy consumption for meeting stringent climate change targets. *Clim. Change* 124, 79–91. doi: 10.1007/s10584-014-1104-5

Hedlund-de Witt, A., de Boer, J., and Boersema, J. J. (2014). Exploring inner and outer worlds: a quantitative study of worldviews, environmental attitudes, and sustainable lifestyles. *J. Environ. Psychol.* 37, 40–54. doi: 10.1016/j.jenvp.2013.11.005

Howell, A. J., Dopko, R. L., Passmore, H. A., and Buro, K. (2011). Nature connectedness: associations with well-being and mindfulness. *Pers. Indiv. Differ.* 51, 166–171. doi: 10.1016/j.paid.2011.03.037

Hunecke, M., and Richter, N. (2019). Mindfulness, construction of meaning, and sustainable food consumption. *Mindfulness* 10, 446–458. doi: 10.1007/s12671-018-0986-0

IPCC (2014). "Climate change 2014: synthesis report," in *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Vol. 218, eds R. K. Pachauri, L. Meyer, and Core Writing Team (Geneva: IPCC), doi: 10.1016/S0022-0248(00)00575-3

Jacob, J., Jovic, E., and Brinkerhoff, M. B. (2009). Personal and planetary well-being: mindfulness meditation, pro-environmental behavior and personal quality of life in a survey from the social justice and ecological sustainability movement. *Soc. Indic. Res.* 93, 275–294. doi: 10.1007/s11205-008-9308-6

Kasser, T. (2017). Living both well and sustainably: a review of the literature, with some reflections on future research, interventions and policy. *Philos. Trans. A Math. Phys. Eng. Sci.* 375:20160369. doi: 10.1098/rsta.2016.0369

Kennedy, E. H., and Kmec, J. (2018). Reinterpreting the gender gap in household pro-environmental behaviour. *Environ. Sociol.* 4, 299–310. doi: 10.1080/23251042.2018.1436891

Kiken, L. G., Garland, E. L., Bluth, K., Palsson, O. S., and Gaylord, S. A. (2015). From a state to a trait: trajectories of state mindfulness in meditation during intervention predict changes in trait mindfulness. *Pers. Indiv. Differ.* 81, 41–46. doi: 10.1016/j.paid.2014.12.044

Kormos, C., and Gifford, R. (2014). The validity of self-report measures of proenvironmental behavior: a meta-analytic review. *J. Environ. Psychol.* 40, 359–371. doi: 10.1016/j.jenvp.2014.09.003

Lange, F., and Dewitte, S. (2019). Measuring pro-environmental behavior: review and recommendations. *J. Environ. Psychol.* 63, 92–100. doi: 10.1016/j.jenvp.2019.04.009

Latkin, C. A., Edwards, C., Davey-Rothwell, M. A., and Tobin, K. E. (2017). The relationship between social desirability bias and self-reports of health, substance use, and social network factors among urban substance users in Baltimore, Maryland. *Addict. Behav.* 73, 133–136. doi: 10.1016/j.addbeh.2017.05.005

Lee, E., Park, N.-K., and Han, J. H. (2013). Gender difference in environmental attitude and behaviors in adoption of energy-efficient lighting at home. *J. Sust. Dev.* 6, 36–50. doi: 10.5539/jsd.v6n9p36

Loy, L. S., and Reese, G. (2019). Hype and hope? Mind-body practice predicts pro-environmental engagement through global identity. *J. Environ. Psychol.* 66:101340. doi: 10.1016/j.jenvp.2019.101340

Lucas, T., and Horton, R. (2019). The 21st-century great food transformation. *Lancet* 393, 386–387. doi: 10.1016/S0140-6736(18)33179-9

Lyubomirsky, S. (2020). *Subjective Happiness Scale*. Available online at: https://ppc.sas.upenn.edu/resources/questionnaires-researchers/subjective-happiness-scale (accessed January 24, 2020).

Lyubomirsky, S., and Lepper, H. S. (1999). A measure of subjective happiness: preliminary reliability and construct validation. *Soc. Indic. Res.* 46, 137–155. doi: 10.1023/A:1006824100041

Macdiarmid, J. I., Douglas, F., and Campbell, J. (2016). Eating like there's no tomorrow: public awareness of the environmental impact of food and reluctance to eat less meat as part of a sustainable diet. *Appetite* 96, 487–493. doi: 10.1016/j.appet.2015.10.011

Mackay, C. M. L., and Schmitt, M. T. (2019). Do people who feel connected to nature do more to protect it? A meta-analysis. *J. Environ. Psychol.* 65:101323. doi: 10.1016/j.jenvp.2019.101323

Mason, A. E., Epel, E. S., Kristeller, J., Moran, P. J., Dallman, M., Lustig, R. H., et al. (2016). Effects of a mindfulness-based intervention on mindful eating, sweets consumption, and fasting glucose levels in obese adults: data from the SHINE randomized controlled trial. *J. Behav. Med.* 39, 201–213. doi: 10.1007/s10865-015-9692-8

Matko, K., and Sedlmeier, P. (2019). What is meditation? Proposing an empirically derived classification system. *Front. Psychol.* 10:2276. doi: 10.3389/fpsyg.2019.02276

Mayer, F. S., and Frantz, C. M. P. (2004). The connectedness to nature scale: a measure of individuals' feeling in community with nature. *J. Environ. Psychol.* 24, 503–515. doi: 10.1016/j.jenvp.2004.10.001

Medvedev, O. N., Bergomi, C., Röthlin, P., and Krägeloh, C. U. (2018). Assessing the psychometric properties of the comprehensive inventory of mindfulness experiences (CHIME) using rasch analysis. *Eur. J. Psychol. Assess.* 35, 650–657. doi: 10.1027/1015-5759/a000453

Office for National Statistics (2019). *Overview of the UK Population. Overview of the UK Population August 2019*. Newport: Office for National Statistics.

O'Riordan, T., and Stoll-Kleemann, S. (2015). The challenges of changing dietary behavior toward more sustainable consumption. *Environment* 57, 4–12. doi: 10.1080/00139157.2015.1069093

Panno, A., Giacomantonio, M., Carrus, G., Maricchiolo, F., Pirchio, S., and Mannetti, L. (2018). Mindfulness, pro-environmental behavior, and belief in climate change: the mediating role of social dominance. *Environ. Behav.* 50, 864–888. doi: 10.1177/0013916517718887

Park, H. J., and Dhandra, T. K. (2017). Relation between dispositional mindfulness and impulsive buying tendency: role of trait emotional intelligence. *Pers. Indiv. Differ.* 105, 208–212. doi: 10.1016/j.paid.2016.09.061

Pelletier, L. G., Baxter, D., and Huta, V. (2011). "Personal autonomy and environmental sustainability," in *Human Autonomy in Cross-Cultural Context*, eds V. I. Chirkov, R. M. Ryan, and K. M. Sheldon (Berlin: Springer Science + Business Media), 257–277. doi: 10.1007/978-90-481-9667-8_12

Pelletier, L. G., Green-Demers, I., Tuson, K. M., and Noels, K. (1998). Why are you doing things for the environment? The motivation toward the environment scale (MTES). *J. Appl. Soc. Psychol.* 28, 437–468. doi: 10.1111/j.1559-1816.1998.tb01714.x

Pereira, P., and Forster, M. (2015). The relationship between connectedness to nature, environmental values, and pro-environmental behaviours. *Reinvention* 8, 1–9. doi: 10.1371/journal.pone.0127247

Perrin, J. L., and Benassi, V. A. (2009). The connectedness to nature scale: a measure of emotional connection to nature? *J. Environ. Psychol.* 29, 434–440. doi: 10.1016/j.jenvp.2009.03.003

Plamondon, R. (2016). *FAQ: Free Range and Yarding for Chickens | Practical Poultry Tips*. Available online at: http://www.plamondon.com/wp/faq-free-range-yarding/ (accessed February 17, 2020)

Richter, N., and Hunecke, M. (2020). Facets of mindfulness in stages of behavior change toward organic food consumption. *Mindfulness* 11, 1354–1369. doi: 10.1007/s12671-020-01351-4

Ryan, R. M., and Deci, E. L. (2017). *Self-determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness*. New York, NY: The Guilford Press.

Scarborough, P., Appleby, P. N., Mizdrak, A., Briggs, A. D. M., Travis, R. C., Bradbury, K. E., et al. (2014). Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. *Clim. Change* 125, 179–192. doi: 10.1007/s10584-014-1169-1

Schutte, N. S., and Malouff, J. M. (2018). Mindfulness and connectedness to nature: a meta-analytic investigation. *Pers. Indiv. Differ.* 127, 10–14. doi: 10.1016/j.paid.2018.01.034

Shapiro, S., Siegel, R., and Neff, K. D. (2018). Paradoxes of mindfulness. *Mindfulness* 9, 1693–1701. doi: 10.1007/s12671-018-0957-5

Singer, T., and Engert, V. (2019). It matters what you practice: differential training effects on subjective experience, behavior, brain and body in the ReSource Project. *Curr. Opin. Psychol.* 28, 151–158. doi: 10.1016/j.copsyc.2018.12.005

Stanszus, L. S., Frank, P., and Geiger, S. M. (2019). Healthy eating and sustainable nutrition through mindfulness? Mixed method results of a controlled intervention study. *Appetite* 141:104325. doi: 10.1016/j.appet.2019.104325

Steentjes, K., Pidgeon, N., Poortinga, W., Corner, A., Arnold, A., Böhm, G., et al. (2017). *European Perceptions of Climate Change: Topline Findings of a Survey Conducted in Four European Countries in 2016*. Cardiff: Cardiff University. Available online at: http://orca.cf.ac.uk/98660/7/EPCC.pdf (accessed June 18).

Steg, L., and Nordlund, A. (2018). "Theories to explain environmental behaviour," in *Environmental Psychology*, eds L. Steg, A. van de Berg, and J. I. M. de Groot (Hoboken, NJ: John Wiley and Sons Ltd), 217–227. doi: 10.1002/9781119241072.ch22

Steg, L., Perlaviciute, G., and van der Werff, E. (2015). Understanding the human dimensions of a sustainable energy transition. *Front. Psychol.* 6:805. doi: 10.3389/fpsyg.2015.00805

Steg, L., and Vlek, C. (2009). Encouraging pro-environmental behaviour: an integrative review and research agenda. *J. Environ. Psychol.* 29, 309–317. doi: 10.1016/j.jenvp.2008.10.004

Subar, A. F., Freedman, L. S., Tooze, J. A., Kirkpatrick, S. I., Boushey, C., Neuhouser, M. L., et al. (2015). Addressing current criticism regarding the value of self-report dietary data. *J. Nutr.* 145, 2639–2645. doi: 10.3945/jn.115.219634

Thiermann, U. B., and Sheate, W. R. (2020a). Motivating individuals for social transition: the 2-pathway model and experiential strategies for pro-environmental behaviour. *Ecol. Econ.* 174:106668. doi: 10.1016/j.ecolecon.2020.106668

Thiermann, U. B., and Sheate, W. R. (2020b). The way forward in mindfulness and sustainability: a critical review and research agenda. *J. Cogn. Enhancement*. doi: 10.1007/s41465-020-00180-6

Vago, D. R., and Silbersweig, D. A. (2012). Self-awareness, self-regulation, and self-transcendence (S-ART): a framework for understanding the neurobiological mechanisms of mindfulness. *Front. Hum. Neurosci.* 6:296. doi: 10.3389/fnhum.2012.00296

Van Dooren, C., Marinussen, M., Blonk, H., Aiking, H., and Vellinga, P. (2014). Exploring dietary guidelines based on ecological and nutritional values: a comparison of six dietary patterns. *Food Policy* 44, 36–46. doi: 10.1016/j.foodpol.2013.11.002

Vicente-Molina, M. A., Fernández-Sainz, A., and Izagirre-Olaizola, J. (2018). Does gender make a difference in pro-environmental behavior? The case of the Basque Country University students. *J. Cleaner Prod.* 176, 89–98. doi: 10.1016/j.jclepro.2017.12.079

Vieten, C., Wahbeh, H., Cahn, B. R., Maclean, K., Estrada, M., Mills, P., et al. (2018). Future directions in meditation research: recommendations for expanding the field of contemplative science. *PLoS One* 13:e0205740. doi: 10.1371/journal.pone.0205740

Wamsler, C., and Brink, E. (2018). Mindsets for sustainability: exploring the link between mindfulness and sustainable climate adaptation. *Ecol. Econ.* 151, 55–61. doi: 10.1016/j.ecolecon.2018.04.029

Wamsler, C., Brossmann, J., Hendersson, H., Kristjansdottir, R., McDonald, C., and Scarampi, P. (2017). Mindfulness in sustainability science, practice, and teaching. *Sustain. Sci.* 13, 143–162. doi: 10.1007/s11625-017-0428-2

Werner, A., Spiller, A., and Meyerding, S. G. H. (2020). The yoga of sustainable diets: exploring consumers mind and spirit. *J. Cleaner Prod.* 243:118473. doi: 10.1016/j.jclepro.2019.118473

Whitburn, J., Linklater, W., and Abrahamse, W. (2019). Meta-analysis of human connection to nature and proenvironmental behavior. *Conserv. Biol.* 34, 180–193. doi: 10.1111/cobi.13381

WWF (2017). *Eating for 2 Degrees New and Updated Livewell Plates*. Gland: WWF.

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"Health in" and "Health of" Social-Ecological Systems: A Practical Framework for the Management of Healthy and Resilient Agricultural and Natural Ecosystems

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The past two decades have seen an accumulation of theoretical and empirical evidence for the interlinkages between human health and well-being, biodiversity and ecosystem services, and agriculture. The COVID-19 pandemic has highlighted the devastating impacts that an emerging pathogen, of animal origin, can have on human societies and economies. A number of scholars have called for the wider adoption of "*One Health* integrated approaches" to better prevent, and respond to, the threats of emerging zoonotic diseases. However, there are theoretical and practical challenges that have precluded the full development and practical implementation of this approach. Whilst integrated approaches to health are increasingly adopting a social-ecological system framework (SES), the lack of clarity in framing the key concept of resilience in health contexts remains a major barrier to its implementation by scientists and practitioners. We propose an operational framework, based on a transdisciplinary definition of Socio-Ecological System Health (SESH) that explicitly links health and ecosystem management with the resilience of SES, and the adaptive capacity of the actors and

agents within SES, to prevent and cope with emerging health and environmental risks. We focus on agricultural transitions that play a critical role in disease emergence and biodiversity conservation, to illustrate the proposed participatory framework to frame and co-design SESH interventions. Finally, we highlight critical changes that are needed from researchers, policy makers and donors, in order to engage communities and other stakeholders involved in the management of their own health and that of the underpinning ecosystems.

Keywords: health, biodiversity, agriculture, social-ecological systems, resilience, co-learning

INTRODUCTION

The past two decades have seen an accumulation of theoretical and empirical evidence for the interlinkages between human health and well-being, biodiversity and ecosystem services, and agriculture (1, 2). The emergence of infectious diseases associated with human manipulations of animal species and their habitats can have significant impacts on human societies and economies, and on biodiversity conservation (3–5). The COVID-19 global crisis illustrated how devastating and persistent such a pandemic can be, calling for major changes of human-animal interactions: "If no changes are made, it is inevitable that zoonotic pathogens will continue to emerge and threaten global health and economies" (6). However, this is far from the first major pandemic in the history of humankind (7, 8). Major changes in attributes and intensity of agriculture, and the domestication of livestock species, had an important impact in perturbing local value chains and natural resources management, thereby amplifying the transmission rate of pathogens from animals to humans (9). The frequency and magnitude of emerging zoonotic diseases outbreaks have increased in recent decades, with a sequence of epidemics suspected to have resulted from human practices directly or indirectly impacting on wildlife ecology: Avian Influenza viruses, Nipah virus, SARS-Cov-1, MERS-CoV, and SARS-Cov-2, to name the most deadly. While there has been a proliferation of proposed approaches for improved and concerted human and animal health and environmental management, the lack of a common, coherent framework (10) and a consensus on what defines healthy social-ecological systems (SES) (11) have impeded operational implementation thus far (12, 13).

The productivity paradigm that has been dominating since the industrial revolution (14, 15) has brought human activities beyond Earth's capacity to sustain them, and many of the current public health challenges are directly linked to the degradation of ecosystems and the services they provide to humanity (16, 17). A decade ago, Rockström et al. (18) highlighted how the boundaries for a safe operating space for humanity have already been exceeded for several essential interlinked planetary systems, including climate change and rate of biodiversity loss, both linked to direct impacts on human, animal and environmental health (18). These trends have worsened, and additional key parameters are even more rapidly closing in on the safe boundaries (19). This is the case of global freshwater use (20) and the rate of land use conversion (19), which are two of the main factors associated with the emergence of human pathogens (21), and of biogeochemical flows of Nitrogen and Phosphorus. Among all the human activities that have detrimental environmental impacts, capitalistic intensive agriculture, part of a complex political ecology in which global to local dynamics of social and political power shape social-ecological change (22, 23), is a major force behind some of the most significant threats (24). This includes the conversion of natural habitats, degradation of soils and freshwater, and the contribution of greenhouse gases (25, 26). All these parameters have also been shown to impact negatively on the health of people, animals and plants. With the global human population expected to rise to between 9 and 11 billion by 2050, sustainable agriculture, food security and global health are at the forefront of the global development agenda (27, 28).

Among the diverse array of opinions and recommendations on COVID-19 crisis management, several scholars have called for a *One Health* approach (29–32) echoing earlier calls for the management of MERS coronavirus outbreak (33). The recognition of the interdependencies between the health of humans, non-human-animals and ecosystems, may seem relatively new for the general public and some decision-makers, although it has already generated a considerable amount of literature (34). Since the initial elaboration of an "ecosystem approach to human health" (35), several systemic approaches to health have been developed, including the *EcoHealth* (36) and *One Health* initiatives (37), ultimately converging (38, 39), and Planetary Health. There has been increasing acknowledgment, at least among scientists and some policy makers, that health and environmental issues must be managed holistically across multiple bio-physical, economic and social scales and across landscape, national and global levels (40–42).

One Health integration has been impaired by animated debates between divergent disciplines (38, 39, 43), competing schools of thought (44) and delayed convergence of relevant systemic and participatory modeling approaches (45, 46), that have constrained effective interdisciplinary and cross-sectorial collaborations (47). While efforts have been made to implement *One Health* approaches in practice (48, 49), there is still an acute need to operationalize health management based on a social-ecological system and resilience framework (12, 13) that recognizes power dimensions in the "coupling" of human and natural systems (22, 23). The multiplicity of competing "systemic holistic approaches" to health have added to the confusion (39, 50). Antoine-Moussiaux et al. (10) argue that the main barrier to inter- and trans-disciplinary solutions to improve the management of health risks and benefits lies in the lack of reflexivity and reflection by scientists about their respective

operational framing, which is also acknowledged by Wilcox et al. (12), along with the ill-defined problem structuring of policy makers (51). In this paper we highlight the main theoretical and practical challenges that have precluded the full development and implementation of collaborative and participatory integrated approaches that support collective actions in health. We propose an operational framework, based on a transdisciplinary definition of Social-Ecological System Health (SESH) explicitly linking health and ecosystem management with the adaptive capacity of the actors and agents of coupled social-ecological system to prevent and cope with emerging health and environmental risks. We focus on agricultural transitions which play a critical role in both disease emergence and biodiversity conservation, and highlight critical process changes that are needed from researchers, practitioners, policy makers and donors, in order to engage communities and other stakeholders involved in the management of their health and that of the ecosystems that underpin it.

METHODS

Social-Ecological System Health: Framing Health in Nature and Society

A critical step in inter-disciplinary and cross-sectoral *One Health* collaborations lies in the way questions and issues are framed (10, 13), especially when addressing complex inter-linkages such as the Health-Biodiversity-Agriculture nexus (52). Despite repeated early calls for closer collaboration, the medical and veterinary spheres (53, 54), and the environmental (55) and social sciences (37, 56), have struggled to establish strong, long-lasting collaborations grounded on a clear shared framework (10, 57). *One Health* has been presented as an approach to address health threats at the "human-animal-environment interface", also referred to as "human-animal-ecosystem interface" (34, 58), with both formulations used interchangeably by the same operators, including the tripartite coalition of UN agencies spearheading the concept (59, 60). Beyond the semantic debate, these ambiguities illustrate the confusion as to the framing of the proposed systemic approach, which has been a major factor contributing to the misunderstanding between disciplines (56), and a barrier for inter- and trans-disciplinary solutions to improve inter-sectoral management of health risks and benefits (10). Clearly it is of paramount importance to define the boundaries and the components of the complex system through which the approach analyses health and environmental issues, as it may refer to very different definitions of health and contrasted views about human-nature relationships (i.e., are humans, and non-human animals, part of ecosystems or outsiders?), which are supported by distinct disciplines and management sectors. Defining and comparing all the various holistic approaches to health that have been proposed in recent decades is beyond the scope of this paper, and we refer to recent review papers for an exhaustive list and more details regarding each approach (12, 34, 50). As illustrated in **Figure 1**, approaches to health and environmental management have progressively converged (61), and two main frameworks should be distinguished, based on the spatio-temporal boundaries of the systems and the health outcomes considered by each approach:

1) Health(s) ***within*** Social-Ecological contexts: Initially presented as an analogy (health of organisms ∼ health of human, or animal populations, or other components of the ecosystem), health issues have been progressively included within increasingly complex social-ecological contexts, and at larger levels: Human-Animal-Wildlife-Ecosystems-Biosphere (62). The focus of the management or research activities remains on the health of the "nested" object (human, or domestic animal, or wildlife etc.), situated in its social and ecological contexts. Different approaches have been successively defined depending on which health components of the system they focused on, and the associated disciplines (34): *One Medicine* focusing on Human-Animal interactions, *Ecosystem Health* promoting linkages between ecology and medicine, *Conservation Medicine* focusing on biodiversity conservation and wildlife health, and *Global health* placing a priority on improving health and equity for all people worldwide (63).

2) Health ***of*** Social-Ecological Systems: complex human-environment systems are best defined as coupled social-ecological systems (64, 65). The health of these complex adaptive systems has been related to the concept of resilience [SESR; (12)], as proposed seminally by Holling (66) for natural ecosystems and further adapted to social-ecological systems (12, 67). The integrated approaches under this group are bound to adopt a more holistic perspective, accounting for influences across wider temporal and spatial scales, and a wider range of stakeholders, for which transdisciplinary is essential (68). The integrated approaches under this group include *EcoHealth*, defined as systems approaches to promote the health of people, animals, and ecosystems in the context of social and ecological interactions (69), *Planetary Health*, defined as the health of human civilizations and the natural systems on which they depend (16, 70), and some of the latest developments of "One World One Health TM"/*One Health* (34). *One Health* promotes interdisciplinary collaborations to optimize the health of people, animals and the environment, which falls under "Health *within* SES" category. However, *One Health*, embedded within the concept of *EcoHealth* thinking, was further extended to complex human-environment systems (71), ultimately addressing "Health ***of*** SES" as well as "Health ***within***". The holistic understandings of some Indigenous societies, in which human and ecosystem health are regarded as closely interdependent, are also consistent with this perspective (72, 73).

A Transdisciplinary Context-Dependent Definition of SESH

Social-Ecological System Health is a comprehensive, multi-scale, and dynamic measure of the state/health of a functional social-ecological system, capable of delivering health and well-being resulting from the state/health status of its main components (e.g., human health, animal health, environmental health, and socio-economic health), and from the interactions among these individual health components. As suggested by Wilcox et al. (12) the resilience of such systems [SESR as defined in

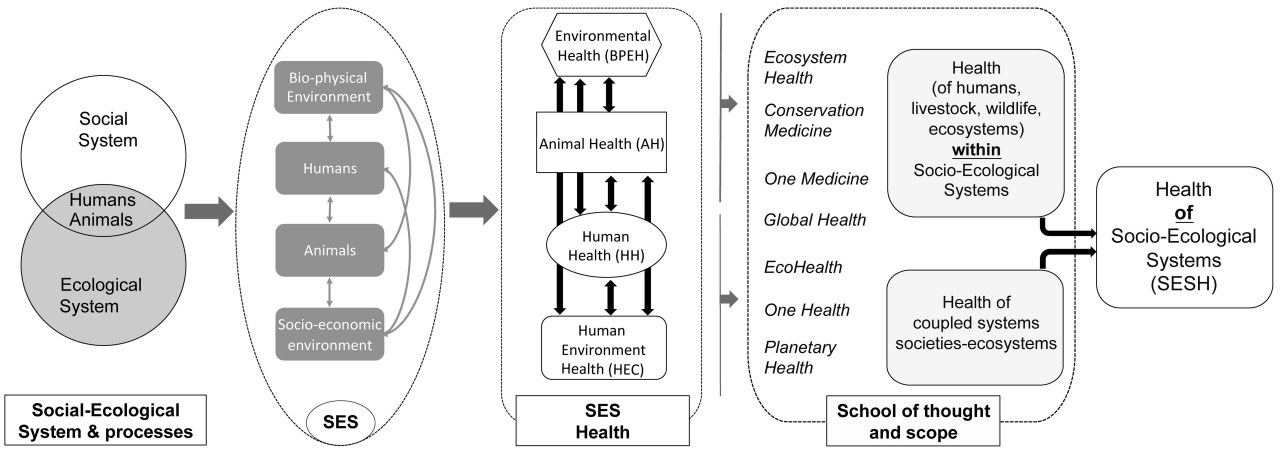

FIGURE 1 | Expanding the concept of social-ecological systems to Social-Ecological System Health. Conceptual model connecting a social-ecological system template to the health of its components and the health of the whole social-ecological system (left and central parts of the graph); main integrated approaches associated with the specific health components and their interactions [definitions as in (12, 34); right part of the graph]. BPEH, bio-physical environment health; AH, Animal Health; HH, Human Health; HEC, Human Environment Health; SESH, Social-Ecological System Health.

Social-Ecological Systems theory; (66)] is an essential property associated with their adaptive capacities. Health is a central criterion for the sustainability of social-ecological systems (36), and SESR is thus closely dependent on SESH.

Figure 1 illustrates how the health/state of the various components of the SES are interdependent and contribute to the health/state (i.e., resilience and its related attributes) of the whole system, including humans (and their institutions and governance systems, cultures, economic systems and power relations and influence) as an integral part of the ecosystem. As the proposed SESH concept aims to provide a catalyst for interactions between those investigating, those generating, and those responding to interlinked health and environmental issues, viewed from biomedical, ecological, socio-cultural and economic perspectives (43), the SESH operational framework explicitly includes the following components easily identifiable by the operators:

- Health of Humans (HH), Animals (AH, including domestic and non-domestic animals) as components of the health status of social-ecological systems (37), which are the focus of public and veterinary health interventions, including the prevention and control of zoonotic and vector-borne diseases and other biological threats (74). Plant Health (PH) may also be highlighted in contexts where crop production and protection are prominent (see **Figure 2** and **Box 2**). Alternatively, plant health may refer to plant species diversity, in which case crop plants will be included in the health of the environment component (BPEH, see hereafter) associated with all plant species, often together with animal biodiversity/wildlife.

- Health of the Environment: this includes the bio-physical Environment (BPEH), which relates to actions aiming at preserving biodiversity and ecosystem integrity (75), and at maintaining environmental health above the "critical natural capital" necessary to provide essential services for the health and well-being of communities (62, 76), which are typically the focus of interventions promoting biodiversity conservation and community based natural resource management; Health of the human environment (HEH), corresponding to the components of the social, cultural and economic environments, including the institutions and legal setups, that contribute to health and well-being of communities (77) and are key components of SESH, and maybe aggregated with SESH, or singled out as Health component contributing to SESH. The Health of the Human Environment may include collective resources such as social capital (78) and solidarity (79), efficient governance systems (80), and all social determinants of health considered as public goods or within a commons health approach (81).

- Social-Ecological System Health (SESH) is directly linked to the capacity of the system to sustainably deliver health to the different constitutive components, which links to the definition of the resilience of a SES, and has been typically targeted by sustainable development and resilience building projects (12, 82).

Since the early conceptual developments of ecosystem health in the early 1990's, ecologists and environmental scientists have questioned the appropriateness of the *Ecosystem Health* concept, overwhelmingly rejecting the idea that it can be measured as an objective, quantifiable property of an ecosystem (83), and questioning the superorganism paradigm of ecosystems that assumes an equilibrium in reference to a desirable and stable state (75). In contrast, the theory of social-ecological systems has robustly defined the concept of resilience, which does not assume the existence of equilibrium states and "measures the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" (66). This approach acknowledges the possibility of the existence of multiple stable states, and resilience is related to how actors navigate systems changes across these states (67). We have also seen, in recent years, more calls for a "personalized ecology" (84), especially in line with human–nature interactions at the level of individual people, driven by concerns around "unhealthy" human–nature interactions, which

STEPWISE SEQUENCE

STEP 1. Preliminary definition of SESH **in reference to a specific intervention (SESHI)** in agriculture/health/environment (e.g. new farming practice, vaccination campaign, protected area), in a specific context (area, stakeholders,…)

STEP 2. Define the **boundaries of the SES of interest** in reference to the intervention (step 1.), **and identify groups of relevant stakeholders** (government officials, donors, decision-makers, managers, and experts/ academics; communities, local authorities, extension officers, practitioners and experts)

STEP 3. participatory **co-construction of the conceptual SESH model** HH/AH/ SEcH/EH/SESH (dynamics, interactions, impacts)

STEP 4. co-construction/negotiation of Indicator variables for each Health component (and interactions), and define/ negotiate **acceptable range for each Health component/indicator**

STEP 5. implement SESHI, **monitor variable-indicators**, **model/assess trajectory of the SES** (SESH from T0 to T0+t)

STEP 6. Revise/propose new intervention
(back to step 1.)

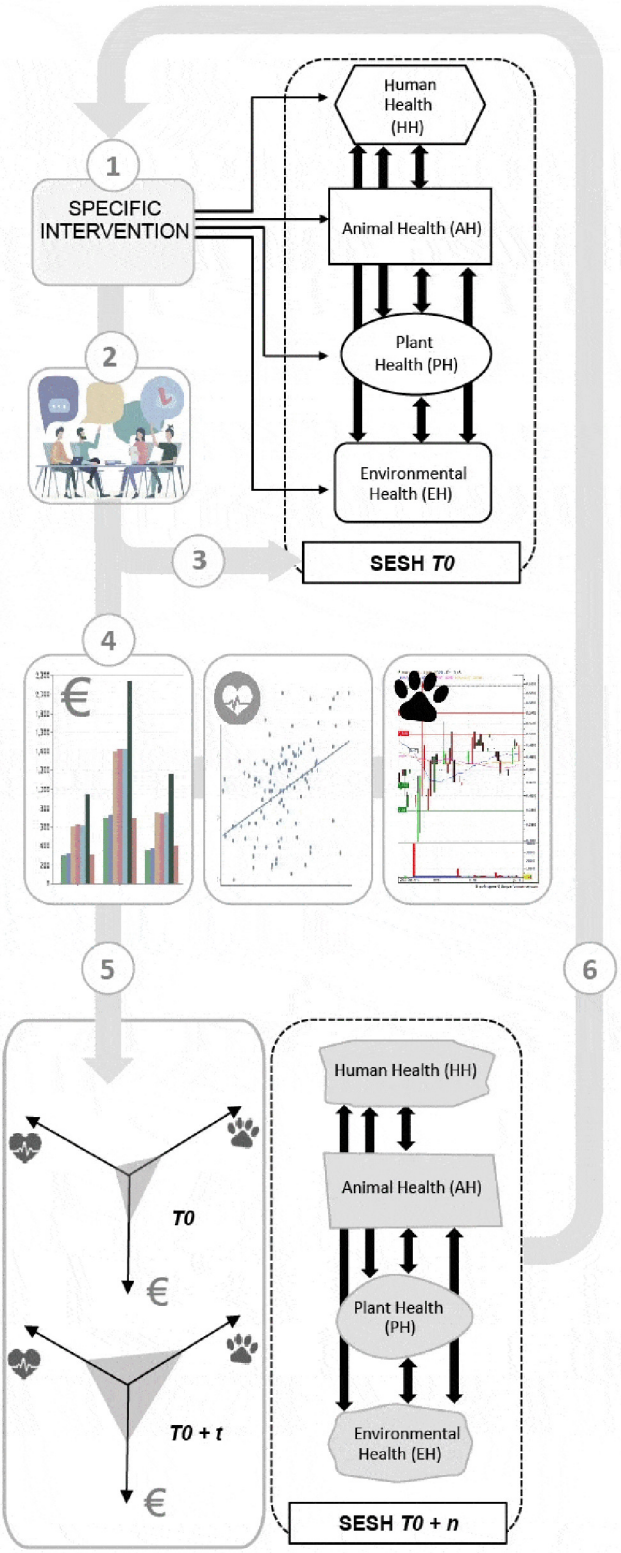

FIGURE 2 | SESH operational stepwise approach.

have undoubtedly further increased worldwide after the COVID-19 pandemic. There are several examples that illustrate how health and well-being may be framed from the perspectives of place-based communities (85, 86). Further, elaborations of resilience thinking have pointed out the importance of power relationships (and social diversity) in creating the varying and changing social-ecological conditions and processes which frame ecosystem health (87). In essence, the characterization of SES, in which humans are part of nature, may not be independent from anthropogenic views (88). Rather, the SESH approach suggests that the state of the local SES can be defined in a context-dependent way, which may nevertheless be used as a robust reference point by a group of stakeholders in order to navigate their health and its linkages within their specific SES (89). Health, and illness, are social constructions, deeply ingrained in the culture and history of the social groups which define them (90). Similarly, SESH should be viewed as a transdisciplinary context-dependent participatory exercise, a place-based process during which the framework, its constitutive components and how they interact, are co-designed with the local stakeholders (i.e., designed collaboratively by adding/removing/modifying components and interactions in order to ensure that they match the local context, knowledge and understanding of the issues at stake). The proposed SESH framework should be flexible and negotiable according to the context and the objectives of the intervention, and should not appear as a top-down imposed view. However, it is important that the initial framework proposed for the co-design team does explicitly mention the main health components, usually targeted by each sectorial operator (human and animal health, plant and crop health, biophysical environment, human environment), and allows for the clarification between "health in" vs. "health of" ecosystems as illustrated in **Figure 1**.

SESH Operational Framework

Each SESH intervention should be negotiated with key stakeholders as a transformational sustainability intervention (91) addressing a specific problem that they have identified as affecting locally their health or their environment. A shared conceptual framework is essential for such transdisciplinary initiatives open to subsequent revision, adaptation and adoption by stakeholders (92), especially for health related issues (10). We propose an operational framework divided into successive steps organized in an iterative action-research process (12, 48, 93), to co-design a context-dependent SESH conceptual model, and co-design, implement, monitor and evaluate a practical field intervention (**Figure 2**). We illustrate the first steps of the proposed SESH transdisciplinary process with examples of projects workshops aiming at accompanying agro-ecological transitions in agroecosystems (i.e., social-ecological systems where human manipulations alter natural ecosystems).

Firstly, the process must be acknowledged as necessary/desirable by a majority of people in the local communities in order to address a problem associated with their lived context. This should be followed by the initial identification of some particular "intervention" aiming at modifying one or several health components (e.g., improved crop health resulting from an innovation in agriculture practice, increased biodiversity following the protection of natural habitats, human health benefits of alternative livestock disease control, etc.). This step sets the reference which will begin to define the dynamics of the SES, and upon which further contextualization and integration will be built (**Figure 2**/Step 1).

The next steps (**Figure 2**/Steps 2–4) are similar to those suggested for the definition of participatory sustainability indicators (94), adopting a participatory modeling approach to define the boundaries of the SES (e.g., village, river catchment, sub-district…), involving the relevant groups and legitimate actors, co-designing the conceptual models representing the linkages between SESH and its components parts (through iterative negotiations), as well as predicting/evaluating the impacts of the intervention. Step 4 plays a key role in the participatory process as it consists of the negotiation of indicator variables that will be used to monitor the change in the SES, including developing a consensus regarding the acceptable range of each indicator variable. Such indicator variables may include quantitative variables (e.g., levels of antibiotics or pesticides residues in the aquifer, financial benefits of organic farmers, number of birds…), and qualitative variables (e.g., self-assessed individual health and well-being, organization of market-chains, innovations in agroecological practices…), identified by the stakeholders as relevant to reflect the trajectory of their SES. This key step involves co-learning and negotiation among stakeholders, including donors, managers and decision makers for performance indicators, and communities, practitioners and local authorities for monitoring of the intervention (**Figure 2**/Step 4). The participants are invited to share and blend local and scientific knowledge in order to co-design variables indicators of key health/conservation/resilience and evaluate the costs and logistics of the associated research and training programs. This step also clarifies roles and responsibilities regarding the measurements of the indicators and how they will be used, and by whom, thereby building ownership of the process beyond the trans-disciplinary cognitive exercise. This also allows for the identification of necessary innovations, social and otherwise, which will contribute to improve the health of individual components, and the adaptive capacity of, the SES of interest.

The last steps (**Figure 2**/Steps 5 and 6) are dedicated to the implementation and monitoring of the intervention, with the participatory assessment of the trajectory of the SES, in order to revise the intervention and the conceptual SESH model, back to the initial step in an adaptive management iterative loop (89).

SESH Framework in Practice

The proposed SESH framework has not yet been used to support the full cycle of a project co-design, implementation and monitoring, as described in **Figure 2**. However, we report hereafter on two practical examples for which the framework has proved useful to initiate the first phases of the process (steps 1 to 3; **Figure 2**) in the context of agricultural transitions. We present a summary of these applications with transdisciplinary groups

BOX 1 | Using SESH as a heuristic for a transdisciplinary vision of agro-ecological systems in transitions: livestock mobility in highlands landscapes of South-East Asia.

Context of application and stakes: overview of livestock-related challenges in South-East Asia

Livestock management exemplifies the notion of a social-ecological system under transition. As a production system, livestock (i) plays an essential role in securing the livelihoods of millions of small-scale farmers; (ii) often contributes to the social identity of the place; (iii) shapes the natural environment through grazing and mobility patterns; (iv) is an interface between humans and wildlife; and, (v) is impacted by multiple social-ecological feedbacks. In South-East Asia, as in most regions across the world, livestock producers are challenged by social, economic and ecological dynamics such as competing claims for space and feeding resources, and the need to integrate crop- and livestock-systems, market fluctuations, and issues around the traceability of animals and animal products, zoonotic diseases, biodiversity loss, or climate change. These seem to call for an agro-ecological transition of the sector. Rethinking and transforming the management of livestock movements could be key to addressing some of the challenges faced by small-holder, extensive livestock production systems in SE Asia.

A transdisciplinary group to address complex agro-ecological systems dynamics

The issues associated with livestock mobility are particularly acute in the mountainous regions of northern SE-Asia, where this work was situated. To explore these challenges and potential solutions, we invited 20 participants from different backgrounds and expertise to participate in 3 days' workshop in Hanoi in December 2019, including: 2 livestock farmers; 1 local government services (DARD) representative from a province in the Northern highlands of Vietnam; 7 Vietnamese researchers (NIAS and TUAF); 12 regional and international researchers (KU, CIRAD, CIAT, ILRI); and, a Vietnamese-English translator.

Objectives: Co-designing action-research activities based on a shared SESH framework

The objective of the workshop was to produce a concept-note for a regional action-research grant application. This was done through collective discussions aiming at negotiating a shared context-based definition of SESH, which was then used to identify gaps in our understanding of livestock mobility management and related social-ecological challenges and stakes, and ultimately identify a first group of action-research questions and methods to address these.

Implementation and outputs of the SESH process

We mobilized the SESH framework as a heuristic to frame systemic thinking and collective discussions within this heterogeneous group. Using several facilitation methods (i.e., sticky notes, conceptual mapping, theory of change), we explored participants' visions of animal, plant, human and environmental health, and identified basic indicators for each. This stage allowed participants to enrich the shared definitions of health and well-being as well as collectively highlighting the interlinkages between SES components. We then proceeded to collectively producing a conceptual model of the SESH of livestock-based systems in the area of interest, and agreed upon the general ambitions of the upcoming project: *"Improve sustainable health and well-being of small scale livestock farmers, animals and the environment by (i) co-developing and promoting access by women and youth to innovative technologies and approaches, and, (ii) promoting healthy interactions between the components of the social-ecological system to improve the knowledge and management of livestock mobility within landscapes of SE Asia."* Finally, we identified 4 clusters of specific objectives and related activities to achieve our ambitions: conducting a baseline survey and identifying target population for the project interventions, developing adapted tracking devices for livestock, co-designing innovative livestock management practices with a pilot group, and scaling up/scaling out these practices.

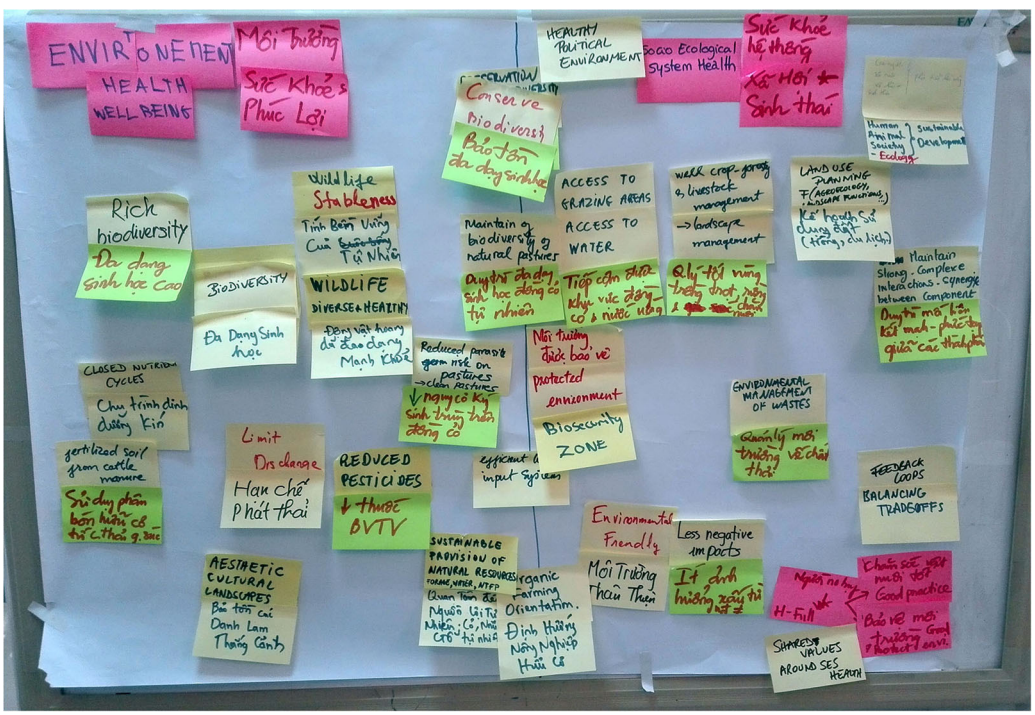

FIGURE 3 | Key words and concepts suggested by participants for the collective definition of a context-based SESH of livestock-based systems (Hanoi, Vietnam, December 2019). The picture shows two the four boards produced (Environment Health, Socio-Ecological System Health) to co-design the components of the system (see **Figure 2**, steps 1–3). All key words and concepts were written in English and Vietnamese, and all discussions were expressed in any of these two languages and simultaneously translated.

BOX 1 | continued

Conclusion: the added value of using SESH-operational framework

Challenges caused and faced by livestock production in SE Asia cover a wide range of domains and in many regards, they are wicked problems which call for innovative approaches. As a heuristic, SESH constituted a relevant frame within which all participants could think, share, discuss and collectively apprehend complex social-ecological dynamics. Throughout the 3 days' workshop, SESH proved to be an effective bridge between the disciplines and domains of knowledge represented: local knowledge and expert knowledge, veterinary sciences, ecology, epidemiology, agronomy, electronic engineering and resilience science. As an operational framework, it allowed the group to produce a concept note articulating heterogeneous visions and ambitions, and identifying practical needs and research frontiers, which corresponds to steps 1 to 3 of SESH framework (**Figure 2**).

of researchers, agriculture extension officers and farmers in Asia (**Box 1**, **Figure 3**) and in Europe (**Box 2**, **Figure 4**).

Participatory Methods for SESH Process

The practical implementation of the proposed SESH framework may draw from several tools and methods developed for similar participatory processes (45). For instance, the Companion Modeling approach (95) can be adapted to define the boundaries of the SES, to map the stakeholders' interactions and the resources they mobilize, and to co-design the conceptual SESH model and the interactions and dynamics of the SESH components in reference to the intervention (**Figure 2**/Steps 2–4; **Box 1**). Companion Modeling involves the different stakeholders of a given SES, together with decision makers and researchers in identifying the problems they face in the context of their SES, co-develop a model (interaction diagrams, maps, etc.) of the dynamics and processes specific to their SES, and simulate the expected consequences of their actions. For example, it was used for health and environment management at the scale of municipalities in Thailand (96), and with villagers in Cambodia to produce transdisciplinary epidemiological models implemented in the form of a role playing game about zoonotic disease transmission (97). The approach allowed stakeholders at local village to explore the value of cooperation between the sectors concerned (e.g., environment, agriculture and public health) and actively revise the proposed health and environment interventions. The example presented in **Box 1** illustrates how a Companion Modeling approach allowed the co-design of a SESH conceptual model in relation with the intensification of livestock production in Northern Vietnam, including the definition of the system's boundaries, health components of SESH and their interactions.

Several related outcomes- and learning-based methodologies can be used to support the SESH framework intervention, and the supporting participatory modeling approach described above. For example, a Theory of Change approach (98) can provide a framework that enables stakeholders and decision makers, from all levels (local to transnational), to exchange views and visions of the future and identify the range of resources, activities, intended outcomes, and underlying causal assumptions underpinning wider program success. Allen et al. (99) illustrated how the use of an outcomes-based approach in conjunction with decision support revealed the underlying causal assumptions underpinning wider program success with a diverse group of stakeholders in Southern Asutralia including farmers, researchers, conservation managers. The use of a Theory of Change associated with a SESH logic model made the causal relationships among the health components (within/of) of agro-ecosystems more visible, and proved very useful to indicate different outcomes for the groups of stakeholders involved in the workshops addressing agricultural transitions (**Boxes 1**, **2**).

A key aspect of the SESH process that we have not yet implemented in practice, will be the negotiation and implementation of the monitoring and evaluation system (steps 4–6, **Figure 2**). The negotiation of SESH indicators will be an output of both the Companion Modeling and Theory of Change processes initiated, including a consensus regarding the acceptable ("healthy") ranges of values within which these indicators may fluctuate in response to the SESH intervention. Outcomes mapping and harvesting is a related methodology that can help increase the visibility of the boundaries, gaps, and ties that characterize social networks across the continuum of health care systems (100). The adoption of a system viability framework may allow participants to characterize a range of strategies for maintaining the long-term survival of their particular system of interest, as demonstrated in response to environmental challenges in South America (101). We suggest that this approach could be adapted to model the "negotiated viability domain" of SESH, as a measure of the co-viability of Social and Ecological Systems (102). Flexible budgets that support an adaptive management approach are also needed in order to make the operational SESH framework possible in complex environmental and social settings. It is important to have linked performance management and evaluation approaches that enable the different elements in such complex interventions to be constantly reviewed and adapted.

Co-learning among the participants is a crucial aspect for the success of SESH, and requires specific monitoring throughout the process, especially to assess whether co-learning has occurred during co-design of the model and the indicators (**Figure 2**/Steps 3–4), and before revising the conceptual model and revising interventions through learning loops (89) (**Figure 2**/Step 6). The active and systematic facilitation and measurement of learning implies that SESH projects must explicitly aim to reveal the *ex-ante* knowledge and belief orientations of decision makers, and the factors likely to either influence the fate of new knowledge and beliefs, or mobilize new knowledge configurations *ex-post* participation in the SESH process. elaborated monitoring and evaluation methods, such as those developed by Smajgl and Ward (103, 104) and applied at national and supra-national levels with

BOX 2 | Using SESH as a heuristic for a transdisciplinary vision of agro-ecological systems in transitions: livestock parasite control in biodiverse landscapes of Southern France.

Context of application and stakes: challenges of controlling ticks and tick-borne diseases at the socioecological system level in South of France (Millau)

On the periphery of Montpellier (South of France), agricultural intensification, climate change, and various forms of land use planning, have major impacts on the health of humans, animals and the ecosystems. The management of parasite infestations on livestock farming, and in particular the risks associated with ticks and tick-borne diseases, is challenging because this problem requires consultation among stakeholders who are not used to cooperating (no dedicated institutional structure), each with a different vision of the key issues at the scale of their territory. This work focused on the area of the "Grands Causses" Regional Park, a socio-ecological system rich in biodiversity, and with a diversity of landscapes.

This region is home to numerous activities that are regulated within the framework of a charter for sustainable tourism. It hosts social groups with very varied interests, including sheep breeders who supply products to the prestigious Roquefort cheese industry. Ticks represent risks in terms of loss of sheep production performance, in terms of the risk of chemical contamination of the environment (via acaricide medication), and in relation with potential transmission of zoonotic diseases to humans (Lyme disease and Crimean-Congo haemorrhagic fever).

A transdisciplinary process to address complex systems dynamics

In February and March 2020, we proposed to local actors a modified SESH conceptual framework to address these risks. The SESH outlined a transdisciplinary approach aiming, in the long term, to accompany the co-construction of management principles shared by researchers, private actors, local institutions, and citizen groups. The next step in our approach aims to bring out health indicators of socio-ecological systems that make sense locally, and can guide collective actions to control and monitor ticks and tickborne diseases, and meet the needs of local actors in a context where there was no official institutional structure in place to deal with these risks.

Objectives: define a shared framework to address local Social-Ecological System Health and identify local needs and knowledge gaps

The project focused on launching a process for ticks and tickborne diseases with local stakeholders (medical doctors, veterinarians, breeders, technicians, biodiversity management associations, national park manager) by combining a phase of individual interviews involving the actors of the territory, and a phase of exchanges with these actors, to lay the foundations of a co-construction process based on a common representation of the health issues of the territory, which will make it possible to collectively negotiate the integrated management of the risks associated with ticks. In particular, we questioned the current methods of tick management and their consequences, the actions of surveillance, control, and prevention, the actors involved, and the vision that the local actors have of the stakes associated with a "*One Health*" type approach. Based on the analysis of the discourse of the local actors, we have updated the representations they have of the attributes of human, animal, environmental, plant and territorial health (**Figure 2**). This analysis was presented and discussed during a workshop where all the people interviewed were invited. This allowed us to discuss perspectives for managing the risks associated with ticks that [1] make sense at the level of this territory, [2] meet the needs of local actors, and [3] would improve the overall health of the socio-ecological system.

Implementation and outputs of the SESH process

The conceptual framework that guided our analysis of the discourse of local stakeholders in Millau had emerged from discussions among international researchers during a workshop ("Santé-Territoire," Novembre 2019). The original SESH framework (**Figure 1**) was mobilized as a heuristic to frame systemic thinking and collective discussions. Using several facilitation methods (i.e., sticky notes, conceptual mapping, theory of change), we explored participants' visions of human health, animal health, and environmental health. Plant health was added as a component to echo the importance of crop production and agronomy in the context of agro-ecological transitions. Each health component was identified by basic cross-cutting attributes, as well as emerging attributes at the level of the territory, linked to the agroecological transition process. Then, we used this modified conceptual framework to classify the expression of ideas from local actors, and for the elicitation of their needs and priorities (**Figure 4**).

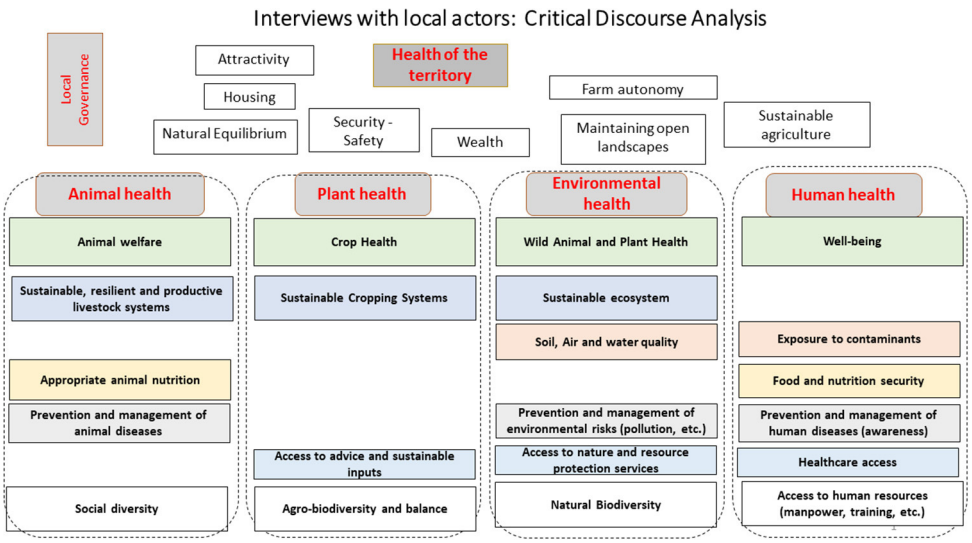

FIGURE 4 | Attributes of the Health of the Territory, following a critical analysis of local stakeholders' discourses using a framework derived from SESH framework (**Figure 1**) to account for the specific context of agroecological transitions in Southern France.

BOX 2 | continued

Conclusion: the added value of using the SESH-operational framework

The complex challenges identified for an integrated management of ticks and tick-borne diseases at local level called for a shared conceptual framework to elicit local stakeholder views and needs. This first step in the design of such a co-conception approach was enabled by the flexibility of the SESH, the framework being proposed as a tool to be modified and redesigned in order to fit local context's specificities and actors views and priorities. In the Millau experiment, SESH framework was first mobilized as a heuristic by researchers in order to conceptually address health at territory level and to integrate human, plant and animal health's attributes within the agroecological transition framework (Santé-Territoire). Then, we used this modified framework to elicit local stakeholders' views and needs regarding ticks and tick-borne diseases management, and to explore the desirable changes in practices, knowledge and interactions needed at local level.

decision makes of the Greater Mekong Subregion (103, 104), may be modified to the requirements of social and ecological systems health, geared toward learning throughout each step of the SESH process (**Figure 2**). In practice, the measurable learning exercise requires: (i) explicit articulation of stakeholders' visions of a desirable, plausible future; (ii) measurement and recording of extant causal beliefs; (iii) controlled introduction of new knowledge; and, (iv) measurement and recording of changes to causal beliefs, value orientations and attitudes throughout a structured set of facilitated discussions as a measure of learning.

DISCUSSION

The COVID-19 pandemic has dramatically highlighted to decision makers, managers and the general public worldwide the crucial need to understand, and adaptively manage, the complex inter-linkages between health and biodiversity, and the human and bio-physical environments. Focusing on health, both as an essential desirable state of social-ecological systems, and an expected outcome of their sustainable functioning, is a powerful way to frame sustainable development interventions. This focus on health as a strong and consensual leverage point for collective actions toward sustainable development (105) is likely to promote reconciliation of the gap between sectoral interventions in ecosystem management, biodiversity conservation and public and veterinary health (12, 47). We concur with earlier suggestions that the social-ecological system theory, and the associated concept of resilience, offer an appropriate theoretical background (12, 45, 106). However, using the concept of resilience to operationalize holistic approaches for integrated health and environmental management interventions requires clarification about the framing of issues of concern and active engagement with stakeholders at relevant levels (13).

Resilience means different things for different groups of scholars and practitioners, and it is, unfortunately, seldom clearly defined and measured, even among the members of the "resilience thinking" schools of thought (107). In health, Morand and Lajaunie (102) showed that resilience has several different meanings, for instance in psychology, sociology of health, health care or public health systems. For projects that focus only on the resilience of human and ecological communities, the implementation in practice is often less than optimal because of the absence of a common lexicon and clearly framed objectives agreed to by resilience scholars, practitioners, local communities and stakeholders (108). For integrated holistic health and environment management projects, it is of paramount importance to frame the issues related to public, veterinary and environmental health, and that these are clearly identified and articulated with reference to the resilience of coupled social-ecological systems.

The proposed operational Social-Ecological System Health (SESH) framework emphasizes the opportunity for inter-disciplinary and multi-sectoral project management teams to negotiate interventions with communities and stakeholders at an early stage through a co-designed conceptual model. A SESH participatory process allows the clarification and joint definition of the boundaries of the socio-ecosystem, and the interlinkages between the health components and attendant resilience ("Health within" vs. "Health of SES"). The proposed co-design process, which leads to the development of a common language and framing of the health and environment issues, is likely to transcend the barriers for inter- and trans-disciplinary collaboration that currently constrain collaborative inter-sectoral solutions (10, 47). In addition, and most importantly, health is a social construct (102), deeply rooted in the culture, history and norms shared within social groups and shaped by their ecosystems. The definition of healthy ecosystems is, therefore, necessarily a place-based process, likely to emerge from a transdisciplinary definition with disciplinary experts (medical doctors, veterinarians, ecologists, epidemiologists, social scientists), decision makers, local communities and stakeholders. Because such a participatory definition accounts for and understands local human, environmental, and spiritual aspects that are often overlooked in standard health assessments (86), it is likely to lead to a more consensual definition of healthy ecosystems (11), while empowering the participants to take part in the management of their health and environment.

Conventional equilibrium approaches to managing human, economic, and natural resources are prone to failure because they do not capture the dynamic interactions between humans and the constantly changing contextual environment. Health and environmental issues are often embedded in complex cross-scale and cross-sectorial interactions, and more often than not can be considered as "wicked" or "messy" issues, characterized by high levels of uncertainties and equally high stakes. As a result, they escape definitive formulations and defying absolute solutions, and only allow relative remedies (109, 110). The extent of contested values, and the capacity of affected interests to negotiate competing claims, are crucial political factors

(111, 112). Laswell (113) emphasized the interdependence of knowledge contributions and value classes in a context of policy argumentation, challenging the efficacy of linear instrumental and conceptual models to explain science-policy interactions and the willingness of decision makers to utilize scientific knowledge.

These issues challenge the "conventional" approach whereby a management strategy is legitimate because it is designed by experts who resort to robust methodologies to predict and anticipate the outcomes of their actions. In such situations, legitimacy can only exist through the social consent of those likely to have a stake in the research/policy formulation or its consequences (114–116). Decision makers regularly deploy strategies to reduce the complexity of policy choice arenas, minimizing scrutiny of proposed initiatives and limiting the exploration of alternatives that correspond with stated objectives (103, 117, 118). Common strategies involve containment biases that either limit or omit the representation of contested values, or restrict knowledge and arguments to those that correspond with criteria acceptable to current political beliefs (111). Gasper and Apthorpe (119) and Cornwall (120) argue that containment biases are a function of existing power relations, constraining social values and actions, framing problems and policy solutions, and thus legitimizing certain knowledge, actions, and actors, while delegitimizing others (121, 122).

This calls for a major change in the postures and practices of health researchers and practitioners, policy makers and donors. We believe the SESH operational framework described above is relevant because it advocates for a post-normal approach (114, 117), involving an extended peer community which can provide social consent (123). With the benefit of our own experiences as practitioners supporting interventions in multi-stakeholder settings involving the types of tools and processes outlined in the Methods section (ToCs, logic models, Companion Modeling and other participatory modeling, monitoring and evaluation methods) we recognize that it takes both time and skills to facilitate SESH as an adaptive process [e.g., (99)]. As Allen et al. (124) remind us, developing a shared understanding of different viewpoints and knowledge systems is not just a matter of bringing people together. Successful collaborations require time to build a culture of trust, respect and sharing among members of the different stakeholder parties, through a combination of formal and informal interactions and relationships.

Adopting the concept of resilience to design sustainable "healthy" social-ecological systems will also imply operating at levels which are usually not handled by classical investigations in public or veterinary health (102). One critical issue in establishing resilient SES is the identification of appropriate levels where the demands on ecosystems by human societies are compatible with the quantum of services ecosystems are capable of providing (125, 126). Many of the problems encountered by societies in managing resources lie in the mismatch between the scale of management and the scale(s) of the ecological processes being managed (127). Similar problems may be expected when managing health "within/of" entire river catchments, biomes or entire agricultural systems, if the scales of the epidemiological processes and their management do not match. However, because the health and life of people, and the planet, are compelling reasons for seeking dialogue between individuals and coherence in the dimensions of socio–ecosystem sustainability (128), the transdisciplinary process prompted through SESH interventions are likely to identify the appropriate scale and stakeholders. This will nevertheless require a major shift in the policy of central governments to ensure that the devolution of the rights, responsibilities and means to manage such SESH interventions are effective through appropriate decentralized adaptive governance arrangements and operating protocols (13).

External factors and actors, operating at higher levels outside the system defined, may have key impacts on social-ecological dynamics influencing local landscapes (129). In the case of agro-ecological transitions for instance, such drivers/actors operating outside the system at national, regional or even global levels, may include reluctant dominant operators in food processing and distribution along the value-chains, associated with reduced marketing opportunities, competing agro-businesses, drug and pest-control dealers, public health and veterinary policy-makers, and extractive natural resources activities etc. For small-scale farmers, and other local stakeholders engaged in agroecological transitions, these external actors may be "out of reach," or just not willing to take part in a participatory process, to address local issues associated with desired agricultural transitions, that may compete with their own political or economic interests. The SESH process alone will not redress such power asymmetries, and this should be clarified if and when such situations occur in order to avoid unreasonable expectations regarding the political power of the initiative and of scientific evidence (as stated in the previous paragraph). However, such resistance and blockage will be revealed and documented through the proposed SESH process, which should provide appropriate material for targeted communication, advocacy and political lobbying.

Here, we proposed an operational framework, based on the participatory, context-based and dynamic definition of Social-Ecological System Health, which promotes the active involvement of communities and stakeholders from the interlinked sectors of agriculture, public and veterinary health, and environment. Although partial, the application of our SESH operational framework in contrasted socio-cultural and professional contexts (in **Boxes 1**, **2**) confirmed that it helps frame and facilitate fruitful transdisciplinary conversations, ultimately promoting ontological plurality (130, 131). In Vietnam and in France, it allowed us to transcend disciplines and sectors to produce shared and situated definitions of the SESH, integrating point of views, aspirations, knowledge and know-how of a variety of stakeholders. In the two case studies, using SESH as a heuristic allowed for the exploration of complex social-ecological issues associated with agricultural transitions, and the drafting of local interventions grounded in the target social-ecological systems.

Such an integrated approach, based on transdisciplinary, iterative processes, implemented to solve important issues affecting people's health (*lato sensu*), is likely to promote the emergence of adaptive governance for social–ecological resilience of landscapes, not only to current conditions and in the short-term (i.e., the SESH intervention of reference) but for decades (82). However, the implementation of our framework

requires a significant paradigm shift for all stakeholders involved in the process, including donors and development agencies, acknowledging that SESH interventions address "wicked problems" which call for a post-normal scientific position to handle uncertainty, issue framing, participation, power relations and information asymmetries, politics, and attitudes toward evidence (117, 123). Adopting a participatory SESH framework will help, but it will nonetheless require a change in attitude by "experts", donors and decision makers in order to accept that the health status (of people, animal, societies…) has to be negotiated, that local communities are co-creators of positive ways forward, and that engaging in this process, with uncertain outcomes and assessed through co-constructed indicators, is worth supporting. These paradigm shifts are necessary if we are to achieve transformations toward "healthier" development pathways, which will be one of the greatest challenges for humanity in the decades to come (82), especially in the traumatized post COVID-19 crisis context.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

MG-W, AB, JW, HR, PP, RD, and PE contributed to the initial ideas and development of the rationale. MG-W, AB, JW, RD, and PE drafted the first version of the manuscript. All authors contributed to revising it critically for important intellectual content, read, and approved the final version of the manuscript.

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REFERENCES

1. Clark NE, Lovell R, Wheeler BW, Higgins SL, Depledge MH, Norris K. Biodiversity, cultural pathways, and human health: a framework. *Trends Ecol Evol.* (2014) 29:198–204. doi: 10.1016/j.tree.2014.01.009
2. Galvani AP, Bauch CT, Anand M, Singer BH, Levin SA. Human–environment interactions in population and ecosystem health. *Proc Natl Acad Sci USA.* (2016) 113:14502–6. doi: 10.1073/pnas.1618138113
3. Hays JN. *Epidemics and Pandemics: Their Impacts on Human History*. Santa Barbara, CA: ABC-CLIO (2005).
4. Morand S. *La Prochaine Peste: une Histoire Globale des Maladies Infectieuses*. Paris: Fayard (2016). doi: 10.3917/quae.moran.2016.01
5. Cunningham AA, Daszak P, Wood JL. One health, emerging infectious diseases and wildlife: two decades of progress? *Philos Trans Roy Soc B Biol Sci.* (2017) 372:20160167. doi: 10.1098/rstb.2016.0167
6. Waters A. People are to blame for covid-19. *Vet Record.* (2020) 186:467. doi: 10.1136/vr.m1747
7. Scoones I. *Avian Influenza: Science, Policy and Politics*: *Earthscan*. London: Earthscan (2010). doi: 10.4324/9781849775045
8. Morand S. Diversity and origins of human infectious diseases. In: *Basics in Human Evolution*. Amsterdam: Elsevier. (2015). p. 405–14. doi: 10.1016/B978-0-12-802652-6.00029-3
9. Morand S, McIntyre KM, Baylis M. Domesticated animals and human infectious diseases of zoonotic origins: domestication time matters. *Infect Genet Evol.* (2014) 24:76–81. doi: 10.1016/j.meegid.2014.02.013
10. Antoine-Moussiaux N, de Bisthoven LJ, Leyens S, Assmuth T, Keune H, Jakob Z, et al. The good, the bad and the ugly: framing debates on nature in a one health community. *Sustain Sci.* (2019) 14:1729–38. doi: 10.1007/s11625-019-00674-z
11. Destoumieux-Garzón D, Mavingui P, Boetsch G, Boissier J, Darriet F, Duboz P, et al. The one health concept: 10 years old and a long road ahead. *Front Vet Sci.* (2018) 5:14. doi: 10.3389/fvets.2018.00014
12. Wilcox BA, Aguirre AA, De Paula N, Siriaroonrat B, Echaubard P. Opertionalizing one health employing socio-ecological systems theory: lessons from the greater mekong sub-region. *Front Public Health.* (2019) 7:85. doi: 10.3389/fpubh.2019.00085
13. de Garine-Wichatitsky M, Binot A, Morand S, Kock R, Roger F, Wilcox BA, et al. Will the COVID-19 crisis trigger a one health coming-of-age? *Lancet Planet Health.* (2020) 4:e377–e8. doi: 10.1016/S2542-5196(20)30179-0
14. Haraway D. Anthropocene, capitalocene, plantationocene, chthulucene: making kin. *Environ Hum.* (2015) 6:159–65. doi: 10.1215/22011919-3615934
15. Moore JW. The capitalocene Part II: accumulation by appropriation and the centrality of unpaid work/energy. *J Peasant Stud.* (2018) 45:237–79. doi: 10.1080/03066150.2016.1272587
16. Whitmee S, Haines A, Beyrer C, Boltz F, Capon AG, de Souza Dias BF, et al. Safeguarding human health in the anthropocene epoch: report of the rockefeller foundation–lancet commission on planetary health. *Lancet.* (2015) 386:1973–2028. doi: 10.1016/S0140-6736(15)60901-1
17. Aronson JC, Blatt CM, Aronson TB. Restoring ecosystem health to improve human health and well-being: physicians and restoration ecologists unite in a common cause. *Ecol Soc.* (2016) 21:39. doi: 10.5751/ES-08974-210439
18. Rockström J, Steffen W, Noone K, Persson Å, Chapin III FS, Lambin EF, et al. A safe operating space for humanity. *Nature.* (2009) 461:472. doi: 10.1038/461472a
19. Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, Bennett EM, et al. Planetary boundaries: Guiding human development on a changing planet. *Science.* (2015) 347:1259855. doi: 10.1126/science.1259855
20. Famiglietti JS. The global groundwater crisis. *Nat Clim Change.* (2014) 4:945–8. doi: 10.1038/nclimate2425
21. Woolhouse M, Gowtage-Sequeria S. Host range and emerging and reemerging pathogens. *Emerg Infect Dis.* (2005) 11:1842–7. doi: 10.3201/eid1112.050997
22. Ingalls ML, Stedman RC. The power problematic: exploring the uncertain terrains of political ecology and the resilience framework. *Ecol Soc.* (2016) 21:6. doi: 10.5751/ES-08124-210106
23. Hoque SF, Quinn CH, Sallu SM. Resilience, political ecology, and well-being: an interdisciplinary approach to understanding social-ecological change in coastal Bangladesh. *Ecol Soc.* (2017) 22:45. doi: 10.5751/ES-09422-220245
24. Buks J, Obiedzińska A, Prandecki K. Environmental externalities and food security. *J Agribus Rural Dev.* (2016) 2:257–64. doi: 10.17306/JARD.2016.29

25. Power AG. Ecosystem services and agriculture: tradeoffs and synergies. *Philos Trans Roy Soc B Biol Sci.* (2010) 365:2959–71. doi: 10.1098/rstb.2010.0143
26. Arneth A, Denton F, Agus F, Elbehri A, Erb KH, Osman Elasha B, et al. Framing and context. In: *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Geneva: Intergovernmental Panel on Climate Change (2019). p. 1–98. Available online at: https://www.ipcc.ch/site/assets/uploads/2019/08/2b.-Chapter-1_FINAL.pdf
27. Gordon IJ, Alonso S, Crump L, Dominguez-Salas P, de Garine-Wichatitsky M. Chapter 26_food security and nutrition. In: Zinsstag J, Schelling E, Crump L, Whittaker M, Tanner M, Craig S, editors. *One Health: The Theory and Practice of Integrated Health Approaches*. Wallingford: CABI (2020). p. 327–343. doi: 10.1079/9781789242577.0327
28. Frison E, Clément C. The potential of diversified agroecological systems to deliver healthy outcomes: making the link between agriculture, food systems & health. *Food Policy.* (2020) 96:101851. doi: 10.1016/j.foodpol.2020.101851
29. *CBD-WHO. 2015*. Available online at: https://www.cbd.int/health/SOK-biodiversity-en.pdf (accessed July 17, 2018).
30. El Zowalaty ME, Järhult JD. From SARS to COVID-19: a previously unknown SARS-CoV-2 virus of pandemic potential infecting humans–call for a one health approach. One *Health.* (2020) 9:100124. doi: 10.1016/j.onehlt.2020.100124
31. Kock RA, Karesh WB, Veas F, Velavan TP, Simons D, Mboera LE, et al. 2019-nCoV in context: lessons learned? *Lancet Planet Health.* (2020) 4:e87–8. doi: 10.1016/S2542-5196(20)30035-8
32. Amuasi JH, Walzer C, Heymann D, Carabin H, Haines A, Winkler AS. Calling for a COVID-19 one health research coalition. *Lancet.* (2020) 395:1543. doi: 10.1016/S0140-6736(20)31028-X
33. Zumla A, Dar O, Kock R, Muturi M, Ntoumi F, Kaleebu P, et al. Taking forward a 'One health'approach for turning the tide against the middle east respiratory syndrome coronavirus and other zoonotic pathogens with epidemic potential. *Int J Infect Dis.* (2016) 47:5–9. doi: 10.1016/j.ijid.2016.06.012
34. Aguirre AA, Basu N, Kahn L, Morin X, Echaubard P, Wilcox BA, et al. Transdisciplinary and social-ecological health frameworks—novel approaches to emerging parasitic and vector-borne diseases. *Parasite Epidemiol Control.* (2019) 4:e00084. doi: 10.1016/j.parepi.2019.e00084
35. Forget G, Lebel N. An ecosystem approach to human health. *Int J Occup Environ Health.* (2001) 7:S1–38. Available online at http://dl.handle.net/10625/33649
36. Wilcox BA, Aguirre AA, Daszak P, Horwitz P, Martens P, Parkes M, et al. EcoHealth: a transdisciplinary imperative for a sustainable future. *EcoHealth.* (2004) 1:3–5. doi: 10.1007/s10393-004-0014-9
37. Zinsstag J, Schelling E, Waltner-Toews D, Tanner M. From "one medicine" to "one health" and systemic approaches to health and well-being. *Prev Vet Med.* (2011) 101:148–56. doi: 10.1016/j.prevetmed.2010.07.003
38. Zinsstag J. Convergence of ecohealth and one health. *EcoHealth.* (2012) 9:371. doi: 10.1007/s10393-013-0812-z
39. Roger F, Caron A, Morand S, Pedrono M, de Garine-Wichatitsky M, Chevalier V, et al. One health and ecohealth: the same wine in different bottles? *Infect Ecol Epidemiol.* (2016) 6:30978. doi: 10.3402/iee.v6.30978
40. Gibson C, Ostrom E, Ahn TK. The concept of scale and the human dimensions of global change: a survey. *Ecol Econ.* (2000) 32:217–39. doi: 10.1016/S0921-8009(99)00092-0
41. Dore J, Lebel L. Deliberation and scale in Mekong Region water governance. *Environ Manag.* (2010) 46:60–80. doi: 10.1007/s00267-010-9527-x
42. Berkes F, Ross H. Community resilience: toward an integrated approach. *Soc Nat Resour.* (2013) 26:5–20. doi: 10.1080/08941920.2012.736605
43. Waltner-Toews D. Zoonoses, one health and complexity: wicked problems and constructive conflict. *Philos Trans Roy Soc B Biol Sci.* (2017) 372:20160171. doi: 10.1098/rstb.2016.0171
44. Spencer J, McRobie E, Dar O, Rahman-Shepherd A, Hasan N, Hanefeld J, et al. Is the current surge in political and financial attention to one health solidifying or splintering the movement? *BMJ Global Health.* (2019) 4:e001102. doi: 10.1136/bmjgh-2018-001102
45. Duboz R, Echaubard P, Promburom P, Kilvington M, Ross H, Allen W, et al. Systems thinking in practice: participatory modeling as a foundation for integrated approaches to health. *Front Vet Sci.* (2018) 5:303. doi: 10.3389/fvets.2018.00303
46. Berbés-Blázquez M, Oestreicher JS, Mertens F, Saint-Charles J. Ecohealth and resilience thinking: a dialog from experiences in research and practice. *Ecol Soc.* (2014) 19:24. doi: 10.5751/ES-06264-190224
47. Binot A, Duboz R, Promburom P, Phimpraphai W, Cappelle J, Lajaunie C, et al. A framework to promote collective action within the one health community of practice: using participatory modelling to enable interdisciplinary, cross-sectoral and multi-level integration. One *Health.* (2015) 1:44–8. doi: 10.1016/j.onehlt.2015.09.001
48. Richter CH, Steele JA, Nguyen-Viet H, Xu J, Wilcox BA. Toward operational criteria for ecosystem approaches to health. *Ecohealth.* (2015) 12:220–6. doi: 10.1007/s10393-015-1028-1
49. Zinsstag J, Schelling E, Waltner-Toews D, Whittaker M, Tanner M. One *Health: the theory and practice of integrated health approaches* Wallingford, CT: CABI (2015). doi: 10.1079/97817806434 10.0000
50. Lerner H, Berg C. A comparison of three holistic approaches to health: one health, EcoHealth, and planetary health. *Front Vet Sci.* (2017) 4:163. doi: 10.3389/fvets.2017.00163
51. Hobbs NT, Baker DL, Bear GD, Bowden DC. Ungulate grazing in sagebrush grassland: effects of resource competition on secondary production. *Ecol Appl.* (1996) 6:218–27. doi: 10.2307/2269565
52. Liu J, Hull V, Godfray HCJ, Tilman D, Gleick P, Hoff H, et al. Nexus approaches to global sustainable development. *Nat Sustain.* (2018) 1:466–76. doi: 10.1038/s41893-018-0135-8
53. Marcotty T, Thys E, Conrad P, Godfroid J, Craig P, Zinsstag J, et al. Intersectoral collaboration between the medical and veterinary professions in low-resource societies: the role of research and training institutions. *Comp Immunol Microbiol Infect Dis.* (2013) 36:233–9. doi: 10.1016/j.cimid.2012.10.009
54. Schelling E, Wyss K, Bechir M, Moto DD, Zinsstag J. Synergy between public health and veterinary services to deliver human and animal health interventions in rural low income settings. *BMJ.* (2005) 331:1264–7. doi: 10.1136/bmj.331.7527.1264
55. Barrett MA, Bouley TA. Need for enhanced environmental representation in the implementation of one health. *EcoHealth.* (2015) 12:212–9. doi: 10.1007/s10393-014-0964-5
56. Wolf M. Is there really such a thing as "one health"? Thinking about a more than human world from the perspective of cultural anthropology. *Soc Sci Med.* (2015) 129:5–11. doi: 10.1016/j.socscimed.2014.06.018
57. Barnett T, Pfeiffer DU, Hoque MA, Giasuddin M, Flora MS, Biswas PK, et al. Practising co-production and interdisciplinarity: challenges and implications for one health research. *Prev Vet Med.* (2020) 177:104949. doi: 10.1016/j.prevetmed.2020.104949
58. Allen-Scott LK, Buntain B, Hatfield JM, Meisser A, Thomas CJ. Academic institutions and one health: building capacity for transdisciplinary research approaches to address complex health issues at the animal–human–ecosystem interface. *Acad Med.* (2015) 90:866. doi: 10.1097/ACM.0000000000000639
59. FAO-OIE-WHO. *The Tripartite's Commitment Providing Multi-sectoral, Collaborative Leadership in Addressing Health Challenges*. (2017). p. 4. Available online at: https://www.who.int/zoonoses/tripartite_oct2017.pdf?ua=1
60. FAO-OIE-WHO. *Memorandum of Understanding Regarding Cooperation to Combat Health Risks at Human-Animal-Ecosystems Interface in the Context of the One Health Approach and Including Microbial Resistance*. (2018). p. 7. Available online at: https://www.who.int/zoonoses/MoU-Tripartite-May-2018.pdf?ua=1
61. Wilcox BA, Aguirre AA. Connecting ecology, health, and sustainability. In: Aguirre AA, Ostfeld R, Daszak P, editors. *New Directions in Conservation Medicine: Applied Cases of Ecological Health*. New York, NY: Oxford University Press. (2012). p. 17–33.
62. Costanza R. Ecosystem health and ecological engineering. *Ecol Eng.* (2012) 45:24–9. doi: 10.1016/j.ecoleng.2012.03.023

63. Koplan JP, Bond TC, Merson MH, Reddy KS, Rodriguez MH, Sewankambo NK, et al. Towards a common definition of global health. *Lancet.* (2009) 373:1993–5. doi: 10.1016/S0140-6736(09)60332-9
64. Ostrom E. A diagnostic approach for going beyond panaceas. *Proc Natl Acad Sci USA.* (2007) 104:15181–7. doi: 10.1073/pnas.0702288104
65. Ostrom E. A general framework for analyzing sustainability of social-ecological systems. *Science.* (2009) 325:419–22. doi: 10.1126/science.1172133
66. Holling CS. Resilience and stability of ecological systems. *Ann Rev Ecol Syst.* (1973) 4:1–23. doi: 10.1146/annurev.es.04.110173.000245
67. Berkes F, Colding J, Folke C. *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Cambridge, UK: Cambridge University Press (2008).
68. Wilcox B, Kueffer C. Transdisciplinarity in ecohealth: status and future prospects. *EcoHealth.* (2008) 5:1–3. doi: 10.1007/s10393-008-0161-5
69. Parkes M, Waltner-Toews D, Horwitz P. Ecohealth. In: Michalos AC, editor. *Encyclopedia of Quality of Life and Well-Being Research*. Dordrecht: Springer Netherlands. (2014). p. 1770–4. doi: 10.1007/978-94-007-0753-5_4172
70. Prescott SL, Logan AC, Albrecht G, Campbell DE, Crane J, Cunsolo A, et al. The canmore declaration: statement of principles for planetary health. *Challenges.* (2018) 9:31. doi: 10.3390/challe9020031
71. Zinsstag J, Waltner-Toews D, Tanner M. Theoretical issues of one health. In: Zinsstag J, Schelling E, Waltner-Toews D, Whittaker M, Tanner M, editors. One *Health: the Theory and Practice of Integrated Health Approaches*. Wallingford: CABI. (2015). p. 16–25. doi: 10.1079/9781780643410.0016
72. Allen W, Ataria JM, Apgar JM, Harmsworth G, Tremblay LA. Kia pono te mahi putaiao—doing science in the right spirit. *J Roy Soc New Zealand.* (2009) 39:239–42. doi: 10.1080/03014220909510588
73. Maclean K, Ross H, Cuthill M, Rist P. Healthy country, healthy people: an australian aboriginal organisation's adaptive governance to enhance its social–ecological system. *Geoforum.* (2013) 45:94–105. doi: 10.1016/j.geoforum.2012.10.005
74. Zinsstag J, Crump L, Winkler M. Biological threats from a 'one health' perspective. *OIE Revue Sci Techn.* (2017) 36:671–80. doi: 10.20506/rst.36.2.2684
75. Aarts BG, Nienhuis PH. Ecological sustainability and biodiversity. *Int J Sustain Dev World Ecol.* (1999) 6:89–102. doi: 10.1080/13504509909469998
76. Chiesura A, De Groot R. Critical natural capital: a socio-cultural perspective. *Ecol Econ.* (2003) 44:219–31. doi: 10.1016/S0921-8009(02)00275-6
77. Whittaker M. The role of social sciences in one health: reciprocal benefits. In: Zinsstag J, Schelling E, Waltner-Toews D, Whittaker M, Tanner M, editors. One *Health: The Theory and Practice of Integrated Health Approaches*. Wallingford: CABI. (2015). p. 60–72. doi: 10.1079/9781780643410.0060
78. Poortinga W. Social relations or social capital? Individual and community health effects of bonding social capital. *Soc Sci Med.* (2006) 63:255–70. doi: 10.1016/j.socscimed.2005.11.039
79. Rock MJ, Degeling C. Public health ethics and more-than-human solidarity. *Soc Sci Med.* (2015) 129:61–7. doi: 10.1016/j.socscimed.2014.05.050
80. Ciccone DK, Vian T, Maurer L, Bradley EH. Linking governance mechanisms to health outcomes: a review of the literature in low-and middle-income countries. *Soc Sci Med.* (2014) 117:86–95. doi: 10.1016/j.socscimed.2014.07.010
81. Nichols LM, Taylor LA. Social determinants as public goods: a new approach to financing key investments in healthy communities. *Health Affairs.* (2018) 37:1223–30. doi: 10.1377/hlthaff.2018.0039
82. Folke C. Resilience: The emergence of a perspective for social–ecological systems analyses. *Glob Environ Change.* (2006) 16:253–67. doi: 10.1016/j.gloenvcha.2006.04.002
83. Wicklum D, Davies RW. Ecosystem health and integrity? *Can J Bot.* (1995) 73:997–1000. doi: 10.1139/b95-108
84. Gaston KJ, Soga M, Duffy JP, Garrett JK, Gaston S, Cox DT. Personalised ecology. *Trends Ecol Evol.* (2018) 33:916–25. doi: 10.1016/j.tree.2018.09.012
85. McCarter J, Sterling E, Jupiter S, Cullman G, Albert S, Basi M, et al. Biocultural approaches to developing well-being indicators in Solomon Islands. *Ecol Soc.* (2018) 23:32. doi: 10.5751/ES-09867-230132
86. Donatuto J, Campbell L, Gregory R. Developing responsive indicators of indigenous community health. *Int J Environ Res Public Health.* (2016) 13:899. doi: 10.3390/ijerph13090899
87. Fabinyi M, Evans L, Foale SJ. Social-ecological systems, social diversity, and power: insights from anthropology and political ecology. *Ecol Soc.* (2014) 19:28. doi: 10.5751/ES-07029-190428
88. Roche PK, Campagne CS. From ecosystem integrity to ecosystem condition: a continuity of concepts supporting different aspects of ecosystem sustainability. *Curr Opin Environ Sustain.* (2017) 29:63–8. doi: 10.1016/j.cosust.2017.12.009
89. Gillson L, Biggs H, Smit IP, Virah-Sawmy M, Rogers K. Finding common ground between adaptive management and evidence-based approaches to biodiversity conservation. *Trends Ecol Evol.* (2019) 34:31–44. doi: 10.1016/j.tree.2018.10.003
90. Langdon EJ, Wiik FB. Anthropology, health and illness: an introduction to the concept of culture applied to the health sciences. *Rev Latino-Am Enfermagem.* (2010) 18:459–66. doi: 10.1590/S0104-11692010000300023
91. Wiek A, Lang DJ. Transformational sustainability research methodology. In: *Sustainability science*. Netherlands: Springer (2016). p. 31–41. doi: 10.1007/978-94-017-7242-6_3
92. Min B, Allen-Scott L, Buntain B. Transdisciplinary research for complex One Health issues: a scoping review of key concepts. *Prev Vet Med.* (2013) 112:222–9. doi: 10.1016/j.prevetmed.2013.09.010
93. Baum F, MacDougall C, Smith D. Participatory action research. *J Epidemiol Commun Health.* (2006) 60:854–7. doi: 10.1136/jech.2004.028662
94. Santana-Medina N, Franco-Maass S, Sánchez-Vera E, Imbernon J, Nava-Bernal G. Participatory generation of sustainability indicators in a natural protected area of Mexico. *Ecol Indic.* (2013) 25:1–9. doi: 10.1016/j.ecolind.2012.09.002
95. Étienne M. *Companion Modelling: A Participatory Approach to Support Sustainable Development*. Netherlands: Springer Science & Business Media (2013).
96. Thongyuan S, Tulayakul P, Ruenghiran C, Khuntamoon T, Viriyarumpa S, Binot A. Assessment of municipal opened landfill and its impact on environmental and human health in central Thailand. *Int J Infect Dis.* (2019) 79:55. doi: 10.1016/j.ijid.2018.11.146
97. Duboz R, Binot A. Animal and human health: tackling uncertainty through participatory modelling and simulation. *Perspective.* (2017) 41:1–4. doi: 10.19182/agritrop/00011
98. Taplin DH, Clark H, Collins E, Colby DC. *Theory of Change. Technical Papers: a Series of Papers to Support Development of Theories of Change Based on Practice in the Field*. New York, NY: ActKnowledge (2013).
99. Allen W, Cruz J, Warburton B. How decision support systems can benefit from a theory of change approach. *Environ Manage.* (2017) 59:956–65. doi: 10.1007/s00267-017-0839-y
100. Tsasis P, Evans JM, Forrest D, Jones RK. Outcome mapping for health system integration. *J Multidiscipl Healthc.* (2013) 6:99. doi: 10.2147/JMDH.S41575
101. Berardi A, Mistry J, Tschirhart C, Bignante E, Davis O, Haynes L, et al. Applying the system viability framework for cross-scalar governance of nested social-ecological systems in the Guiana Shield, South America. *Ecol Soc.* (2015) 20:42. doi: 10.5751/ES-07865-200342
102. Morand S, Lajaunie C. Landscape dynamics and the control of infectious diseases: the question of integrating health into coviability. In: Barrière O, Behnassi M, David G, Douzal V, Fargette M, Libourel T, et al. editors. *Coviability of Social and Ecological Systems: Reconnecting Mankind to the Biosphere in an Era of Global Change*. Cham: Springer (2019). p. 61–76. doi: 10.1007/978-3-319-78111-2_3
103. Smajgl A, Ward J, Foran T, Dore J, Larson S. Visions, beliefs, and transformation: exploring cross-sector and transboundary dynamics in the wider mekong region. *Ecol Soc.* (2015) 20:1–16. doi: 10.5751/ES-07421-200215
104. Smajgl A, Ward J. A framework to bridge science and policy in complex decision making arenas. *Futures.* (2013) 52:52–8. doi: 10.1016/j.futures.2013.07.002
105. Abson DJ, Fischer J, Leventon J, Newig J, Schomerus T, Vilsmaier U, et al. Leverage points for sustainability transformation. *Ambio.* (2017) 46:30–9. doi: 10.1007/s13280-016-0800-y
106. Bunch MJ, Morrison KE, Parkes MW, Venema HD. Promoting health and well-being by managing for social–ecological resilience: the potential of integrating ecohealth and water resources management approaches. *Ecol Soc.* (2011) 16:6. doi: 10.5751/ES-03803-160106

107. Pimm SL, Donohue I, Montoya JM, Loreau M. Measuring resilience is essential to understand it. *Nat Sustain.* (2019) 2:895–7. doi: 10.1038/s41893-019-0399-7
108. Glandon DM. Measuring resilience is not enough; we must apply the research. Researchers and practitioners need a common language to make this happen. *Ecol Soc.* (2015) 20:27. doi: 10.5751/ES-07576-200227
109. Rittel HW, Webber MM. 2.3 planning problems are wicked. *Polity.* (1973) 4:e169. doi: 10.1007/BF01405730
110. Balint PJ, Stewart RE, Desai A, Walters LC. *Wicked Environmental Problems: Managing Uncertainty and Conflict.* Washington: Island Press (2011). doi: 10.5822/978-1-61091-047-7
111. Hisschemöller M, Hoppe R. Coping with intractable controversies: The case for problem structuring in policy design and analysis. In: Hoppe R, Hisschemöller M, Dunn WN, Ravetz JR, editors. *Knowledge, Power and Participation in Environmental Policy Analysis*. New Brunswick, NJ: Transaction Publishers (1996). p. 47–2. doi: 10.4324/9781351325721-4
112. Sen AK. *The Idea of Justice*. Harvard University Press (2009). London: Penguin Books.
113. Laswell HD. *A Re-view of policy sciences*. New York, NY: Elsevier (1971).
114. Funtowicz S, Ravetz J. *Post-Normal Science. International Society for Ecological Economics (ed), Online Encyclopedia of Ecological Economics.* (2003). Available online at: http://www.ecoeco org/publica/encyc htm
115. Cornwall A, Gaventa J. Bridging the gap: citizenship, participation and accountability. *PLA Notes.* (2001) 40:32–5. Available online at: https://pubs.iied.org/pdfs/G01307.pdf (accessed November 2020).
116. D'aquino P, Le Page C, Bousquet F, Bah A. Using self-designed role-playing games and a multi-agent system to empower a local decision-making process for land use management: the selfcormas experiment in senegal. *J Artif Soc Soc Simul.* (2003) 6:1–14. Available online at http://jasss.soc.surrey.ac.uk/6/3/5.html
117. Funtowicz SO, Ravetz JR. Science for the post-normal age. *Futures.* (1993) 25:739–55. doi: 10.1016/0016-3287(93)90022-L
118. Clay E, Schaffer B. *Room for Manoevre. An Explanation of Public Policy in Agriculture and Rural Development*. London: Heinemann. (1986)
119. Gasper D, Apthorpe R. *Introduction: Discourse Analysis and Policy Discourse*. London: Frank Cass (1996). doi: 10.1080/09578819608426650
120. Cornwall A. Buzzwords and fuzzwords: deconstructing development discourse. *Dev Prac.* (2007) 17:471–84. doi: 10.1080/09614520701469302
121. Dryzek J. *Rational Ecology: Environment and political Economy*. Oxford: Basil Blackwell (1987).
122. Leach M, Mearns R, Scoones I. Environmental entitlements: dynamics and institutions in community-based natural resource management. *World Dev.* (1999) 27:225–47. doi: 10.1016/S0305-750X(98)00141-7
123. Turnpenny J, Lorenzoni I, Jones M. Noisy and definitely not normal: responding to wicked issues in the environment, energy and health. *Environ Sci Policy.* (2009) 12:347–58. doi: 10.1016/j.envsci.2009.01.004
124. Allen W, Ogilvie S, Blackie H, Smith D, Sam S, Doherty J, et al. Bridging disciplines, knowledge systems and cultures in pest management. *Environ Manage.* (2014) 53:429–40. doi: 10.1007/s00267-013-0180-z
125. Cumming GS, Olsson P, Chapin F, Holling C. Resilience, experimentation, and scale mismatches in social-ecological landscapes. *Landsc Ecol.* (2013) 28:1139–50. doi: 10.1007/s10980-012-9725-4
126. Lee KN. Greed, scale mismatch, and learning. *Ecol Appl.* (1993) 3:560–4.
127. Cumming GS, Cumming DHM, Redman C. Scale mismatches in social-ecological systems: causes, consequences and solutions. *Ecol Soc.* (2006) 11:14–34. doi: 10.5751/ES-01569-110114
128. Morandín-Ahuerma I, Contreras-Hernández A, Ayala-Ortiz DA, Pérez-Maqueo O. Socio–ecosystemic sustainability. *Sustainability.* (2019) 11:3354. doi: 10.3390/su11123354
129. Preise R, Biggs R, De Vos A, Folke C. Social-ecological systems as complex adaptive systems: organizing principles for advancing research methods and approaches. (2018). 23:46. doi: 10.5751/ES-10558-230446
130. Howitt R, Suchet-Pearson S. Ontological pluralism in contested cultural landscapes. In: *Handbook of cultural geography*. London: Sage Publications. (2003). p. 557–69. doi: 10.4135/9781848608252.n41
131. Howitt R, Suchet-Pearson S. Rethinking the building blocks: ontological pluralism and the idea of "management". *Geografiska Annaler.* (2006) 88:323–35. doi: 10.1111/j.1468-0459.2006.00225.x

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Conceptualizing Responsibility in Food Research and Innovation to Promote Healthy and Sustainable Food Systems

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Responsibility is crucial to governance and key to achieving legitimacy within complex systems, yet there is limited attention to how it should be conceptualized within the context of food research and innovation (R&I). Understanding how diverse stakeholders in food R&I conceptualize responsibility is vital because it shapes the way problems are identified, goals are set and solutions are put in place. We report on empirical research with diverse stakeholders across Europe to understand and map the dimensions of responsibility for food R&I to support healthy and sustainable food systems. Semi-structured interviews were conducted with 32 stakeholders working in R&I in the cutting-edge domains of: cultured meat as a substitute for livestock meat; new crop breeding of potatoes; and a new approach to obesity reduction that focuses on weight acceptance. Drawing from the empirical evidence collected, we developed a classification system that reflects various conceptualizations of stakeholders' responsibility for food R&I to support healthy and sustainable food systems. Our thematic analysis revealed four overlapping rationales of responsibility—accountability, impact, reflexivity, and responsiveness, and characterized them in terms of: who the researcher is responsible to; whether the assessments of responsibility focus on R&I processes or impact; whether responsibility implies societal engagement; and how responsibility is assessed—retrospectively or prospectively. The article provides a basis for systematic application of these criteria to the specific instances of food R&I governance and for future joint decisions, about the ways to allocate responsibilities.

Keywords: research and innovation, responsibility, accountability, food system, impact, sustainability, obesity, cultured meat

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INTRODUCTION

The modern food system is a globalized, multi-sector and inter-dependent network, structured as a complex web of private and public partnerships of diverse actors such as transnational corporations, international agencies, interest groups, non-governmental and civil society organizations, and national, regional and local governments (Barling, 2008; Friel, 2017). Governance of the food system network is enabled via international and national trade and investment agreements and a plethora of regulatory, fiscal, and voluntary (self-regulatory) approaches that go beyond state-led regimes, increasing its segmentation and fragmentation (Biermann and Pattberg, 2008; Kraak et al., 2014). It is driven by the supply-push factors that prioritize efficiency, traceability and

resource allocation and the demand-pull factors of consumer perceived private benefits, with market forces taking over many of the functions previously seen as a state prerogative (Kraak et al., 2014; Swinburn et al., 2015). However, the contribution of the existing food system to the global climate and health threats requires a re-orientation of the system to go beyond the narrow focus on productivity and cost-effectiveness (Whitmee et al., 2015; Lawrence and Friel, 2019), toward alternative sets of drivers such as resilience, social justice and sustainability (Ingram, 2011; Niles et al., 2018). There is little evidence for the effectiveness of strategic public-private partnerships, although they have ostensibly had a limited success in tackling global public health nutrition and sustainability challenges (Kraak et al., 2014; Swinburn et al., 2015). Key contributing factors are insufficient clarity about how responsibility is allocated within such complex networks of actors, and lack of accountability frameworks through which they are governed (Kraak et al., 2014). Indeed, governance implies allocation of responsibility (Löfmarck et al., 2017), and transparent governing of food system networks requires clarity about how responsibility is conceptualized and enacted (Kraak et al., 2014; Swinburn et al., 2015). Within the current paper we report on a study which explores the conceptualizations of responsibility within the context of food research and innovation (R&I), as a specific domain of food system operation. Our purpose was to conduct empirical research with a diverse set of stakeholders across Europe to understand and map the rationales of responsibility for food R&I to support healthy and sustainable food systems. Drawing from the empirical evidence collected, we develop a classification system that reflects various conceptualizations of stakeholders' responsibility for food R&I to support healthy and sustainable food systems.

In the sections that follow, we first provide an overview of the current efforts to understand responsibility in the context of the globalized food system. We then explore conceptual developments of the notion of responsibility from the social science perspective before we set the scene for the current empirical study.

Conceptualizations of Responsibility in Food System Governance Literature

There are relatively few papers discussing responsibility within the food systems governance context. Responsibility within the modern food system has historically been discussed in terms of causal responsibility for the outcomes of "irresponsible" action (e.g., obesity); the prevailing narrative has focused on personal responsibility for healthy and sustainable choices, shaping the policy responses toward prioritization of private initiatives and self-regulatory solutions (Kraak et al., 2014; Roberto et al., 2015). The individualistic conceptualizations of responsibility that focus on who "caused" the problem, obfuscate the inter-dependencies within the complex food system, and cannot guide governance decisions about future problems arising out of the food system's inherent uncertainties. More recent frameworks have recognized that such approaches have resulted in governance gaps that have led to the excessive influence of the food industry and the erosion of the stronger mechanisms controlling for undue influence of vested interests over food policy (Mindell et al., 2012).

An alternative conceptualization of responsibility has emerged from a small body of literature that examines governance processes within this complex and diffused network of actors (e.g., Kraak et al., 2014; Swinburn et al., 2015; Hospes and Brons, 2016; Friel, 2017; Lawrence and Friel, 2019). A recent United Nations System Standing Committee on Nutrition (UNSSCN) report maps this complex network and contends that, since no one sector has responsibility for nutrition, clarifying actor responsibility for nutrition and developing effective mechanisms to hold all actors accountable for actions that impact nutrition remains a task critical to the development of workable governance mechanisms (Friel, 2017). Kraak et al. (2014) developed a framework of accountability of all actors within the complex food system in order to enable transparent, open and fair governance. The authors distinguished between responsibility and accountability. They defined the former as a commitment or an obligation imparted upon an individual or a group based on social, moral and/or legal standards, and accountability as an ability of different actors within the system to hold each other to account, which is ultimately about "how and why decisions are made, who makes decisions, how power is used, shared, and balanced, whose opinions are important, and who holds whom to account" (Swinburn et al., 2015, p. 2,535). Governance was defined as different behaviors and activities ("steps") that enable the process of "accounting," enacted through taking the account (evidence collection); sharing the account (dissemination, communication of evidence); holding the account (carrying out actions) and responding to the account (taking remedial actions). Accountability, in this articulation, is concerned with the ability to justify decisions and the ex-post evaluation of the reasons for action, which is particularly relevant for governing distributed networks where there is no single authority imposing sanctions for the system's transgressions. Swinburn et al. (2015) developed this framework further by identifying the policy levers that could be used to ensure accountability within these four steps and suggested regulatory and non-regulatory approaches through which each actor within the system can hold the other to account.

It has often been commented that implementation of governance driven by accountability mechanisms can have an unfortunate effect of obscuring judgments about ethical responsibility by prioritizing only those values which can be measured and accounted for (Collini, 2017), a problem particularly apposite in the context of food innovation and research. For instance, the drive toward accountability in food and health research and innovation has inconspicuously led to prioritization of the innovations that have tangible, measurable economic benefits (Khan et al., 2016). Furthermore, because an accountability framework is primarily concerned with backward responsibility, an ex-post accounting of the web of decisions, it ignores those responsibilities for which roles, decisions and future consequences are more difficult to allocate. Achieving sustainability (environmental, social, and economic) is marred by uncertainty not only about how to organize governance of sustainable food system, but also about the values by

which to judge governance decisions (Partzsch, 2011). Sharpe and Barling (2019) illustrated this through their study of stakeholders from various food supply chain organizations about their conceptualizations of the kind of responsibility which requires re-orientation toward greater social sustainability. Their study showed that, whilst re-orientation of business toward sustainability is recognized by stakeholders as "the right thing to do" (a moral imperative), practically, it was difficult to implement. The perceived requirement for more pragmatic focus on calculations and programmatic focus on economic efficiencies means that the accountability framework prioritizes those elements of business activities that can be more easily quantified and accounted for. In short, simply focusing on accountability as a means of governing global food systems may not be enough to achieve a lasting shift toward sustainability. New conceptualizations of responsibility to influence governance within a non-linear food system characterized by uncertainties and volatility are needed (Pereira and Ruysenaar, 2012; Clancy, 2014).

The concept of responsibility recently discussed within the context of R&I emphasizes wider conceptualization of responsibility within the overall innovation process. The concept of Responsible Research and Innovation (RRI, Von Schomberg, 2011) questions the accepted roles and responsibilities of all research process stakeholders in relation to both R&I process and outcomes. It defines responsibility as ethical responsibility achieved through engagement at all stages of the R&I process with the impacts and outcomes of innovation as well as the broader societal values and expectations of R&I (Owen et al., 2012), calling for all innovators to be responsive to these in their design process, anticipating, reflecting and responding to emerging challenges. This is a future-oriented notion of responsibility (ex-ante), focused on aligning current practices with the value expectations and societal representations of a desirable future. The definition of RRI is rather open-ended (Zwart et al., 2014) and its delineation from the other, aligned concepts such as ELSA (ethical, legal, and social aspects of emerging sciences and technologies) and Precautionary Principle, is poorly articulated. Furthermore, a common criticism of the concept of RRI is that, in the absence of frameworks specifying dimensions of responsibility and how it should be translated into specific innovation process, it lacks broader applicability (Burget et al., 2017; Timmermans et al., 2017). Despite a growing body of empirical studies exploring the application and implementation of RRI in specific R&I domains, there is limited empirical work on responsibility in food R&I.

Defining Responsibility

Responsibility is a multifaceted construct that subsumes the considerations of a responsible actor (their motivations, intentions, identities), their actions, and the rules or norms through which these actions are judged. Pellizzoni (2004) developed a conceptual framework of responsibility through which responsibility can be more clearly articulated and assessed. The framework combines two dominant dimensions of responsibility: answerability (an ability to justify one's actions) and imputability (causal attribution of action to someone as its actual author). Answerability largely depends on whether we are focused on understanding the past actions (ex post) or on developing a set of rules that help respond to future challenges (ex ante). Imputability can vary by the degree of uncertainty surrounding actions, or the absence or presence of knowledge on which to base causal attributions of actions. Pellizzoni argued that responsibility can be categorized along these two dimensions through which we come to understand how the relationships of responsibility are organized within society:

- Accountability focuses on justifying past actions in the context of high uncertainty (high uncertainty ex-post); it requires identification of the means of accounting for actions, typically through accepted standards and codes of conduct.
- Liability is relevant in the contexts characterized by clearly specified rules according to which past action are to be judged (high certainty, ex-post); it requires unequivocal compliance with these rules.
- Care is a type of responsibility driven by the concern for doing the right thing which is clearly understood and socially accepted; it is oriented toward the future well-being of that which is cared for (high certainty, ex-ante).
- Responsiveness is oriented toward future goals characterized by uncertainty; responsibility is enacted through being "responsive" to the changing environment (high uncertainty, ex-ante).

Different dimensions of responsibility can be elaborated in relation to other concepts crucial to governance of non-linear systems characterized by uncertainty and diversity of actors within the complex systems such as the global food system (Termeer et al., 2018; Simon et al., 2019): trust, legitimacy, and power.

Trust is a relational construct which, like responsibility, is closely linked with the challenge of uncertainty: it is an attitude of confidence in the future outcomes based on uncertain or imperfect current information and has a psychological role in reducing social complexity and uncertainty (Luhmann, 1979; Simmel and Bottomore, 2004). Certain types of responsibility—such as care and responsiveness—are grounded in the relationships of trust, as they are based on a kind of faith that the trustor (the person with responsibility) has the best interest of the trustee in mind. Accountability arguably functions within the contexts in which the highly diffused and complex web of actors cannot be supported through the relationships of trust. Accountability enables checks and balances within the network, which allow system control and aim to build *confidence* (Siegrist et al., 2003) in the system's ability to function in the future. Arguably, the food system is managed through a combination of liability and accountability, operating through systems of codes of conduct, standards and certification schemes (Bingen and Lawrence, 2006) by which different agents are held to account.

Legitimacy is a construct closely linked to responsibility as both deal with the issue of authority. Scharpf (1998) distinguished between input legitimacy based on adherence to agreed processes of authority, and output legitimacy, which is derived from the achievement of an agreed set of outcomes.

Global food systems are characterized by the reduced authority of a single institution—the state—and therefore legitimacy is gleaned from the balancing of various actors' responsibilities. The dominance of corporate actors in the modern food system is based on output-based legitimacy, judged through the system's ability to effectively support the commonly agreed goals (Partzsch, 2011). Timotijevic et al.'s (2019) study of 300 EU stakeholders' assessments of food R&I demonstrated that inadequate consideration for input legitimacy is of a major concern for civil society and public sector actors. For the corporate sector, in contrast, governance is considered legitimate if it achieves the system's aims regardless of the means by which it does so.

Different dimensions of responsibility have different implications for how power is shared, exercised and controlled within a system of governance. Accountability can easily lead to hierarchical organization of relationships because it is premised on the fair and mechanistic process of accounting of decisions made. It can often lead to differentiation of power based on the ability to exercise controls over the accounting process. For instance, actors will have a varying ability to collect indicators and evidence to account for actions. However, the desired transformation within the global food system can only be achieved through sharing of power between a broader set of actors, through "democratization" of governance (Lawrence and Friel, 2019), which in turn emphasizes the relational aspects of responsibility that are underplayed when only looking at accountability (Vetterlein, 2018). In other words, it opens up the space to deliberate about what responsibility means and how best to enact it. The dimensions of care and responsiveness allow for participatory decision-making and sharing of power to both identify and construct possible solutions to global food system challenges (Lawrence and Friel, 2019).

Pallizzoni's nuanced extrapolation of different types of responsibility has been applied to the environmental domain (e.g., forestry management—Löfmarck et al., 2017; biomass refinery Sonck et al., 2020), where it has been shown to have analytical relevance in exploring the governance processes, but it is yet to be examined in relation to the food system. Within this paper we report on a study which explores the conceptualizations of responsibility within the context of food research and innovation (R&I). We are guided by Peillizzoni's understanding that responsibility cannot be reduced to a single notion (e.g., of accountability) and explore stakeholders' understandings of responsibility as they play out in the context of food R&I.

R&I are key to the current global and national efforts to achieve the targets in the Sustainable Development Goals (SDGs) (UN SDGs, 2015) 2030 Agenda such as SDG2 (address hunger), SDG3 (health and wellbeing for all), SDG 12 (sustainable consumption and production) and SDG17 (partnerships to achieve the goals). Simultaneously, R&I raises diverse and unprecedented ethical, legal and social challenges, which call for greater clarity about responsibility within R&I networks. R&I within the food system is largely characterized as an interaction between industry and academia, aligning innovation with the dynamic of an unconstrained market (Khan et al., 2016) and raising issues about responsibility within such strategic public-private networks. Understanding how diverse stakeholders in the food R&I conceptualize responsibility is vital because it shapes the way problems are identified, goals are set, and solutions are put in place. Burget et al. (2017) call for more empirically-based studies to better develop understanding of the concept and what it means for those called upon to apply it in real world R&I. This is especially noticeable in the area of research on the challenges currently surrounding the food system, whereby responsibility raises diverse and unprecedented issues of animal welfare, public health, sustainability and social justice. Our study uses three cutting-edge R&I domains—hybrid potato breeding, cultured meat and weight acceptance programme as examples to draw upon common conceptual threads that reveal the dimensions of responsibility for the various food system actors or stakeholders such as public sector, private sector, R&I institutions and civil society. The three domains selected provide a broad scope of ethical and governance challenges that enable rich discussions about responsibility.

METHODOLOGY

We identified the domains of R&I from which to draw our stakeholders through a systematic process of search and selection. Our aim was to identify stakeholders clustered around R&I projects which gave rise to dilemmas about responsibility in terms of who the innovation is for, what kind of relationships it espouses between different actors in the society, and how it is likely to influence the future food systems. The selection was carried out through key informants' consultations and extensive searches of EU CORDIS (Community Research and Development), which led to the creation of a long list of projects based on the following inclusion criteria: projects were conceived between 2011 and 2016 (the period that the RRI concept entered the policy discourse), were at least partially publicly funded, and recognized the need for societal engagement. We then created the short list of six projects which had a strong innovation element; were of diverse provenance (geographic location) and were innovations with different ethical challenges. The final selection of three projects was based on achieving maximum diversity of challenges relevant to the food system (covering agriculture, food technology, and public health nutrition domains), from which to draw our interviews. The three projects identified included: an international project on hybrid potato breeding; an international project relevant to cultured meat; and a national weight-acceptance obesity intervention. By selecting these projects, the study was contextualized within three key challenges: (1) the need to increase the crop yields to feed the growing population; (2) the need to develop an ethical and sustainable protein production system; and (3) the need to address the global obesity crisis in the developed world. Below we summarize the three projects with reference to the ethical and societal dilemmas that they give rise to.

Empirical Application: the Examples of Research and Innovation

Hybrid Potato Breeding (HPB) Project

The HPB project was set up to protect potatoes against diseases by developing hybrid seeds which accelerate breeding and allow rapid modification. Hybrid breeding is an innovative technology to improve crops by crossing the crops that demonstrate favorable traits in order to create a completely new line (Lindhout et al., 2011); the selected project is developing methods of breeding potatoes that will allow them to be reproduced more quickly using true hybrid seeds (https://www.solynta.com/about-solynta/, accessed 12/01/21). This could increase the speed at which potatoes can be modified through breeding, but also help their transportation as the seeds occupy a fraction of the weight and volume of potato tubers. However, growing potatoes from seed poses ethical and legal challenges, including: (a) How ethical is patenting a new strain of seed as a living material for commercialization purpose? (b) Can plant breed patents be used to restrict access to agricultural innovations, creating an imbalance in power between large agri-tech companies and local farmers, and between the developed global North and the developing global South? (c) How to balance economic interests of innovators with the interests of local farmers and create global legal regimes that cater for different interests?

Cultured Meat (CM) Project

The selected CM research project mapped out the challenges faced by CM at the levels of policy-making, funding and industry right down to that of the individual consumer to address a question—should society invest in the development of cultured meat? There is a broad consensus that conventional production of meat based on intensive animal husbandry is difficult to sustain due to its environmental, ethical and human health impacts (Stephens et al., 2018). A technological innovation in meat production is being developed as a replacement for livestock meat: the growing field of *in-vitro* meat (IVM—now more commonly referred to as "cultured meat") represents a new innovation pathway called "cellular agriculture" (Post, 2012). It involves using stem cell research to grow animal muscle tissue in a lab that can then be layered to produce food for human consumption. Despite its promise, cultured meat has been linked with a number of challenges. New techniques capable of developing CM more quickly and on a much larger scale would need to be developed for these benefits to be realized (Hocquette, 2016). Its adoption will largely depend on whether it leads to new social and economic inequalities in terms of who is able to produce and who will be able to consume it (Stephens et al., 2018). The main concern is that introduction of CM into our food system would inevitably shift the balance of power into the hands of global agribusiness, and may potentially exacerbate the global North/South divide. The current regulatory and institutional context are woefully inadequate, and safety of the CM products will need to be assessed not only in terms of processing and food safety, but also for their long-term effects upon human genetic, metabolic, reproductive and physiological functioning (Stephens et al., 2018).

Weight Acceptance (WA) Project

The rapid rise in obesity is thought to be caused by the current global food system which creates an "obesogenic environment" (Swinburn et al., 1999), the physical, economic, social and cultural environments that encourage positive energy balance in their populations. However, current public health policies ultimately place responsibility to avert the rapid progression of the obesity epidemic upon an individual, and by singling out weight as a determinant of ill health, prioritize weight management and reduction as the main route to achieving public health. This approach has been criticized for not recognizing the broader, systemic causes of obesity, leading to instances of discriminatory healthcare practices (such as withdrawal of some treatments—e.g., knee replacement, fertility treatment—due to weight), raising complex ethical dilemmas. This final research project challenges the dominant weight-based paradigm of dealing with the obesity crises. It pioneered social innovation developed and implemented to tackle obesity through the "weight inclusive" approach that promotes the acceptance of bodies of all sizes, whilst simultaneously drawing attention to broader determinants of health.

Participants

Participants were purposefully selected to represent a range of stakeholder perspectives on the innovation and occupying diverse roles within the domain-specific R&I process—some were directly linked to the project, as either directly funding or conducting research (e.g., scientists; research funders); whilst others were sitting outside the immediate process of R&I in the respective domains (e.g., civil society organizations, policy actors). Representing all stakeholder groups equally was logistically impossible. Industry stakeholders proved harder to recruit as they were fewer in number to begin with, tended to be less involved in the research process than the researchers and have been less invested in having a specific agenda heard than the third sector organizations. The Weight Acceptance project was run entirely in the context of the UK health services, drew on the UK National Health Service (NHS) for support that might otherwise have come from industry or the private sector and therefore had no meaningful relationship to industry, and thus no industry stakeholders. However, the fact that interviews were unevenly distributed across stakeholder groups was not considered a major obstacle as this paper does not seek to generalize findings or speak for entire stakeholder groups or research domains. Moreover, as a qualitative analysis, generalization is not the objective. Instead, it aims to explore the thematic categories cited as important by these particular examples of stakeholders within different groups. Every effort was made, however, to engage the stakeholders who were either existing inside the R&I process, or who were sitting outside it though had a stake in the innovation domain. The participants are detailed in **Table 1** below.

Due to the small number of interviewees and their often-unique expertise, roles and prominent standing in three relatively

TABLE 1 | Participants by case study.

Stakeholder category	Cultured meat	Hybrid potato breeding	Weight acceptance	Total
Third/Fourth sector organization[a]	2	1	2	5
Policy maker	0	1	12	13
Research Funder	0	0	2	2
Researcher	4	4	1	9
Industry	0	3	0	3
Total	6	9	17	32

[a]*Third Sector organization (TSOs) are citizens' interest groups, such as civil society organizations and labor unions, as well as religious organizations and informal networks of citizens, often motivated by moral, ethical and ideological concerns.*

narrow domains, only the demographic information deemed necessary to address the research questions was collected, in order to maintain the confidentiality of interviewees. Moreover, because actors spoke as representatives of their organizations rather than as individuals, gathering personal information was deemed irrelevant. In addition, delineating participants by country was not found to be useful as many spoke for international projects, were based in countries other than their countries of origin and very often the most meaningful geographic unit of analysis was that of the EU rather than that of individual nations. The exception to this was the Weight Acceptance project, which took place entirely in the UK and involved only UK stakeholders.

Procedure and the Interview Schedule

Semi-structured interviews were chosen to allow flexibility in following up on participant-relevant issues. The broadest aim of the research was to talk to the actors within the R&I system about how they understood responsible R&I and what "responsibility" meant to them. Participants were firstly asked to describe the project and explain their roles within it, after which two main issues were explored: how responsibility in R&I was conceived in general, and in the context of the project; and the process of societal engagement within the project. The interview schedule also prompted the interviewees about how the concept of responsibility related to the notions of trust, impact, openness, and engagement with society. The interviewees were not asked to apportion blame or indicate their understanding of the causal attributions of responsibility within the context of their respective R&I domain, to avoid biasing the discussion. Interviews were transcribed from audio-recordings. Informed consent was obtained, and the interviews were conducted in person or via telephone.

The University of Surrey Ethics Committee granted this project a favorable ethical opinion on 19th July 2016 (UEC/2016/031/FHMS). The interviews were carried out during the period of Nov 2016-March 2017.

Analyzing Data

Thematic analysis (Braun and Clarke, 2006) was conducted within, and then across the three cases. Thematic analysis was chosen as it allows the accounts of different types of stakeholders to be examined without privileging any particular perspective or framework. It does this by using the data itself as the basis for generating and refining categories on an ongoing basis. This both facilitates a rigorous methodological approach and allows the flexibility to validly reflect the arguments of participants whilst maintaining a reflexive awareness of researchers' own biases and preconceptions. Our epistemological orientation was that of social constructivism (Burr, 1995), which posits that meaning and experiences are created through social interactions—the focus was not on individual motivations, but on the meanings and (lay) theories as emergent properties of the socio-cultural contexts of those group interactions. Our approach to thematic analysis was a combination of inductive and deductive coding—whilst we engaged in a close reading of the transcripts, we were nevertheless guided by the existing frameworks of responsibility. The initial coding structure was developed by two researchers, following which, the team discussed and developed the themes with an aim of identifying dimensions of responsibility.

RESULTS

Differences in how interviewees conceptualized responsibility in R&I were not clearly aligned with a single R&I domain or any groups of stakeholders. While participants offered a variety of opinions about responsibility, these were more likely to vary between individuals than by stakeholder group or indeed the R&I domain. It was even common for the same participant to characterize responsibility in different ways when discussing different aspects of R&I. Within the analysis we explicitly attribute quotes to different projects, which allows us to draw attention to any differences in conceptualization of responsibility that may be associated with the specific domain in question.

Four overlapping rationales of responsibility were identified across all three case studies: (1) responsibility as accountability; (2) responsibility as impact; (3) responsibility as reflexivity; and (4) responsibility as responsiveness.

These four varied most meaningfully by the degree to which they depicted the assessment of responsibility as focusing on the process of research or its outputs and the extent to which doing so was depicted as requiring societal engagement. This can be described on a 2×2 matrix, as illustrated in **Figure 1** below.

The following sections describe each of these rationales of responsibility in R&I in turn, focusing on how it might be achieved within the current food R&I governance.

Accountability

Under this rationale, responsibility is assessed in terms of individual actors working within the research process as agents accountable to their principal for servicing specified goals in compliance with ethical and institutional guidelines. Under the accountability rationale research goals are chiefly decided upon by those holding the purse strings.

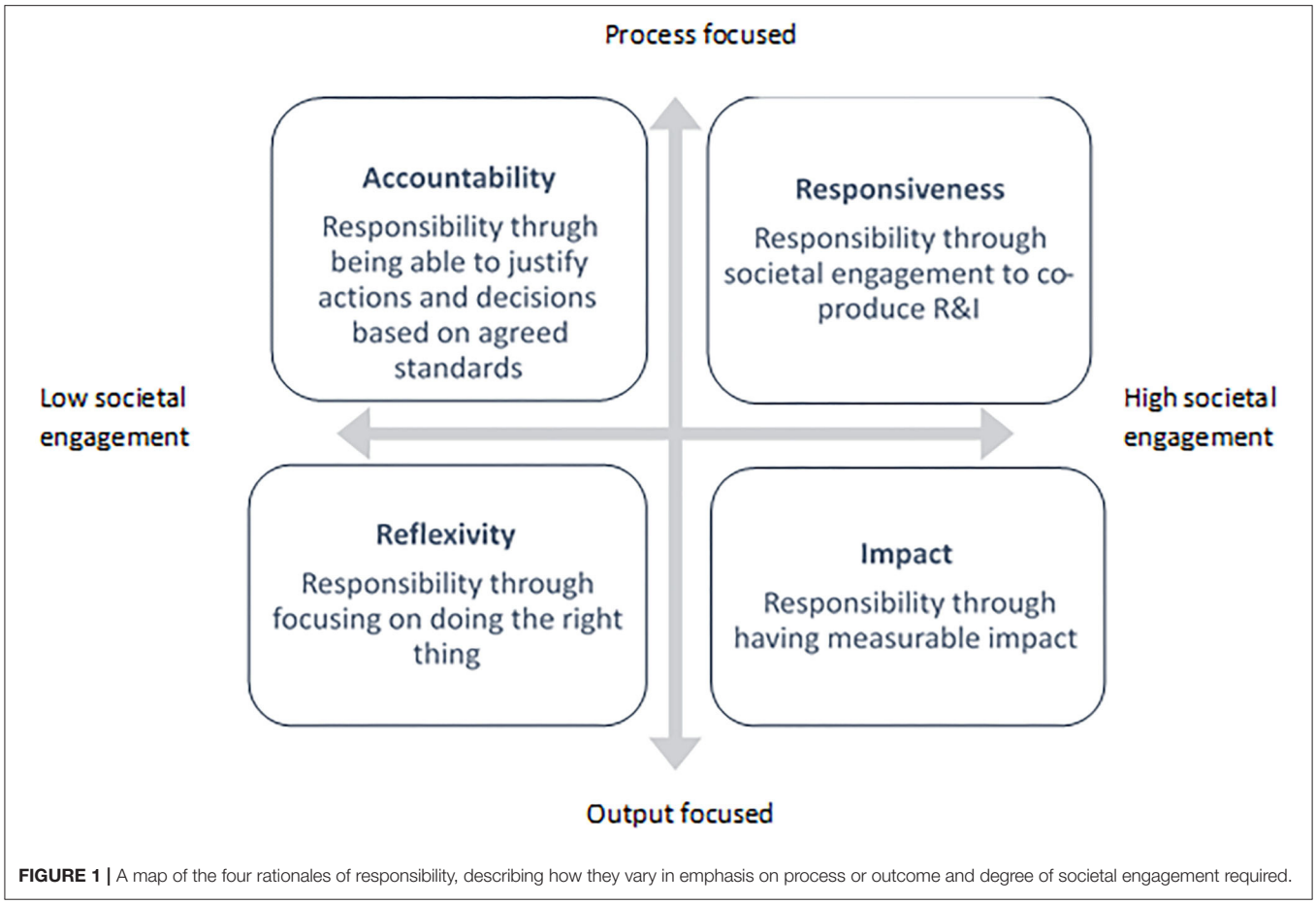

FIGURE 1 | A map of the four rationales of responsibility, describing how they vary in emphasis on process or outcome and degree of societal engagement required.

Participants recognized that the modern principal-agent relationship (which applies a customer-contractor relationship to science governance, Cooksey, 2006), was a significant divergence from the cognitive authority model of science that is based on assumptions of expertise, impartiality, and the need to protect science from the external influences, such as governmental pressures to make science "useful" ("The Haldane Principle," Haldane, 1918). It re-cast responsibility as no longer simply deriving from the cognitive authority of scientists to speak truth to power, but instead as a narrower, relational responsibility *to* the relevant authority (Guston, 1996).

> *"I can imagine that a researcher in the past had more freedom to operate and to investigate what he thought was best, now there are limitations in what can be done due to money availability." (Researcher, HPB)*

The above extract is typical of interviewees in suggesting researchers now bear limited responsibility in steering the direction of their research rather than merely for fulfilling their allotted role in its process.

Participants from each of the three domains (CM, HBP, and WA) identified two fundamental shortcomings of this narrow conceptualization of responsibility through the lens of accountability: its failure to acknowledge the uncertainty inherent to the research process in how it is governed, and its implication for trust.

Some participants argued that the accountability model of responsibility creates pressure to explain away uncertainties and ambiguities inherent in the science process via external pressure to comply with the procedures that often do not permit deviation from the outcomes and processes agreed upon with the principal *apriori*. One interviewee argued that principals' desire for clear and unambiguous answers risks misrepresenting a process that was, in truth, often messy and unpredictable.

> *"I would like to see modes of accounting that allow ambiguity and uncertainty to be visible in the account. I think there's a general sense that, you know, acknowledging uncertainty is not done as widely as I would like to see…" (Researcher, CM)*

The most common criticism of this rationality was the fundamental imbalance of power and the trust vacuum that it creates. In the following extract, a CM researcher describes a "principal's" (funder's) freedom to entirely discount researchers' ability to judge what constitutes a responsible research process as symptomatic of a deeper distrust.

> *"I think one of the things that should…that should be done is make it sort of less bureaucratic—lose a lot of the red tape because that's basically a sign of distrust in how people are doing*

their work. It has gone completely awry and it's sending the wrong message. It's sending the message, you know, "We don't trust you when we give you money, you need to tell us exactly what you're doing, how you're doing it, when you're doing it, and that turns into a very bureaucratic, automatic system that really doesn't support creativity." (Researcher, CM)

When responsibility is primarily conceptualized in terms of accountability, it is perceived to have a detrimental effect on trust between key actors within publicly funded science. Emphasis upon accountability introduces external criteria for "responsibility," based on (often backward-looking) assessments of compliance with due processes, rather than enabling a conversation about what constitutes responsibility within the framework of meeting the principal's needs. The deeper consequence of conceptualizing responsibility as accountability is that it is only relevant to those stakeholders who are directly involved in R&I process, precluding the wider interested actors such as civil society organizations.

Impact

Assessing responsibility as impact required being able to demonstrate positive real-world research outcomes:

"*'Responsible' is R&I having a positive societal impact, and there, of course, you introduce a value, positive, which can be debated in all kind of ways. It's very subjective. So, we started with, when I think back, with that concept, how can we make Intellectual Property (IP) in plant breeding having a positive impact on farmers, and, at the same time, avoiding that it will ever have a negative impact on some kinds of farmers. So that is on what you want to achieve with your research in terms of output." (Researcher, HPB)*

Such assessments typically emphasized measurable short-term economic benefits assumed to generate longer-term prosperity and ultimately to help society meet broader challenges such as sustainability and food security. The relationship of innovation and economic prosperity was spelled out by a scientist on the HPB project.

"*It's economic, and we usually don't consider that as a value, but of course it is a value, it's something to be valued. It provides jobs, and it brings money to the country, and it brings good potatoes to the world! And then, you know, we try to incorporate other values than just that, and that's part of our challenge." (Researcher, HPB)*

There were several concerns raised by different stakeholders associated with this rationale of responsibility, which included: emphasis on commercialization of innovation; short-termism; and imbalance of power in deciding innovation pathway.

Conceptualization of responsibility as an ability to achieve impact positions it outside the process of research and the purview of scientists, which raises questions of where control over the R&I actually resides. A policy maker involved in the HPB project was one of several participants who suggested this often amounts to allowing research directions to be primarily determined by "commercial players."

"*I think the whole debate about the public good is put in the hands of the markets, and of course the commercial players, and so I think this is a sort of very fierce, uphill struggle that you have, you will have with RRI [responsible research and innovation], because this is also the sort of wall you will come against in thinking about RRI." (Policy maker, HPB)*

This positions "the markets" as exerting considerable control over which outputs are judged responsible and therefore on what future work is commissioned, but what of the influence of government funding bodies whose remit includes ensuring that research impacts serve the needs of wider society? The following account from the same policy maker suggests that while governments do play a role in allocating funds under the Impact rationale, it is often private sector organizations who lead the way:

"*You have the Ministry that is stimulating innovation but, in a way, that basically, positions the commercial parties as the drivers of innovation. And doesn't see a role for itself in really shaping these innovation trajectories. So in that sense I think that responsible R&I is a concept that will not really be seen by our parliamentarians as a very important issue." (Policy maker, HPB)*

The tendency for governments to let industry have the first say in setting "innovation trajectories" is here explicitly linked to the imperative to achieve economic growth through innovation, and reducing the role of science primarily to the economic value:

"*As soon as the industry shows interest, the government is willing to match that kind of money, to enhance research anyway. They see the benefit of the working relationship between researchers and the companies." (Researcher, HPB)*

It is suggested that having to take on faith this hope that economically motivated research will also contribute to a better society is problematic. If, as the following extract suggests, it is only the short-term economic impacts that can be validly measured in the limited timeframe principals are interested in, then funding research largely on the basis of longer-term societal benefits can no longer be considered responsible. At this point the logic of the Impact rationale becomes as self-perpetuating as the power of those who profit from it.

"*Perhaps it's very naïve of me, but I hope that then the, yeah, ultimate goal is for societal benefits, as opposed to monetary ones. I think it's really hard to ever judge social or societal impacts of any single project. Ask me in 5 years or 10 years and I might be able to answer your question more thoughtfully. So, I think that the funder's need to assess and justify impact doesn't fit right with how we can actually truthfully measure impact [laughing]." (CSO stakeholder, CM)*

Interviewees across all three cases manifestly differentiated between economic and societal impact decoupling the former from its positive connotations. The same CSO stakeholder emphasized the need to ensure that responsibility is no longer conceptualized solely in terms of economic impact, as a way of democratizing the process of R&I.

"*I think research, recently, seems to have become very tied to industry, and it has to have economic outcomes at some point, and so, hopefully, responsible R&I [laughing] is saying, well, it doesn't have to have an economic output, as long as it has a societal benefit." (CSO stakeholder, CM)*

The danger of creating self-perpetuating structures of power intolerant of dissenting views was particularly strongly argued by participants from the WA domain. The project's founder argued that her funding was jeopardized precisely because it challenged dominant assumptions about food.

"*The drive for a monolithic ideology, which is what I discovered [name of other health programme] was. Perhaps I did know it on some level. It wasn't what I was working toward, but being silenced absolutely drove that home to me, and that… that's fascism." (Researcher, WA)*

The Impact rationale of responsibility, unlike the Accountability, does include a role for members of the public, though not as citizens who might help align research trajectories to societal needs but as consumers or potential innovation users.

"*… [large company] is too much short-term in their way of thinking, so if they want to do research, they want their money back in 2 years. No, that's not going to work in this kind of research. And yeah, they listen very closely to what their consumers want and they simply deliver that." (Researcher, HPB)*

Engagement therefore takes place as part of design process, follows set lines and is targeted downstream at user/consumer groups whose uptake is required, as distinct from the more participatory, upstream approaches to engagement:

"*I strongly believe that research is a two-way street. I mean, you have to communicate with the people who are going to use your knowledge because, for one thing, you want to know the questions they have and that makes what I'm saying more relevant, if I take their response into account." (Researcher, HPB)*

Engagement within this rationale focused on delivering an innovation better adapted to its intended market. However, participants across case studies expressed the desire to embrace more flexible definitions of socially responsible impacts that challenged the "hegemonic" assumptions about what constitutes impact through careful reflection and by opening up engagement to those sitting outside the process of innovation.

Reflexivity

The participants argued that they had a duty to be reflexive about their own research processes and anticipate all potential outcomes for society. A researcher on the HPB project described this in terms of a collective responsibility amongst scientists, one born of the culture of science but not bound by its rigid organizational structures.

"You have the responsibility to think about the impact of your research outside of your domain of research. I think it's also very much the structure of science, which is organized so that it does not promote this kind of thinking, so yeah, it's not the scientists' personal responsibility, but it is our responsibility as science, as a science system or as scientists together, to think about society." (Researcher, HPB)

The interviewee's insistence on collective rather than personal responsibility also distances it from the belief that responsibility requires the ability to trace negative consequences back to individual actors in the research process and hold them accountable. Instead, the community of scientists and the values it embodies become the crucible through which responsible research is forged.

Crucially, while the Accountability and Impact rationales focused primarily on retrospective assessments of responsibility, the Reflexivity rationale locates responsibility in anticipating unforeseen challenges and absorbing future shocks. In the following extract it is argued that responsibility means being aware of all potential future consequences of introducing a powerful new technology, not just whether it will achieve the intended goal:

"In the context of this innovation, you can think about the development of technology in a purely instrumental way. So you have a particular goal set for what you would like to achieve, and the technology is a means to realize that goal. And in my view, responsibility means that you are open for the fact, that I would say, the fact that technology is always more than just a means to an end. It will also, it will always interfere in unexpected ways in all kinds of processes. And then for me, responsibility in that context would mean that you really take care in the sense that you see yourself as someone who should be part of the conversation about these different effects, and that might result from the development of a particular technology." (Researcher, HPB)

Responsibility here takes an important step beyond the scope of the innovation's intended impacts to examine its unintended consequences. What is implied to be irresponsible is treating a new technology as nothing more than a value-free instrument for achieving a specified goal. For a CSO stakeholder on the WA project this extended to considering the risk of exacerbating existing social and health inequalities.

"The responsible bit suggests to me that you need to be very clear about the impact of what is going to be said because so much of our research has actually skewed things in a way that a population, usually the most deprived in a community, have been further disadvantaged by that. So, I guess that's what I mean about the social justice bit." (Researcher, WA)

This frames the danger of research widening existing social divisions as not just a possibility to be guarded against, but a common occurrence. Participants on the WA project were especially likely to raise this issue, of the three case studies they after all had the closest connection to the people affected by their innovation. Indeed, it was rare for participants on this project to discuss social injustice without addressing the related question

of—to what extent the privilege of working within the innovation process made them responsible for challenging this injustice.

> *"I want it to shift our way of being in the world, and that means our relationship with language and our relationship with power; it doesn't mean deskilling people, doesn't mean deskilling myself, but it means recognizing that I have a certain cache of social capital and that, if I'm serious about social change, it has to be radical." (Researcher, WA)*

This frames responsibility as a moral imperative to question existing power relations, including one's own role, to reflect on the parts played by language, symbols and social hierarchies in deciding how innovations and research are promulgated. Equally, though, it is also a call to action. In the following example, a researcher on the HPB project discusses a researcher's obligation to act in a scenario in which an innovation endangers the livelihood of smallholders by rendering their potato growing methods obsolete.

> *"The company that's involved in this programme, well, they have a very clear technological solution for [the problem] but that technological solution is going to change the landscape of potato production in the [country], very much so, and probably in the world, . . . so yeah, you can't simply just start and say "Okay, this is the new technology—you better adopt it because otherwise you won't be in business anymore." You have to really change the whole. . . the whole thing." (Researcher, HPB)*

This process of being reflexive about underpinning assumptions, the way language frames research questions and shapes research processes, was considered an important way of enacting responsibility.

> *"It wasn't only about values, it was also about the framing of, for example, what is a child or what is a neuro-scientific researcher, what should the teacher be doing, and then you see that there's all these things that are actually not really mentioned, these assumptions that are. . . that it's good to bring them into the open, just to create some sort of. . . understanding, and also reflexivity about your own assumptions." (Researcher, WA)*

In contrast to the Accountability rationale, researchers are not merely responsible for the conduct of the work itself. Rather, in addition to following ethical and professional guidelines, they must continually strive to connect the underpinning assumptions and values they bring to the project with its potential societal impacts. In the following extract, an HPB researcher frames the ongoing nature of this attentiveness as a way of acknowledging the limits of one's ability to realistically anticipate all possible outcomes.

> *"It's a way of better dealing with the uncertain future, but the future is still uncertain, you know... and I think there's just in that sense limitations on what kind of values you can take into account, because you know, you basically don't know all the values that may pop up, you have to keep being attentive...it is a continuous process. So what we're doing is not, you know, this is RRI and then you tick the box." (Researcher, HPB)*

In addition to being a way of pre-empting negative outcomes the participant positions continually "being attentive" as a way of being transparent about the fact that not all negative outcomes can be predicted, nor all damages prevented. Responsibility through reflexivity distances researchers from the need to account for all steps in their day-to-day research. As discussed in the earlier sections on Accountability and Impact, such reductionist conceptualizations of responsibility preclude engagement with the uncertainties and the unknowns in the process of R&I and has a contradictory effect of arguably reducing anticipatory reflexivity to just those issues that can easily be measured or accounted for. Reflexivity rationality instead reframes responsibility as a duty to anticipate and seek to communicate the future challenges that R&I are addressing and the ultimate need to articulate a framework for collective leadership and responsibility in R&I, as argued for by a researcher from the CM project:

> *"But this is a huge challenge, isn't it? I mean, we're talking about thin, tiny, little attempts at a task that is formidable. We're talking about a change in the culture of R&I. We're talking about changing the social contract of science and society." (Researcher, CM)*

Responsibility as reflexivity calls for a form of collective leadership based on the moral imperative to achieve public good. The extract below is an emotional plea to move away from the demand-pull understanding of innovation that gave rise to Accountability and Impact rationales of responsibility toward the responsibility based on ethical deliberations and value judgments that go beyond the market dynamics.

> *"What struck me most, was that also people from the sector said 'this is not what we are going to do, because the consumers don't want it'. And I really was a bit angry about it, I must say, because then my question would be, and I posed this question to them, 'if you, if you think there are very good reasons to take up this kind of potato, er. . . why could you, why couldn't you tell this to the consumer?' And promote this potato as something that really is something that might interest you as a consumer, because it is a response to, to very important problem in potato production. So, it, is just using the consumer as a sort of shield . . . " (Researcher, HPB)*

Participants from all case studies were more likely to describe reflexive responsibility being realized in interdisciplinary collaboration and consultations within the research community than by speaking to members of the public.

> *"Responsible research does not necessarily have to fit in a kind of straightjacket of participation, not necessarily. I think it is almost always interdisciplinary though because you want to include different social sciences in your natural science research, in order to properly think about societal impact. It does not necessarily have to involve societal partners." (CSO stakeholder, HPB)*

The point suggested by the straightjacket analogy, suggests that responsibility through reflexivity involves an opening up of

definitions and participation amongst a community of allied experts rather than conforming to a strict externally imposed formula of societal engagement. This frames responsible R&I as depending less on societal engagement and inclusivity and more on a collective commitment to honest reflexivity about research outcomes, including unintended outcomes and those affecting disadvantaged groups in society. Nonetheless its focus on introspection within the research community lays it open to charges of lacking transparency, inclusivity and potentially saying much but doing little to address the role of power relations in deciding the future of science.

Responsiveness

The final rationale envisages responsibility as shared decision-making through active engagement with societal actors. It frames co-production as the essence of responsible R&I, distancing itself from the Impact rationale's understanding of engagement as solely an instrument for eliciting needs in order to inform, rather than influence, decisions. Instead, co-production implies openness to diverse values, skills and forms of knowledge, empowering each stakeholder to contribute on the basis of their uniqueness. This is a process-oriented (performative) notion of responsibility as opposed to output-oriented (substantive), one which brings democratic processes to science governance. Like other rationales, however, this one is also problematized by respondents, who expressed two main concerns: regression to the mean, or the rule of the average intrinsic to the practice of societal engagement; and the practical difficulty of achieving consensus among disparate positions. Both of these problems were ultimately considered to be barriers to R&I. Sharing power in a balanced way across networks of collaborators was crucial to this rationale of responsibility.

> *"I see RRI as part of an ongoing socio-technical discursive, dialogue, set of practices, constellation of actors and interests, that are trying to frame appropriate relationships between various forms of innovation, some notion of democratic representability, you know, political accountability, and, notions of expertise, which again are flexible." (Researcher, CM)*

The focus on networks of evolving relationships echoes Stahl's claim that "*Responsibility can be understood as a social construct that establishes relationships between a set of different entities.*" (Stahl et al., 2013, p. 200). Crucially, this approach combines the need for some form of accountability as science is a largely publicly funded endeavor, with democratic responsibility, because science ultimately impacts society.

> *"Researchers have a responsibility toward society because their research will be in society if it needs to impact society, but you are doing research within society and you're also being paid by society, and yeah, I think responsibility is very much paired with an idea of the democratic science system." (Researcher, HPB)*

The concept of "democratized system of science" is a move away from the binary understanding of responsibility through the lens of expertise—whereby responsibility is narrowly centered on the networks of experts and their principals. Instead, Responsiveness is manifested in engagement with broadest sections of society, as an opportunity to question existing power imbalances and dissolve the distinction between the notional expert and the member of the public:

> *"It's…just a neoliberal…it's completely neoliberal. Even sustainability, you know, food sustainability, it's 'How can we help them?', so there's a 'them and us', you know, 'How can we help them to eat well?' not "How can we change the power relations?" And also 'How can we use our work, how can we use food work to shift power relations?' and that's what I want from [WA project name], to have different conversations." (Researcher, WA)*

The distinction between a well-intentioned but paternalistic and implicitly elitist approach to engagement and one that enables "different conversations" between equals came through most clearly from participants from the WA study with the closest relationship to the wider public.

Nonetheless, even in the less public-facing HPB project, another researcher went so far as to frame this new, more democratic relationship between innovation and the public as a radical inversion of traditional roles.

> *"... RRI is really an attempt, quite a radical attempt to change this…by putting up-front the question of the needs for innovation, the sort of societal challenges that should direct innovation, and the interesting thing is that then you could say that the societal stakeholders then become the enactors, and the technologists become critical responders in a way, because they have to think about whether, indeed, their science is able to respond to that question. And that, of course, has to be a real conversation, because both parties… it's mutual learning." (Researcher, HPB)*

What initially seems an inversion of roles between experts and society here is eventually transformed into a leveling in which expertise and power, and therefore responsibility, become properties of all actors in the network. All are now responsible for their own contribution to the process and, collectively, for the process itself. This is reinforced by the use of the same description of engagement as a "conversation" in the excerpt above, suggesting some level of equity between different kinds of stakeholders and, by extension, the different types of expertise they bring to the table.

Casting members of the public not as outsiders to the research process but as "societal stakeholders" within it, recalls earlier descriptions of research as a "two-way street" under the Impact rationale but goes far beyond that model in terms of the purposes of engagement. Rather than simply using public input to make the products of innovation more likely to succeed, the above account affords societal stakeholders a key role far earlier in the research process. Participants did not necessarily portray early societal engagement an impediment to fulfilling the goals of funders, but an essential part of innovation process.

> *"I recognize the importance of people like me, but also people doing lots of other things that are different to what I'm doing, being actively involved in the debates that shape*

modes of innovation and being involved in them early on." (Researcher, CM)

The following account framed engagement more as a way of contextualizing those goals within the needs of society and gaining a better understanding of the network of relationships currently making up the specific sector involved.

"We started with a study of what you could call the potatoes sector, which is to some extent a value chain, but it's in many respects a value chain which has a network character. And studying this, on the one hand, the purpose of making ourselves familiar with everything that relates to the potato, and all the different parties involved. But, we also see it as a very important starting point for thinking about future scenarios, because every scenario you might think of, of course, has to start in the present and will be shaped in different ways by the established relationships and goals and values that are part of this network." (Researcher, HPB)

Responsibility for R&I then becomes a collective responsibility distributed across the network of various societal actors as an emergent property of that network that could not be generated by any one actor or set of stakeholders working alone. This shared responsibility implies freedom from personal accountability but also a surrendering of individual control. This can be a problem for those who associate innovation with accountability of actions linked to the specific actors within the network. It also can challenge the demand-pull concept of innovation which relies on the motivation to innovate in order to achieve and exploit the Intellectual Property rights and would require being able to preserve one's unique vision rather than achieving consensus and compromise:

"Science, well, especially the multi-reviewer type of things, tend to be very democratic and sort of regressing to an average, so you have to find the common denominator between the different reviewers, and that's—for radical innovations—that's tough." (Researcher, CM)

In short, societal engagement is a manifestation of Responsive responsibility because it creates conditions for consensual and collective decisions within the network. It is a process-oriented responsibility, one which is open to criticism of ignoring the pragmatic difficulties of making any powerful innovation work in practice.

DISCUSSION

Our research examined the discourses of stakeholders currently engaged with food R&I. Through thematic analysis we identified coherent accounts about what constitutes responsibility and mapped these to four distinctive rationales of responsibility. Each rationale is characterized by a specific R&I governance arrangement which emphasizes either the process of R&I or its outcomes, implies different roles for societal engagement, and promotes alternative methods for assessing responsibility. **Table 2** summarizes the classification and the associated policy implications. These to a large extent echo Pellizzoni's typology of responsibility. To some extent they also reflect the typology created by Glerup and Horst (2014), who, based on their review of 263 published articles (albeit not within food R&I), have highlighted process vs. outcome-focused assessment of responsibility as an important dimension in their typology.

Our results suggest that being responsible means not just implementing one rationale of responsibility but balancing many—a kind of "meta-responsibility" (Stahl et al., 2013) that indicates potentially competing models of food R&I governance. The diverse rationales discussed by the participants co-exist across the three cases. Within each, Accountability and Impact are recognized as current drivers of food R&I governance. The participants link this to the concentration of investment in research areas most amenable to quantifiable cost-benefit assessments, and in turn, R&I being increasingly held responsible for economic growth, research output exploitation and furthering of commercial interests. The participants recognized that such reductive understandings of responsibility are particularly problematic within the R&I relevant to building a socially fair and sustainable food system, as it needs to recognize uncertainties, co-dependencies and values that go beyond the quantifiable metrics. Both Reflexivity and Responsiveness rationales articulate these uncertainties and inter-dependencies, locating responsibility not within a single individual but either within the collective conscience of innovators and researchers or within the wider network of food actors. Both rationales seem to endorse "technology of humility" (Jasanoff, 2016): within Reflexivity rationale, it is explicitly linked to the ethical deliberation of those directly involved in R&I; within Responsiveness rationale, this is done through societal engagement with those sitting outside the research community. The participants unequivocally recognized the need for cultural embeddedness of ethical and social deliberation within R&I for a sustainable food system that recognizes responsibility as an emergent property of the food R&I network. The process of R&I and the attendant responsibilities will cease to rest with Foucault's "responsibilized" individual stakeholders (Lemke, 2015), but with the network of relationships connecting them, echoing May (1992) and Young's (2006) Social Connection Model of responsibility. Young argued that structural injustice can emerge as a consequence of actions of many individuals and institutions within a network, each acting in pursuit of their particular goals and interests within the norms of their institutions. Even when the actions of each individual are clearly compliant with these rules and norms, the system itself might nonetheless generate unintended outcomes, which cannot be traced back to any individual. Our study suggests that the challenges of food R&I for a sustainable food system require a greater recognition of different rationales of responsibility, echoing these arguments. This does not mean removing accountability as a backward-looking rationale for adjudging responsibility, but asks of all actors within the network to anticipate how accountability as one of key rationales of responsibility frames the problem and the possible solutions, inadvertently obstructing transformation toward sustainable food system. The forward-looking assessments of responsibility (Responsiveness and Reflexivity) shift the focus toward greater

TABLE 2 | Rationales of responsibility in the context of food R&I.

Rationales of responsibility	Responsible to whom	Governance of R&I	Relationship between society and R&I	Methods for assessing responsibility
Accountability	Describes researchers' contractual obligation to those who commission, fund and evaluate their work as reflected in principle-agent R&I governance.	*Process-oriented R&I governance* Focuses on processes of accounting based on pre-agreed measures.	Social contract between society and science managed through a nexus of institutions established to ensure transparency in the governance of R&I, in keeping with the social contract. No explicit requirement for the engagement of society – different institutions (e.g., retailers, funding agencies) act as the guardians of societal interests.	*Backward-looking evaluations* of responsibility, assumes an ability to identify *causal factors* for any shortfalls in the process of R&I. Approximates a legal concept of responsibility as liability for consequences resulting directly from research process and traceable to individual actors in the system.
Impact	Responsibility to those who stand to benefit from R&I—users and consumers.	*Output-oriented R&I governance* Links R&I to explicit measures of impact as reflected in the innovation-oriented science governance.	Relationship with society is through demonstrable impact, primarily in the ability of R&I to generate economic and user benefit. Engagement as user or consumer, rather than as citizen – thus, engagement is further downstream, and is open only to those who have vested interest in the innovation.	*Backward-looking evaluations* of responsibility in terms of identifying *causal pathways* and researchers' explicit goals that are traceable to the impact.
Reflexivity	Responsibility to the collective identity of science as ethical institution.	*Output-oriented R&I governance* Focuses on social justice and fairness as outcomes of reflexive engagement with the societal challenges R&I are tackling.	Does not mandate societal engagement as it is not considered a necessary part of ethical reflexivity. The lack of societal engagement is morally justified by the assumption that optimal outcomes (ethically, socially) will result from the un-biased deliberation of those with the best access to knowledge.	*Forward-looking evaluations* of responsibility, evaluations of the hidden *conditions that shape and propel research and innovation*, which may produce injustices in the future.
Responsiveness	Responsibility to society as a network connecting all actors within the food system.	*Process-oriented R&I governance* Oriented toward democratizing scientific processes through equality of opportunity offered to all to influence and shape technology for the future.	Shared decision-making and co-production of solutions: empowers society to actively contribute to the shaping of innovation and research at the earliest stages of R&I cycle of priority and agenda setting. Collective responsibility for research and innovation process itself through reasoning together. The complex socio-technical system is characterized by inter-dependency of actors and their actions—and this is what creates conditions for collective responsibility.	*Forward-looking evaluation* of responsibility as reflexivity and collective dialogue about our *future and different paths* it might take. Openness to pursue different options for the future based on collective reasoning.

clarity about the intentions and motivations underpinning R&I for sustainable food system; and broaden the framing through which future impacts are evaluated. Therefore, responsibility allocations within a complex food system network should be concerned both with the backward-looking (Accountability and Impact) and forward-looking (Reflexivity and Responsiveness) assessments of responsibility aimed not at assigning blame but ensuring future justice for all. Of course, it remains an empirical question how the governance that advocates that the focus on accountability and impact is complemented by reflexivity and responsiveness might be implemented in practice. Strong governance frameworks specifying procedural aspects including inclusiveness and representation, overseen by clear frameworks of accounting, may be needed to provide oversight and control against vested interests usurping governance processes (Kraak et al., 2014).

Our study has some limitations. Some categories of stakeholders were more prevalent or accessible than others, and whilst we made efforts to equally represent different stakeholders, this was difficult to achieve. Despite these constraints, it was nevertheless thought less important to equally represent different categories of stakeholders because their categorization and roles varied between R&I domains in ways that made operationalizing these definitions problematic. Rather, it was thought more useful to differentiate on the basis of which types of stakeholders were currently described as influencing research from within

the research process and which were described as existing outside it and requiring access via gatekeepers in order to exert influence. Arguably, with scientists now sitting on funding councils, advising policy makers and consulting for industry, the most significant boundary to be examined no longer lies between the institution of science and everything else. A more useful way to examine the roles of responsibility within food R&I and the concomitant governance processes may be to juxtapose those stakeholders who are currently part of the extended professional infrastructure involved in R&I—not just researchers, but funding bodies, policy makers, industry– with those who are not, for example groups in wider society, and this differed by project.

CONCLUSIONS

Responsibility needs to be re-imagined as a matter of social negotiation; R&I as achieving legitimacy through ethical and social deliberation, aimed at what is (socially, ethically, environmentally) desirable, rather than merely accountable. Our mapping of responsibility rationales as they specifically play out in the context of food R&I, and the identification of the key criteria on which these rationales are differentiated provides a basis for systematic application of these criteria to the specific instances of food systems R&I governance and for future joint decisions, within the food network, about the ways to allocate responsibilities.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analyzed during the current study are not publicly available. This is because the consent from the participants to re-purpose the anonymized data was given under the condition that the data would only be made available if relevant legal, professional, and ethical approvals were provided. Anonymized data is available from the corresponding author on reasonable request. Requests to access the datasets should be directed to l.timotijevic@surrey.ac.uk.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The University of Surrey Ethics Committee which granted this project a favorable ethical opinion on 19th July 2016 (UEC/2016/031/FHMS). The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

LT had an overall responsibility for the study, the design and the analysis of the study, and wrote the article. CH contributed to the analysis and writing of the article. MP collected, analyzed data, and contributed to the writing of the article. MR contributed to the design of the study, analysis, and writing of the article. All authors contributed to the article and approved the submitted version.

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REFERENCES

Barling, D. (2008). "Governing and governance in the agri-food sector and traceability," in *Ethical Traceability and Communicating Food. The International Library of Environmental, Agricultural and Food Ethics*, eds C. Coff, D. Barling, M. Korthals, and T. Nielsen (Dordrecht: Springer) 15, 43–62. doi: 10.1007/978-1-4020-8524-6_3

Biermann, F., and Pattberg, P. (2008). Global environmental governance: Taking stock, moving forward. *Annu. Rev. Environ. Resour.* 33, 277–294. doi: 10.1146/annurev.environ.33.050707.085733

Bingen, J., and Lawrence, B. (2006). (eds.). *Agricultural Standards: The Shape of the Global Food and Fiber System*. New York, NY: Springer.

Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Q. Res. Psychol.* 3, 77–101. doi: 10.1191/1478088706qp063oa

Burget, M., Bardone, E., and Pedaste, M. (2017). Definitions and conceptual dimensions of responsible research and innovation: a literature review. *Sci. Eng. Ethics* 23, 1–19. doi: 10.1007/s11948-016-9782-1

Burr, V. (1995). *An Introduction to Social Constructionism*. London: Routledge. doi: 10.4324/9780203299968

Clancy, K. (2014). DIGGING DEEPER: bringing a systems approach to food systems: food system governance. *J. Agricult. Food Syst. and Communi. Dev.* 4, 3–6. doi: 10.5304/jafscd.2014.042.012

Collini, S. (2017). *Speaking of Universities*. London: Verso Books.

Cooksey, D. (2006). *A Review of UK Health Research Funding*. Norwich: The Stationery Office.

Friel, S. (2017). *Global Governance for Nutrition and the Role of UNSCN*. Rome: United Nations.

Glerup, C., and Horst, M. (2014). Mapping 'social responsibility' in science. *J. Respon. Innov.* 1, 31–50. doi: 10.1080/23299460.2014.882077

Guston, D. H. (1996). Principal-agent theory and the structure of science policy. *Sci. Public Policy* 23, 229–240.

Haldane, R. B. (1918). *The Haldane Report: Report of the Machinery of Government Committee Under the Chairmanship of Viscount Haldane of Cloan.* London: HMSO.

Hocquette, J. F. (2016). Is in vitro meat the solution for the future? *Meat Sci.* 120, 167–176. doi: 10.1016/j.meatsci.2016.04.036

Hospes, O., and Brons, A. (2016). "Food system governance. A systematic literature review," in *Food Systems Governance*, eds A. Kennedy and J. Liljeblad (London; New York, NY: Routledge), 13–42. doi: 10.4324/9781315674957-2

Ingram, J. (2011). A food systems approach to researching food security and its interactions with global environmental change. *Food Secur.* 3, 417–431. doi: 10.1007/s12571-011-0149-9

Jasanoff, S. (2016). "Technologies of humility: citizen participation in governing science." in *Communicating Biological Sciences*, eds B. Nerlich, R. Elliott, and B. Larson (London; New York, NY: Routledge), 29–48. doi: 10.4324/9781315572888-3

Khan, S. S., Timotijevic, L., Newton, R., Coutinho, D., Llerena, J. L., Ortega, S., et al. (2016). The framing of innovation among European research funding actors: Assessing the potential for 'responsible research and innovation'in the food and health domain. *Food Policy* 62, 78–87. doi: 10.1016/j.foodpol.2016.04.004

Kraak, V. I., Swinburn, B., Lawrence, M., and Harrison, P. (2014). An accountability framework to promote healthy food environments. *Public Health Nutr.* 17, 2467–2483. doi: 10.1017/S1368980014000093

Lawrence, M., and Friel, S. (eds.). (2019). *Healthy and Sustainable Food Systems*. London: Routledge. doi: 10.4324/9781351189033

Lemke, T. (2015). New materialisms: foucault and the 'government of things'. *Theory Cult. Soc.* 32, 3–25. doi: 10.4324/9781315634609

Lindhout, P., Meijer, D., Schotte, T., Hutten, R. C., Visser, R. G., and van Eck, H. J. (2011). Towards F 1 hybrid seed potato breeding. *Potato Res.* 54, 301–312. doi: 10.1007/s11540-011-9196-z

Löfmarck, E., Uggla, Y., and Lidskog, R. (2017). Freedom with what? Interpretations of "responsibility" in Swedish forestry practice. *Forest Policy Econom.* 75, 34–40. doi: 10.1016/j.forpol.2016.12.004

Luhmann, N. (1979). "Trust: a mechanism for the reduction of social complexity, in *Trust and Power: Two Works by Niklas Luhmann*, ed N. Luhmann, (Chichester: John Wiley and Sons), 1–103.

May, L. (1992). *Sharing Responsibility*. Chicago, IL; London: University of Chicago Press.

Mindell, J. S., Reynolds, L., Cohen, D. L., and McKee, M. (2012). All in this together: the corporate capture of public health. *BMJ* 345:e8082. doi: 10.1136/bmj.e8082

Niles, M. T., Ahuja, R., Barker, T., Esquivel, J., Gutterman, S., Heller, M. C., et al. (2018). Climate change mitigation beyond agriculture: a review of food system opportunities and implications. *Renew. Agricul. Food Syst.* 33, 297—308. doi: 10.1017/S1742170518000029

Owen, R., Macnaghten, P., and Stilgoe, J. (2012). Responsible research and innovation: from science in society to science for society, with society. *Sci. Public Policy* 39, 751–760.

Partzsch, L. (2011). The legitimacy of biofuel certification. *Agricult. Hum. Values* 28, 413–425. doi: 10.1007/s10460-009-9235-4

Pellizzoni, L. (2004). Responsibility and environmental governance. *Environ. Polit.* 13, 541–565. doi: 10.1080/0964401042000229034

Pereira, L. M., and Ruysenaar, S. (2012). Moving from traditional government to new adaptive governance: the changing face of food security responses in South Africa. *Food Secur.* 4, 41–58. doi: 10.1007/s12571-012-0164-5

Post, M. J. (2012). Cultured meat from stem cells: challenges and prospects. *Meat Sci.* 92, 297–301. doi: 10.1016/j.meatsci.2012.04.008

Roberto, C. A., Swinburn, B., Hawkes, C., Huang, T. T., Costa, S. A., Ashe, M., et al. (2015). Patchy progress on obesity prevention: emerging examples, entrenched barriers, and new thinking. *Lancet* 385, 2400–2409. doi: 10.1016/S0140-6736(14)61744-X

Scharpf, F. W. (1998). *Interdependence and Democratic Legitimation*. (No. 98/2). MPIfG working paper, Köln. Available online at: http://www.mpifg.de/pu/workpap/wp98-2/wp98-2.html

Sharpe, R., and Barling, D. (2019). 'The right thing to do': ethical motives in the interpretation of social sustainability in the UK's conventional food supply. *Agricul. Hum. Values* 36, 329–340. doi: 10.1007/s10460-019-09924-3

Siegrist, M., Earle, T. C., and Gutscher, H. (2003). Test of a trust and confidence model in the applied context of electromagnetic field. (EMF) risks. *Risk Anal. Int. J.* 23, 705–716. doi: 10.1111/1539-6924.00349

Simmel, G., and Bottomore, T. B. (2004). *The Philosophy of Money*. New York, NY; London: Routledge; Psychology Press.

Simon, D., Kuhlmann, S., Stamm, J., and Canzler, W. (eds.). (2019). *Handbook on Science and Public Policy*. Cheltenham: Edward Elgar Publishing. doi: 10.4337/9781784715946

Sonck, M., Asveld, L., and Osseweijer, P. (2020). Meta-responsibility in corporate research and innovation: a bioeconomic case study. *Sustainability* 12:38. doi: 10.3390/su12010038

Stahl, B. C., Grace, E., and Marina, J. (2013). Responsible research and innovation in information and communication technology: Identifying and engaging with the ethical implications of ICTs. *Respons. Innovat.* 2013, 199–218. doi: 10.1002/9781118551424.ch11

Stephens, N., Di Silvio, L., Dunsford, I., Ellis, M., Glencross, A., and Sexton, A. (2018). Bringing cultured meat to market: technical, socio-political, and regulatory challenges in cellular agriculture. *Trends Food Sci. Technol.* 78, 155–166. doi: 10.1016/j.tifs.2018.04.010

Swinburn, B., Egger, G., and Raza, F. (1999). Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prevent. Med.* 29, 563–570. doi: 10.1006/pmed.1999.0585

Swinburn, B., Kraak, V., Rutter, H., Vandevijvere, S., Lobstein, T., Sacks, G., et al. (2015). Strengthening of accountability systems to create healthy food environments and reduce global obesity. *Lancet* 385, 2534–2545. doi: 10.1016/S0140-6736(14)61747-5

Termeer, C. J., Drimie, S., Ingram, J., Pereira, L., and Whittingham, M. J. (2018). A diagnostic framework for food system governance arrangements: the case of South Africa. *NJAS-Wagening. J. Life Sci.* 84, 85–93. doi: 10.1016/j.njas.2017.08.001

Timmermans, J., Yaghmaei, E., Stahl, B. C., and Brem, A. (2017). Research and innovation processes revisited–networked responsibility in industry. *Sustain. Acc. Manag. Policy J.* 8, 307–334. doi: 10.1108/SAMPJ-04-2015-0023

Timotijevic, L., Khan, S. S., Raats, M., and Braun, S. (2019). Research priority setting in food and health domain: european stakeholder beliefs about legitimacy criteria and processes. *Food Policy* 83, 116–124. doi: 10.1016/j.foodpol.2018.12.005

UN SDGs. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. A/RES/70/1. Available online: https://sustainabledevelopment.un.org/post2015/transformingourworld (accessed September 25, 2015).

Vetterlein, A. (2018). Responsibility is more than accountability: from regulatory towards negotiated governance. *Contemp. Polit.* 24, 545–567. doi: 10.1080/13569775.2018.1452106

Von Schomberg, R. (2011). *Towards Responsible Research and Innovation in the Information and Communication Technologies and Security Technologies Fields*. Available online at: SSRN 2436399. doi: 10.2139/ssrn.2436399

Whitmee, S., Haines, A., Beyrer, C., Boltz, F., Capon, A. G., de Souza Dias, B. F., et al. (2015). Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation–Lancet Commission on planetary health. *Lancet* 386, 1973–2028. doi: 10.1016/S0140-6736(15)60901-1

Young, I. M. (2006). Responsibility and global justice: a social connection model. *Soc. Philosoph. Policy* 23, 102–130. doi: 10.1017/S0265052506060043

Zwart, H., Landeweerd, L., and Van Rooij, A. (2014). Adapt or perish? Assessing the recent shift in the European research funding arena from 'ELSA'to 'RRI'. *Life Sci. Soc. Policy* 10, 1–19. doi: 10.1186/s40504-014-0011-x

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Policies, Multi-Stakeholder Approaches and Home-Grown School Feeding Programs for Improving Quality, Equity and Sustainability of School Meals in Northern Tanzania

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Malnutrition among children of school-going age is a challenge of serious concern in developing countries especially Sub-Saharan Africa. Many programs focus on mothers and under-5-year-old children, leaving the school going age unattended. It has been shown that school meals can reduce school absenteeism, improve concentration in class and reduce early dropouts. In Tanzania, successful home-grown school feeding programs are localized in few areas but have not been scaled-out. The objective of this study was to analyze the policy and organizational environment which enables or promotes home-grown school feeding approaches. The study consisted of a systematic review, key informant interviews and focus group discussions in Arumeru and Babati Districts, Tanzania. In total, 21 key informant interviews with 27 participants and 27 focus group discussions with 217 participants were conducted. The results show that Tanzania lacks a clear policy on school feeding; there are no guidelines for school meal quality, participation in school feeding programs is not mandatory, leading to many students being left out and going hungry. Students in private schools tend to be better off than those in public schools in terms of provision and quality of school meals. We recommend that policies and practices are developed based on positive experiences of home-grown school feeding programs implemented in Tanzania by the World Food Programme and Project Concern International and emphasize that these policies need to be developed in a multi-sectoral manner. A conceptual framework for improving home-grown school feeding in public schools in Tanzania highlights four critical components: leadership and public awareness; operational modalities; contributions from parents; and meal diversity and nutrition. The home-grown school feeding model provides mechanisms to improve diversity of meals and their nutritional value, increase participation of communities and inclusion of students. Parents will still be responsible for the largest part of food supplies,

but the model also requires participation of multiple stakeholders, and provision of natural resources such as land and water by the local government for production of nutritious food for young students. Minimum levels of social protection are recommended to ensure that no student is denied school meals.

Keywords: supply chains, food system, behavior, vegetables and fruits, dietary diversity, farm to school

INTRODUCTION

Despite the progress made towards ending hunger and malnutrition, more than 820 million people are still undernourished globally (FAO et al., 2019). School-age children are often left out as many nutrition interventions focus on combating malnutrition during the first 1,000 days of a child's life starting from conception. The World Food Programme (WFP) estimated that there at least 66 million primary school-age children who attend classes across the developing world who are hungry, with 23 million in Africa alone (WFP, 2015). Furthermore, studies on the nutritional status among school children revealed high levels of malnutrition and micronutrient deficiencies in primary schools in 76 countries (Best et al., 2010) and underweight in secondary schools in India and Nigeria (Banerjee et al., 2011; Omobuwa et al., 2014).

Malnutrition in children is associated with a broad range of adverse functional and developmental consequences, including delayed motor development and impaired cognitive function if it occurs during the formative years resulting in low school enrolment rates, higher school absenteeism, and poor performance among school-going children (Bundy et al., 2009). If allowed to continue, malnutrition will seriously undermine the achievement of several United Nations' Sustainable Development Goals related to ending poverty, ending hunger and achieving food security, ensuring healthy lives at all ages, and achieving inclusive and equitable quality education.

Despite nutrition enhancing efforts to date, malnutrition continues to be a major issue of concern in Tanzania. The country has one of the highest malnutrition burdens in East and Southern Africa, threatening not only individual lives but the next generation's economic advancement in lost educational achievement, lost income, and lost opportunities. About one-third of the population is malnourished, while under-weight and wasting among children is high (CIAT and WorldBank, 2017; Teblick et al., 2017). An estimated 450,000 children in Tanzania are acutely undernourished or wasted, with over 100,000 suffering from the most severe form of acute undernutrition (IARAN, 2017). Several studies conducted in Tanzania (Kinabo et al., 2016; Ochieng et al., 2017; Kejo et al., 2018) have primarily focused on children (0–59 months) and women of reproductive age. While this age group is presumed to be the most susceptible to under-nutrition, the lack of data on older children (primary school age) can mask the rate and importance of malnutrition in the group. Undernutrition levels for children are dropping though, from 50% stunting in 1991–1992 to 34% stunting in 2015–16 to 31.8 in 2018 (MoHCDGEC et al., 2016, 2018).

School feeding programs have increasingly gained recognition in developing countries due to their triple role, acting as a productive safety net to improve nutrition for children in the short-term, increasing enrollment and attendance rates, and supporting livelihoods for farmers who supply produce to schools (NE, 2018; PCD, 2020). Today, an estimated 368 million children worldwide are fed daily at school through school feeding programs (WFP, 2013). The Tanzanian government has been concerned about the health and nutritional status of primary school children, realizing that there is a relationship between nutritional status and school attendance (Sanya, 2015). High absenteeism, lack of concentration in class and early dropouts are the results of short-term hunger among the school going children. About 50–70% of the students go to school without breakfast and they do not get any meal during school hours. Hunger can have serious consequences in the long run, such as stunting, diminished cognitive abilities, reduced school performance, increased morbidity, and mortality rates. All these effects can adversely affect productivity, income, and national development.

In Tanzania, school feeding programs have mainly been led by WFP with minimum involvement of the government through the Ministry of Education and Vocational Training (Sanya, 2015). In most cases school feeding programs have targeted areas with high poverty and school drop-out rates, poor primary school performance, and high levels of malnutrition. WFP started implementing school feeding programs in three regions in Tanzania in the year 2000: Dodoma, Arusha, and Singida. In 210 schools, 72,120 day scholars were given porridge in the morning break and lunch in the afternoon (URT, 2013). Oganga (2013) reports that by 2013 school feeding programs extended to Shinyanga, and Singida Regions, covering a total of 1,166 schools in 15 districts with a total of 601,572 students. In 2003, the New Partnership for Africa's Development (NEPAD), launched home-grown school feeding (HGSF) in Tanzania supported by WFP and other international organizations (WFP, 2017). HGSF programs have been described as cost-effective school feeding programs using food that is locally grown by smallholder farmers, creating triple win action improving diets, enhancing school attendance, and improving farmer livelihoods (DevelopmentInitiatives, 2017). In some schools, parents contribute foodstuffs from their farms to the school to feed their children directly. In other cases, parents contribute money to enable the schools to purchase foods from the local markets. Some trade-offs defined by Bundy et al. (2009) of HGSF indicate that it requires community involvement, which is less required with alternative feeding programs such as snacks, high energy biscuits or take-home rations. FAO and WFP (2018) mention that the major risks associated with HGSF are assessing and managing food safety and quality, while also mentioning

challenges related to ensuring constant supply. Some private schools provide a midday meal throughout the school year at a relatively low cost, with similar objectives as the school feeding program (Musamali et al., 2007).

Similar to HGSF programs is the Farm-to-school (F2S) approach which is often used in developed country contexts. F2S is defined as an approach that connects schools and local farms with the objectives of serving locally produced healthy foods in schools, improving student nutrition, providing health and nutrition education opportunities and at the same time supporting farmers (FIC, 2018; Christensen et al., 2019). Local food procurement, nutrition education, and school garden development are some of the basic elements that characterize F2S networks (FIC, 2018). While school feeding was pioneered by Brazil in 1953, the application of a new law in 2009 made it mandatory for 30% of federal budgets for school feeding to be used to purchase from local family farmers. This in turn inspired Brazil to develop the Purchase from Africans for Africa (PAA) pilot program to promote food security and economic inclusion in rural areas (Beltrame et al., 2016). The F2S movement has grown rapidly over the past two decades (Chabite et al., 2018; FIC, 2018). In Africa, this concept has been adapted into the HGSF program, which combines the objectives of a traditional school feeding program (e.g., educational, nutritional, or social safety nets outcomes) with the additional goals of homegrown aspects (smallholder farmers' access to a stable market). HGSF was piloted by WFP in collaboration with the Government of Tanzania and other partners including Plan Concern International (PCI) between 2011 and 2016 (WFP, 2016).

The overall aim of this study was to review the enabling environment for home-grown school feeding programs in northern Tanzania, and to identify ways of scaling out feasible programs that will benefit more students and farming communities. Specific objectives were to:

- Assess the current policy environment, other influencing factors and capacity to plan and deliver nutritious school meals for school-aged children.
- Carry out a comprehensive analysis of the institutional settings in the different locations, current public procurement mechanisms and costing frameworks at school level.
- Review existing programs in Tanzania in which school feeding is linked to food supply chains in the community; find opportunities to intervene where more food diversity from farmers could be introduced; assess the suitability of a HGSF program in Tanzania with a workable food procurement approach that can be scaled out.

METHODS

Literature Review

A literature review was conducted to review the policy frameworks regarding school feeding programs in Tanzania, to understand the institutional settings in selected locations in northern Tanzania, current livelihood and food security contexts, nutritional aspects, public procurement mechanisms, and costing frameworks capturing fixed and recurrent costs incurred at school level. The screening process was based on the preferred reporting items for systematic reviews and meta-analyses (PRISMA) (Moher et al., 2009). The materials included in the review were mainly searched electronically with the Google internet based search engine using keywords such as home-grown school feeding programs; school meals; public or institutional food procurement; value chain; gender; nutrition; biodiversity; food for education; food procurement; Tanzania; and developing countries. Published and gray literature, relevant reports, national databases, policy documents, and strategies were reviewed.

Informal Interviews

Information gaps were filled using focus group discussions (FGDs) and key informant interviews (KII). FGDs and KIIs were also used to explore household food security gaps and opportunities for school meals to introduce traditional local foods. The participants in the study comprised of community leaders (elders, representatives of farmer associations, policy makers in government or NGOs, market- and value chain actors) and schools (students, headmasters, procurement officers, caterers) and representatives of parent-teacher associations and school boards and committees.

KIIs were used to gather information from the representatives of the government departments and NGOs, the head teachers, representatives of farmer groups and extension officers. Questionnaires were used to obtain in-depth information on the existing policy framework for school feeding programs and market opportunities for establishing farm-to-school networks. The interviews were conducted at district level with the government officials and at school or village level for school and community representatives. A few interviews were conducted with purposively selected relevant partners. Plan Concern International (PCI) was selected because of its experience in school feeding and the earlier mentioned piloted HGSF programs in Tanzania. The Tanzania Food and Nutrition Center (TFNC) was selected because of its national mandate to provide guidelines, education and community awareness on food and nutrition. In total, 21 KIIs with 27 participants (15 men and 12 women) were conducted.

A focus group discussion guide was prepared to direct the discussion with each group consisting of 6–12 participants. FGDs were conducted at school with teachers, parents and student representatives separately. Only schools that provided meals at schools were included in the study. To cover the entire spectrum of schools, interviews were carried out in: primary public and private schools, secondary public and private schools as well as schools with special needs. In each of these categories, one school was randomly selected to be included in the study in each district. A total of 10 schools were included in the study and a total of 27 FGDs with 217 participants (104 male and 113 female) were conducted.

Study Sites

The study was conducted in Arumeru and Babati Districts. In Arumeru District, the study focused in Meru District Council (Meru DC) while in Babati District the study covered both Babati Town Council (Babati TC) and Babati District Council (Babati DC). Both districts, located in Northern Zone of Tanzania, which are rich in biological diversity, have agro-ecological zones and sufficient rain suitable for growing a diverse range of crops. In both areas, agriculture is the largest source of employment and income with most farmers practicing subsistence agriculture on a mixed crop-livestock production system. The locations of the study areas are indicated in the map of **Figure 1**.

Data Analysis

Audio recordings of the interviews were made using digital recorders to complement the notes taken during the interviews and discussions. The recordings were transcribed following the Gisted transcription approach (Paulus et al., 2013) prior to analysis. The transcripts were anonymous. Gray literature as well as other collected qualitative data were analyzed by using direct content analysis (Hsieh and Shannon, 2005).

Ethical Considerations

This study was approved by World Vegetable Center's (WorldVeg) Institutional Bio-safety and Research Ethics Committee (IBREC) on 2 November 2018. Permission to conduct the study was obtained from Local Government Authorities (LGAs). A written informed consent was obtained from the KIIs and FGDs participants. Enumerators explained the purpose of the research and confidentiality issues to the respondents. Participants signed a consent form prior to the interviews or discussions.

Study Limitations and Risks

No interviews with the national government officials were conducted due to issues of accessibility. However, attempts were made to obtain similar information through desk review of gray literature as well as KIIs interviews with partners who have worked with the government in school feeding programs.

RESULTS

Policy Environment

The persistent prevalence of malnutrition did not feature high in the Tanzania Development Vision 2025, which was developed in the nineties. There have been inadequate institutional arrangements in place at national and local authority levels for nutrition (SavetheChildren, 2012) but Tanzania has benefited from bilateral development programs in recent years, funded by USAID, EC, and other donors, aiming to tackle malnutrition. The low prioritization of nutrition has for a long time been evident by the shortage of district and regional coordinators for nutrition in many areas, the poor coverage of many key nutrition services and the slow progress in reducing school child malnutrition, such as promotion of school feeding programs and good nutrition in schools (URT, 2013). In Tanzania, many policies were formulated during the 1990s and only two policies were formulated earlier than 1990, i.e., the National Agricultural Policy and National Science and Technology Policy. In 2000, some of the policies were reviewed and others are currently being reviewed. Policy review in the country takes a long time and some have been under review for more than 5 years, including the Food and Nutrition Policy (SavetheChildren, 2012).

In this study, different policy and strategic documents related to food and nutrition were reviewed in order to understand the plan, strategies, and implementation of school meals programs; an overview of policies that are related to nutritional issues is presented in **Table 1**. The documents discuss general nutritional issues and strategize how to combat malnutrition focusing on children under 5 years, women and adolescents. It becomes clear that most reviewed policy documents have incorporated nutritional issues but not necessarily related to school meals programs; it is only from 2010 that school feeding starts to be mentioned in five different policy documents. When school meals are mentioned, it is mostly in the context of primary schools. Some policy documents that mentioned school meal programs include: National Multisectoral Nutrition Action Plan (NMNAP); Education and Training Policy; National Strategy for Growth and Poverty Reduction (MKUKUTA II); Tanzania National Nutrition Strategy; and Education Circular No. 3 of 2016. Although the issue of school meals has been mentioned, it has received very little support.

The review also revealed that there are limited statements on inter-sectoral collaboration during planning and implementation of policies. This may lead to one sector not knowing what other sectors are planning to implement; overlap of activities with suboptimal allocation of resources; while leaving other activities unattended such as school meal programs. An exception is the National Multisectoral Nutrition Action Plan (URT, 2016) which has placed strong emphasis on improving nutrition of children, adolescents, women, and men in Tanzania, using an approach involving many stakeholders within and outside the government.

Characterization of School Meal Programs in Meru and Babati Districts

Almost all schools in Arumeru and Babati Districts had some form of school feeding program. In Arumeru District, 152 out of 162 public primary school had some form of feeding program. At the time of visit (2–3 weeks after school opened from long year-end holidays), some schools were still mobilizing contributions from parents. At the time of visit, 52 out of 143 schools in Babati District were operating some form of school feeding, while the rest of the schools were still struggling to mobilize contributions from parents. The school feeding program varied from one school to another depending on whether they were public or private, and whether they were primary or secondary schools. With a few exceptions of donor support, public schools did not have established kitchens. Some of them used temporary wooden structures roofed with iron sheets. Private schools had well-established kitchens. The feeding program for public schools was coordinated and operated by parents through their own established committees. Members of school food committees were nominated in a parents' meeting.

FIGURE 1 | Map of Tanzania with administrative boundaries indicating the study areas in red circles. Source: OPNO (2020).

The roles and responsibilities of the school food committee included: raising contributions from parents either in monetary terms or in kind; procuring food in case parents contributed in monetary terms; storing the collected or purchased food; hiring cooks; supervising the preparations and distributions of food; issuing meal coupons to students whose parents have contributed; liaison with heads of school (HoS) and the Local Government Authority (LGA) about the school feeding program.

TABLE 1 | Policy content covered in relation to nutrition and school meals.

Policy document and year of publication	Aspects related to nutrition	Aspects related to school meals
Food and Nutrition Policy for Tanzania, Published in July 1992	Malnutrition; food security; diseases; nutrition education; care; child nutrition; maternal nutrition; school children nutrition	None
Child Development Policy, Published in October 1996	Nutrition knowledge; awareness; education (recognizes nutrition to be an important factor for child growth and survival)	None
National Science and Technology Policy for Tanzania, Published in April 1996	Achievement of food self-sufficiency; security; improvement of methods of preparing, drying, preserving and handling food to ensure nutritive values, palatability, and reduction post-harvest losses	None
Community Development Policy, Published in June 1996	Nutrition knowledge, awareness, education (recognizes nutrition to be one of the indicators that can be used to show the levels of development and welfare in communities)	None
Women and Gender Development Policy, Published in 2000	Nutrition knowledge; awareness; education (recognizes good care to be necessary for nutrition well-being of women and children)	None
National Population Policy, Published in 2006	Infant mortality as they relate to better health care; food security; water and sanitation; food and nutrition education; controlling micronutrient deficiencies; cultural barriers related to nutrition	None
National Youth Development Policy, Published in December 2007	Nutrition knowledge; awareness; education (recognizes good nutrition to be among the necessary rights for the youth)	None
National Strategy for Growth and Poverty Reduction (MKUKUTA II), Published in July 2010	Malnutrition; food insecurity; diseases; nutrition knowledge, awareness and education; high dependency ratio; child growth and development; maternal nutrition	School meals programs: implement school feeding programs at all levels in public schools with community involvement
Tanzania National Nutrition Strategy, Published in 2011	Dietary improvement in schools, hospitals, orphanage, prisons, and other institutions	Requires that public and private schools should provide meals with appropriate dietary content
National Agricultural Policy, Published in October 2013	Production of nutrient dense crops; disease burden to households that hampers food and livelihood insecurity; enhancement of food security through production of sufficient quantity and quality foods; monitoring trends of food security	None
Sera ya Elimu (Education and Training Policy), Published in 2014	Education on environment and public health (diseases, malnutrition)	Mentions that the government will ensure that basic services including nutritious foods are available in schools and colleges
Tanzania Food and Nutrition Center-Strategic Plan, Published in October 2014	Malnutrition; food security; diseases; nutrition education; care; child nutrition; maternal nutrition; school children nutrition; nutrition information system; nutrition knowledge, awareness, education (recognizes nutrition to be an important factor for child growth and survival)	None
National Multisectoral Nutrition Action Plan (NMNAP) July 2016–June 2021, Published in October 2016	Maternal, Infant, Young Child and Adolescent Nutrition (MIYCAN); promote optimal intake of essential micronutrient; Integrated Management of Acute Malnutrition (IMAM); prevention and management of Diet Related Non-Communicable Diseases (DRNCDs); promote multisectoral nutrition sensitive interventions; strengthen multisectoral nutrition governance; establish a multisectoral nutrition information system	Mentions school feeding and school gardens in primary and secondary schools without further details
Education Circular No. 3 of 2016 (Waraka wa elimu namba 3 wa mwaka 2016 kuhusu utekelezaji wa elimu msingi bila Malipo)	None	Specifies that parents and teachers together should design and implement their own school feeding programs.
National Health Policy, Published in 2007. The National Health Policy of 2017 (6th Draft)	Malnutrition; diseases; care of children and the sick; maternal nutrition; child growth and development; food quality and safety at all stages; environmental health and sanitation; water quality and safety	None

Updated from SavetheChildren (2012).

Some school food committees operated bank accounts for the funds raised for the school feeding program. Out of six visited public schools, only two school food committees had opened and operated bank accounts. For the majority of school food committees, the raised funds were physically kept by a designated committee member appointed by parents. This did raise issues of trust, leading to some parents being reluctant to contribute, worrying about safety of funds among other reasons. In private schools, the school feeding program was mainly operated by directors or owners of schools rather than school management or other committees. In these schools, the school feeding program was mandatory. The majority of such schools issued school fees as a package without necessarily providing a break down for the cost of food. It was clear that at private schools, parents were more

concerned with the academic performance of students than the meals they took at school, as they assumed that the school meal program was adequate. General differences observed between public and private school feeding programs are summarized in **Table 2**.

In general, the school feeding program was regarded as highly important by teachers, students, and parents. Although many parents in public schools were reluctant to contribute, they still wanted their children to eat at school. Teachers, parents, and students mentioned various important reasons why they valued feeding programs in public schools:

- Distance—some students come from far away, walking up to 7 km to school. It is difficult for these students to go home for lunch and come back again for the afternoon sessions. Other students become hungry because of walking long distances to school.
- When students eat at school it is easier to adhere to the school timetable than when students go home for lunch. Some would return to school late after lunch or not come back until the next day. Those going home for lunch may not find anything to eat as parents may not be home yet.
- To reduce the burden to students of preparing food on their own in the afternoon when their parents are still working in farms or in their businesses.
- Increasing attendance—students who are not guaranteed food at home come to school to eat. Many students live with poor grandparents who cannot afford food even for themselves. In some schools it was estimated that up to 50% of students lived with grandparents.
- Increase academic performance—students who have eaten have higher levels of concentration. Without lunch, afternoon classes are not attentive.
- Many students are adolescents who need to eat frequently and cannot stay the whole day without eating.

Generally, the importance of school feeding programs cannot be overemphasized. Teachers considered school feeding as a basic human right considering that when students do not eat their mental cognition process slows down.

Contributions and Food Purchases for School Feeding Programs

Most schools made *ad hoc* food purchases from local markets. With the exception of one private school, there were no contractual arrangements with traders or farmers. **Table 3** presents the procurement modalities of the school feeding programs for different schools visited in this study. School feeding programs in public day schools is governed by parents through their own established food committees. Teachers were not directly involved in the school feeding program for many reasons including the lack of trust from parents. Teachers illustrated this lack of trust by quoting parents: "you are a teacher and your job is to teach; why do you bother about contributions for meals?" Parents feared that teachers would gain financially or in kind from the school feeding program. Teachers, on the other hand, mentioned that they should not be involved in school feeding programs as stated by the government. There were challenges after the introduction of free basic education system as contribution of food for school feeding was not mandatory. As a result, school food committees and HoS had to spend a lot of time and energy raising awareness and mobilizing parents to contribute for school meals.

At public day schools, teachers were involved in sensitization and awareness raising of the school feeding program, as well as sourcing wood and water for cooking, maintaining the kitchen and storage facilities. They also helped preparing lists of students whose parents had contributed or paid for food. In some schools, teachers and student leaders helped the school food committee with the daily food issues such as rationing, preparing, and serving food to students. However, in other schools, teachers were completely withdrawn or excluded from participation.

In terms of contributions to the school feeding program, there were two main approaches; (1) contribution in kind plus some cash for hiring cooks and purchase of cooking oil, salt, sugar, and other supplies; and (2) contribution in monetary terms only. In all private schools (primary and secondary), contributions were in monetary terms only as part of a mandatory fee, but parents were not aware how much exactly was allocated for food. In the majority of public day schools, in kind contributions plus some cash was practiced, while in a few schools contributions were made in monetary terms.

There was no standard for the amount of food required for each student. As a result, the contributions in kind or in monetary terms varied greatly among schools. As seen in **Table 3**, in-kind contributions in public schools varied from 20 kg of maize, 5 kg of beans plus TZS 6,000 (USD 2.61) per year to 40 kg of maize, 20 kg of beans plus TZS 30,000 (USD 13.04) per year. Contributions in monetary terms at public schools ranged from TZS 36,400 (USD 15.83) to TZS 100,000 (USD 43.48) per year. Converting these to total monetary value using average wholesale prices of USD 0.20 per kg of maize and USD 0.70 per kg of beans (FEWSNET, 2018), contributions ranged from USD 10.10 to USD 35 per student. This variability raises the issue of how much food is required per student per year.

Schools sourced food in various ways. Private schools sourced food directly from farmers, especially during harvest season when prices were relatively low. For instance, three of the private schools visited in January 2019 had a stock of food that was acquired in July 2018. Also, some private schools had relatively large plots and contracted farmers or hired causal laborers to produce food. One school produced maize, beans, vegetables, banana, and cattle for beef and had its own milling plant. In case of deficit the school purchased food from nearby farmers. Public day schools, on the other hand, could not take advantage of food price fluctuations and bulking during the harvest season because of irregular monetary contributions. Even when they were able to purchase or collect food in bulk, they lacked storage facilities.

Access to School Meals

For public day schools, not all students benefited from the school feeding program. With the exception of a few schools, eligibility for the school feeding program was based on contributions. For public schools with boarding facilities, the food cost for the

TABLE 2 | Public versus private school feeding programs.

	Public schools	Private schools
1.	Operated by school food committees formed by parents.	Operated by the director who often is the owner of the school.
2.	Limited involvement of teachers.	High involvement of Head of School and teachers.
3.	Food is procured by the school food committee.	Food is procured by the school director.
4.	Contribution is non-mandatory. Parents decide whether or not to contribute or whether or not to have a school feeding program.	Contribution is mandatory. Parents pay as part of school fees.
5.	Parents contribute food either in kind or in monetary terms or both.	Parents contribute in monetary terms.
6.	Not all students eat at school. Eligibility is based on contribution.	All students eat at school.

boarding students was included in the government budget but the food cost for the day students wasn't. Students whose parents had paid for the school feeding program were given meal coupons. Most students who didn't contribute to the school feeding program had poor parents or were raised by poor grandparents. It was mentioned during the FGDs though that students whose parents were unable to contribute were the ones who needed it most as they were not assured of any meals at home. Students who were part of the school feeding program felt sad for their friends who were excluded. It was hard for them to eat in front of friends who were hungry, and sometimes they shared their food. During the school interviews, researchers saw some students lying lethargically in the grass while others were eating.

Surprisingly, not all parents who had not paid were unable to pay. Students who participated in FGDs estimated that about a half of parents whom they knew had not paid were actually able to do so. It could be that they were not paying because they expected that food would also be provided for free after the introduction of the free basic education system. Also, it was learnt that parents were more willing to contribute food in monetary terms for students enrolled in secondary school than those in primary school. For primary schools, parents seemed to prefer to contribute food in-kind rather than in monetary terms. The willingness to pay for meals in secondary schools originated from being used to pay for secondary school fees and meals before the introduction of the free school system. Value of contributions for school meals in the two secondary public schools ranged from USD 35.04 to USD 43.48 and in the two primary schools from USD 10.11 to USD 18.61, including in kind contributions. All students with special needs in the special education schools had access to meals.

Quality of School Meals in Tanzania

Ochola and Masibo (2014) point out that school-age children in developing countries are mainly consuming plant-based diets which are predominantly derived from cereals, roots and tubers, and limited animal source foods and that this dietary pattern is especially common in rural communities. Cereal meals are the most important sources of energy while dairy products are missing from the diet. They mention that in Zambia school meals are mainly stiff cereal porridge and beans, while green vegetables were rarely consumed. In some schools, pupils produce vegetables for their lunches from school gardens, but a challenge is the integration of class activities and school gardening programs.

Information on the composition of school meals in Tanzania is very scarce. Very few studies have been conducted to assess the type and quality of meals provided in schools (Muhimbula and Zacharia, 2010). Oganga (2013) carried out one of the few studies and found that the meals provided to pupils in Chamwino District of Dodoma Region did not meet their nutrient requirements (**Table 4**). The results show that the meals provided in the beneficiary schools are not adequate to meet the pupils' daily nutrient requirements. Main foods provided were stiff maize porridge (*ugali*) and pigeon pea as energy and protein sources, respectively. Besides, Sanya (2015) concludes that the quality of food provided to pupils in Tanzania is low. Her study of the impact of school feeding on student attendance in schools in Kiteto District Tanzania show that 97% of the pupils were not satisfied with the food which they ate every day. The food provided, however, was common for all schools. *Kande* (mix of maize and beans), *ugali* and beans were consumed during lunch time. The main cause of this poor quality of food was poor parents' contribution and lack of government support of the implementation of this program. Only 40% of the parents were able to contribute maize and beans for their children at schools and the others weren't due to poverty.

School Gardens and Other Agricultural Activities at the Schools

Most schools in Arumeru District had vegetable gardens. Details about their school gardens, types of meals provided, types of food served, rations, availability of vegetables and fruits, and considerations for nutritious foods are shown in **Table 5**. However, during the time of this study, most school gardens were not yet operational after the long end of year holidays. In one case, a well-functioning garden was too small to feed all students. This school also kept poultry and a fish pond as a separate business rather than for food for students. It was reported that students in this school once suffered from scurvy due to shortage of vitamin C which prompted the establishment of a vegetable garden. In Babati District, only one school had a vegetable garden, produced maize, beans, and bananas and kept cattle for beef. The school was self-sufficient regarding the vegetables and food crops for the school meals.

Nutritional Aspects of School Meals in the Study Area

The type and frequency of meals varied among schools. Some non-boarding schools provided two meals (porridge during the morning break time and a meal in the afternoon) while others provided just one meal in the afternoon. If breakfast was provided, it was during the morning break and consisted of maize porridge. In boarding schools, three or four meals per day were

TABLE 3 | Procurement modalities of food for school feeding programs.

School	Nature of school	Overseer of school feeding program	Procurement of food	Financing	Nature of contributions	Source of food	Eligibility for school meals	Proportion of students taking school meals	Distribution of food to students
Meru District Council									
School 1	Public primary school	School food committee of parents	School food committee of parents	Contributions from parents	In-kind (maize 32 kg, beans 8 kg) plus TZS 15,200/year	Direct contributions from parents	Students whose parents contributed	All (301) students irrespective of contributions	Non-selective
School 2	Private primary school	Director (owner of school)	Director (owner of school)	Parents pay as part of school fees	Monetary contributions, TZS 160,000/year	Purchased from market	Students whose parents paid for food	92% of 221 students whose parents have paid	Selective based on payment
School 3	Public secondary school	School food committee of parents	School food committee of parents	Contributions from parents	Monetary contributions, TZS 100,000/year	Purchased from farmers and market	Students whose parents paid for food	About 40% of 511 students	Selective through the use of coupons
School 4	Private primary and secondary	Director (owner of school)	Director (owner of school)	Parents pay as part of school fees	Fees 1,500,000–1,850,000 for hostel and 900,000 for day students	Purchased from farmers and market	Students whose parents have paid school fees	All students were allowed to eat irrespective of fees payment	Non-selective
School 5	Public special education primary school	• Head teacher for special education students • School food committee for regular students	• Head teacher for students with special needs • School food committee for regular students	• Government for students with special needs • Contribution from parents for regular students	• Capitation grant for students with special needs • Monetary contributions, TZS 36,400/year for regular students	• Public tenders for special education program • Purchased from farmers or market for regular students	• Students with special needs eat at school • For regular students it is based on contribution from parents	• All students with special needs eat at school • For regular students only about 25% were eating at school in 2018. Mobilization was ongoing for 2019	Selective for regular students through the use of coupons
Babati District (Babati DC and Babati TC)									
School 6	Private primary school	Director (owner of school)	Director (owner of school)	Parents pay as part of school fees	Fees TZS 550,000 for class IV and VII, 350,000 for pre-school and 450,000 for other students	Purchased directly from farmers and market	All students. School feeding program is mandatory	All students eat at school	Non-selective
School 7	Public primary school	School food committee of parents	School food committee of parents	Contributions from parents	In-kind (maize 20 kg, beans 5 kg) plus TZS 6,000/year	Direct contributions from parents	• Students whose parents contributed • Vulnerable students (e.g., orphans)	All (427) students eat at school. However, 25% of students have not contributed for food	• Non-selective • Food committee is considering to use coupons
School 8	Private Catholic boarding secondary school	School management and school food committee of teachers	School management	Parents pay as part of school fees	Fees TZS 1,600,000 per students per year	Produces own food (maize, beans, vegs, banana, cattle). Additional purchases from farmers	All students; school feeding program is mandatory	All students eat at school	Non-selective
School 9	Public secondary school	School food committee of parents	School food committee of parents	Contributions from parents	In-kind (maize 40 kg, beans 20 kg) plus TZS 30,000/year/child	Direct contributions from parents	Students whose parents contributed	About 50% of 460 students	Selective through the use of coupons
School 10	Public special education primary school	• Head teacher for special education students • School food committee for regular students	• Head teacher for students with special needs • School food committee for regular students	• Government for students with special needs • Contribution from parents for regular students	• Capitation grant for students with special needs • In-kind for regular students (40 kg of maize, 10 kg of beans per year) plus TZS 4,000 per month	• Public tenders for special education program • Direct contributions for regular students	• Students with special needs eat at school • For regular students it is based on contribution from parents	• All students with special needs eat at school • For regular students only about 12% of 797 had contributed	Selective for regular students through the use of coupons

TABLE 4 | Daily food ration per pupil in school feeding programs in Chamwino District.

Commodity	Ration (g)	Energy (Kcal)	Protein (g)	Fat (g)
Cereals	120	420	12	5.5
Pulses	30	101	6.6	0.5
Vegetable oil	5	45	–	5
Corn Soy Blend (CSB)	40	152	7.2	2.4
Total	**195**	**718**	**25.8**	**13.7**
Min. Recommended Value		**2,100**	**45.6**	**50**
% supplied by ration		**34.2%**	**56.6%**	**27.3%**

Oganga (2013).

provided and the nature of the food differed among schools. One private school provided tea with bread during the morning break. For lunch and supper, the typical meals were *ugali* with beans or *kande*. A few schools provided rice and beef occasionally. A few day schools provided *kande* only throughout the year (**Table 5**).

Vegetables and fruits were hardly served in schools. In most schools, the meals were far from balanced. For public schools, it was reported that the amount of contributions from parents determined the type of meals students took at school. However, vegetables were sometimes also left out because of cultural reasons when eating vegetables was not common especially among children and among men. Sometimes vegetables were offered but students left the vegetables on their plate without eating them, because they were not used to eating them or didn't know the benefit. The few schools that served vegetables mixed them with beans to stimulate consumption of vegetables.

Generally, nutritional aspects were not taken into account in the school feeding programs. What mattered mostly to parents was there being any type of food for students to eat. Parents mentioned that even at home they were eating similar meals and they themselves had grown up in similar situations, thus there was nothing to worry about. Even more so, parents stated that when they ate vegetables it wasn't for nutritional reasons but out of poverty, saying that if there were options, they would not eat vegetables. **Figure 2** presents some illustrative quotes about these type of parent perceptions. Some parents forbid their children to take vegetables at school out of fear of agro-chemicals in the food. They complained that safety of vegetables was not guaranteed and urged the government to regulate application of chemicals on vegetables. There was some skepticism on quality and safety of food for the school feeding programs. For example, in one public secondary school the food committee changed from accepting contributions in-kind to cash because of quality concerns.

Private schools had more consideration for nutrition and diversity than public schools. For instance, one private boarding secondary school had a privately operated canteen in which students ate at their own cost. Although some students had to trick their parents to get additional money to spend at the canteen, other parents voluntarily provided allowances for their children to eat at the canteen. The school controlled the range and prices of food in the canteen. As a result, there was more diversity albeit not very different from other school meals. Parents supported the presence of this private canteen in the school and it was noted that these parents were relatively well-off.

Parents and farmers had limited knowledge about nutritious foods. Although nutritious foods were available in their localities they were not adequately included in meals. In Meru DC, for example, some parents were involved in selling vegetables at market places, but all vegetables were sold leaving only beans at home. Vegetables were more for commercial purpose than for home consumption. The FGDs with teachers indicated the need to emphasize nutritional education to influence their culture so that when students grow up, they will have improved eating habits.

Challenges Analyzed Through a New Conceptual Framework

There are a number of factors that seem to influence the capacity to plan and deliver nutritious meals to students. Bundy et al. (2009) present these factors in many different conceptual frameworks, related to multisectoral interaction, food systems, school meal quality, or community feedback systems. They also use an analytical model consisting of policy, institutional framework, funding, program design, and community aspects, to analyze examples of school feeding programs in different countries. This model has formed the basis of a more recently developed SABER-SF framework, which is a rubrics analytical and assessment framework for school feeding programs at national level (WB et al., 2016). We are presenting a different conceptual framework in **Figure 3**, based on a decentralized system that is heavily dependent on community involvement, yet harboring similar factors. The challenges in **Figure 3** can be grouped into four categories: coordination; operational modalities; contributions from parents; and type of foods, dietary diversity and nutrition.

Coordination Related Challenges

The education circular No. 3 (JMT, 2016) mentions that parents need to work with the school management to put in place procedures to provide meals to the students, to be endorsed by the Council Director. No further details are provided, and all activities related to school feeding programs for public schools have been left to the respective school food committees. Parents lacked wider understanding on school feeding which made them reluctant to contribute. There was no involvement of LGA officials in providing clarity on what constituted the free education system. In rare situations, when LGA officials participated in raising awareness to mobilize contributions for school feeding, other key stakeholders were not involved, such as Community Development Officers (CDOs). The involvement of CDOs is important in many ways. They are familiar with participatory community planning processes that ensure ownership of projects by the local communities. Secondly, the department of community development is linked to Tanzania Social Action Fund (TASAF) that supports poor households

TABLE 5 | Type of meals and dietary diversity in school feeding programs.

School	Type of school	School or farm garden	Type of meals	Type of foods	Ration served	Time of meals	Vegetables served	Fruits served	Consideration for nutritious food in meals
Meru District Council									
School 1	Public primary school	Had a school vegetable garden in 2018	• Porridge for early years • Lunch for other students	• Maize porridge • *Ugali* with beans • *Kande* (maize boiled with beans)	No standard unit established	• 10 a.m. for early years • 12 noon lunch	Not served. Waiting to revive the garden	No fruits served	No considerations for nutrition. What matters is that the students get something
School 2	Private primary school	No vegetable garden	• Porridge • Lunch	• Maize porridge • *Ugali* with vegetables • Rice with beans • Cooked banana with beans or beef	No standard unit established	• 10 a.m. for porridge • 12.20 p.m. for lunch	Vegetables (kale and amaranth) are served more often than beans	No fruits served	Dietary diversity and nutrition are considered. However, fruits are not served
School 3	Public secondary school	Has vegetable garden operated by students	• Porridge for hostel students • Lunch • Supper for hostel	• Maize porridge • *Ugali* with beans • Rice with beans • *Kande*	No standard unit established	• 6.30 a.m. for porridge • 1 p.m. for lunch • 7.00 p.m. supper	Vegetables are served in almost all meals	No fruits served	To some extent. Mostly based on availability of vegetables in the school garden
School 4	Private primary and secondary	Operates a vegetable garden. Has large plot of land that can be used for food production	• Porridge (early breakfast for hostel) • Tea with bread • Lunch • Supper for hostel	• Maize porridge • Tea with bread • *Ugali* with beans or meat • Rice with beans or meat • *Kande*	• 1 kg rice for 5 students • 1 kg maize flour for 4 students	• 6.00 a.m. porridge • 10.40 a.m. tea break • 1.10 p.m. lunch • 7.10 p.m. supper	Vegetables served occasionally. Priority is given to students with special diet needs	Fruits are rarely served	To some extent. Vegetables are served based on availability from school garden. Students had not taken vegetables for the past 3 weeks
School 5	Public special education primary school	Has a garden although it was not operational at time of survey	• Four meals a day for (boarding) students with special needs • Lunch for regular students	*Kande* every day for regular students	No standard unit established	12.20 p.m. for lunch (*kande*) for regular students	Not served for regular students	Not served for regular students	Not at all for regular students. It is *kande* every day.
Babati District (Babati DC and Babati TC)									
School 6	Private primary school	No vegetable garden	• Porridge • Lunch	• Maize porridge • *Ugali* with beans • *Kande*	• 55 kg rice for 300 students • 13 kg beans for 300 students	• 9.30 a.m. porridge for pre-school • 10 a.m. porridge for students • 12.30 p.m. lunch	No vegetables served	No fruits served	Not much considerations for nutrition or diversity of food
School 7	Public primary school	No vegetable garden	• Lunch only	• No timetable for meals but often *kande*	No standard unit established	• 12.30 p.m. lunch	No vegetables served	No fruits served	Not considered at all. Yet meals are better than their home meals
School 8	Private Catholic boarding secondary school	Owns a school vegetable garden operated by causal laborers	• Porridge for breakfast • Lunch • Supper	• Maize porridge • *Ugali* with beans • Rice with beans • *Kande* • Meat once a month	N/A	• 10 a.m. porridge for breakfast • 1 p.m. for lunch • 7.00 p.m. supper	Served two to three times a week	Bananas from school farm	To some extent. The school has a private operated canteen to enhance nutrition and diversity which students use at own expense

(Continued)

TABLE 5 | Continued

School	Type of school	School or farm garden	Type of meals	Type of foods	Ration served	Time of meals	Vegetables served	Fruits served	Consideration for nutritious food in meals
School 9	Public secondary school	No vegetable garden but has large plot of land. Water is the main challenge for a vegetable garden	• Porridge in the morning • Lunch • Supper for a few hostel students (40 girls)	• Maize porridge • *Ugali* with beans • *Kande*	No standard unit established	• 10 a.m. porridge for breakfast • 1 p.m. for lunch • 7.00 p.m. supper	Not served at all	No fruits served	No considerations for nutrition. What matters is that the students get something
School 10	Public special education primary school	No vegetable garden due to shortage of water	• Lunch for regular students • Students with special needs have own arrangements similar to Patandi	*Kande* every day for regular students	1 kg of maize for 6 students	12.20 p.m. for lunch (*kande*) for regular students	Not served for regular students	Not served for regular students	Not at all for regular students. It is *kande* every day.

with small grants and income generating activities. Thirdly, the department of community development coordinates and provides interest free group loans which could be used by parents to contribute to the school feeding program and meet other basic household requirements.

Challenges Related to Operational Modalities

The limited coordination further affects how the school feeding program is implemented at school level. At operational level a number of challenges were identified including limited cooperation between parents and teachers, limited use of bank account by the school food committees, committee members spending most of their time at school at the expense of their own economic activities, and challenges related to infrastructure such as limited storage facilities, kitchen, water, and energy or fuel for cooking. Moreover, the effectiveness and efficiency of school food committees are questionable in many respects:

- They have no mandate to enforce parents to contribute for the school feeding program, while some parents think that contributing for the school feeding program is optional.
- Instead of operating bank accounts, the funds were physically stored by a trusted member of the school food committee. Some examples of funds embezzlement were mentioned, not surprisingly leading to distrust of parents toward school food committees.
- For efficient functioning, at least one member of the school food committee has to be always present to collect contributions and supervise the storage, rationing, preparation, and provision of food to students. However, it was reported that food committee members do not show up to school regularly, and when they do, they don't come on time. Cooks explained that in the past when the program was coordinated by teachers, things used to run smoothly and all students were eating at school. Pointing to the inefficiencies of school food committees, cooks said:

"... Sometimes the storekeeper (a member of the school food committee) closes the store earlier than normal and does not collect contributions from parents until the following day. So, parents have to go back home carrying with them the in-kind contribution they brought to school. Sometimes they are disappointed and often they don't come back the following day..."

"... The school food committee gives out a small ration and asks cooks to add more water to beans or kande so that all students who have contributed get something to eat..."

Reliable sources of water for cooking, food stores, and a suitable kitchen are often missing. Students often have no dining hall and sometimes eat while seated on the grass or under trees, raising concerns about hygienic conditions. A few schools had received support to establish rain water harvesting systems, water storage tanks, and modern kitchens. Some of the cited supporters in both districts included Save the Rain, the Rotary Club of Arusha, and World Vision International.

Poor Contributions From Parents

The challenges in operational modalities of school feeding programs negatively affects willingness of parents to contribute.

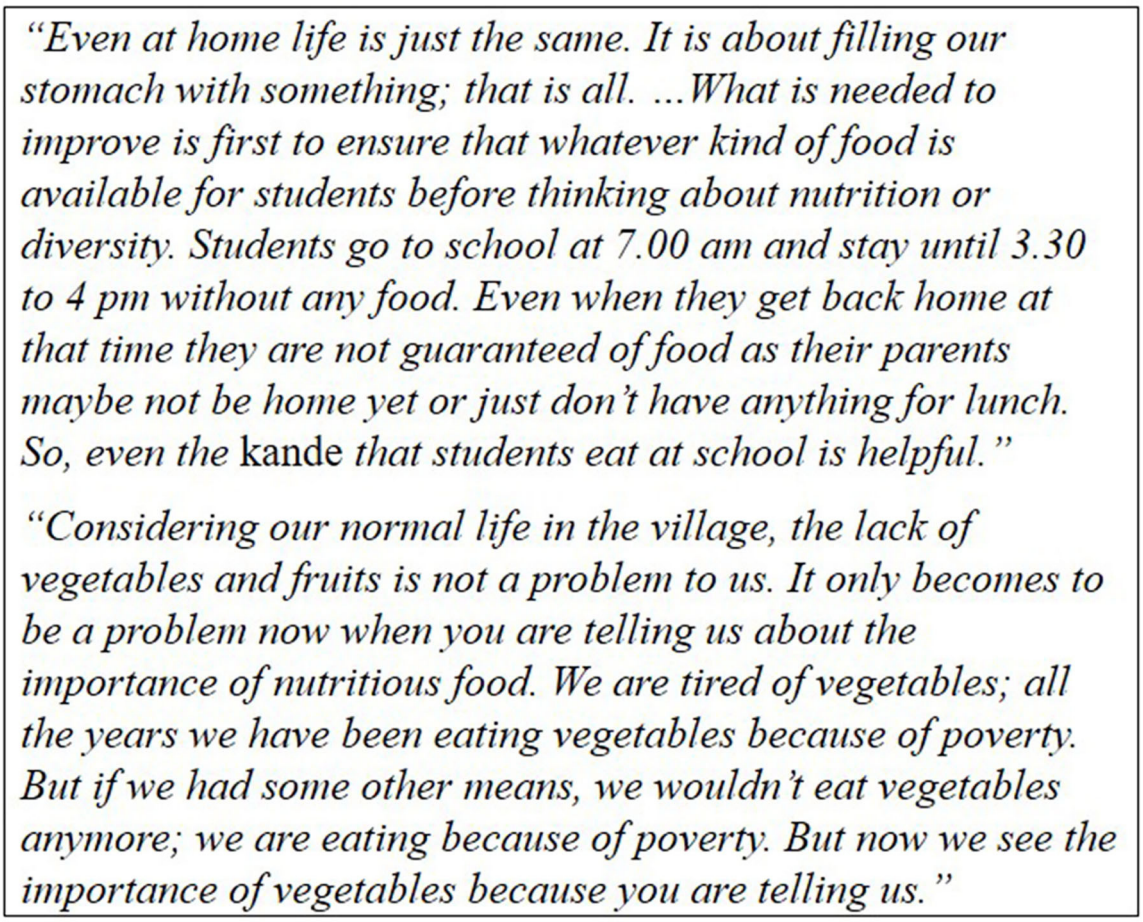

FIGURE 2 | Perceptions of parents toward vegetables in meals.

The variations in contributions among similar schools also reduce trust. Although students in secondary schools are bigger and eat more than students in primary schools, this cannot not fully justify the large range in the total value of monetary and in-kind contributions in public schools from USD 10 to USD 44 per student; it raises the question why variations are so high for the same type of school in the same locality. Limited understanding of the free basic education system is another challenge. Parents perceived that the free education system included free school meals.

Poverty of parents and grandparents coupled with limited understanding of free basic education was cited as one of the major challenges in raising contributions for the school feeding program. The FGDs with student representatives showed that some students were occasionally visiting neighbors to get something for supper. Related to inability of parents to contribute to the school feeding program is the number of children enrolled in school per household, particularly in polygamist communities such as the Maasai. Some families had up to seven children enrolled in school, in primary or secondary school or both, making the total amount of required contributions too high.

Challenges Related to Access, Dietary Diversity and Nutrition of Meals

Lack of parent contributions affected the number of meals served, portion sizes, diversity, and nutritive value of meals. Meal portions were too small to satisfy those students who were lucky to benefit, and the number of meals were not enough to provide all students. In many cases, but especially in public primary and secondary schools, students were not satisfied with the amount, nor the type of food served. Eligibility for the school feeding program was based on contributions from parents. This resulted in discrimination and stigmatization of the students whose parents were either unable or unwilling to contribute. While many schools used coupons to classify eligible students, a few schools allowed all students to take school meals irrespective of contributions to avoid stigmatization. Nonetheless, allowing all students to take school meals irrespective of contributions demotivated other parents to contribute in the future, threatening the sustainability of the very program.

The incorporation of vegetables in school meals was rare for various reasons: first, because of poor contributions from

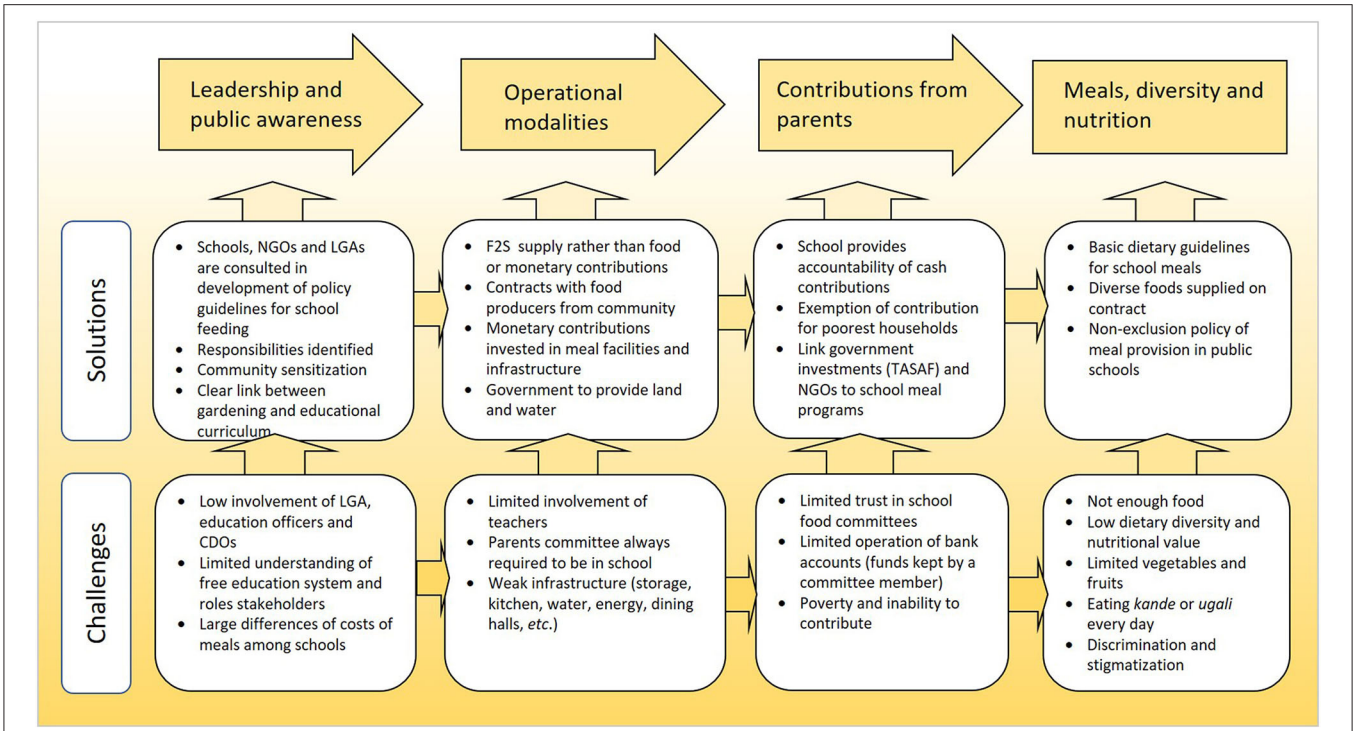

FIGURE 3 | Conceptual framework for planning and delivering nutritious meals in schools.

parents; second, because of absence or limited space for vegetable gardens; third, because school committees had limited funds to hire cooks and purchase kitchen utensils; fourth, due to lack of parents' awareness on importance of vegetables; fifth, because of traditional practices whereby parents associated the eating vegetables with poverty; and, sixth, because of the earlier mentioned health and safety concerns of vegetables. Fruits were mostly absent from school meals due to lack of funds and lack of awareness about their importance. With exception of a few private schools, nutritional value of meals was not taken into account in the school feeding program. School food committees had to serve whatever was available rather than what would be considered a nutritious meal.

Experiences From HGSF Projects in Tanzania

HGSF was piloted by WFP in collaboration with the Government of Tanzania and other partners including PCI. Between 2011 and 2016, WFP piloted HGSF programs in Mara and Singida Regions to link local production supplies with food requirements of the local schools (WFP, 2016). The transitioning of WFP from the traditional school meal programs to HGSF was part of the sustainability plan to ensure that local communities could continue supply food to schools beyond the project lifetime. Through the HGSF program, local government and schools received cash from WFP to purchase and distribute locally grown food to schools in Ikungi District in Singida Region and Bunda District in Mara Region. Over 28,000 students from 40 primary schools received a mid-day meal (WFP, 2016). The program procured maize and beans locally whereby school meals were complemented with key essential package interventions, such as nutrition- and health education, and water and sanitation. The program included provisions of imported fortified vegetable oil (with vitamins A and D) because the oil produced and processed locally did not meet WFP's and the government's standards. The ration per person per day was of 120 g of maize, 30 g of beans and 5 g of oil. The program was managed by school food committees in each school. The committees oversaw commodity management; food preparation and distribution as well as recruiting and paying the cooks.

KIIs with PCI showed that after successfully piloting HGSF under WFP in Bunda, PCI started a similar program in Musoma District. PCI, with funds from USDA, mobilized local communities to supply nutritious foods to primary schools. At the time of writing, PCI supplied food 2 days a week while the community supplied foods for 3 days a week. The intention was that the local community would become fully responsible for supplying nutritious foods to the schools. PCI mobilized local communities surrounding a particular school in the form of farmer groups to supply nutritious foods for school meals. The groups then entered into agreement with the schools, either through sales or donations. For example, a school would provide a plot for a farmer group to cultivate and produce foods such as passion fruits, banana, and sweet potatoes. After harvest, harvested products were shared between the group and the school. PCI also promoted school gardens which were managed

by students and other staff. Despite many positive outcomes, PCI listed a couple of challenges while implementing this approach:

- Mobilizing farmers and parents to organize themselves into working groups at the initial stages of the project, as parents took time to fully understand the initiative.
- Availability of land for the groups.
- When production increases and becomes a commercial engagement in near future, farmers might not supply to school anymore because of lower prices and untimely payments.

According to Watson et al. (2012), another possible challenge is the amount of time involved in the HGSF program by everyone at the expense of time spent on academic activities. This might result in Districts and schools withdrawing from HGSF programs. This argument is consistent with findings from the FGDs with teachers, who mentioned that parents were more concerned with academic performance of students than school meals. Thus, there is a need to strike a balance between academic and nutritious objectives in any school feeding program.

SUGGESTED IMPROVEMENTS FOR SCHOOL FEEDING PROGRAMS IN PUBLIC SCHOOLS

The study has revealed that there are challenges in the school feeding programs in the study area, but discussions with KII and FGDs also revealed many suggestions to tackle them. Solutions have been summarized in the conceptual framework of **Figure 3**.

Policy Implications

Clear guidelines for school feeding programs in public schools are missing. Although some policy documents have mentioned school meal programs, there are no specific strategies of ensuring that nutritious foods are provided in schools. No implementation plan or strategy for school meals was found in the reviewed documents. Only education circular No. 3 of 2016 indicated the responsibility of parents in the implementation of school feeding programs. Tanzania has prepared a multi-sectoral approach regarding nutrition in 2016, building on the existing linkages in the overall and sectoral development policies and strategies of a country. TFNC has a mandate to coordinate all food and nutrition issues including linkages with other sectors. The multi-sectoral approach is a great first step, but it needs to be followed up with an approach to improve the quality of school feeding programs. Such a policy document needs to maintain the multi-sectoral nature, and cover all four stages in the conceptual framework: leadership and public awareness; operational modalities; contributions from parents; meal diversity and nutrition. It was also learned during the study that the Ministry of Education, Science and Technology (MoEST) was collaborating with PCI through their HGSF program in Musoma to develop a national guideline for school feeding.

No school feeding program reaches its objectives if the most vulnerable students are excluded from benefiting, as it leads to stigmatization, hunger, sickness and poor school performance. This paper recommends mainstreaming a HGSF system in those parts of the country where it is possible to grow a diversity of crops, such as the various highland areas, the western part, and the coastal area. HGSF provides more opportunities for poor farming households to contribute, while at the same time it offers opportunities to improve diversity and quality of school meals. Despite these increased opportunities to participate, however, there might still be households that cannot afford to contribute part of their farm produce as they have no other sources to feed themselves. Building on good examples from the field, we recommend that guidelines at national level and bye-laws at local government level are formulated to incorporate social protection which enables all students, rich or poor, to benefit from school meals.

Home Grown School Feeding

Although school representatives, teachers, farmers, and parents who participated in this study did not know the concept of HGSF, some schools have been indirectly practicing it, particularly private schools. Private schools sourced foods directly from farmers especially during harvest seasons to take advantage of lowest prices. One private school in Babati District had entered into an agreement with farmers to produce food in the school farms and supply the food to the same school at market prices. This enabled the school to control food safety, which was a serious concern of parents.

Based on the findings of this study and the experience from PCI-HGSF program in Musoma, it is expected that HGSF can be further scaled out in Tanzania. In the HGSF program in Musoma, smallholder farmers, majority being women, have been mobilized to form producer groups, which have entered into contractual arrangements to supply nutritious food to public primary schools. Farmers and parents in Meru and Babati have expressed their eagerness to supply nutritious food to schools and generate income. If this is implemented, it can also address the issue of food safety, because some external suppliers bring food of poor quality knowing that nobody checks its quality. This was one of the reasons why some schools did not accept contributions in-kind. This can be avoided by contracting farmers whose kids are in school. When farmers are aware that the food, they produce will be eaten by their own children in the school they are unlikely to apply unnecessary agrochemicals or poor quality water. And according to Galluzzi et al. (2010), there are additional benefits: the closer the producer is to the consumer the more sustainable is the food system as it increases trust, reduces transport costs and removes other market barriers such as involvement of middlemen in the value chain. Several authors (Morgan and Sonnino, 2008; Gelli et al., 2016; UNSCN, 2017) also mention that school procurement and meals, if linked to local producers, can have a range of positive outcomes, such as: improved nutrition, engendered economic development by promoting small and medium enterprises; greater crop diversity in supply chains, diversification of agricultural landscapes, and resilience and adaptation to climate change. However, these effects are heterogeneous and context-specific and require a deeper and more rigorous analysis of the agro-ecological conditions and

market linkage settings. HGSF could be improved to incorporate nutritious traditional vegetables which would enhance quality of school meals as well as crop diversity on-farm. In Tanzania there is a wealth of diversity of traditional vegetables to tap into that have much higher nutrient contents than global vegetables (Roothaert et al., 2020).

Influencing Knowledge, Attitudes, and Practices Toward Healthy Eating

Influencing consumer behavior toward healthy eating is a complex challenge that many nutrition initiatives all over the world have been dealing with. Consumers choose what to eat based on knowledge, preferences, and affordability of the food that is available. Preferences in turn are influenced by cultural norms and practices. In many ways, the quality of meals that students consume is subject to similar influences. It becomes even more complex as knowledge about what constitutes a healthy school meal needs to be improved at various levels for it to have an effect on quality of school meals: parents, heads of schools, CDOs, cooks, teachers, and students. Similarly, healthy food preferences can be cultivated, but are more effective when children are influenced at a young age, and when eating habits of others in the community conform the desired consumption pattern. Knowledge and attitudes of students toward healthy eating can be influenced in a positive way as research in Nepal has shown (Schreinemachers et al., 2017). Nutrition, health, and food production needs to be embedded in the school curricula. In school, pupils can learn how to choose a healthy diet through the meals and snacks provided at school and can develop a range of consumer-based skills including food growing, handling, preparation, and cooking. Learning about vegetable production in school gardens and the nutritional value of crops in the garden will help reinforce nutritional knowledge and attitudes, as has been illustrated by many examples in the book of Hunter et al. (2020). But it will be equally important to educate all other adult stakeholders in the school feeding program. A pilot HGSF program in Nepal therefore included a nutritional literacy component for students and training of cooks (Shrestha et al., 2020).

Fortunately, our policy analysis shows that nutrition in general is incorporated in many policy documents in Tanzania, which creates a positive environment for non-governmental and public initiatives to increase nutritional awareness among the general public. Schools should not only be recipients of these initiatives, but they also have a role to influence the community that they serve on stressing the importance of healthy diets. A school garden is a core element of F2S programs as it provides education activities related to agriculture, food, health, and nutrition (Christensen et al., 2019). According to McGovern-Dole (2015), apart from supplying vegetables to schools, school gardens are regarded as an educational tool for students as well as surrounding communities. Through this study we found that PCI established demonstrations garden in schools for students and parents to learn. Public schools in Tanzania are often constrained with access to land and water for school gardens and local governments can play an important role in providing these fundamental resources.

Stakeholder Engagement

For HGSF to be successful there is a need to get a buy-in from the government at regional and district levels. The examples of HGSF in Bunda and Musoma Districts show that involvement of the Regional Administration and LGAs has been critical for the support HGSF. One of the main challenges faced by PCI in their initial stages was mobilizing and engaging local communities. Education on importance of school feeding, availability of nutritious foods, awareness raising on the concept of HGSF, and roles and responsibilities of parents and farmers turned out to be crucial. Most parents and farmers have had past experience with other projects, both positive and negative. A new concept such as an HGSF program therefore needs some explanation. The importance of engagement and empowerment became clear in one FGD where parents mentioned the case of Eluway primary school in Babati that was constructed by parents without external funds, saying: "… this school was constructed by our own efforts. The idea of HGSF will help to bring us together even more. … we need to understand how it works and what our roles will be." Although in the past, WFP was a major initiator and promotor of school feeding programs in Tanzania, in order to mainstream the program across as many public schools as possible, it requires a multi-stakeholder effort and commitment.

Improving the Quality of Meals

There is only very limited information available on the type and quality of meals provided to school children in Tanzania, which limits the assessment of the adequacy of the food provided to the children. The little information that is available from a few areas in the country shows that meals are not adequate in terms of providing macro- and micronutrients. These observations stress the need to improve the monitoring of school meal programs, and the need to improve quality of diets. The school diets are limited in diversity and meal patterns are inappropriate, consequently interfering with the spreading of nutrient intake over the day. Tanzania does not have a set of food based dietary guidelines for its citizens yet as being recommended by WHO and FAO (1996), although the TFNC has developed National Guidelines for Nutrition Care and Support of People with HIV. Similar guidelines are urgently needed for school meal programs.

Many parts of Tanzania, such as the highland areas, coastal area and western part of the country have suitable climates and soils to promote cultivation of a diverse pattern of crops as well as rearing livestock. Some of the sampled schools in this study are outside those high potential areas, but are still within diverse agricultural systems. In the biggest part of Tanzania, school feeding programs can tap into these diverse agricultural systems and communities. HGSF programs in such contexts have the advantage over the current in-kind and monetary contribution systems, in the sense that contractual arrangements can be made between farmers and schools to provide diverse, healthy, and safe foods for school meals. HGSF therefor can improve quality of

school meals in Tanzania while at the same time improving the livelihoods of farmers.

Limitations of the HGSF Model for Tanzania

There are also exceptions for which recommendations of this study will not apply. First, in rainfed farming systems in arid and semi-arid areas, cultivation of vegetables will be constrained without irrigation water, limiting the diversity of crops to be supplied from the community to schools, and therefore quality of meals of HGSF. Monetary contributions might be inevitable to supplement starchy staple crops with nutritious foods. Second, communities in urban areas are likely to be employed in other sectors than agriculture, hence HGSF is not very feasible. Third, community ownership of a feeding program for private schools is likely to be limited as directors or owners directly select farmer supply chains. Students in private school are fortunate though as they tend to come from wealthier families and school meals are of higher quality than in public schools.

CONCLUSION

Although the reviewed policies, strategies, guidelines, and circulars included nutrition aspects, only a few mentioned school feeding programs, and none provided strategies on how to source food, whether school feeding program is mandatory, how to deal with parents who cannot and don't want to contribute to the program, or whether it is the school's plight to provide school meals to students whose parents haven't contributed. The result is a mismatch of expectations from parents and schools, with students from poor families often taking the brunt and forfeiting meals. Parents coordinate the programs, but due to the absence of clear accounting mechanisms it is hard to prevent mismanagement and distrust. Policies also remain silent on rations, quality standards and costs of meals leading to poor quality of diets and sometimes too small portions. We identified two entities who are working on guidelines for school feeding programs in Tanzania, MoEST and PCI. The authors recommend policies for school feeding are developed in a multi-sectoral manner, in the same way the TFNC coordinated the National Multisectoral Nutrition Action Plan which aims to improve nutrition for the vulnerable people in the whole nation. Policies need to cover all four critical stages for successful school feeding: leadership and public awareness; operational modalities; contributions from parents; meal diversity and nutrition. Political will must not stop at policy level but encompass implementation and allocation of resources. If the recommended policies and guidelines are implemented, parents will still be responsible for the largest part of food supplies. Local governments must complement these efforts by providing resources to public schools such as land and water, and enforce minimum levels of social protection, so that students from the poorest families are no longer discriminated and excluded from school meals. Planning and implementation of HGSF requires a multi-stakeholder approach involving parents, farmers, schools, students, and local government. The proposed model is particularly recommended for public schools, as private schools tend to successfully operate independent commercial food supply chains. Limitations for HGSF are water- or land constrained ecosystems and urban areas, where home grown food production is difficult to realize.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: HARVEST; doi: 10.22001/wvc.73744.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the World Vegetable Center's (WorldVeg) Institutional Bio-safety and Research Ethics Committee (IBREC) on 2 November 2018. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RR, DH, and JO were involved in the design of the study. JO coordinated data collection. HM conducted the systematic literature review and participatory research processes. HM and RR analyzed the data, interpreted the results, and wrote the first report. RR turned the report into a paper. All authors read, edited, re-edited, and approved the final manuscript.

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REFERENCES

Banerjee, S., Dias, A., Shinkre, R., and Patel, V. (2011). Under-nutrition among adolescents: a survey in five secondary schools in rural Goa. *Natl. Med. J. India* 24, 8–11.

Beltrame, D. M., Oliveira, C. N. S., Borelli, T., de Andrade Cardoso Santiago, R., Monego, E. T., Vera de Rosso, V., et al. (2016). Diversifying institutional food procurement – opportunities and barriers for integrating biodiversity for food and nutrition in Brazil. *Revista Raízes* 36, 55–69. doi: 10.37370/raizes.2016.v36.459

Best, C., Neufingerl, N., van Geel, L., van den Briel, T., and Osendarp, S. (2010). The nutritional status of school-aged children: why should we care? *Food Nutr. Bull.* 31, 400–417. doi: 10.1177/1564826510031 00303

Bundy, G., Burbano, C., Grosh, M. E., Gelli, A., Juke, M., and Lesley, D. (2009). *Rethinking School Feeding: Social Safety Nets, Child Development, and the Education Sector*. Washington, D.C.: The World Bank.

Chabite, I. T., Garrine, C., and Ferrão, L. J. (2018). Malnutrition and school feeding programmes. *J. Nutr. Health Food Eng.* 8, 340–344. doi: 10.15406/jnhfe.2018.08.00292

Christensen, L., Jablonski, B. B. R., Stephens, L., and Joshi, A. (2019). Evaluating the economic impacts of farm-to-school procurement: an approach for primary and secondary financial data collection of producers selling to schools. *J. Agric. Food Syst. Commun. Dev.* 8, 73–94. doi: 10.5304/jafscd.2019. 08C.002

CIAT and WorldBank (2017). *Climate-Smart Agriculture in Tanzania*. World Bank, Washington, D.C.: International Center for Tropical Agriculture (CIAT)

DevelopmentInitiatives (2017). *Global Nutrition Report 2017: Nourishing the SDGs*. Bristol.

FAO, IFAD, UNICEF, WFP, and WHO (2019). *The State of Food Security and Nutrition in the World 2019. Safeguarding Against Economic Slowdowns and Downturns*. Rome: FAO.

FAO and WFP (2018). *Home-Grown School Feeding. Resource Framework*. Rome: Food and Agriculture Organization and World Food Programme.

FEWSNET (2018). *Tanzania Market Fundamentals Summary August 20, 2018*. Geneva: Famine Early Warning Systems Network.

FIC (2018). *The State of Farm to School in San Diego County 2016-17*. San Diego, CA: Community Health Improvement Partners, Farm to Institution Center.

Galluzzi, G., van Duijvendijk, C., Collette, L., Azzu, N., and Hodgkin, T. (2010). "Biodiversity for Food and Agriculture: contributing to food security and sustainability in a changing world," in *Outcomes of an Expert Workshop Held by FAO and the Platform on Agrobiodiversity Research* eds G. Galluzzi, C. van Duijvendijk, L. Collette, N. Azzu, and T. Hodgkin (Rome: Food and Agriculture Organization of the United Nations and the Platform for Agrobiodiversity Research).

Gelli, A., Masset, E., Folson, G., Kusi, A., Arhinful, D. K., Asante, F., et al. (2016). Evaluation of alternative school feeding models on nutrition, education, agriculture and other social outcomes in Ghana: rationale, randomised design and baseline data. *Trials* 17, 37–37. doi: 10.1186/s13063-015-1116-0

Hsieh, H. F., and Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qual. Health Res.* 15:11. doi: 10.1177/1049732305276687

Hunter, D., Monville-Oro, E., Burgos, B., Roel, C. N., Calub, B. M., Gonsalves, J., et al. (2020). *Schools, Gardens and Agrobiodiversity: Promoting Biodiversity, Food, Nutrition and Healthy Diets*. Routledge: Earthscan.

IARAN (2017). *Overcoming the Challenges of Under Nutrition in Tanzania Through 2021*. London: IARAN.

JMT (2016). "Waraka wa Elimu Namba 3 Wa Mwaka 2016 Kuhusu Utekelezaji wa Elimu Msingi bila Malipo," in *Wizara ya Elimu*, ed S. n. Teknolojia. (Dar es Salaam: Jamhuri ya Muungano wa Tanzania), p. 10.

Kejo, D., Mosha, T. C., Petrucka, P., Martin, H., and Kimanya, M. E. (2018). Prevalence and predictors of undernutrition among underfive children in Arusha District, Tanzania. *Food Sci. Nutr.* 6, 2264–2272. doi: 10.1002/fsn3.798

Kinabo, J., Mamiro, P., Dawkins, N., Bundala, N., Mwanri, A., Majili, Z., et al. (2016). Food intake and dietary diversity of farming households in Morogoro Region, Tanzania. *J. Food Agric. Nutr. Dev.* 16, 11295–11309. doi: 10.18697/ajfand.76.16045

McGovern-Dole (2015). *The Global Effort to Reduce Child Hunger and Increase School Attendance*. Washington, DC: Report to the United States Congress, Fiscal Year 2015. McGovern-Dole International Food for Education and Child Nutrition Program.

MoHCDGEC, M., TFNC, NBS, OCGS, and UNICEF (2018). *Tanzania National Nutrition Survey Using SMART Methodology (TNNS) 2018*. Dar es Salaam: Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC) [Tanzania Mainland]; Ministry of Health (MoH) [Zanzibar]; Tanzania Food and Nutrition Centre (TFNC); National Bureau of Statistics (NBS); Office of the Chief Government Statistician (OCGS) [Zanzibar] and UNICEF).

MoHCDGEC, MoH, NBS, OCGS, and ICF (2016). *2015-16 TDHS-MIS Key Findings*. Rockville, MD: Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC) [Tanzania Mainland]; Ministry of Health (MoH) [Zanzibar]; National Bureau of Statistics (NBS); Office of the Chief Government Statistician (OCGS) and (ICF).

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., and Prisma Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 6:e1000097. doi: 10.1371/journal.pmed.1000097

Morgan, K., and Sonnino, R. (2008). *The School Food Revolution: Public Food and the Challenge of Sustainable Development*. London: Earthscan.

Muhimbula, H., and Zacharia, A. (2010). Persistent child malnutrition in Tanzania: risks associated with traditional complementary foods (A review). *Afr. J. Food Sci.* 4, 679–692. doi: 10.5897/AJFS.9000219

Musamali, B., Walingo, M. K., and Mbagaya, G. M. (2007). Impact of school lunch programmes on nutritional status of children in Vihiga district, western Kenya. *Afr. J. Food Agric. Nutr. Dev.* 7. doi: 10.18697/ajfand.17.2010

NE (2018). Nourishing the sustainable development goals: global nutrition report 2017. *Nutr. Exchange* 9:4. Available online at: https://globalnutritionreport.org/reports/2017-global-nutrition-report/

Ochieng, J., Afari-Sefa, V., Lukumay, P. J., and Dubois, T. (2017). Determinants of dietary diversity and the potential role of men in improving household nutrition in Tanzania. *PLoS ONE* 12:e0189022. doi: 10.1371/journal.pone.0189022

Ochola, S., and Masibo, K. (2014). Dietary intake of schoolchildren and adolescents in developing countries. *J. Nutr. Metab.* 64, 24–40. doi: 10.1159/000 365125

Oganga, B. (2013). Feeding students? Examining views of parents, students and teachers on the world food program's school feeding initiatives in Chamwino District in Tanzania (Master of Education), Amherst, MA: The University of Massachusetts.

Omobuwa, O., Alebiosu, C. O., Olajide, F. O., and Adebimpe, W. O. (2014). Assessment of nutritional status of in-school adolescents in Ibadan, Nigeria. *South Afr. Family Prac.* 56, 246–250. doi: 10.1080/20786190.2014. 953891

OPNO (2020). *Administrative Map of Tanzania*. Bangkok: One Planet Nations Online.

Paulus, T., Lester, J., and Dempster, P. (2013). *Digital Tools for Qualitative Research*. London: SAGE Publications Ltd.

PCD (2020). *Home Grown School Feeding*. London: The Partnership for Child Development (accessed April 3, 2020).

Roothaert, R. L., Afari-Sefa, V., and Schreinemachers, P. (2020). "Household gardening with traditional African vegetables to improve diets of children and young women in East Africa," in *International Symposium on Survey of Uses of Plant Genetic Resources to the Benefit of Local Populations,* ed R. Ramananarivo (Antananarivo: International Society for Horticultural Science), 13–20.

Sanya, H. (2015). *The impact of school feeding on student attendance in school: A case of Kiteto District, Tanzania* (Master Degree of Education), Dar es Salaam: Open University of Tanzania.

SavetheChildren (2012). *Nutrition Policy Mapping for Tanzania*. Dar es Salaam: Save the Children Tanzania, Sokoine University of Agriculture, PANITA.

Schreinemachers, P., Bhattarai, D. R., Subedi, G. D., Acharya, T. P., Chen, H.-p., Yang, R.-y., et al. (2017). Impact of school gardens in Nepal: a cluster randomised controlled trial. *J. Dev. Effect.* 9, 329–343. doi: 10.1080/19439342.2017.1311356

Shrestha, R. M., Schreinemachers, P., Nyangmi, M. G., Sah, M., Phuong, J., Manandhar, S., et al. (2020). Home-grown school feeding: assessment of a pilot program in Nepal. *BMC Public Health* 20, 28. doi: 10.1186/s12889-019-8143-9

Teblick, A., De Deken, S., Vanderbruggen, W., Vermeersch, M., Teblick, S., Ruymaekers, M., et al. (2017). Anthropometry and nutritional status of primary school children in a sub-urban region in Tanzania. *Int J School Health* 4, 1–7. doi: 10.5812/intjsh.46079

UNSCN (2017). *Schools as a System to Improve Nutrition. A New Statement for School-Based Food and Nutrition Interventions*. Rome: United Nations System Standing Committee on Nutrition.

URT (2013). "Nutrition Country Paper – The United Republic of Tanzania," in *CAADP Agriculture Nutrition Capacity Development Workshops* (Dar es Salaam).

URT (2016). *National Multisectoral Nutrition Action Plan (MNNAP) for the period July 2016 - June 2021*. ed P. M. Office (Dar es Salaam: United Republic of Tanzania).

Watson, M. C., Escalante, C. L., Ames, G. C. W., Wolfe, K., and Kane, S. P. (2012). "Motivations and challenges in farm to school participation: nutrition versus food hardship considerations," in: *2013 Annual Meeting* (Orlando, FL: Southern Agricultural Economics Association).

WB, WFP, and PCD (2016). *SABER School Feeding - Manual for SABER-SF Exercise*. Washington, DC: The World Bank, The World Food Programme, The Partnership for Child Development.

WFP (2013). *State of School Feeding Worldwide 2013*. Rome: World Food Programme.

WFP (2015). Two *Minutes to Learn About School Meals*. Rome: World Food Programme.

WFP (2016). *Country Programme - Tanzania (2011-2015): Standard Project Report 2016*. Dar es Salaam.

WFP (2017). *Home Grown School Feeding Resource Framework. Synopsis - March 2017*. Rome: World Food Programme.

WHO and FAO (1996). *Preparation and Use of Food-Based Dietary Guidelines. Report of a Joint FAO/WHO Consultation*, ed N. Programme (Nicosia: World Health Organization, Food and Agriculture Organization of the United Nations).

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Telephone Survey Versus Panel Survey Samples Assessing Knowledge, Attitudes and Behavior Regarding Animal Welfare in the Red Meat Industry in Australia

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Surveys are used extensively in social research and, despite a lack of conclusive evidence of their 'representativeness,' probability internet panel (PIP) surveys are being increasingly used to make inferences about knowledge, attitude and behavior in the general population regarding a range of socially relevant issues. A large-scale survey of Australian public attitudes and behavior toward the red meat industry was undertaken. Samples were obtained using a random digit dialing telephone survey (Computer-Assisted Telephone Interviewing-CATI, $n = 502$ respondents) and a PIP survey (PANEL, $n = 530$ respondents) to examine differences between the two samples regarding attitudes and behavior relating to livestock use and welfare. There was little difference in demographics between the CATI and the PANEL surveys apart from highest level of education. However, there were differences between the two samples in both attitudes and behavior toward the red meat industry after controlling for education levels. The PANEL respondents gave generally more conservative responses than did the CATI respondents in the sense that they were more positive toward the livestock industries and animal welfare within these industries. Differences were also found between the respondents of the two samples regarding behavior that relates to the red meat industry, both community and consumer behavior. PANEL respondents were less engaged in community behaviors performed in opposition of the red meat industry when compared with the CATI sample. The majority of CATI and PANEL respondents were red meat eaters and there was no difference between respondents of the two samples in relation to red meat consumption, however, there were fewer vegetarians and vegans in the PANEL survey. Possible reasons for the observed differences are discussed, however, a definitive answer will depend on further research to identify the specific psychological factors that differ between samples derived from different survey methodologies.

Keywords: public attitudes, behavior, random digit dialing telephone survey, probability internet panel survey, animal use, animal welfare, red meat industry

INTRODUCTION

Social research relies heavily on surveys. High marginal costs and low response rates have reduced the viability of random telephone surveys (RDD; random digit dialing) whilst increasing the viability of surveys delivered online (internet surveys) (Berrens et al., 2003; Li et al., 2004; Ansolabehere and Schaffner, 2014). Whilst telephone surveys reportedly generated higher participant response rates than online or mail delivery (Yu and Cooper, 1983) and data quality that was comparable to that obtained from face-to-face interviews (Groves and Kahn, 1979), it has become increasingly difficult to maintain participant response rates and, as a result, the costs of telephone data collection has risen considerably (Lavrakas, 1997; Holbrook et al., 2007; Chang and Krosnick, 2009). Internet surveys offer several advantages, including low marginal cost per completed response, an ability to provide respondents with large quantities of information, speed and the elimination of interviewer bias (see review by Couper, 2000; Berrens et al., 2003). Ansolabehere and Schaffner (2014) compared internet, mail and telephone surveys and found response rates of 42.9, 21.1, and 19.5%, respectively, with completion times of 8.9, 11.8 and 14.3 min, respectively. A comparison of the internet and telephone attitude responses to a range of political issues showed that they were quite similar and that the main differences were in cost (telephone more expensive than internet), response rates and completion time. Given the increasing access to the internet, these cost differences are likely to have increased in the 10 years since the Ansolabehere and Schaffner (2014) study was carried out. More recently, Lee et al. (2019) conducted a comparison between a computer web survey, a smartphone web survey and a computer-assisted telephone interviewing (CATI) survey on student time use, opinions on university life and courses, health status, online access for health information, and demographic information. The CATI survey achieved the highest response rate, but also the highest cost and the longest completion time.

There are two primary methodologies that have been employed by commercial survey companies to conduct internet surveys; non-probability samples and probability samples (Couper, 2000; Chang and Krosnick, 2009). Non-probability sampling involves internet surveys of volunteers that are not recruited using conventional random sampling methods, i.e., do not have known non-zero probabilities of selection. Non-probability samples involve 'self-selection' and employ a range of methods to recruit survey participants including advertisements placed on websites inviting people to sign up to do regular surveys and email invitations that are widely distributed in ways designed to yield responses from heterogeneous population subgroups with internet access (Yeager et al., 2011). A comparison of responses to a health care survey from non-probability internet samples and probability samples using an RDD telephone survey have shown that there are differences in responses even when the internet sample was propensity weighted (Schonlau et al., 2004). About 80% of questions were responded to differently, however, there was no systematic reason for the differences in responses. One unexplained outcome was that "web survey responses were significantly more likely to agree with RDD responses when the question asked about the respondent's personal health (9 times more likely), was a factual question (9 times more likely), and only had two as opposed to multiple response categories (17 times more likely)" (Schonlau et al., 2004).

Probability internet panel (PIP) sampling most commonly involves the use of a pre-existing online panel sample, whose panel lists were originally recruited to the panel using random sampling methods such as RDD telephone surveys. Initial telephone interviews are used to collect background information and invite eligible people to join the online panel. The aim is to obtain a probability sample of internet users who, following agreement to join the online panel, are sent email requests to participate in internet surveys (Couper, 2000), usually for a monetary or points reward. Studies involving this type of probability internet survey are largely reported as random participant recruitment (Duncan, 2015). Online panels are being increasingly used in social science to recruit participants for community surveys and questionnaires, where inferences are often made about the general population based on the findings of a 'random' sample of participants. At present, however, there remains little conclusive evidence demonstrating that internet surveys based on probability sampling (i.e., 'random' online panel samples) are in fact representative of the general population, both in terms of demographic and psychological aspects. Despite commercial online panels largely employing random sampling methods to recruit panel lists and the opportunity to use stratification to control for demographic factors, it has still been suggested that there remain substantial differences between the online population (PIP survey) and the general population (RDD telephone survey) with regards to the substantive variables of interest such as attitudes and behaviors (see review by Couper, 2000). Previous research investigating differences between the two populations has been inconclusive, with some studies from countries other than Australia finding differences between respondents from PIP surveys and RDD telephone surveys (for example, United States: Flemming and Sonner, 1999; United Kingdom: Erens et al., 2014; South Korea: Lee et al., 2015) and others finding no difference (for example, United States: Berrens et al., 2003; Li et al., 2004).

In those studies where differences were found, the survey content was related to co-morbidities associated with gambling (Lee et al., 2015) and politics and voting (Flemming and Sonner, 1999). In the lead up to an election, Flemming and Sonner (1999) compared respondents from a RDD telephone survey and a weighted (by sex and education level) PIP survey. Important differences were found between the samples on a variety of attitudinal items, including interest in the election, attitudes toward impeachment and the role of national issues in congressional voting. The authors conclude "there were no predictable patterns to the success or failure of the internet surveys. Respondents . . . were not consistently more conservative or liberal than those in nationwide telephone surveys, nor were they more optimistic or pessimistic". This "raises important questions about the utility of internet polls to replace traditional telephone survey practices" (Flemming and Sonner, 1999, 13). More recently, Lee et al. (2015) used a

stratified sampling method to ensure age X gender quotas and a *post hoc* weighting method to compensate for age X gender sampling deviations from the population. Despite this, they found significant differences between RDD and online samples on tobacco use, drug and alcohol problems, happiness level and mental health problems, with the higher pathologies occurring in the online sample. In those studies where differences were not found, the surveys targeted climate change (Berrens et al., 2003) and global warming (Li et al., 2004).

There appears to have been a tendency recently for researchers investigating public attitudes to farm animal welfare to utilize PIP samples (for example, Worsley et al., 2015; Malek et al., 2018; Bir et al., 2019; Connor and Cowan, 2020; Jackson et al., 2020) and few examples where RDD telephone samples have been used. There have been no investigations into whether PIP samples and RDD telephone samples yield similar results when targeting public perceptions of farm animal welfare. It is important to know whether the substantive results from PIP surveys represent the population from which the samples were drawn or whether there are systematic biases. Such research may provide a cost-effective alternative to RDD telephone surveys in animal welfare research.

The data analyzed in this paper were derived from a current research project examining public and producer attitudes and knowledge toward sheep and beef cattle welfare in Australia. Literature suggests that public attitudes to animal welfare impact the livestock industries not just by influencing purchasing of animal products, but also by underpinning a range of community behaviors in opposition of the livestock industry, such as signing petitions, donating money to welfare organizations and speaking to colleagues about animal welfare issues (Coleman et al., 2017; Coleman, 2018). Public attitudes toward the livestock industries, livestock animal welfare and trust in the livestock industries were related to meat consumption as well as behaviors that people engage in that may impact on the pork industry (i.e., community behaviors). Regression analyses demonstrated that these variables accounted for significant proportions of the variance in both pork consumption and in community behavior (Coleman et al., 2017; Coleman, 2018). These behaviors and the attitudes driving them can have a considerable influence on how Governments either react to publicized 'animal welfare events' or regulate contentious management practices in industry. Our current research project extended this into the investigation of these relationships in the Australian red meat industry. In addition to the range of general attitudes, knowledge of husbandry practices and trust of livestock industry people and information sources, we also assessed in our current research project, behavior-specific attitudes utilizing the Theory of Planned Behavior (TPB: Ajzen, 1988). These latter variables comprise attitudes to the specific behavior of interest, normative beliefs (beliefs about the expectations of salient others) and control beliefs (beliefs about personal capacity to perform the behavior). Because of the substantial cost associated with RDD telephone surveys, it was decided that two samples drawn from the Australian public were to be obtained; one using a RDD telephone survey (Computer Assisted Telephone Interview – CATI) which was high cost and the other a PIP survey (PANEL, based on probability samples) which was relatively low cost. The aim in this paper therefore was to determine whether there were differences between the two survey samples in attitudes and behavior relating to animal welfare in the Australian red meat industry. Specifically, two broad questions were addressed: were the two samples similar in terms of attitudes and behavior and were the relationships between attitudes and behavior similar for the two samples?

MATERIALS AND METHODS

Development and Structure of Questionnaire

A questionnaire was developed using an iterative process that began with questionnaires that had been developed by the Animal Welfare Science Centre (AWSC) for livestock industries including the pork, egg and red meat industries (see Coleman and Toukhsati, 2006; Coleman et al., 2016, 2017). These questionnaires were adapted to target attitudes toward the red meat industry, animal welfare and husbandry practices. The questionnaires also assessed the participant's knowledge of farm animals and farm animal welfare, the frequency with which they accessed information on animal welfare, the source of information they most frequently used and trusted and the extent to which they engaged in community behaviors such as calling talk-back radio and writing to a politician to express dissatisfaction toward the red meat industry. The sections of the questionnaire are reported in **Table 1**.

Participant Recruitment and Collection of Data

Human ethics approval was obtained from The University of Melbourne's Human Ethics Advisory Group (Ethics ID: 1750676.3). Before the questionnaire was undertaken, respondents were given a plain language statement (i.e., an explanatory statement outlining the research aims), advised that participation was entirely voluntary and that they could withdraw at any time if so desired and consent was sought.

TABLE 1 | Structure of the questionnaire.

Section	Information gathered
Demographics	Age, Gender, education, location, red meat consumption,
Animal welfare	General attitudes toward animal welfare, trust of people involved in farm animal production, normative and control beliefs in relation to animal welfare
Knowledge of farm animals and farm animal welfare	Perceived and actual knowledge of beef cattle and sheep production practices (e.g., curfew, mulesing, castration, etc.)
Attitudes toward red meat farming practices	Approval of red meat farming practices, importance of social contact, fresh air, exercise, etc., concern about transport conditions.
Behavior in relation to farm animal welfare	Animal rights group membership, community behaviors, sources of animal welfare information, discussions about animal welfare

I-View, a specialized market and social research data collection agency, were contracted to deliver the questionnaire to 1000 members of the Australian general public, using two 'random' participant recruitment methods; 502 participants were surveyed using a RDD telephone recruitment (CATI) and a further 530 participants from a PIP (PANEL). Both samples were subjected to a 50:50 gender split and an age distribution consistent with Australian census data. The average duration of the CATI survey was 33.3 min and the response rate was 15%. For the PANEL survey, the median duration was 19 min (median used because of occasional outliers caused by respondents being logged on for very long periods) and the response rate estimated to be 10% based on the number of respondents emailed who clicked on the survey link. Data collection for CATI commenced on 21st March 2018 and was completed on the 16th April 2018, while the PANEL commenced on 29th March 2018 and was completed on the 16th April 2018.

CATI involved dialing random fixed-line ($n = 246$) and mobile telephone numbers ($n = 256$) and inviting potential respondents to complete the questionnaire by telephone. Recent research (Kennedy et al., 2018) has suggested that using both fixed-line and mobile telephone numbers provides the most demographically representative sample and does not bias data collected. In each call, the consultant requested the youngest male in the household (over the age of 18 years) in order to counteract the expected bias for older female participants commonly encountered in telephone surveys. This was used as a first step after which any available person was interviewed if they met the quota requirements. The PANEL "MyView" was originally recruited by recruitment service providers, conducting email marketing campaigns, social media marketing campaigns and traditional marketing campaigns using a points-rewards based system for incentives where participants are awarded points by completing surveys. All panelists undergo a comprehensive validation process to ensure no duplication and are screened for IP address within Australia and age groups over 14 years old. Email confirmations are also used to ensure that the email is valid and belongs to the person that completed the recruitment questionnaire. MyView panel participants over the age of 18 were invited via email to participate in the current survey for a payment of 300 points (AUD $3.00). If a respondent accessed the survey and was in an age or gender group that had met the quota requirements, they were screened out of the survey. The survey was then displayed on their Panel dashboard and appeared as a notification on their mobile device if they had downloaded the application.

Statistical Analysis

Statistical analyses were performed using the statistical package SPSS 25.0 (SPSS Inc., Chicago, IL, United States). The attitude, beliefs and trust sections of the questionnaire (sections B and D of the questionnaire, see **Table 1**) data were analyzed using Principal Components Analysis (PCA), followed by either a Varimax or an Oblimin rotation, to identify commonalities amongst the questionnaire items (see **Table 2**). The suitability of the data for the analysis was assessed using criteria outlined by Pallant (2013); the correlation matrix coefficients were all above the required 0.3, the Kaiser-Meyer-Olkin (KMO) values exceeded the recommended value of 0.6, and Bartlett's Test of Sphericity reached statistical significance. Items that were established as belonging to a common underlying component were then summed to produce a composite score for that component. Before conducting the PCAs, items were recoded where appropriate so that high scores reflected positive attitudes, high trust, etc. Scale reliabilities were measured using Cronbach's α coefficients with an $\alpha >= 0.70$ as the criterion for acceptable reliability (DeVellis, 2003). Items were included in a scale if their loading on the relevant component exceeded 0.33 (Tabachnick and Fidell, 2012) and if, on the basis of face validity, they could be summarized by just one construct.

A summary of the details of the component structures are reported in **Table 2**, and most Cronbach's α coefficients exceeded 0.7 with the exception of "Caring for and balancing the needs of pets and people" and "Easy to act" (0.57 and 0.48, respectively). In both cases the decision was made to retain the component because their component groupings showed good face validity and only two items comprised the composite score which is known to reduce the magnitude of Cronbach's α coefficients (Nunnally et al., 1967).

Perceived knowledge was measured by asking the respondent "How much do you feel you know about beef cattle and sheep production?". In addition, actual knowledge was assessed through a series of 13 multiple choice questions in relation to some common farming practices (e.g., mulesing, de-horning, castration, curfew, pre-slaughter stun, etc.). Respondents were then given a score (knowledge score) based on the proportion of correctly answered questions.

Community behavior was measured by the sum of the self-reported occurrences with which respondents said that they had engaged in acts such as calling talk-back radio, writing to newspapers and writing to politicians to express dissatisfaction with the red meat industry. Consumption of beef and lamb was measured by single items asking for the frequency of consumption of each.

Analyses of the demographic frequencies were carried out using Pearson χ^2 tests of independence. Multivariate analysis of covariance (MANCOVA) with education as a covariate were conducted to compare the CATI and the PANEL samples on all composite variables. Independent 2-tailed *t*-tests with education as a covariate were then conducted on each of the composite variables separately to compare the responses of the CATI and the PANEL respondents. Correlations between the composite variables identified from the PCA on the attitudes, beliefs and trust items, perceived and actual knowledge, self-reported meat consumption, and community behaviors were conducted using Pearson product moment correlations. Separate stepwise multiple linear regressions were used to identify those variables that predicted each of the behaviors of interest – self-reported beef consumption, self -reported lamb consumption and community behaviors.

TABLE 2 | Components from the questionnaire grouped into composite scores, a high score indicating a positive attitude or strong agreement to the statements.

Topic	Assigned attitude component label	Cronbach's Alpha	Questionnaire item
The meaning of animal welfare	Humane treatment	0.82	Humane treatment of animals
			Preventing animal cruelty
			Protecting the rights of animals
	Best practice handling	0.78	Farmers and farm animal handlers using best practice
			Farmers and farm animal handlers caring for their animals
	Caring for and balancing the needs of pets and people	0.57	Caring for our pets
			Balancing the needs of animals and people
Acceptability of animal uses	Red meat attributes	0.81	I believe beef and lamb are healthy foods
			It is appropriate to use sheep and beef cattle to produce food for humans
			Sheep and beef cattle farming is environmentally sustainable
			Sheep and beef cattle are raised in a humane and animal friendly manner
	Red meat animal rights	0.69	Sheep and beef cattle have the same right to life as domestic animals
			Sheep and beef cattle have the same feelings as domestic animals
Behavioral beliefs	Public engagement beliefs	0.89	I think it is important to lobby governments to improve the welfare of farm animals
			I should encourage my friends to support animal welfare causes
			It is important for me to be actively involved in the promotion of farm animal welfare
			It is important for me to encourage family and friends to be actively involved in the promotion of animal welfare
Normative beliefs	Negative normative beliefs	0.74	The welfare of farm animals is not something that my partner/family would expect me to consider when making meat shopping choices
			Lobbying the government to improve the welfare of farm animals is not something my partner/family would expect me to do
			My partner/family would not expect me to encourage my family and friends to be actively involved in the promotion of animal welfare
	Positive normative beliefs	0.78	My partner/family would expect me to buy lamb and beef that is produced with good animal welfare practices
			My partner/family would expect me to encourage my friends to support animal welfare causes
			My partner/family would expect me to be actively involved in the promotion of farm animal welfare
Control beliefs	Difficult to act	0.48	I find it takes too much effort to buy beef and lamb that is produced with good animal welfare practices.
			I would find it too difficult to lobby the government to improve the welfare of farm animals
	Easy to act	0.75	I can easily encourage my friends to support animal welfare causes
			I can easily be involved actively in the promotion of farm animal welfare
Trust of livestock industry people	Trust	0.92	I trust farmers to properly care for their sheep and beef cattle
			I trust farm animal handlers to properly care for their sheep and beef cattle
			I trust those responsible for transporting sheep and beef cattle by land to properly care for them
			I trust abattoir workers who work with sheep and beef cattle to properly care for them and use humane slaughter methods
Attitudes toward red meat farming practices	Approval of husbandry practices	0.89	Mulesing
			Crutching
			Dehorning
			Pre-slaughter stunning
			Curfew
			Tail docking
			Ear tagging
			Hot iron branding
			Castration
			Feedlotting
			Spaying

(Continued)

TABLE 2 | Continued

Topic	Assigned attitude component label	Cronbach's Alpha	Questionnaire item
Importance of farming attributes	General welfare	0.95	Social contact with animals of the same species
			Contact with their young
			Shelter
			Access to water
			Freedom to roam outdoors
			Good nutrition
			Regular exercise
			Fresh air
			Protection from predators
			Pain relief during painful husbandry procedures
	Medication	0.8	Medications (i.e., antibiotics) for health
			Vaccinations for health
Comfort of beef cattle	Land beef transport conditions	0.94	Space per animal
			Provision of food and water
			Ventilation
			Journey length
			Road/truck conditions (e.g., sound, vibration, braking levels
			Loading of animals onto vehicles (e.g., use of handling aids, human handling)
	Sea beef transport conditions	0.96	Space per animal
			Provision of food and water
			Ventilation
			Journey length
			Boat conditions (e.g., sounds, vibration, unsteady ground)
			Loading of animals onto boats (e.g., use of handling aids, human handling)
Comfort of sheep	Land sheep transport conditions	0.96	Space per animal
			Provision of food and water
			Ventilation
			Journey length
			Road/truck conditions (e.g., sound, vibration, braking levels
			Loading of animals onto vehicles (e.g., use of handling aids, human handling)
	Sea sheep transport conditions	0.97	Space per animal
			Provision of food and water
			Ventilation
			Journey length
			Boat conditions (e.g., sounds, vibration, unsteady ground)
			Loading of animals onto boats (e.g., use of handling aids, human handling)
Accessing information	Commercial media	0.79	Government advertisements/promotions
			Celebrity chef/cook
			Industry bodies
			Supermarkets (e.g., Coles, Woolworths, IGA)
			Labels (product labels)
	Social and internet media	0.8	Internet
			Friends, relatives or colleagues
			Animal welfare organizations e.g., RSPCA
			Social network sites, related social media (e.g., Facebook, YouTube, Twitter, blogs)
	Conventional media	0.75	Television (e.g., TV news, documentaries)
			Radio
			Print media (e.g., magazines, newspapers, scientific papers)

(Continued)

TABLE 2 | Continued

Topic	Assigned attitude component label	Cronbach's Alpha	Questionnaire item
Trust of information sources	Trust social and internet media	0.84	Television (e.g., TV news, documentaries)
			Radio
			Internet
			Print media (e.g., magazines, newspapers, scientific papers)
			Friends, relatives or colleagues
			Animal welfare organizations e.g., RSPCA
			Social network sites, related social media (e.g., Facebook, YouTube, Twitter, blogs)
	Trust conventional media	0.82	Government advertisements/promotions
			Industry bodies
			Supermarkets (e.g., Coles, Woolworths, IGA)
			Labels (product labels)
			Celebrity chef/cook

RESULTS

Differences Between CATI and PANEL Samples: Demographics

Comparisons of CATI and PANEL respondents' sociodemographic characteristics are reported in **Table 3**. The two survey samples are reasonably consistent with the most recent census data from the Australian Bureau of Statistics [ABS], 2016) and respondents from both surveys resided in all states and territories of Australia. There were no significant differences between the two samples regarding respondents' geographical location ($\chi^2_6 = 14.69$, $p > 0.05$), 50:50 gender split ($\chi^2_2 = 2.33$, $p > 0.05$), or age distribution ($\chi^2_5 = 3.46$, $p > 0.05$), with the 18–24 age group under-represented in both the CATI and PANEL samples (**Table 3**).

With regard to respondents' highest level of education, there were significant differences between the CATI and PANEL samples ($\chi^2_3 = 11.04$, $p < 0.05$; **Table 3**). The CATI sample had fewer technical and school leaver educated respondents than did the PANEL sample ($\chi^2_1 = 9.52$, $p < 0.05$), but the other categories were not significantly different between the two samples. Numerically, the census percentages for technical and further education percentages were midway between the those for the two samples, while the census percentages for university or other higher education were below those for the two samples.

There was a significant difference between the samples in terms of who performs the household shopping (**Table 3**), with the CATI sample containing more respondents who did the shopping less frequently than the PANEL respondents ($\chi^2_3 = 21.48$, $p < 0.05$). Despite the differences between the samples, most respondents from both samples were responsible for shopping in their households.

In relation to meat consumption, while most respondents from both samples were meat eaters, there was a significant difference between the samples in number of vegetarians and vegans, with fewer vegetarians and vegans in the PANEL sample ($\chi^2_2 = 6.98$, $p < 0.05$). The vegetarian/vegan sample is relatively small, particularly in the PANEL survey (5 vs. 8%) and thus caution is required in interpreting this difference between the two samples.

Differences Between CATI and PANEL Samples: Composite Variables and Behavioral Variables

Because the two survey samples differed with regard to education level, a MANCOVA with education as a covariate was used to compare the CATI and the PANEL sample on the composite variables. There was a significant effect for education ($F_{43,987} = 2.66$, $p < 0.01$). Following the MANCOVA, univariate tests were performed on each of the composite variables. Comparison of the CATI sample with the PANEL sample on the composite variables showed that the PANEL respondents gave generally more conservative responses than did the respondents from the CATI survey ($F_{43,987} = 8.85$, $p < 0.01$), in the sense that they were more positive toward the livestock industries and animal welfare within these industries (**Table 4**). The multivariable effect size for education was substantially smaller than that for sample type (Partial $^2\eta = 0.10$ and 0.28, respectively). The effect sizes (Cohen, 2016) of the significant univariate differences that were observed ranged from very small (< 0.2) to those in the small to medium range (> 0.2 but < 0.5). The PANEL sample also reported greater perceived knowledge (but not actual knowledge) of livestock production and were less engaged in communication activities and community behaviors.

In general, CATI respondents were more engaged in community behaviors when compared with the PANEL sample, with significantly more respondents having posted/shared information about an issue on social media, signed a petition and spoken to colleagues, family members or friends in opposition of beef cattle and sheep farming (**Table 5**).

There was no significant difference between CATI and PANEL respondents in relation to the regularity of their red meat consumption (**Table 6**).

TABLE 3 | Chi square comparison of CATI ($n = 502$) and PANEL ($n = 530$) respondents' sociodemographic characteristics.

			CATI		PANEL		Census
			Count	%	Count	%	%
$\chi^2_6 = 6.10$, $p > 0.05$	State/Territory	Victoria	137	28	135	26	24
		New South Wales	137	28	177	34	29
		Queensland	109	22	108	21	22
		South Australia	41	8	40	8	8
		Western Australia	50	10	49	9	12
		Tasmania	14	3	10	2	3
		Australian Capital Territory	10	2	6	1	2
$\chi^2_2 = 2.33$, $p > 0.05$	Are you...?	Male	231	46	263	50	49
		Female	270	54	267	50	51
		Other	1	0	0	0	0
$\chi^2_5 = 3.46$, $p > 0.05$	Which of these age groups are you in?	18–24	48	10	36	7	12
		25–34	75	15	78	15	19
		35–44	84	17	99	19	17
		45–54	96	19	106	20	17
		55–64	94	19	106	20	15
		65 +	105	21	105	20	20
$\chi^2_3 = 11.04$, $p < 0.05$	What is your highest level of education?	No Formal Schooling	0	29	0	29.2	42.3
		Primary School	9		6		
		Secondary School	135		149		
		Technical or further educational institution (including TAFE College)	116	24.7	168	32	28.1
		University or other higher educational institution	230	46.3	204	38.8	27.3
$\chi^2_3 = 21.48$, $p < 0.05$	How often do you do the grocery shopping for your household?	Rarely	48	10	21	4	
		Sometimes	86	17	69	13	
		Mostly	120	24	121	23	
		Always	247	49	319	60	
$\chi^2_2 = 6.98$, $p < 0.05$	Would you describe yourself primarily as a...?	Meat and vegetable eater (A person who eats a variety of foods including red and white meat)	449	89	498	94	
		Vegetarian (A vegetarian is a person who does not eat red or white meat, including fish, but eats eggs and dairy products)	42	8	25	5	
		Vegan (A vegan is a person who eats no animal products at all)	11	2	7	1	

Data for the Northern Territory and No formal schooling were not included in the analysis because of expected frequencies < 5. Census data of the Australian Bureau of Statistics [ABS] (2016) is also presented for geographical location, gender, age distribution and level of education.

Comparing CATI and PANEL Samples: Relationships Between Attitudes, Knowledge and Community Behavior

Correlations amongst the composite attitude variables and the four outcome variables (actual knowledge, community behavior and both perceived knowledge scores) are given in **Table 7**. For the correlations between attitudes and actual knowledge, in every case where significant differences exist between the two survey samples, the PANEL correlations are significantly larger than the CATI correlations. With one exception, this is also the case for correlations between attitudes and perceived knowledge for both beef cattle and sheep.

Correlations between attitudes and behavior show the opposite pattern to the knowledge and perceived knowledge correlations. In most instances where significant differences exist between the two survey samples, the PANEL correlations are significantly larger than the CATI correlations. However, where the correlations are between accessing the three media types (commercial, conventional and social) and behavior, the correlations are significantly larger for the CATI sample.

When all composite variables were entered into a linear regression model with community behavior as the dependent variable, five variables uniquely contributed to predicting community behavior for respondents of the CATI survey (Public engagement beliefs, Positive normative beliefs, Trust, Social and internet media and Eats meat) and accounted for 47% of its variance (**Table 8**). For the PANEL sample, five variables uniquely contributed to predicting Community behavior (Public engagement beliefs, Commercial media, Social and internet media, Eats meat and Trust Commercial media) and these variables accounted for 48% of its variance (**Table 9**).

TABLE 4 | Independent 2-tailed *t*-tests (df = 1029) comparing the responses of the CATI and the PANEL respondents with education as a covariate.

			Adjusted Mean				
	t	Sig.	CATI	PANEL	Mean Difference (CATI-PANEL	Cohen's D	Interpretation
Animal welfare humane	2.34	0.02	**4.41**	**4.29**	**0.12**	0.15	CATI respondents have a greater belief that animal welfare involves humane animal care/treatment
Animal welfare handling	1.54	0.12	4.28	4.20	0.08	0.09	No significant difference in CATI and PANEL respondents' belief that animal welfare involves appropriate animal handling
Animal welfare people animals	2.71	0.01	**4.07**	**3.92**	**0.15**	0.17	CATI respondents have a greater belief that animal welfare involves a positive human-animal relationship.
Red meat attributes	−2.18	0.03	**3.65**	**3.77**	**−0.12**	−0.14	PANEL respondents have a more positive attitude toward red meat attributes, regarding human health, environmental impact, animal use and animal welfare
Red meat animal rights	4.17	0.00	**3.99**	**3.73**	**0.24**	0.26	CATI respondents have a more positive attitude toward red meat (beef cattle and sheep) animal rights
Public engagement beliefs	4.50	0.00	**3.52**	**3.22**	**0.30**	0.28	CATI respondents have a more positive attitude toward public engagement (i.e., lobbying government, supporting animal welfare causes, and animal welfare promotion)
Negative normative beliefs	−4.25	0.00	**2.89**	**3.17**	**−0.28**	−0.26	PANEL respondents have a greater belief that relevant others would not expect them to show public engagement (i.e., lobbying government, supporting animal welfare causes, and animal welfare promotion)
Positive normative beliefs	4.62	0.00	**3.30**	**3.00**	**0.30**	0.29	CATI respondents have a greater belief that relevant others would expect them to show public engagement (i.e., lobbying government, supporting animal welfare causes, and animal welfare promotion)
Easy to act	−3.92	0.00	**2.81**	**3.05**	**−0.24**	−0.24	CATI respondents see greater ease in supporting or promoting positive animal welfare
Difficult to act	3.16	0.00	**3.13**	**2.91**	**0.22**	0.20	PANEL respondents see greater difficulty in supporting or promoting positive animal welfare
Trust	−1.20	0.23	3.38	3.46	−0.08	−0.07	No significant difference in CATI and PANEL respondents' trust of farmers and animal handlers to appropriately care for beef cattle and sheep
Approval of husbandry practices	2.36	0.02	**3.04**	**2.92**	**0.12**	0.15	CATI respondents have a more positive attitude toward the husbandry practices used in the red meat industry
General welfare	9.01	0.00	**4.77**	**4.43**	**0.34**	0.56	CATI respondents have a greater belief that good animal welfare requires a range of different factors to be met
Medication	6.10	0.00	**4.55**	**4.25**	**0.30**	0.38	CATI respondents have a greater belief that it is important to provide medication to beef cattle and sheep
Land beef transport conditions	−4.47	0.00	**2.50**	**2.82**	**−0.32**	−0.28	PANEL respondents have a more positive attitude toward land transport conditions for beef cattle
Sea beef transport conditions	−6.53	0.00	**2.11**	**2.57**	**−0.46**	−0.41	PANEL respondents have a more positive attitude toward sea transport conditions for beef cattle
Land sheep transport conditions	−4.11	0.00	**2.36**	**2.65**	**−0.29**	−0.26	PANEL respondents have a more positive attitude toward land transport conditions for sheep
Sea sheep transport conditions	−6.23	0.00	**2.03**	**2.47**	**−0.44**	−0.39	PANEL respondents have a more positive attitude toward sea transport conditions for sheep
Commercial media	0.53	0.59	2.02	1.99	0.03	0.03	No significant difference in CATI and PANEL respondents' attitude toward commercial media as a source of knowledge
Social and internet media	5.10	0.00	**2.73**	**2.42**	**0.31**	0.32	CATI respondents have a more positive attitude toward social and internet media as a source of knowledge
Conventional media	4.99	0.00	**2.61**	**2.33**	**0.28**	0.31	CATI respondents have a more positive attitude toward conventional media as a source of knowledge
Eats meat	2.59	0.01	**1.11**	**1.06**	**0.05**	0.16	CATI respondents are more likely to be a vegetarian or vegan

(Continued)

TABLE 4 | Continued

	t	Sig.	Adjusted Mean CATI	Adjusted Mean PANEL	Mean Difference (CATI-PANEL	Cohen's D	Interpretation
Trust conventional media	−1.04	0.30	3.02	3.08	−0.06	−0.06	No significant difference in CATI and PANEL respondents' trust of conventional media
Trust Commercial media	−4.86	0.00	**2.61**	**2.85**	**−0.24**	−0.30	PANEL respondents are more trusting of commercial media
Trust social and internet media	−3.51	0.00	**2.96**	**3.14**	**−0.18**	−0.22	PANEL respondents are more trusting of social and internet media
Perceived knowledge of beef cattle production	−0.55	0.00	**2.80**	**3.25**	**−0.45**	−0.41	PANEL respondents have a greater perceived knowledge of beef cattle production
Perceived knowledge of sheep production	−5.07	0.00	**2.93**	**3.29**	**−0.36**	−0.32	PANEL respondents have a greater perceived knowledge of sheep production
Knowledge Score	0.68	0.50	72.25	71.46	0.79	0.04	No significant difference in CATI and PANEL respondents' knowledge score
Behavior	2.41	0.02	**2.00**	**1.72**	**0.28**	0.15	CATI respondents perform more community behaviors
During the past 6 months, how many people have you told about farm animal welfare in Australia?	**4.71**	**0.00**	**2.34**	**1.95**	**0.39**	0.29	CATI respondents perform more communication activities
Compared with your friends, how likely are you to be asked about farm animal welfare in Australia?	**3.50**	**0.00**	**2.25**	**1.98**	**0.27**	0.22	CATI respondents perform more communication activities
Overall, in all of your discussions with friends and neighbors how often are you used as a source of advice on farm animal welfare in Australia?	1.48	0.14	1.88	1.78	0.10	0.09	No significant difference in CATI and PANEL respondents being used as a source of advice on farm animal welfare

Comparing CATI and PANEL Samples: Relationships Between Attitudes and Red Meat Consumption

Correlations between the composite attitude variables and self-reported frequency of beef and lamb consumption are given in **Table 10**. In every case where significant differences in the correlations exist between the two survey samples, the CATI correlations are significantly larger than the PANEL correlations.

When all composite variables were entered into linear regression models with self-reported consumption of beef as the dependent variable, two variables uniquely contributed to predicting beef consumption (Red meat attributes and Trust) for respondents of the CATI survey and accounted for 38% of its variance (**Table 11**). For the PANEL sample, five variables uniquely contributed to predicting beef consumption (Red meat attributes, Red meat animal rights, Negative normative beliefs, Approval of husbandry practices and Medication) and these variables accounted for 19% of its variance (**Table 11**). Unlike the analysis of behavior, a much smaller percentage of the variance in beef consumption was predicted in the PANEL sample compared to the CATI sample.

When all composite variables were entered into linear regression models with self-reported consumption of lamb as the dependent variable, two variables uniquely contributed to predicting lamb consumption for respondents of the CATI survey (Red meat attributes and Public engagement beliefs) and accounted for 25% of its variance (**Table 11**). For the PANEL sample, only one variable uniquely contributed to predicting lamb consumption (Red meat attributes) and this variable accounted for 9% of its variance (**Table 11**). Similar to beef consumption, a much smaller percentage of the variance in lamb consumption was predicted in the PANEL sample compared to the CATI sample.

DISCUSSION

The primary aim in this paper was to determine whether there were differences between the CATI (RDD telephone) and the PANEL (PIP) survey samples in animal welfare-related attitudes and behavior, and the interrelationships amongst these variables. As a first step, it was important to compare the two samples in demographic characteristics. In some respects, it is not surprising that the results of this study showed that the demographic characteristics of the two samples were quite similar. Quotas were applied to age and gender and the data showed the two samples to be similar in these respects. However, geographical

TABLE 5 | Independent 2-tailed *t*-tests (df = 1029) comparing engagement with individual community behaviors between the CATI survey and the PANEL survey respondents with education as a covariate.

			Mean				
	t	**Sig.**	**CATI**	**PANEL**	**Mean Difference (CATI-PANEL)**	**Cohen's D**	**Interpretation**
Written a letter to a politician	−1.68	0.09	0.06	0.09	−0.03	−0.10	No significant difference between CATI and PANEL respondent's prevalence of writing a letter to a politician
Posted/shared information about an issue on social media	4.37	0.00	**0.35**	**0.23**	**0.12**	0.27	CATI respondents post or share more information about an issue on social media
Called a radio talk back segment	−3.95	0.00	**0.01**	**0.05**	**−0.04**	−0.25	PANEL respondents called a radio talk back segment more frequently
Attended a public rally or demonstration	0.02	0.98	0.07	0.07	0.00	0.00	No significant difference in CATI and PANEL respondents' attendance at public rally or demonstration
Signed a petition	1.94	0.05	**0.40**	**0.34**	**0.06**	0.12	CATI respondents sign petitions more frequently
Donated money to animal welfare organizations	2.20	0.03	**0.48**	**0.41**	**0.07**	0.14	CATI respondents donate money to animal welfare organizations more frequently
Donated goods other than money to animal welfare organizations	−0.33	0.74	0.24	0.25	−0.01	−0.02	No significant difference in CATI and PANEL respondents' donation of goods other than money to animal welfare organizations
Volunteered your services to animal welfare organizations	−0.20	0.84	0.12	0.12	0.00	−0.01	No significant difference in CATI and PANEL respondents' volunteering their services to anima welfare organizations
Spoken to colleagues, family members, or friends	7.11	0.00	**0.66**	**0.45**	**0.21**	0.44	CATI respondents speak with colleagues, family members and friends about animal welfare more frequently
Written a letter to a newspaper	−3.15	0.00	**0.02**	**0.05**	**−0.03**	−0.20	PANEL respondents have a greater prevalence of writing a letter to a newspaper

TABLE 6 | Independent 2-tailed *t*-tests (df = 1029) comparing the consumer behavior of the CATI survey and the PANEL survey respondents with education as a covariate.

			Mean				
	t	**Sig.**	**CATI**	**PANEL**	**Mean Difference (CATI-PANEL)**	**Cohen's D**	**Interpretation**
How often would you eat beef in an average week?	−0.53	0.59	3.30	3.34	−0.04	0.03	No significant difference in CATI and PANEL respondents' average weekly beef consumption
How often would you eat lamb in an average week?	0.45	0.65	2.40	2.37	0.03	0.03	No significant difference in CATI and PANEL respondents' average weekly lamb consumption

distributions which had not been sampled by quota were also similar to both each other and also to the Australian census data. The one demographic variable where the survey samples differed from each other was in education. It is not clear why there were fewer technical and further education educated people in the CATI sample and (although not significant) more university or other higher educational institution educated people compared to the PANEL sample. Given these differences, we accounted for the potential impact of education in analysis of the data by adjusting for level of education achieved.

A second point of comparison that will assist in interpreting the similarities and differences between the samples is response rate. Response rates for internet and telephone surveys consistently show that telephone surveys take longer to complete than do internet surveys. As indicated earlier, Ansolabehere and Schaffner (2014) compared internet and telephone surveys and found response rates of 42.9% and 19.5%, respectively. Similarly, Link and Mokdad (2005) reported response rates of 40.1% and 15.4%, respectively. In the current study the response rates were 10% and 15%, respectively. It is not clear why the differences in response rates between this study and previous studies occurred.

For the telephone survey, Ansolabehere and Schaffner (2014) reported a response rate of 20.9% for landline telephone numbers and 8.6% for mobile telephone numbers. They received 807 landline and 100 mobile telephone responses. If these numbers are recalculated for a sample consisting of a 50:50 split of landline and mobile telephone respondents, the average response time for all telephone contacts in Ansolabehere and Schaffner's (2014) study would be 14.8% compared to 15% in the current study

TABLE 7 | Correlations (df = 1030) between Knowledge, Community behavior and all composite variables.

	Actual Knowledge		Behavior		Perceived Knowledge beef		Perceived Knowledge sheep	
	CATI	PANEL	CATI	PANEL	CATI	PANEL	CATI	PANEL
Animal welfare humane	**0.03**	**0.29**	0.19	0.20	−0.05	0.00	−0.01	−0.01
Animal welfare handling	**0.12**	**0.25**	0.01	0.11	−0.09	−0.10	−0.04	−0.10
Animal welfare people animals	**0.00**	**0.17**	0.13	0.11	−0.02	−0.14	0.00	−0.13
Red meat attributes	0.08	0.10	−0.34	−0.20	−0.15	−0.04	−0.15	−0.03
Red meat animal rights	−0.04	0.05	0.27	0.24	0.04	−0.04	0.01	−0.05
Public engagement beliefs	−0.15	−0.08	0.51	0.49	**0.03**	**−0.16**	**0.02**	**−0.16**
Negative normative beliefs	0.08	−0.03	**−0.35**	**−0.15**	0.05	0.12	0.04	0.14
Positive normative beliefs	−0.11	−0.07	0.41	0.44	**−0.04**	**−0.23**	**−0.09**	**−0.22**
Easy to act	−0.08	−0.17	−0.19	−0.14	0.15	0.19	0.19	0.20
Difficult to act	−0.09	−0.13	0.44	0.42	−0.12	−0.21	−0.06	−0.20
Trust	0.02	−0.05	**−0.39**	**−0.21**	−0.13	−0.02	−0.14	−0.01
Approval of husbandry practices	0.17	0.05	**−0.31**	**−0.07**	−0.24	−0.16	−0.19	−0.14
General welfare	**0.03**	**0.30**	**0.28**	**0.09**	0.04	−0.05	0.05	−0.07
Medication	0.01	0.15	0.04	0.06	0.04	−0.08	0.02	−0.08
Land beef transport conditions	**−0.03**	**−0.20**	**−0.32**	**−0.16**	−0.16	−0.04	**−0.18**	**−0.02**
Sea beef transport conditions	**−0.01**	**−0.27**	**−0.35**	**−0.16**	−0.10	−0.05	−0.09	−0.01
Land sheep transport conditions	**−0.02**	**−0.23**	**−0.33**	**−0.19**	−0.12	−0.06	−0.14	−0.02
Sea sheep transport conditions	**0.00**	**−0.28**	**−0.35**	**−0.18**	−0.08	−0.05	−0.07	−0.01
Commercial media	−0.06	−0.15	**0.20**	**0.48**	**−0.14**	**−0.27**	**−0.14**	**−0.27**
Social and internet media	−0.09	−0.04	**0.53**	**0.64**	**−0.02**	**−0.27**	**0.03**	**−0.25**
Conventional media	0.13	0.01	**0.15**	**0.47**	**−0.19**	**−0.32**	−0.24	−0.32
Trust conventional media	−0.07	−0.03	0.14	0.22	0.10	−0.01	0.11	−0.01
Trust Commercial media	−0.15	−0.15	0.05	0.15	0.12	0.00	0.07	0.02
Trust social and internet media	−0.17	−0.05	0.39	0.40	0.10	−0.06	0.09	−0.04

Pairs of correlations in bold are significantly different at $p < 0.05$.

TABLE 8 | Linear regression with Community behavior as the dependent variable and all composite variables entered as the predictors, for the CATI sample.

	Beta coefficient (standardized)	t	Sig.
(Constant)		−2.0	0.04
Public engagement beliefs	0.15	2.72	0.01
Positive normative beliefs	0.13	2.73	0.01
Trust	−0.17	−3.50	0.00
Social and internet media	0.32	7.10	0.00
Eats meat	0.10	2.50	0.01

$R^2 = 0.47$

TABLE 9 | Linear regression with Community behavior as the dependent variable and all composite variables entered listwise as the predictors, for the PANEL sample.

	Beta coefficient (standardized)	t	Sig.
(Constant)		−3.52	0.00
Public engagement beliefs	0.18	2.86	0.00
Commercial media	0.15	2.69	0.01
Social and internet media	0.35	5.78	0.00
Eats meat	0.07	2.07	0.04
Trust commercial media	−0.11	−2.20	0.03

$R^2 = 0.48$.

and 40.1% in the study by Link and Mokdad (2005). However, the methodology used by Link and Mokdad (2005) was quite different from both Ansolabehere and Schaffner (2014) and the current study because telephone respondents first received the questionnaire via mail and were then contacted by telephone. Thus, it appears that the response rate for telephone respondents in the current study are similar to those obtained by at least one other study that used similar methodology.

For the PANEL survey, the response rate in the current study is much lower than that obtained by Ansolabehere and Schaffner (2014), however, it is difficult to compare the methodologies used in the two studies. Ansolabehere and Schaffner (2014) used a procedure where everyone in the target sample as defined by census data is matched with at least one person from the internet panel. The survey link is then sent to the selected panelists and the responses are weighted to ensure that the matched sample is representative of the population target sample.

Given the length of the questionnaire used in the current study (CATI: 33.3 min, PANEL: 19 min) it might be expected that the response rates would be lower than that obtained in other studies. For example, completion times in Ansolabehere and Schaffner's (2014) study were 14.3 min for telephone respondents and 8.9 min for internet respondents.

TABLE 10 | Correlations (df = 1030) between beef and lamb consumption and all composite variables.

	Beef		Lamb	
	CATI	**PANEL**	**CATI**	**PANEL**
Animal welfare humane	**−0.16**	**0.02**	−0.11	0.01
Animal welfare handling	0.08	0.10	0.07	0.09
Animal welfare people animals	−0.04	0.07	0.00	0.04
Red meat attributes	**0.55**	**0.38**	**0.48**	**0.29**
Red meat animal rights	−0.22	−0.14	−0.16	−0.04
Public engagement beliefs	**−0.26**	**−0.12**	−0.12	0.01
Negative normative beliefs	0.22	0.15	**0.16**	**0.03**
Positive normative beliefs	−0.11	−0.03	−0.05	0.07
Easy to act	0.01	0.03	0.06	−0.03
Difficult to act	−0.18	−0.06	−0.15	0.06
Trust	**0.48**	**0.28**	0.34	0.23
Approval of husbandry practices	**0.41**	**0.13**	**0.33**	**0.15**
General welfare	**−0.16**	**0.01**	−0.12	−0.02
Medication	0.12	0.08	0.10	0.00
Land beef transport conditions	**0.40**	**0.15**	**0.33**	**0.09**
Sea beef transport conditions	**0.34**	**0.14**	**0.28**	**0.10**
Land sheep transport conditions	**0.40**	**0.18**	**0.33**	**0.09**
Sea sheep transport conditions	**0.32**	**0.14**	**0.25**	**0.11**
Commercial media	0.04	0.01	0.07	0.09
Social and internet media	−0.22	−0.12	**−0.18**	**−0.02**
Conventional media	0.01	0.01	−0.01	0.11
Trust conventional media	−0.08	−0.05	−0.04	0.06
Trust Commercial media	0.11	−0.01	0.11	0.13
Trust social and internet media	−0.24	−0.11	−0.15	0.01

Pairs of correlations in bold are significantly different at $p < 0.05$.

TABLE 11 | Linear regression with beef consumption or lamb consumption as the dependent variable and all composite variables entered listwise as the predictors.

Beef consumption		**Beta coefficient (standardized)**	**t**	**Sig.**	**R^2**
CATI	(Constant)		2.19	0.03	0.38
	Red meat attributes	0.36	6.62	0.00	
	Trust	0.13	2.48	0.01	
PANEL	(Constant)		4.39	0.00	0.19
	Red meat attributes	0.36	6.20	0.00	
	Red meat animal rights	−0.14	−2.80	0.00	
	Negative normative beliefs	0.10	2.07	0.04	
	Approval of husbandry practices	−0.11	−2.30	0.03	
	Medication	0.12	2.01	0.04	
Lamb consumption					
CATI	(Constant)		1.22	0.22	0.25
	Red meat attributes	0.41	7.10	0.00	
	Public engagement beliefs	0.16	2.58	0.01	
PANEL	(Constant)		3.22	0.00	0.09
	Red meat attributes	0.25	4.10	0.00	

Although the underlying explanation for the differences between the studies is unclear, it seems reasonable that the two samples used in the current study should be comparable in terms of representativeness because of similarities in the demographic data, consistency with census data except for education, and similar response rates, even if they do not correspond to those obtained in other studies.

A comparison of the CATI sample with the PANEL sample on the composite variables showed that the PANEL sample gave generally more conservative responses than did the CATI sample, in the sense that they were more positive toward the red meat industry and animal welfare within these industries. In evaluating these differences between the two samples, it is important to consider their practical importance. The analysis of the demographic factor of education level that differed between the two samples showed an effect size of a partial ${}^2\eta = 0.10$ compared with an effect size associated with the substantive dependent variables of ${}^2\eta = 0.28$. While the sample difference in education is substantial, the differences in the substantive variables after controlling for education is quite large. Further, many of the univariate effect sizes are in the small to medium range. While care needs to be taken not to interpret sample differences in each of the dependent variables in isolation because of the multiple tests carried out with the consequent increase in Type I error rate, the multivariate test and the overall pattern of univariate results suggest that there is a meaningful difference between the two samples in many of the attitude and behavior measures.

It is unclear why the PANEL sample gave what appear to be generally more conservative responses than did the CATI sample. There are few studies that have investigated the relationship between survey type and conservatism. Ansolabehere and Schaffner (2014) in their study of US respondents, reported that, compared to telephone survey respondents, internet respondents were more likely to say, for example, that budget cuts should come more from defense spending. Further, the internet survey produced much lower estimates of the proportion of the population that were supportive of Congress and of affirmative action. It is difficult to infer the orientation underpinning these response patterns; results regarding support for affirmative action suggest that internet survey respondents may be more conservative than telephone survey respondents. However, support for budget cuts coming from cuts to defense spending and lack of support for Congress seem to imply the opposite orientation. It also may be that the political view reflected in these responses are not indicators of the same sort of conservatism that is reflected in the responses observed in the current study.

It may be that people who have agreed to participate in surveys on a regular basis (the PANEL sample), who are recorded on a register by the market research company and who receive a reward for participating, may be more susceptible to socially desirable responses than those who have responded to a "cold call" on a telephone (the CATI sample). There are no data from this study to support this and it is a different conclusion to that reached by Lee et al. (2015) who concluded that, when the subject matter was gambling and its co-morbidities (alcohol, drug and tobacco use), online responses were less susceptible to social desirability because the online survey ensured greater anonymity. Further, Vesely and Klöckner (2020) found little evidence for social desirability to be a confounder of people's

survey responses regarding environmental actions, and, to the extent that animal welfare attitudes might align with attitudes toward environmental action, this might apply to the results reported here. However, this is a speculative argument and requires empirical investigation to determine its relevance or validity. If anonymity is the determining factor, then the results of Lee et al. (2015) are consistent with those found here, because in the current study it was the CATI survey that provided greater anonymity.

Differences between the two survey samples in response distributions is important if the prevalence of attitudes, knowledge and behavior is of interest. This is because it is the prevalence of these measures of the public and/or consumers that may inform responses by legislators, welfare groups and industry to people's attitudes. It would be worthwhile, therefore, to establish the reliability of the differences observed here by replicating the study and to establish, through the inclusion of some follow-up questions, whether perceived anonymity was the factor that led to the observed differences.

In addition to differences in distributions of responses, it is important to establish that the importance of the attitudes in relation to people's behavior is similar in the two samples. If one sample is more compliant, it may be that respondents' attitudes are less related to their actions than in a sample where responses are less susceptible to social desirability. In fact, where significant differences in correlations were found, the PANEL sample showed higher correlations with knowledge scores, but lower correlations with community and consumption behaviors when compared to the CATI sample. This is consistent with the hypothesis that where self-reported subjective matters are involved, the PANEL sample responds consistently with a social desirability bias. On the other hand, where attitudes are correlated with a self-reported objective behavior, the stronger correlations occur in the CATI sample which may be less susceptible to social desirability bias. There is a clear speculative element to this argument, and it needs to be tested in a study that identifies the factors discussed in the previous paragraph.

The differences in correlations between the composite variables and meat consumption were also reflected in the amount of variance in consumption that was predicted in the two samples. The PANEL sample showed consistently lower prediction of consumption than did the CATI sample. Not only were demographics similar for the two samples, so were beef and lamb consumption. The differences that occurred in predicting consumption between the two samples are not related to actual consumption. It is unclear why the two samples differed in the prediction of consumption; it is difficult to attribute it to overall differences in attitudes to the livestock industries.

Berrens et al. (2003) compared RDD telephone surveys with PIP surveys on the issue of global climate change and found that the internet sample produced relational inferences similar to that of the telephone sample despite many differences also existing. In their study it was unclear whether it was possible to identify characteristics of respondents from the internet sample. Also, it may be that attitudes to climate change are less susceptible to factors associated with the data collection method than animal welfare attitudes and associated behaviors. Berrens et al. (2003) suggest that, in addition to offering a viable means of data collection, PIP surveys also provide advantages over RDD telephone surveys in terms of response quality. Respondents' previous experience completing surveys is believed to be the reason for increased response quality among the internet sample when compared to the telephone sample. In contrast to the findings by Berrens et al. (2003), studies such as those by Flemming and Sonner (1999) and Taylor (2000) and the review by Couper (2000) report significant differences between RDD telephone and PIP survey samples regarding both background characteristics as well as other research variables, including attitude items, health indicators, and voting tendencies. Flemming and Sonner (1999) suggest that a lack of predictable patterns to the differences found between the survey approaches raises important questions about the viability of PIP surveys to replace RDD telephone surveys. Furthermore, Lee et al. (2015) and Couper (2000) suggest that while some of the differences lessen with propensity weighting, other differences between the samples remain unaffected by such weighting. It is clear that further investigation of the psychological variables that systematically differ between samples collected using different survey methodologies is needed.

Interestingly, despite the differences in prevalence of community behaviors, the composite scores predicted a similar proportion of the variance in such behavior in both samples in the current study. There was some commonality in the predictors of community behavior (e.g., Public engagement beliefs and Eats meat), but the other predictors differed between the samples, consistent with the differing patterns of correlations. This suggests that attitudes generally are strong predictors of community behavior even if the salient beliefs differ. This is consistent with the findings of Coleman et al. (2017) who found that attitude variables in a CATI sample of Australians accounted for 44% of the variance in community behavior. The implications of this for the current study are that there is a robust relationship between attitudes and community behavior, regardless of the sampling technique employed. However, care needs to be taken when interpreting such results in terms of which attitude is the most important driver.

In addition to social desirability, factors such as internet access may account for some of the differences found between RDD telephone and PIP survey samples. However, the differences may also relate to prosocial behavior, i.e., survey participation (taking time to complete a survey that does not directly benefit them). Like volunteering, participation in surveys is a form of prosocial behavior (Bekkers, 2012). Whilst the reason why a person might choose to participate in a PIP is likely to involve the financial compensation, it may also involve an element of volunteerism. If this is the case, volunteerism will be associated with any form of survey participant, however, this may be greater in PIPs because they have volunteered for ongoing survey participation. If volunteerism does involve a prosocial element, then it may be that they are more susceptible to social desirability, consistent with results indicating PANEL

respondents reporting less concern about the red meat industry and animal welfare in comparison to the respondents from the RDD telephone survey (CATI sample). Therefore, in this case a PIP survey may underestimate concern about red meat farming in Australia in the general population. Given the increased use of PIP surveys, the reasoning behind this type of ongoing online panel participation and its impact on survey results requires further investigation.

Furthermore, if research is aimed at assessing the prevalence of public attitudes toward animal welfare issues, a PIP survey may not be the most appropriate method. It is not clear why the PIP survey sample is more conservative with regard to animal use and animal welfare in the red meat industry when compared to the RDD telephone survey sample, and it may be useful to explore this further because of the implications for interpreting the results from other kinds of surveys.

CONCLUSION

We found differences between the two survey samples in both attitudes and behavior toward the red meat industry. The PANEL respondents generally gave more conservative responses than did the CATI respondents in that they were more positive toward the red meat industry and animal welfare within these industries. This was also reflected in behavior relating to the red meat industry, both community and consumer behavior. Thus, a PIP survey may underestimate concern about red meat farming in Australia in the general population. However, further research is required to identify the specific psychological factors that underpin the differences between samples derived from the different survey methodologies.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because: Our ethics approval specifies that "The survey results will only be reported for groups, so individual responses cannot be identified". Therefore, we cannot supply the raw data even if it has been anonymised without special approval from the ethics committee via an amendment. Requests to access the datasets should be directed to LH, lauren.hemsworth@unimelb.edu.au.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Human Ethics Advisory Group, The University of Melbourne Ethics ID: 1750676.3. Informed consent for participation was required for both the CATI (verbal consent given after PLS statement read) and the PANEL (after reading PLS statement participant completing the questionnaire was taken as inferred consent).

AUTHOR CONTRIBUTIONS

LH, MR, PH, and GC were responsible for conceptualization and design. Data analysis was performed by LH, MR, and GC. LH drafted the manuscript and it was reviewed and edited by all authors.

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REFERENCES

Ajzen, I. (1988). *Attitudes, Personality, and Behavior*. Chicago: McGraw-Hill Education.

Ansolabehere, S., and Schaffner, B. F. (2014). Does survey mode still matter? findings from a 2010 multi-mode comparison. *Polit. Anal.* 22, 285–303. doi: 10.1093/pan/mpt025

Australian Bureau of Statistics [ABS] (2016). *Australian Demographic Statistics, Dec 2019. Cat. no. 3101.0*. Canberra: ABS.

Bekkers, R. (2012). Trust and volunteering: selection or causation? evidence from a 4-year panel study. *Polit. Behav.* 34, 225–247. doi: 10.1007/s11109-011-9165-x

Berrens, R. P., Bohara, A. K., Jenkins-Smith, H., Silva, C., and Weimer, D. L. (2003). The advent of internet surveys for political research: a comparison of telephone and internet samples. *Polit. Anal.* 11, 1–22. doi: 10.1093/pan/11.1.1

Bir, C., Davis, M., Widmar, N., Zuelly, S., and Erasmus, M. (2019). Perceptions of animal welfare with a special focus on turkeys. *Front. Vet. Sci.* 6:413. doi: 10.3389/fvets.2019.00413

Chang, L., and Krosnick, J. A. (2009). National surveys via RDD telephone interviewing versus the Internet: comparing sample representativeness and response quality. *Public Opin. Quart.* 73, 641–678. doi: 10.1093/poq/nfp075

Cohen, J. (2016). "A power primer," in *Methodological Issues and Strategies in Clinical Research*, 4th Edn, ed. A. E. Kazdin (Washington, DC: American Psychological Association), 279–284. doi: 10.1037/14805-018

Coleman, G. (2018). Public animal welfare discussions and outlooks in Australia. *Anim. Front.* 8, 14–19. doi: 10.1093/af/vfx004

Coleman, G. J., Jongman, E., Greenfield, L., and Hemsworth, P. H. (2016). Farmer and public attitudes towards lamb finishing systems. *J. Appl. Anim. Welf. Sci.* 16, 198–209. doi: 10.1080/10888705.2015.1127766

Coleman, G. J., Rohlf, V., Toukhsati, S. R., and Blache, D. (2017). Public attitudes predict community behaviours relevant to the pork industry. *Anim. Prod. Sci.* 58, 416–423. doi: 10.1071/an16776

Coleman, G., and Toukhsati, S. (2006). *Consumer Attitudes and Behaviour Relevant to the Red Meat Industry*. North Sydney NSW: Meat and Livestock Australia Limited.

Connor, M., and Cowan, S. L. (2020). Consumer evaluation of farm animal mutilations. *Res. Vet. Sci.* 128, 35–42. doi: 10.1016/j.rvsc.2019.10.006

Couper, M. P. (2000). Web surveys: a review of issues and approaches. *Public Opin. Quart.* 64, 464–494. doi: 10.1086/318641

DeVellis, R. F. (2003). *Scale Development: Theory and Applications*. Los Angeles: Sage Publications.

Duncan, G. J. (2015). "Panel surveys: uses and applications," in *International Encyclopedia of the Social & Behavioral Sciences*, 2nd Edn, ed. J. Wright (Amsterdam: Elsevier), 462–467. doi: 10.1016/b978-0-08-097086-8.44040-7

Erens, B., Burkill, S., Couper, M. P., Conrad, F., Clifton, S., Tanton, C., et al. (2014). Nonprobability web surveys to measure sexual behaviors and attitudes in the general population: a comparison with a probability sample interview survey. *J. Med. Internet. Res.* 16:e276. doi: 10.2196/jmir.3382

Flemming, G., and Sonner, M. (1999). "Can internet polling work? strategies for conducting public opinion surveys online," in *Proceedings of the 5th Annual Conference Meeting of the American Association for Public Opinion Research*, (St. Petersburg Beach, FL).

Groves, R. M., and Kahn, R. L. (1979). *Surveys by Telephone; a National Comparison with Personal Interviews*. New York: Academic Press.

Holbrook, A., Krosnick, J. A., and Pfent, A. (2007). "The causes and consequences of response rates in surveys by the news media and government contractor survey research firms," in *Advances in Telephone Survey Methodology*, eds J. M. Lepkowski, C. Tucker, J. M. Brick, and E. D. de Leeuw (Hoboken, NJ: Wiley-Interscience), 499–458. doi: 10.1002/9780470173404.ch23

Jackson, A., Green, M., Millar, K., and Kaler, J. (2020). Is it just about grazing? UK citizens have diverse preferences for how dairy cows should be managed. *J. Dairy Sci.* 103, 3250–3263. doi: 10.3168/jds.2019-17111

Kennedy, C., McGeeney, K., Keeter, S., Patten, E. M., Perrin, A., Lee, A., et al. (2018). implications of moving public opinion surveys to a single-frame cell-phone random-digit-dial design. *Public Opin. Quart.* 82, 279–299. doi: 10.1093/poq/nfy016

Lavrakas, P. J. (1997). "Politicians, journalists, and the rhetoric of the 'crime prevention' public policy debate," in *Crime Prevention at a Crossroads*, ed. S. P. Lab (Cincinnati: Anderson Publishing Co).

Lee, C. K., Back, K. J., Williams, R. J., and Ahn, S. S. (2015). Comparison of telephone RDD and online panel survey modes on CPGI scores and co-morbidities. *Int. Gambl. Stud.* 15, 435–449. doi: 10.1080/14459795.2015.1068353

Lee, H., Kim, S., Couper, M. P., and Woo, Y. (2019). Experimental comparison of pc web, smartphone web, and telephone surveys in the new technology Era. *Soc. Sci. Comput. Rev.* 37, 234–247. doi: 10.1177/0894439318756867

Li, H., Berrens, R. P., Bohara, A. K., Jenkins-Smith, H. C., Silva, C. L., and Weimer, L. (2004). Telephone versus Internet samples for a national advisory referendum: are the underlying stated preferences the same? *Appl. Econ. Lett.* 11, 173–176. doi: 10.1080/1350485042000203805

Link, M. W., and Mokdad, A. H. (2005). Effects of survey mode on self-reports of adult alcohol consumption: a comparison of mail, web and telephone approaches. *J. Stud. Alcohol.* 66, 239–245. doi: 10.15288/jsa.2005.66.239

Malek, L., Umberger, W. J., and Rolfe, J. (2018). Segmentation of Australian meat consumers on the basis of attitudes regarding farm animal welfare and the environmental impact of meat production. *Anim. Prod. Sci.* 58, 424–434. doi: 10.1071/an17058

Nunnally, J. C., Bernstein, I. H., and Berge, J. M. T. (1967). *Psychometric Theory*, Vol. 226. New York: McGraw-Hill.

Pallant, J. (2013). *SPSS Survival Manual*. Berkshire: McGraw-Hill Education.

Schonlau, M., Zapert, K., Simon, L. P., Sanstad, K. H., Marcus, S. M., Adams, J., et al. (2004). A comparison between responses from a propensity-weighted web survey and an identical RDD survey. *Soc. Sci. Comp. Rev.* 22, 128–138. doi: 10.1177/0894439303256551

Tabachnick, B. G., and Fidell, L. S. (2012). "Chapter 13: principal components and factor analysis," in *Using Multivariate Statistics*, (London: Pearson), 660–730.

Taylor, H. (2000). Does internet research work? *Int. J. Mark. Res.* 42, 1–11. doi: 10.1177/147078530004200104

Vesely, S., and Klöckner, C. A. (2020). Social desirability in environmental psychology research: three meta-analyses. *Front. Psychol.* 11:1395. doi: 10.3389/fpsyg.2020.01395

Worsley, A., Wang, W., and Ridley, S. (2015). Australian adults' knowledge of Australian agriculture. *Brit. Food J.* 117, 400–411. doi: 10.1108/bfj-07-2013-0175

Yeager, D. S., Krosnick, J. A., Chang, L., Javitz, H. S., Levendusky, M. S., Simpser, A., et al. (2011). Comparing the accuracy of RDD telephone surveys and internet surveys conducted with probability and non-probability samples. *Public Opin. Quart.* 75, 709–747. doi: 10.1093/poq/nfr020

Yu, J., and Cooper, H. (1983). A quantitative review of research design effects on response rates to questionnaires. *J. Mark. Res.* 20, 36–44. doi: 10.2307/3151410

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UN Food Systems Summit 2021: Dismantling Democracy and Resetting Corporate Control of Food Systems

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This article analyzes the development and organization of the United Nations Food Systems Summit (UNFSS), which is being convened by UN Secretary General António Guterres in late 2021. Although few people will dispute that global food systems need transformation, it has become clear that the Summit is instead an effort by a powerful alliance of multinational corporations, philanthropies, and export-oriented countries to subvert multilateral institutions of food governance and capture the global narrative of "food systems transformation." This article places the upcoming Summit in the context of previous world food summits and analyzes concerns that have been voiced by many within civil society. It elaborates how the current structure and forms of participant recruitment and public engagement lack basic transparency and accountability, fail to address significant conflicts of interest, and ignore human rights. As the COVID-19 pandemic illuminates the structural vulnerabilities of the neoliberal model of food systems and the consequences of climate change for food production, a high-level commitment to equitable and sustainable food systems is needed now more than ever. However, the authors suggest that the UNFSS instead seems to follow a trajectory in which efforts to govern global food systems in the public interest has been subverted to maintain colonial and corporate forms of control.

Keywords: United Nations food systems summit, food systems, global governance, right to food, multi-stakeholder partnerships, Committee on World Food Security, multilateralism, corporate control

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INTRODUCTION

On World Food Day in 2019, UN Secretary-General António Guterres announced to the Plenary of the UN Committee on World Food Security (CFS) that he was organizing a high-level UN Food Systems Summit (UNFSS) as part of the Decade of Action to deliver the Sustainable Development Goals. The announcement took many in the room by surprise. Although the CFS is the primary international and intergovernmental platform for food security and nutrition policy, the call for the Summit neither emerged from the CFS, nor even the UN Food and Agriculture Organization (FAO). It was unclear who would organize the Summit, where it would be held, or where the call for the Summit had originated. However, the Secretary-General did provide a few clues to identify the key partners of the Summit—the Rome-Based Agencies of the UN and the World Economic Forum (WEF). Just a few months earlier, Amina Mohammed (Deputy Secretary-General of the United Nations and Chair of the United Nations Sustainable Development Group)

had signed a strategic partnership with the WEF. In its efforts to promote the interests of the world's largest corporations, the WEF has pursued a "Great Reset" intended to allay opposition to neoliberal globalization through a new vision of "stakeholder capitalism" and multistakeholder global governance (Schwab, 2021). In the ensuing months, once Guterres appointed a Special Envoy and the structure of the Summit was announced, the drivers behind the Summit became clear. As the world is increasingly cognizant of social and environmental problems caused by the industrial food system, the UNFSS has emerged as an elaborate process to undermine more democratic arenas of global food governance, while reinforcing corporate control over food systems.

Few people will dispute that global food systems need transformation. *The Lancet* Commission on the Double Burden of Malnutrition describes the current state of food and agricultural systems as a "triple crisis" in which obesity, undernutrition, and climate change are decimating human and planetary health (Swinburn et al., 2019). Despite global commitments to end hunger by 2030 in Sustainable Development Goal 2, the number of people who are food-insecure has risen since 2014. According to the most recent *State of Food Security and Nutrition in the World* report, 746 million people were suffering from severe food insecurity in 2019 and an additional 1.25 billion people experienced moderate food insecurity (FAO et al., 2020). The COVID-19 pandemic has further exacerbated hunger and is anticipated to add between 83 and 132 million more people to the number in chronic undernourishment[1]. Malnutrition, including both micronutrient deficiencies or so-called "hidden hunger" as well as overweight and obesity now plague ∼3.4 billion people worldwide (HLPE, 2020). As a result, the FAO now identifies non-communicable diseases from poor diets as the number one cause of premature death globally (FAO et al., 2020).

Dominant food and agricultural systems pose just as great a threat to the planet as they do to humans. The industrial food system is one of the largest contributors to climate change. The IPCC 2019 report on Climate Change and Land estimated that up to 37% of greenhouse gas emissions come from food systems in total. A recent article claimed that meeting the Paris Climate Agreement's goal of remaining between 1.5 and 2°C of warming will not be possible without reducing emissions from global food production and consumption (Clark et al., 2020). Global food and agricultural production are also the number one cause of deforestation, decreasing biodiversity, and loss of topsoil. Cataclysmic loss of biodiversity documented in the Intergovernmental Platform on Biodiversity and Ecosystem Services will further affect human health through declines of critical ecosystem services ranging from pollination of crops to avoidance of pandemics arising from spillover of wildlife diseases into human populations.

The triple crisis we face today is not spontaneous but rather the consequence of a long struggle over the governance of global food systems. While colonialism laid the foundation for globalization of food systems (Friedmann and McMichael, 1989) since formation of the United Nations Food and Agriculture Organization (FAO), a shifting ensemble of individuals, states, and social movements have sought to build institutions with public regulatory capacity to promote global food security, self-sufficiency, and the human right to food. However, this vision of what we call "public global food governance"—that is, a system of multilateral coordination and regulation premised on democratic deliberation—has been routinely undermined by powerful actors that have instead promoted international finance institutions, global regulatory fragmentation, and public-private partnerships that push industrial agriculture, productivism and trade liberalization at the expense of global food security and the livelihoods of small-scale producers and rural workers. It is this set of industrialized agricultural practices—with their high levels of synthetic inputs and proprietary technologies—that have been most responsible for the triple crisis that we are now experiencing. Nevertheless, in a moment when the global pandemic is exacerbating food insecurity and malnutrition, and as global social movements demand public global food governance that promotes the public good over private profit, powerful states in partnership with those multinational corporations aligned with the WEF are seeking to thwart emerging institutions of democratic public global food governance. This is an undertaking that centers on the UN Food Systems Summit.

This article examines the development and organization of the UNFSS and elaborates concerns that many civil society organizations have raised about the UNFSS[2]. We describe the context in which the Summit was announced, how it has been rolled out, which actors it has empowered, with what resources, and with what objectives. Although the Summit's promoters use the language of food systems, transformation, and inclusivity (even calling it a "People's Summit"), it has become clear that the Summit is instead an effort by a powerful alliance of multinational corporations, philanthropies, and export-oriented countries to subvert the growing power of the Committee on World Food Security—an arena that since the 2007–08 global food crisis has emerged as the primary institution of public global food governance—as well as to capture the narrative of "food systems transformation." We illustrate how promoters of the Summit have put forth a narrow concept of food systems that privileges global value chains over local control and human rights. Although multiple parallel food systems coexist at present (Anderson, 2015; Anderson and Rivera-Ferre, 2021), promoters

[1]Available online at: http://www.fao.org/3/ca9692en/online/ca9692en.html#chapter-executive_summary (accessed January 29, 2020).

[2]We use the term "civil society" throughout this article to refer to the agrarian producer and worker movements and progressive NGOs comprising the Civil Society and Indigenous Peoples Mechanism (CSM) in the CFS. The UNFSS Liaison Group of the CSM has elaborated a clear critique of the UNFSS through an open call to respond to the UNFSS, as well as a letter to the Chair of the CFS in February 2021. However, civil society is heterogeneous and many newer organizations with different agendas, such as the International Land Coalition and Scaling Up Nutrition Movement, are participating in the Food Systems Summit. See: http://www.csm4cfs.org/14024/ (accessed March 5, 2020). La Vía Campesina, the International Peasant Movement, also published a separate critique of the UNFSS: https://viacampesina.org/en/wp-content/uploads/sites/2/2020/12/LVC-Position_EN_UN-Food-Summit_2020_LowRes3.pdf (accessed March 5, 2020). We have drawn on these critiques in our analysis of the UNFSS.

have chosen to focus primarily on those "levers of change" from which multinational corporations can profit, rather than the indigenous and agroecological food systems that have never contributed to today's environmental problems and even help to restore degraded ecosystems.

In analyzing the threat posed by the UNFSS to democratic, public global food governance, the article proceeds as follows. First, we place the upcoming Summit in the context of previous world food summits to show how it departs from precedents and reinforces a constant thread of suppression of civil society and non-exporting countries in the Global South. Next, we explain how the formation, current structure, forms of participant recruitment, and public engagement of the UNFSS lack basic transparency and accountability and fail to address human rights or significant conflicts of interest of the organizers. Finally, we conclude with specific challenges to the UNFSS and Member States of the UN, and our warning that failure to change current ways of operating risks a momentous failure to move toward equitable and sustainable food systems that provide food security and nutrition for all.

GLOBAL FOOD SUMMITS AND THE ARCHITECTURE OF GLOBAL FOOD GOVERNANCE

Since the formation of the United Nations, multilateral international institutions have served as the primary fora responding to successive global food crises. The UNFSS is unique insofar as it departs from the interactive multilateral vision and institutional arenas of global food governance that were established during previous world food summits, up to and including the 2008 Rome Conference. Governments at prior Rome summits wrestled with responding to periodic hunger or food price crises with proposals attuned to resolving uneven regional and national capacities to address food rights and security measures. Past initiatives constructed and reconstructed the multilateral architecture of food governance, often in favor of powerful agro-exporting states, through shifting emphases on aid, trade and/or investment interventions. By contrast, the UNFSS's distinguishing feature is its venue in New York, with a WEF-designed multistakeholder framework. As we note below, this reflects the consolidation of a public-private partnership model, initiated in 2000 with the UN Global Compact encouraging corporations to adopt sustainable and social goals in their programming, as "public goods." Increased partnering of "public" with "private" interests over time has shifted the balance of power to the private sector. The UNFSS exemplifies this shift. By privileging private initiative under WEF auspices, it is overturning the principle of multilateralism to enable corporate capture of food system governance. The WEF intervention, invited by the UN, resembles a "shock doctrine"[3] response to deepening food and environmental insecurities, that have strengthened civil society resistances inside and outside the FAO. This section traces how this intervention and narrative have replaced the principle of UN multilateral governance, with the WEF claiming corporations as "trustees of society"[4].

Early Global Food Governance Tensions: Establishing the FAO

The initial vision of global food governance was embodied in the formation of the FAO and its commitment to public leadership. In the mid-1940's, facing serious food shortages following the collapse of international trade and world war, the FAO's mandate was to stabilize and manage food security on a world scale, with food to be "treated as an essential of life rather than primarily as merchandise" (quoted in Phillips and Ilcan, 2003, p. 441). In this sense, the emerging post-colonial era embodied a public vision of global governance supporting the right to food, embodied in the UN's Universal Declaration of Human Rights (1948). This was promoted by FAO Director-General B.R. Sen's Freedom From Hunger Campaign in the World Food Congress of 1963, and legally grounded in Article 11 of the International Covenant on Economic, Social and Cultural Rights (ICESCR) in 1966. A central tension in the FAO as to whether hunger was "best addressed as an item on an economic development agenda that emphasized the improvement of living conditions" was resolved by Sen's insistence that food was indeed a development issue, for FAO orchestration (Fakhri, 2019, p. 8–9).

The public vision, however, was at odds with US reconstruction of world order, which privileged agro-technologies as the catalyst of agricultural modernization in Europe *via* the Marshall Plan, and in the non-Western world. Accordingly, the US overrode the proposal by the FAO and the UN Relief and Rehabilitation Administration (UNRRA) to establish a World Food Board, preferring to develop its own network of bilateral food aid programs. Meanwhile, dispersal of Green Revolution technology across Third World states from the 1960's undermined the FAO's role in agricultural research (ETC Group, 2009, p. 4), and served as a counterpoint to food aid programming.

Fragmenting Food Governance: The 1974 Conference and Formation of the CFS

Agricultural commodity prices remained relatively stable until the early 1970's, in part due to US food aid (Tubiana, 1989). US détente with the Soviet Union in 1972–73, however, emptied surplus grain stocks for the first time in the post-war period, tripling grain and oilseed prices and contributing to a global food crisis. Famine stalked Bangladesh, India, Ethiopia, and the Sahel region. In response, the Non-Aligned Countries called for an emergency joint conference between the UN Conference on Trade and Development (UNCTAD) and the FAO.

The World Food Conference of 1974 in Rome was an intergovernmental conference, with social movements and NGOs attending a parallel conference (Shaw, 2007). At the Conference, the UN linked food production and distribution to

[3]This refers to free-market forces using their power in crisis periods to preempt progressive change: https://www.vice.com/en_us/article/5dmqyk/naomi-klein-interview-on-coronavirus-and-disaster-capitalism-shock-doctrine (accessed March 5, 2021).

[4]Available online at: https://www.weforum.org/agenda/2019/12/why-we-need-the-davos-manifesto-for-better-kind-of-capitalism/ (accessed March 5, 2021).

an explicitly "humanitarian" goal of food aid *via* grants. FAO Director-General Addeke Boerma claimed: "Food is not like any other commodity. If human beings have a right to life at all, they have a right to food" (quoted in Jarosz, 2009, p. 50). This claim institutionalized the FAO's original public vision of food security as a human right (Fakhri, 2019, p. 15). Meanwhile US aid programming encouraged recipient countries to adopt Green Revolution technologies to increase domestic food production in lieu of aid (Clapp and Moseley, 2020, p. 3).

The Conference was held under the auspices of the United Nations, rather than the FAO, whose mandates were politically contested. The FAO was viewed by OECD states as incapable of managing the crisis, given geo-political tensions associated with food and oil crises, and contention around Third World demands for a New International Economic Order (NIEO).

Boerma's successor, Director-General Edouard Saouma pledged to decentralize and reform the FAO. The UN Committee on World Food Security (CFS) formed in this vortex, as an intergovernmental body to promote policy convergence to develop a global strategic framework for food security and nutrition. Meanwhile, the FAO was weakened by the creation of an alternative funding agency, the International Fund for Agricultural Development (IFAD), delinking of the World Food Program (WFP) from the FAO, and relocation of agricultural research to the Consultative Group on International Agricultural Research (CGIAR) in the World Bank. During this period, the US sought once again to undermine public food governance through the fragmentation of the FAO's authority and establishment of an alternative governing body, the ineffective World Food Council, which folded in 1993 (ETC Group, 2009, p. 4).

Neoliberal Transformations: Free Trade Agreements and the 1996 Summit

The original FAO vision of public global food governance was further weakened by 1986, with the World Bank redefining food security as "the ability to purchase food" (Jarosz, 2009, p. 51). In the same year the Uruguay Round began, the US Secretary of Agriculture challenged the GATT's Article XI food security provisions (1947) alluding to agribusinesses "comparative advantage." In 1989, the USDA further reinforced this position, noting, "The U.S. has always maintained that self-sufficiency and food security are not one and the same. Food security—the ability to acquire the food you need when you need it—is best provided through a smooth-functioning world market" (quoted in Ritchie, 1993, fn. 35).

The Uruguay Round, managed by corporate lawyers and multinational agribusinesses, offered market openings to products from the Global South and the free-trader Cairns Group. In this context, 123 states signed on to the WTO in 1994 and its institutionalization in 1995 of a "free trade" regime deemed necessary for global "food security" *via* its Agreement on Agriculture protocol. This vision of a world food market informed the 1996 UN World Food Summit, organized by the FAO's new Director-General, Jacques Diouf. Here, 185 states committed to reduce world hunger by half by 2015 with the Rome Declaration on World Food Security and a Plan of Action.

However, the Plan of Action was unable to reconcile the various institutional food-system-related initiatives inherited from decentralization of FAO governance in the mid-1970's with the market-oriented vision of food security prioritizing global trade, as instituted *via* the WTO. The trade regime deepened an agrarian crisis in the global South among small-scale farmers, who had lost price supports and food subsidies *via* Structural Adjustment loan conditions. Meanwhile large-scale grain farmers in the US and Europe retained huge subsidies, enabling cheap food dumping in Southern markets (McMichael, 2013a). In addition, WTO liberalization measures promoted export agriculture globally, at the expense of local food crop producers—as underscored in the CFS 1998 report, where Southern states observed that the trade regime was compromising their food security (Jarosz, 2009, p. 53). In the second half of the 1990's up to 30 million peasants were dispossessed, according to a conservative report by the FAO (Madeley, 2000, p. 75).

The Food Sovereignty Countermovement: Agrarian Crisis and CFS Reform

At a parallel summit to the World Food Summit in Rome in 1996, international NGOs together with newly formed transnational social movements denounced "food dumping" and called for "food sovereignty," a concept first developed by La Vía Campesina (LVC), the international peasant coalition. Through the claim of food sovereignty, LVC articulated a vision of democratic, territorially controlled food systems not subject to market-control of the global North and its transnational food corporations.

In 2000, La Vía Campesina joined 51 other civil society organizations to form the International Planning Committee for Food Sovereignty (IPC), a platform dedicated to strengthening social movements' voices, and encouraged the FAO to convene a multilateral forum to address issues of food security. This vision came to pass following the "food crisis" of 2007–08 and a series of cascading food riots in 30 countries, from Haiti to Italy (Patel and McMichael, 2009). At the time, northern government mandates promoting biofuels as a "green" fuel were displacing food crops across the world, attracting "land grab" financial ventures and deepening food insecurity (Houtart, 2010). Such a serious legitimacy crisis for the UN spurred Secretary-General Ban Ki-moon to establish a High-Level Task Force on the Global Food Crisis including the FAO, the World Bank and the World Trade Organization. This particular composition reflected the coalescing of a market-based vision of food governance shared among these three international institutions, holding the line against the food sovereignty movement.

"Food crisis" agitation also prompted reform of the CFS in 2009. While the Committee on World Food Security (CFS) was originally established as a technical intergovernmental body of the FAO, in the crisis context the CFS was reformed to enhance its capacity to govern global food security. In seeking to create greater inclusivity and evidence-based decision-making, Member States established the Civil Society and Indigenous Peoples' Mechanism (CSM) and a Private Sector Mechanism (PSM), both self-organized. The CSM privileges agrarian social movements

and small-scale producers by design, not only because they are so important in nourishing their communities, but also because they bear the burden of hunger and malnutrition. Seventy percent of those who suffer from the most acute forms of hunger are small-scale producers and rural workers (UNCTAD, 2013). Moreover, recent years have seen increasingly criminalization of and violence against social movements fighting for land and water (Hoddy, 2021). While Member States remain the primary voting members of the CFS, the CSM and PSM were invited to participate in setting the agenda and negotiating policy recommendations within the CFS (Duncan, 2015; McKeon, 2015). The 2009 reform of CFS also established a High-Level Panel of Experts as a science-policy interface to provide scientific evidence on issues affecting food security and nutrition, as mandated by the Member States (Gitz and Meybeck, 2011). As a result of the reform, the CFS has asserted itself and its governing model as the "foremost inclusive international and intergovernmental platform for all stakeholders to work together to ensure food security and nutrition for all"[5]. In the years since the reform, the CFS has developed several significant policy instruments including the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (VGGT) and a wide variety of policy recommendations on food security, from the role of biofuels to connecting smallholders to markets. It has also set up monitoring mechanisms for these policy instruments to hold Member States accountable to rights-holders.

Public Food Governance Endangered: The 2008 FAO Conference

Given its mandate rooted in the human right to food, its one-country-one-vote system of governance, and its inclusion of those most affected by food and nutrition security, the CFS is a legitimate arena of public global food governance. However, the CFS faces competing spaces, institutions, and models of governance that have mushroomed in the post-food crisis period.

In June 2008, the FAO High Level Conference on World Food Security confirmed and intensified the WTO's market-based governance of food and nutrition security. The African continent became a key target for neoliberal experimentation. FAO Director-General Jacques Diouf advocated bringing "African agriculture into line with changing conditions worldwide" to prevent "its agricultural trade deficit to deteriorate any further" in the event that food surplus nations reduced exports, further inflating food prices (Diouf and Severino, 2008, p. 16). As the food crisis unfolded, World Bank President Robert Zoellick announced a 50% increase in financial support for global agriculture, amounting to $6 billion, in addition to providing "seeds and fertilizer for the planting season, especially for smallholders in poor countries" (GRAIN, 2008). This reflected the Bank's new agenda, where agriculture would be reorganized by the private sector *via* value-chains to "bring the market to smallholders and commercial farms" (World Bank, 2007, p. 8).

The International Planning Committee for Food Sovereignty, in its *Terra Preta* parallel meeting, responded by resisting this attack on public global food governance.

> The serious and urgent food and climate crises are being used by political and economic elites as opportunities to entrench corporate control of world agriculture and the ecological commons. At a time when chronic hunger, dispossession of food providers and workers, commodity and land speculation, and global warming are on the rise, governments, multilateral agencies and financial institutions are offering proposals that will only deepen these crises through more dangerous versions of policies that originally triggered the current situation[6].

That is, the proposed solution to these crises was not to restore the health and viability of small-scale farming systems across the world with public subsidies and institutional supports. Rather, the Conference's decision to promote corporate value-chain farming in Africa reinforced the World Bank's role as the premier development institution, brokering financial investment and defining the food crisis as a productivity issue, requiring large-scale agricultural investments and/or incorporation of farmers into supply chains. While value-chains have been promoted by the World Bank to improve smallholder productivity, they ultimately serve to embed many farmers in relations of dependency on agro-inputs, and expands food exports at the expense of local food security (McMichael, 2013b).

A number of different value-chain driven initiatives were established subsequently, promoting public-private partnerships and multistakeholder initiatives as the primary form of governance. Among these, the Alliance for a Green Revolution in Africa (AGRA) has had the highest profile. Founded by the Rockefeller and Gates Foundations in 2006, AGRA has leveraged private and public funding to promote an array of public-private partnerships (PPP). AGRA set up an infrastructure of 10,000 agro-dealers folding small-scale farmers into value-chains comprising agro-inputs (seeds, fertilizer, and pesticides) and contracts for delivery of produce to corporate processors and retailers. Partnering with the Millennium Challenge Corporation (MCC), it provided "technologies, infrastructure and financing" to Africa's farmers, unrepresented in a governance structure dominated by large investors and biotechnology representatives (ActionAid, 2009). So, while the 2008 food crisis and UN summit triggered internal reform leading to the introduction of civil society into the CFS, governing powers expanded an industrial farming model to serve global markets at the expense of small-scale farming systems and farmers' rights to produce food primarily for territorial and local markets. La Vía Campesina aptly called this model "agriculture without farmers," given its goal of replacing local farming knowledges and territorial markets with proprietary technologies and global value chains. AGRA, as elaborated below, served as a model for the UN's capitulation to the WEF.

[5] Available online at: http://www.fao.org/cfs (accessed January 26, 2020).

[6] Available online at: https://viacampesina.org/en/civil-society-declaration-of-the-terra-preta-forum/ (accessed January 29, 2020).

Contention With Market-Based Food Governance

Growing global concern about the contributions of industrial agriculture on to climate change and the consequences of climate change for food production led to further struggles between institutions to capture the narrative of sustainability. In 2002, the World Bank initiated the International Agricultural Assessment of Agricultural Knowledge, Science and Technology (IAASTD). In 2009, the IAASTD culminated in internationally negotiated summaries and publications, concluding that "business as usual is not an option." The reports demonstrated that the failure of markets to adequately value environmental and social harm and provide incentives for sustainability necessitated deep changes to achieve more sustainable outcomes. Private sector participants walked away from the IAASTD when it became clear that they could not dictate the narratives about benefits of pesticides and genetically modified organisms; and a few powerful governments (the US, UK, and Australia) attempted to bury the reports by filing objections at the final plenary. For its part, the World Bank published the *World Development Report* (WDR) at the same time as the IAASTD[7]. Their messages could hardly have been more different. Whereas, the WDR recommended economic integration and continued emphasis on agro-industrial economic growth in certain areas with comparative advantage, the IAASTD pointed toward food sovereignty and illuminated structural disadvantages that impeded economic integration. In the years since, the IAASTD has proven increasingly influential and its conclusions have been supported by numerous subsequent reports[8]. After years of propounding the narrative of the necessity of proprietary technologies to feed the world, it has become clear that the industrial food system has not only left communities more vulnerable to climate change as a result of decreased biodiversity and degraded soil health, but also that it is primarily small-scale producers who feed their communities (International Panel of Experts on Sustainable Food Systems, 2017)[9].

Multinational corporations, agro-exporting states, and the Gates Foundation have therefore sought to recapture control of governance through the framework of "climate-smart agriculture" (CSA). First articulated by the FAO in 2009, CSA has been conceptualized as an approach to agricultural development and governance within a "market liberal frame" that emphasizes "pricing, market-making, technology and protecting private property rights in order to meet the twin challenges of climate change and food insecurity" (Newell and Taylor, 2018, p. 113). In turn, opposition to this agenda by La Vía Campesina and the CSM have also led the FAO and CFS to increasingly recognize the concept of agroecology. In 2014 and 2018, the FAO organized two International Symposia on agroecology. In the CFS, the High-Level Panel of Experts published a report on *Agroecological and Other Innovations For Sustainable Food Systems* (2019), promoting agroecology as a transformational pathway for sustainable food systems. This interest in agroecology stems not only from advocacy by civil society, but also the widening global consensus of the failures of the industrial food system.

This institutional support for agroecology, however limited, has spurred backlash from states and multinational corporations that continue to promote agro-industrial production practices. Donald Trump's Ambassador to the Rome-Based Agencies of the United Nations, Kip Tom, attacked the institutions that have supported agroecology in early 2020, lambasting the FAO for deviating from the narrative of the Green Revolution and claiming that agroecology is ideological and unscientific[10]. CropLife International—the global trade organization that represents the interests of the largest global agro-chemical corporations including the "big four" corporations that control over 60% of global commercial seed sales (Mooney, 2018)—has sought to reinterpret agroecology as simply one technique, or "one tool in the agricultural toolbox" (Giraldo and Rosset, 2018). Employing a myriad of strategies, the governing powers of food and agriculture have again sought to undermine the public vision of food once promoted by the FAO.

THE FORMATION AND STRUCTURE OF THE UN FOOD SYSTEMS SUMMIT

UN Secretary-General António Guterres's announcement of the UN Food System Summit may be easier to interpret in light of the history of past world food summits and the struggles described above, in which powerful states have continuously undermined the public vision of global food governance to maintain control. Guterres described the aim of the summit as "maximizing the co-benefits of a food systems approach across the entire 2030 Agenda and meet[ing] the challenges of climate change"[11]. Announced before the COVID-19 pandemic, the Summit was planned to take place in 2021. While it is not yet clear what form the Summit will now take, the Summit is currently in its preparatory stages of information gathering.

Initially, participants of the CSM initially welcomed the announcement of the Summit, which promised to elevate the political significance of food systems; but they were cautious about who was organizing the Summit and why. The IPC, La Vía Campesina, and NGOs have sought to protect and promote the CFS, given its inclusive and evidence-based approach to food security their influence in the CFS has grown. They worry that the Summit is aimed at undermining the authority of the CFS, motivated by WEF's effort to capture the narrative of food system transformation, as the HLPE report on agroecology had given

[7]Available online at: https://openknowledge.worldbank.org/handle/10986/5991 (accessed January 17, 2021).

[8]Available online at: https://www.globalagriculture.org/transformation-of-our-food-systems.html (accessed January 29, 2020).

[9]"80% of the world's food reaches those who consume it not through formal value chains and retail networks, but through territorially-rooted markets" (McKeon, 2018, p. 2).

[10]Agricultural Outlook Speech 6 February 2020. See also, https://www.realclearworld.com/articles/2020/08/05/the_un_should_learn_that_ideology_wont_stop_a_plague_of_locusts_501134.html (accessed January 29, 2020).

[11]Available online at: https://www.un.org/sg/en/content/sg/personnel-appointments/2019-12-16/ms-agnes-kalibata-of-rwanda-special-envoy-for-2021-food-systems-summit (accessed January 29, 2020).

such a positive prognosis of agroecology as key to transformation (HLPE, 2019).

The designation of the Summit as a *food systems* summit is significant. The concept of food systems was developed as a holistic, systems-based approach to account for all the ecological and social activities through which food is produced, distributed, and consumed (Kneen, 1989; Ericksen et al., 2010). Members of the CSM promote the concept of food systems to emphasize the multifunctional role of agriculture and its environmental and social impacts. As the language of "sustainable food systems" has grown more widespread, however, it has been watered down. Components of food systems are often bracketed by different actors in pursuit of their interests and the concept of sustainability is mobilized vaguely and inconsistently (Foran et al., 2014; Béné et al., 2019). As Oliver De Schutter and Olivia Yambi wrote with regard to the UNFSS, the focus on food systems is welcome; but "talking about food systems is not enough. *How* we talk about them and *with whom* is what matters most"[12].

In analyzing the formation and structure of the Summit, we identify three dimensions of the Summit's current processes that raise significant concerns about the UNFSS's fidelity to its own commitments to transparency, accountability, and human rights. These are: its structure and recruitment of leaders and participants, its multistakeholder approach to inclusivity and normative basis, and its failure to address conflicts of interest and corporate influence.

Structure of the Summit and Recruitment of Participants

The initial step in planning the Summit, the appointment of a Special Envoy to lead the Summit, offered the first indication of how the Summit would proceed. Without consulting the CFS or civil society, Guterres appointed Dr. Agnes Kalibata, the President of the Alliance for a Green Revolution in Africa (AGRA) as Special Envoy, allowing opportunities to repackage and promote the narrative of the Green Revolution. While the original Green Revolution is now understood to have fostered rural inequality, environmental degradation, farmer sickness and suicide, the "new" Green Revolution claims greater concern with small-scale food producers and sustainability (Holt-Giménez and Altieri, 2013; Patel, 2013). With support from agribusiness corporations, the WEF, global philanthropies, and development agencies of several governments in the Global North, AGRA has emerged at the front line of efforts to impose the agro-industrial model onto postcolonial rural populations that have resisted incorporation into global markets. Despite two different letters with support from over 500 organizations demanding a termination of the UN/WEF agreement and the appointment of the President of AGRA as Special Envoy[13], the UN Secretary-General failed to respond. The letter of March 2020 explained that civil society concerns were rooted in the expansion of corporate influence on food systems and AGRA's approach to agricultural investment. This roll-out of the Summit seemed to capitulate to the United States' critiques of FAO for promoting agroecology.

The Summit launch and its subsequent development have been non-transparent and chaotic, even according to its supporters. This has been apparent in the selection and recruitment of participants and leaders of different components of the Summit and its confusing structure, with a proliferating expansion of tracks, sub-tracks and committees. The degree of confusion generated by the well-seasoned bureaucrats who seem to be in charge has led some people to speculate that the convoluted structure of the Summit is intentional to allow takeover by corporate participants, or at least frustrate social movements' attempts to stop this.

What was perhaps most surprising about the Summit is its elaborate structure, which replicates already existing bodies in the CFS and reconstitutes them as experts and advisors hand-picked by the Special Envoy. The UNFSS is composed of several political and scientific advisory bodies, or "support structures," which include an Advisory Committee, Scientific Group, UN Task Force and an "Integrative Team" (the existence and composition of which does not appear on the website). In addition to these councils, there is a "Champions Network," divided into "Food Systems Heroes" and "Food System Champions." While anyone can apply to be a Hero, the Champions include "network and institutional leaders from across the food system who commit to mobilizing their networks, sharing information, and taking action to support the Summit"[14].

The substance of the UNFSS was split into five Action Tracks according to a July 27 press release[15] (although the website link leads to an unrelated announcement about the Youth Advisory Group on Climate Change). The Action Tracks are:

(1) Ensure access to safe and nutritious food;
(2) Shift to sustainable consumption patterns;
(3) Boost nature-positive production;
(4) Advance equitable livelihoods; and
(5) Build resilience to vulnerabilities, shocks and stress[16].

Nearly 2 months after announcing the Tracks, the Special Envoy appointed leaders for each one. Each Action Track is led by a Chair, one or two Vice Chairs, and an anchoring UN agency. On top of this structure, Action Tracks have three levels of leadership: a "core team," a "leadership team," and open platforms[17]. Each Action Track is charged with carrying out multistakeholder dialogues and from these to "develop exemplary game-changing

[12] Available online at: https://foodtank.com/news/2020/03/2021-food-systems-summit-started-on-wrong-foot-it-could-still-be-transformational/ (accessed March 5, 2021).

[13] Available online at: http://www.csm4cfs.org/wp-content/uploads/2020/03/EN_CSO-Letter-to-UNSG-on-UN-food-systems-summit.pdf (accessed March 5, 2021).

[14] Available online at: https://www.un.org/en/food-systems-summit/champions-network (accessed January 29, 2021).

[15] Available online at: https://www.un.org/en/food-systems-summit/pressroom (accessed January 29, 2021).

[16] Available online at: https://www.un.org/en/food-systems-summit/action-tracks (accessed January 17, 2021).

[17] Available online at: https://www.un.org/sustainabledevelopment/blog/2020/09/leading-experts-chosen-to-drive-five-priority-areas-for-un-food-systems-summit/ (accessed February 28, 2021).

and systemic solutions" and a review of their key reflections[18]. Starter Discussion Papers were prepared for each Action Track and posted on the Summit's website (sometimes with a revision). Each Action Track also contains a public forum on the Summit's website with announcements of upcoming events, but the leadership within each track other than the Chair, Vice-Chair(s), and supporting UN agency is not publicly available.

How leaders were recruited and how the Action Tracks were developed has raised several concerns. Decision-making processes are quite non-transparent in the UNFSS and crucial information is not publicly available. For example, how "experts" in the Scientific Group were selected is not clear, in sharp contrast to the public invitations and protocols set up for the High-Level Panel of Experts (HLPE) of the CFS. There is almost no overlap with the membership of the HLPE. Some key expertise seems to be missing from the Scientific Group, such as agroecology and global food governance. Perhaps because of this lack of expertise, there are discontinuities with previous interpretations of key concepts. For example, the Scientific Group published a background paper on the concept of food systems, which brackets health, ecological, and energy systems as "neighboring systems" (Braun et al., 2020). This represents a clear divergence from agroecological frameworks, which include all of these components as part of the food system. The definition of food systems for the UNFSS reinforces a problem created by the confusing layers of Action Tracks, Dialogues, Public Forums, and options for participation. Additionally, the budget for the Summit has not been made public. As of August 2020, the Summit was estimated to cost over $20 million. It is neither public where funding is coming from nor how money is being spent. Without this basic transparency, it is unclear how donations are being leveraged to influence the Summit.

Invitations have been extended to individuals and organizations to participate as "leaders" in various ways, but often the invitations have purposefully by-passed established ways that civil society and other institutions self-organize. For example, an initial invitation to lead the Action Track on "nature-positive solutions" was made to a member of the International Panel of Experts on Sustainable Food Systems (IPES-Food), without any terms of reference yet demanding a response within just a few hours. The person who was invited responded that she would need time to consult with the Panel and its Secretariat, and eventually decided that she couldn't accept the invitation. But why weren't the co-Coordinators of IPES-Food consulted originally and why were the organizers making an invitation without clarifying what work was involved or why that person's participation was vital? (One of the co-Coordinators has agreed subsequently to co-lead a sub-topic of this Action Track.) Although the CSM has chosen not to participate in the Summit, many civil society organizations (including some that also are part of CSM) are engaging in various Action Tracks. In fact, representatives from non-governmental organizations are Chairs or Vice-Chairs of most of the Action Tracks. Civil society, like the private sector, is diverse; many organizations have decided that the opportunities opened to them by participating in the Summit exceed any risks.

Just as the invitations bypassed established fora and mechanisms for civil society engagement, the UNFSS' framing disregards much of the previous international work on food system framing and pathways to solutions. The Action Tracks, while being worthwhile goals in themselves, ignore previous international agreements that are vital to finding more systemic solutions. Last year, the HLPE published "Food Security and Nutrition: Building a Global Narrative Toward 2030" that laid out a roadmap with potential policy directions for transforming food systems (HLPE, 2020). In addition, numerous UN institutions have developed frameworks to guide global food governance through a rights-based framework, including the Declaration on the Rights of Peasants and Other People Working in Rural Areas, which was passed by the General Assembly in 2018, as well as General Recommendation 34, issued by the Committee on the Elimination of All Forms of Discrimination Against Women in 2014, which elaborates the rights of rural women. These rights-based approaches are conspicuously absent in many of the UNFSS' documents. The right to food and nutrition is mentioned briefly in the first Action Track's accompanying Discussion Starter Paper as "civil society campaigns"[19] but not as its primary objective or framework. Agroecology is hardly visible in the description of the Action Track on "nature-positive production" nor in its revised Discussion Starter Paper[20], despite the significant work on it by FAO and the High Level Panel of Experts of CFS. In the Discussion Paper, agroecology is mentioned as an example of "efficiency" in production; but for the HLPE as well as peoples' movements and civil society organizations that are struggling for food sovereignty, its benefits extend far beyond making production more efficient (and "efficiency" as a goal is routinely associated with industrial food systems) (HLPE, 2019).

The UNFSS' evasion of existing institutions and frameworks has led the CSM to conclude that the UNFSS is designed to undermine the position of the CFS as the primary seat of global food governance, which the CSM has fought hard to protect since the 2009 reform. Over the past few years, several powerful governments have sought to actively weaken the CFS by slowing down policy-making processes and reducing the CFS's program of work, then criticizing it for moving at a slow pace. More recently, these governments refused to use recent CFS meetings to substantively address the COVID-19 pandemic in anticipation of the UNFSS. Yet the UNFSS is not showing any signs of being able to overcome the underlying barriers to an effective CFS; if anything, it will exacerbate them (see below section on Conflicts of Interest). Many people believe that the CFS should have been the organizing body for the UNFSS; but not only has it been bypassed, but its leadership was neglected in the rather insulting original inclusion of Thanawat Tiensin, the CFS Chair, as one of over 100 self-appointed "champions" of the UNFSS. Organizers

[18] 2021 Food Systems Summit Briefing to Member States. 4 September 2020 [On file with authors].

[19] Available online at: https://www.un.org/sites/un2.un.org/files/unfss-at1-discussion_starter-dec2020.pdf, p. 10 (accessed January 17, 2021).

[20] Available online at: https://www.un.org/sites/un2.un.org/files/unfss-at3-discussion_starter-dec2020.pdf (accessed January 17, 2021).

of the UNFSS invited him to join the Advisory Committee only after the CSM publicly raised concerns about the Summit. Both the CFS and FAO are well-placed to respond to the pandemic and organize a conference on "food systems," but the FAO has no more prominence than any other UN agency. The UN Task Force of the UNFSS is chaired by the Executive Director of the UN Environment Programme Inger Andersen.

Taken altogether, the structure of the UNFSS and its recruitment of leadership has failed to meet basic standards of accountability and transparency that even the organizers claim to espouse. Instead, leaders, experts, and participants have been cherry-picked from organizations that are either unaware of already existing institutions, amenable to the reframing of food systems through the Green Revolution framework, or ignorant of the history and dangers of multistakeholder partnerships undermining multilateral governance. Perhaps most problematically, many of those selected as leaders are unaccountable to constituencies that are at the front lines of food systems.

Inclusivity and the Multistakeholder Model of the Summit

The possibility for "meaningful participation" by those most affected by food insecurity has been rendered hollow by the UNFSS's diffuse and opaque design. The UNFSS exhibits a puzzling combination of top-down closed decision-making (e.g., in formation of the Scientific Group, Advisory Committee and Integrative Team) and simply opening the door to anyone who wants to participate (e.g., in formation of the "Champions" group). The Special Envoy has described the UNFSS as a "People's Summit," but there is no recognition of the need to center voices of front-line food system actors whose rights have been consistently violated and who are not being well-served by food systems. Without prioritizing those constituencies, as required by human rights-based approaches, the most powerful and well-resourced participants will inevitably dominate.

The ambiguity of participation and lack of accountability is most clearly exemplified by UNFSS "dialogues." The dialogues are the main form of popular participation in the Summit. They are being convened as "an opportunity for everyone to engage with the Summit in a meaningful way"[21]. According to the website, dialogues can be initiated by governments ("member state dialogues"), the Special Envoy ("global dialogues"), or anyone at all ("independent dialogues"). Despite the elaborate design of the dialogues (including a 44-page "reference manual" on the Summit's website about how to facilitate them), there is no indication on the website about how the vast amount of input they will generate will be filtered and compiled nor how it will influence activities of the Summit or its outcomes. In addition, all dialogues are "invitation only;" the first one in the United States did not invite members of CSM-North America who have been working on food systems through this official sub-regional constituency of the CSM for over a decade[22]. Whether or not these "dialogues" are designed to diffuse efforts by people's movements to influence the outcome of the Summit, they create a significant opportunity to co-opt the participation of peoples' movements by failing to provide accountability to assure their inputs are incorporated into final outcomes.

The UNFSS website also acts as a sort of dialogue. The website describes itself as a "community platform to encourage public, global conversations as part of a year-long global dialogue leading up to the milestone event to transform food systems worldwide." The website has the feel of a social media platform, including discussion boards, feeds, and an overwhelming number of documents. Photos and short videos are embedded, with captions such as "We Are All Connected." On the website, people are encouraged to participate in the following ways:

1. Sign up to join discussions across all communities.
2. Join a community, respond to ongoing discussions, or start one.
3. Connect with members, and grow your network and community.
4. Share links, videos, photos, and tell your story in any of the communities.

It is unclear how any of the elaborate forms of participation—from the online discussion boards to the virtual dialogues to the other UNFSS events—contribute to the outcomes of the Summit. For example, the "Events" tab includes such wildly disparate fora as the Davos Forum of the WEF and the Oxford Real Farming Conference (the "unofficial gathering of the agroecological farming movement in the UK, including organic and regenerative farming, bringing together practicing farmers and growers with scientists and economists, activists and policy-makers"[23].) That is, the website seems to be absorbing any and all events that touch on food systems governance and portraying them as part of the UNFSS.

These problems stem from the fact that inclusivity in the UNFSS is primarily interpreted through the paradigm of multistakeholderism, a form of governance that has been imported from the corporate sector into the public domain (Pigman, 2007). Multistakeholderism seeks to incorporate all those affected by a given issue into policy-making processes on an imaginary level playing field. The WEF is actively seeking to redesign multilateral global governance through the model of multistakeholderism as part of the "the Great Reset." The Great Reset is an attempt by the WEF to reassert control over global policymaking in a moment when popular movements (on both the right and the left) are mobilizing to oppose the economic inequalities that have proliferated as a consequence of decades of neoliberalism. As a paper posted on the WEF website notes,

> The lack of faith in the "system" has meant that the notion of "taking back control"—including from multilateral organizations—has gained currency in recent years among

[21] Available online at: https://www.un.org/en/food-systems-summit/food-systems-dialogues (accessed January 29, 2020).

[22] Available online at: https://nffc.net/2021-un-food-system-summit-dialogues-rekindle-concerns/ (accessed January 29, 2020).

[23] Available online at: https://orfc.org.uk/about/ (accessed January 29, 2020).

> citizens and leaders alike. The danger in this development is that skepticism over the value of geostrategic institutions, and even of multilateralism itself, risks eroding the global community's ability to properly manage the primary economic, environmental and technological risks facing the world today[24].

For the WEF, multistakeholderism is a strategic approach to maintaining liberal trade agreements and open markets, while reducing risks from environmental degradation and popular resistance. The promotion of multistakeholder platforms is part of a broader vision of stakeholder capitalism that seeks to embed corporations within systems of governance without compromising regulatory control (Schwab, 2021).

Since inequalities of power are not accounted for in these processes, multistakeholderism has been critiqued as a mode of governance that serves to reproduce existing power structures under the guise of inclusivity. A recent report by the CFS High Level Panel of Experts warns that addressing power differentials is critical for the success of any multistakeholder platform. In their report, the HLPE clearly states that,

> There is a risk for MSPs to reproduce existing *power asymmetries* and to strengthen the position of more powerful actors. One of the challenges for MSPs in the field of FSN [food security and nutrition] is to acknowledge and address these power asymmetries. Inclusiveness, transparency and accountability are keys to address this challenge. Full and effective participation of the most marginalized and vulnerable groups, directly affected by food insecurity and malnutrition, will be ensured if weaker partners have the right and capacity to speak, to be heard and influence the decisions. This requires time and resources to participate in discussion, including in physical meetings, as well as information, expertise, and communication skills (HLPE, 2018, p. 16).

Multistakeholder platforms undermine the clear responsibilities of governments and replace political participation with a model that lacks clear rules of participation, subverts traditional means of political representation and erases mechanisms of accountability.

The consistent failure of multistakeholder platforms to address asymmetries in the context of food and agricultural initiatives has led many scholars to be skeptical of their ability to do more than promote the interests of the powerful (Muller, 2011; Cheyns and Riisgaard, 2014; McKeon, 2017; Gleckman, 2018). The Institute for Multi-stakeholder Initiative Integrity recently published a report from its 10 years of research that decisively finds that multistakeholder initiatives "are not effective tools for holding corporations accountable for abuses, protecting rights holders against human rights violations, or providing survivors and victims' with access to remedy" (MSI Integrity, 2020, p. 4). Similarly, the HLPE notes that there is little evidence of the effectiveness of multistakeholder processes.

> Scientists and other actors question the potential benefits and limitations, the performance and even the relevance of MSPs as a suitable institutional mechanism to finance and improve FSN. They also question the conditions for MSPs to contribute effectively to the realization of the right to adequate food (HLPE, 2018, p. 13).

Research on multistakeholderism has shown again and again not only that multistakeholder initiatives are ineffective, but also that when there is not an agreed-upon frame, initiatives are bound to fail (Fung and Wright, 2003; Gray, 2004). This is certainly the case for the UNFSS: exactly what is the problem that the Summit is designed to fix, and how will it help?

The adoption of a multistakeholder approach raises questions about the normative basis of the Summit. As described earlier, previous Summits have been organized through the multilateral institutions of the United Nations. Member States have been the primary participants of these meetings, with civil society participating in "parallel summits." This reflects the normative framework of public international law through which the UN operates. In this framework, states are the primary actors and duty-bearers for human rights obligations. With the embrace of multistakeholderism in the UNFSS, it is an open question whether human rights remain the primary normative framework. These concerns have been raised repeatedly by the Special Rapporteur on the Right to Food, Michael Fakhri, to Dr. Kalibata[25]. As he noted in a recent analysis of the review on Action Tracks, only Action Track four emphasizes the right to food as a core framework, and three of the action tracks do not mention the right to food at all[26]. Moreover, the rights-based institutions of the United Nations, such as the CFS, the International Labor Organization, and the Geneva-based human rights bodies are not well-represented in the Summit's Leadership. This may help to explain why food system actors, who suffer from consistent rights violations, including food-workers, farmworkers, peasants, and Indigenous peoples, are very poorly represented in the UNFSS.

Grounding the Summit in human rights is critical because it is a framework for ensuring meaningful participation of those most marginalized and vulnerable. The 2004 Voluntary Guidelines to support the Progressive Realization of the Right to Adequate Food in the Context of National Food Security describe several procedural principles to guide policy-making processes that address food and nutrition security. Commonly known as the PANTHER framework, these include participation, accountability, non-discrimination, transparency, human dignity, empowerment and the rule of law[27]. This rights-based approach emphasizes that those most affected by food insecurity should not only be able to participate meaningfully, but that governments must be accountable for these rights. This has important implications for the outcome of the Summit. While

[24] Available online at: https://www.weforum.org/agenda/2019/07/multi-stakeholder-risk-resiliency-climate-change-trade/ (accessed January 29, 2020).

[25] Letter from the UN Special Rapporteur on the Right to Food to Dr. Agnes Kalibata. 26 June 2020. On file with authors.

[26] Letter from the UN Special Rapporteur on the Right to Food to Dr. Agnes Kalibata. 13 January 2021. On file with authors.

[27] See: FAO. 2009. "Conducting A Right to Food Assessment." http://www.fao.org/3/a-i0550e.pdf (accessed January 13, 2021).

the Summit aims to generate a voluntary non-negotiated political document with guidelines for stakeholders to promote food system transformation, as Special Rapporteur Michael Fakhri notes: "without relying on human rights… this document will remain aspirational and not practical."

Conflicts of Interest and Corporate Influence in the UNFSS

In addition to the multistakeholder design of the UNFSS, the Summit's failure to safeguard against conflicts of interest risks further enabling corporate influence in the Summit. By conflicts of interest, we mean financial and non-financial interests or commitments either through fiduciary obligations or duties of loyalty that risk impairing non-partial judgment and decision-making. Conflicts of interests "distort decision-making processes and generate inappropriate outcomes, and thereby undermine the well-functioning of both public institutions and markets" (Peters, 2012, p. 3). A corporation that is obliged to maximize profits for its shareholders or which depends for its existence on increasing sales of agrifood system inputs or products has a conflict of interest in the UNFSS because private financial interest should never be allowed to usurp the public interest in food security and nutrition. Such conflicts must be disclosed routinely in scientific or medical research and publications, and they should be equally obligatory in work on food systems. In part, a key problem is that multistakeholder initiatives are designed to promote diverse interests and inclusivity, rather than manage the risks of conflicts of interests. However, failing to guard against the dominance of commercial interests risks undermining the UN's own values of independence, impartiality, and integrity on which it depends for public legitimacy.

By appointing the current President of AGRA as Special Envoy, the UN not only signaled support for AGRA's market-led, technology-driven approach, it invited the rescaling of a corporate-philanthropic alliance developed on the African continent onto the global scale. AGRA explicitly aims to commercialize and industrialize African food systems through its model of "market-led technology adoption." This approach incentivizes farmers to adopt Green Revolution technologies, primarily through government-sponsored farm input subsidy programs (Toenniessen et al., 2008). AGRA has provided over $500 million in grants to encourage the adoption of Green Revolution technologies, primarily hybrid seeds and synthetic fertilizers. Although AGRA promised to "double yields and incomes for 30 million farming households by 2020," a recent independent evaluation found that not only has AGRA failed to meet its objectives, but there has been a 30% *increase* in hunger in the countries where AGRA operates (Wise, 2020, 2021). Despite these failures, the Green Revolution continues to be promoted by AGRA's main donor, the Bill and Melinda Gates Foundation.

Participation of large numbers of people with AGRA connections, and funding through philanthrocapitalists and agribusinesses that belong to the WEF, signal an ongoing revolving door between corporate and public decision-making. WEF's Head of the "Future of Food Initiative," Sean de Cleene, previously served as the Vice President of AGRA and Vice President for Global Initiatives, Strategy, and Business Development for Yara—the world's largest fertilizer corporation. However, the WEF partnership is just one of multiple corporate partnerships developed recently by the UN. In October 2019, Guterres also launched the Global Investors for Sustainable Development (GISD), a group of 30 companies that have vowed to provide funding for sustainable development. Even more recently, in 2020 the Director-General of the FAO, Qu Dongyu, raised major concerns when he signed a cooperation agreement with CropLife International. These agreements between multilateral international institutions and organizations that represent the world's largest corporations suggest that philanthropists and multi-national corporations are taking advantage of the global pandemic to institutionalize the "Great Reset."

AGRA's central role in the UNFSS through the Special Envoy and the UNFSS's staff is also poised to further extend the influence of the Gates Foundation on food system governance. This is worrisome because as the world's largest private foundation [Bill Gates is also the largest owner of US farmland (O'Keefe, 2021)], the Gates Foundation's approach to social change serves to enrich the very same corporations and countries that have been the cause of economic inequalities and environmental degradation (McGoey, 2015; Schwab, 2020). Gates provides extensive global funding to promote private-sector driven technological innovation as the solution to social and environmental problems and promotes policy changes to incentivize this approach through public subsides and intellectual property protections. He is explicit that companies in the Global North should see global problems as opportunities for profit. In his book on climate change—Gates's newest area of advocacy—he explains,

> Rich countries are best suited to develop innovative climate solutions; they're the ones with government funding, research universities, national labs, and start-up companies that draw talent from all over the world, so they'll need to lead the way. Whoever makes big energy breakthroughs and shows they can work on a global scale and be affordable, will find many willing customers in emerging economies (Gates, 2021, p. 35–36).

Gates's projects epitomize conflicts of interest. Yet he is successfully re-organizing global governance across the sectors in which the Foundation works in the image of multistakeholderism. Beyond the UNFSS, the most recent example of this approach is the Gates-backed COVAX facility of the World Health Organization. COVAX was developed to pool resources for equitable vaccine procurement and distribution. Not only is COVAX failing to provide equitable distribution as a result of vaccine nationalism, it has defended patent rights for pharmaceutical corporations in opposition to the world's poorest nations and has been unwelcoming of civil society participation (Amnesty International, 2020; Patnaik, 2020). Similarly, Gates' effort to usurp control of the Consultative Group on International Agriculture Research (CGAIR) has been

decried for institutionalizing control of Northern donors[28]. Seitz and Martens (2017) describe the Bill & Melinda Gates Foundation's effort to wrest control from intergovernmental and multilateral institutions through multistakeholder partnerships in which it sits at the helm as "philanthrolateralism."

As a result of its embrace of corporations and philanthrocapitalists the United Nations is facing creeping corporate influence. For over two decades, analysts have warned of "bluewashing"—the use of the UN imagery and brand to strengthen the reputation of multinational corporations in the name of the public good—especially in relationship to the UN Global Compact and the Sustainable Development Goals (Bruno and Karliner, 2002; Utting and Zammit, 2008; Berliner and Prakash, 2015). Seitz and Martens (2017) point to a promotional UNESCO brochure that clearly describes the benefits for multinational corporations in partnering (i.e., contributing financially) with the United Nations. As it explains, donors will:

- Benefit from a strong image transfer by associating yourself with a reputable international brand and a prestigious UN agency
- Win greater visibility on the international scene
- Gain access to UNESCO's wide and diverse public and private networks
- Benefit from UNESCO's role of a neutral and multistakeholder broker
- Turn your Social Responsibility into reality
- Strengthen your brand loyalty through good corporate citizenship (UNESCO, 2015).

As the brochure makes plain, UN agencies were inviting companies to draw on the legitimacy once extended to the UN as a democratic (one-country, one vote) intergovernmental body.

What's new in this example is that UN agencies were also advertising the possibility of directly participating in UN decision-making through multistakeholder initiatives, which as described above raise concerns over corporate control, especially insofar as intergovernmental and UN partnerships with corporations have relaxed control in extending license to private initiatives *via* multistakeholderism. This is exemplified in two significant ventures early in the second decade of the twenty-first century. In 2012, the *New Alliance for Food Security and Nutrition* (NAFSN) was formed as a partnership between the G8, the African Union, the New Partnership for Africa's Development (NEPAD), nine African governments, and over 100 private corporations. This new multistakeholder public-private initiative was to reframe participating governments' land and food policy to promote cross-national "agricultural growth corridors": enclosing land for large-scale industrial agriculture, and incorporating small producers into corporate value chains to produce foodstuffs primarily for export. The initiative aimed to renew development industry initiative and, as the British PM Cameron claimed: to "unleash the power of the private sector" [Paul and Steinbrecher, 2013; Quoted in Duncan (2015), p. 233]. France has since withdrawn from the project, on grounds that it undermines farming livelihoods of the producers concerned.

The following year, the *UN Global Alliance for Climate Smart Agriculture* (GACSA) formed, with 14 governments and 32 organizations (including food corporations such as Coca-Cola, Dupont, Dow, Monsanto, Walmart, Tyson Foods, and Unilever) to enable 500 million farmers to practice CSA by 2030[29]. Such ventures followed the model established by the G8, the World Bank, IFAD and the African Development Bank in 2006, which encourage African states to fund public infrastructure to enable the Gates Foundation to deploy its philanthrocapitalism for the Alliance for a Green Revolution in Africa (AGRA). This public-private partnership (PPP) model now infuses food governance initiatives underway in the UNFSS, where the WEF represents itself as a global platform for public-private cooperation[30], and corporations as serving the public trust. Early in the COVID crisis, in a joint statement, FAO Director-General Qu Donyu notably warned governments to "ensure that any trade-related measures do not disrupt the [global] food supply chain"[31]. This injunction ultimately serves the interests of transnational corporations that control this food supply chain, not local and regional food systems and territorial markets that were much more resilient than global companies in providing healthy food during the pandemic.

Corporations have made no secret of the fact that they see these partnerships with the UN as good for business. As one corporate executive has put it:

> The SDGs [Sustainable Development Goals] are a gift to business because the economic rewards for delivering to the needs defined in the SDGs are very significant. According to the Business & Sustainable Development Commission, the potential economic reward from delivering solutions to the SDGs could be worth at least $12 trillion each year in market opportunities and generate up to 380 million new jobs by 2030 (Pedersen, 2018, p. 23).

These partnerships not only allow corporations to set the agenda, they serve as a "path to value" for corporations that sense they are losing their public legitimacy (Schramade, 2017). By pursuing partnerships and multistakeholder governance, Schwab aims to position "private corporations as the trustees of society"[32], which implies overriding and displacing the public interest.

As the paragraphs above make clear, the UNFSS is rife with actual and potential conflicts of interest, which are neither disclosed nor even recognized as problematic. This means that the very corporations that are responsible for promoting food that contributes to unhealthy diets, engaging in practices destructive of producers' livelihoods, violating human rights,

[28] See IPES-Food's Open Letter dated 21 July 2020: http://www.ipes-food.org/pages/OneGGIAR (accessed March 2, 2021).

[29] Available online at: http://sdg.iisd.org/news/global-alliance-for-climate-smart-agriculture-launched/ (accessed January 29, 2020).

[30] Available online at: http://www3.weforum.org/docs/WEF_Institutional_Brochure_2016.pdf (accessed January 29, 2020).

[31] Available online at: https://www.dailysabah.com/world/world-to-face-food-crisis-if-coronavirus-pandemic-not-managed-properly-un-wto/news (accessed January 29, 2020).

[32] Available online at: https://www.weforum.org/agenda/2019/12/why-we-need-the-davos-manifesto-for-better-kind-of-capitalism/ (accessed January 29, 2020).

overpaying CEOs, and creating gross inequity in food systems are playing prominent roles in the UNFSS. Are we to think that they have realized the error of their ways, and are seeking wide input in order to do better? Or perhaps the idea is that significant change in food systems won't result without the participation of the largest food corporations. But participation under what terms? And how will ultimate accountability to rights-holders be assured? Are we seeing foxes being invited into the chicken houses, or genuine interest in transformation?

CONCLUSIONS

Peoples' movements and civil society organizations struggling for food sovereignty fear that the outcomes of the UNFSS are baked into its structure and actions to date. These include (1) capturing the narrative of food systems transformation so that it aligns with the kinds of technologies promoted by AGRA and the WEF; (2) diminishing the role of CFS as the premier forum for discussion and negotiation of issues pertaining to food security; (3) usurping the role of FAO as the UN agency with the primary responsibility for food security; (4) engendering confusion about what "democratic participation" and "inclusivity" mean to equate these with multistakeholderism; (5) excluding the voices of producers and workers on the frontlines and pushing people who are already marginalized even farther from meaningful participation; (6) undermining accountability for violations of human rights and ecohealth degradation; and (7) propping up the illusion that a single global food system based on trade and "economic integration" of smallholders into global markets will ensure sustainable food security, at a time when the COVID-19 pandemic and looming climate emergencies portend the dangers of relying on global supply chains. Each of these outcomes is dangerous for its potential to overturn hard-won achievements of civil society.

Based on our analysis, the Civil Society and Indigenous Peoples Mechanism of the CFS, La Vía Campesina, and movements aligned with the International Planning Committee for Food Sovereignty are well-justified in their concerns about the UNFSS. The criticisms we raised above related to the formation, structure, recruitment, non-transparency, inclusivity, normative basis, and conflicts of interest related to the Summit have led many well-intentioned people to agree to participate, in hopes that they can help to achieve something of value. The amount of time and resources that these people will spend is unfathomable, raising an overriding criticism that the UNFSS is a huge time-sink for questionable purposes. The CFS is in place already. It offers a voice to all stake-holders in food systems through transparent mechanisms. Although far from perfect, it offers a more accountable framework of rights-based public food security governance, deriving from its historical evolution as the key forum in the UN responsible for public global food governance. At this crisis moment, it needs greater support.

There is no question that food system transformation is urgently needed, and that it is being stymied by certain vested interests that are committed to agro-industrial "false solutions" and their own advancement far more than to the public good. We argue that the time and money spent on the Summit would be better spent on shoring up the CFS; analyzing and addressing conflicts of interest that have derailed some important negotiations there; seeking and strengthening voices and solutions from below such as food sovereignty; and democratizing public institutions and agencies related to food systems, including the SDGs, so that they serve everyone—in short, strengthening the vision of public global food governance that is necessary to end hunger. We could challenge the UNFSS to show that the outcomes feared by civil society will not come to pass. But the lack of response to criticism to date and unwillingness to discuss terms under which civil society might participate with integrity have not been encouraging. The more important challenge is to Member States of the CFS, to show their abiding commitment to human rights and public governance of food systems. If they cannot rise to this challenge, the chances of making real progress in 2021 toward sustainable and equitable food systems seem slim.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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REFERENCES

ActionAid (2009). *Assessing the Alliance for a Green Revolution in Africa*. ActionAid. Available online at: https://actionaid.org/publications/2009/assessing-alliance-green-revolution-africa-agra (accessed March 5, 2021).

Amnesty International (2020). *A Fair Shot: Ensuring Universal Access to Covid-19 Diagnostics, Treatments, and Vaccines*. London: Amnesty International. Available online at: https://www.amnesty.org/download/Documents/POL3034092020ENGLISH.PDF (accessed March 5, 2021).

Anderson, M. D. (2015). The role of knowledge in building food security resilience across food system domains. *J. Environ. Stud. Sci.* 5, 543–559. doi: 10.1007/s13412-015-0311-3

Anderson, M. D., and Rivera-Ferre, M. (2021). Food system narratives to end hunger: extractive versus regenerative. *Curr. Opin. Environ. Sustain.* 49, 18–25. doi: 10.1016/j.cosust.2020.12.002

Béné, C., Oosterveer, P., Lamotte, L., Brouwer, I. D., de Haan, S., Prager, S. D., et al. (2019). When food systems meet sustainability—current narratives and implications for actions. *World Dev.* 113, 116–130. doi: 10.1016/j.worlddev.2018.08.011

Berliner, D., and Prakash, A. (2015). "Bluewashing" the firm? voluntary regulations, program design, and member compliance with the United Nations Global Compact. *Policy Stud. J.* 43, 115–138. doi: 10.1111/psj.12085

Braun, J. von, Afsana, K., Fresco, L., Hassan, M., and Torrero, M. (2020). *Food Systems – Definition, Concept and Application for the UN Food Systems Summit*. Available online at: https://www.un.org/sites/un2.un.org/files/food_systems_concept_paper_scientific_group_-_draft_oct_26.pdf (accessed March 5, 2021).

Bruno, K., and Karliner, J. (2002). *Earthsummit.Biz: The Corporate Takeover of Sustainable Development*. Oakland, CA: Food First Books.

Cheyns, E., and Riisgaard, L. (2014). Introduction to the symposium: the exercise of power through multi-stakeholder initiatives for sustainable agriculture and its inclusion and exclusion outcomes. *Agri. Hum. Values* 31, 409–423. doi: 10.1007/s10460-014-9508-4

Clapp, J., and Moseley, W. G. (2020). This food crisis is different: COVID-19 and the fragility of the neoliberal food security order. *J. Peasant Stud.* 47, 1393–1417. doi: 10.1080/03066150.2020.1823838

Clark, M. A., Domingo, N. G. G., Colgan, K., Thakrar, S. K., Tilman, D., Lynch, J., et al. (2020). Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. *Science* 370, 705–708. doi: 10.1126/science.aba7357

Diouf, J., and Severino, J.-M. (2008). Africa must grow to rely on its own farms. *Guardian Weekly* 2:18.

Duncan, J. (2015). *Global Food Security Governance: Civil Society Engagement in the Reformed Committee on World Food Security*. New York, NY: Routledge. doi: 10.4324/9781315754130

Ericksen, P., Stewart, B., Dixon, J., Barling, D., Loring, P., Anderson, M., et al. (2010). "The value of a food system approach," in *Food Security and Global Environmental Change*, eds. J. Ingram, P. Ericksen, and D. Liverman (New York, NY: Earthscan), 25–45.

ETC Group (2009). Who Will Govern? Rome's Food Summit May Determine Who Decides Who Will Eat. ETC Group Available at: https://www.etcgroup.org/content/who-will-govern (accessed March 5, 2021).

Fakhri, M. (2019). "The International Political Economy of the right to food," in *Human Rights and Global Governance*, ed N. Bhuta (Oxford: Oxford University Press). Available online at: https://www.academia.edu/40614188/The_International_Political_Economy_of_the_Right_to_Food (accessed March 3, 2021).

FAO, IFAD, UNICEF, WFP, and WHO. (2020). *The State of Food Security and Nutrition in the World 2020. Transforming Food Systems for Affordable Healthy Diets*. Rome: FAO.

Foran, T., Butler, J. R. A., Williams, L. J., Wanjura, W. J., Hall, A., Carter, L., et al. (2014). Taking complexity in food systems seriously: an interdisciplinary analysis. *World Dev.* 61, 85–101. doi: 10.1016/j.worlddev.2014.03.023

Friedmann, H., and McMichael, P. (1989). Agriculture and the state system: the rise and decline of national agricultures, 1870 to present. *Sociol. Ruralis* XXIX, 93–117. doi: 10.1111/j.1467-9523.1989.tb00360.x

Fung, A., and Wright, E. O. (2003). *Deepening Democracy: Institutional Innovations in Empowered Participatory Governance*. New York, NY: Verso.

Gates, B. (2021). *How to Avoid a Climate Disaster: The Solutions We Have and the Breakthroughs We Need*. New York, NY: Knopf.

Giraldo, O. F., and Rosset, P. M. (2018). Agroecology as a territory in dispute: between institutionality and social movements. *J. Peasant Stud.* 45, 545–564. doi: 10.1080/03066150.2017.1353496

Gitz, V., and Meybeck, A. (2011). *The establishment of the High Level Panel of Experts on food security and nutrition (HLPE). Shared, independent and comprehensive knowledge for international policy coherence in food security and nutrition. CIRED Working Papers n2011-30*. Paris.

Gleckman, H. (2018). *Multistakeholder Governance and Democracy: A Global Challenge*. Amsterdam: Routledge. doi: 10.4324/9781315144740

GRAIN (2008). *Seized: The 2008 Landgrab for Food and Financial Security*. GRAIN. Available online at: https://www.grain.org/article/entries/93-seized-the-2008-landgrab-for-food-and-financial-security.pdf (accessed July 6, 2016).

Gray, B. (2004). Strong opposition: frame-based resistance to collaboration. *J. Community. Appl. Soc. Psychol.* 14, 166–176. doi: 10.1002/casp.773

HLPE (2018). *Multi-Stakeholder Partnerships to Finance and Improve Food Security and Nutrition in the Framework of the 2030 Agenda*. Rome: A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.

HLPE (2019). *Agroecological and Other Innovative Approaches for Sustainable Agriculture and Food Systems that Enhance Food Security and Nutrition*. Rome: A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.

HLPE (2020). *Food Security and Nutrition: Building a Global Narrative Towards 2030*. Rome: A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.

Hoddy, E. T. (2021). Peasants' rights and agrarian violence in transitional settings: from transitional justice to transformative agrarian justice. *J. Hum. Rights* 20, 91–109. doi: 10.1080/14754835.2020.1850242

Holt-Giménez, E., and Altieri, M. A. (2013). Agroecology, food sovereignty, and the new green revolution. *Agroecol. Sustain. Food Syst.* 37, 90–102. doi: 10.1080/21683565.2013.809398

Houtart, F. (2010). *Agrofuels: Big Profits, Ruined Lives and Ecological Destruction*. London: Pluto Press.

International Panel of Experts on Sustainable Food Systems (2017). *Too Big to Feed: Exploring the Impacts of Mega-Mergers, Consolidation and Concentration of Power in the Agri-Food Sector*.

Jarosz, L. (2009). The political economy of global governance and the world food crisis: the case of the FAO. *Review (Fernand Braudel Center)* 32, 37–60.

Kneen, B. (1989). *From Land to Mouth: Understanding the Food System*. Chapel Hill, NC: NC Press.

Madeley, J. (2000). *Hungry for Trade: How the Poor Pay for Free Trade*. London: Zed Books.

McGoey, L. (2015). *No Such Thing as a Free Gift: The Gates Foundation and the Price of Philanthropy*. London; New York, NY: Verso Books.

McKeon, N. (2015). *Food Security Governance: Empowering Communities, Regulating Corporations*. New York, NY: Routledge. doi: 10.4324/9781315882529

McKeon, N. (2017). Are equity and sustainability a likely outcome when foxes and chickens share the same coop? critiquing the concept of multistakeholder governance of food security. *Globalizations* 14, 379–398. doi: 10.1080/14747731.2017.1286168

McKeon, N. (2018). *Global Food Governance. Between corporate Control and Shaky Democracy*. Global Governance Spotlight 2. Development and Peace Foundation. Available online at: www.sef-bonn.org

McMichael, P. (2013a). *Food Regimes and Agrarian Questions*. Halifax, NS; Winnipeg, MB: Practical Action Publishing. doi: 10.3362/9781780448794.000

McMichael, P. (2013b). Value-chain Agriculture and Debt Relations: contradictory outcomes. *Third World Quarterly* 34, 671–690. doi: 10.1080/01436597.2013.786290

Mooney, P. (2018). *Blocking the Chain: Industrial Food Chain Concentration, Big Data, Platforms and Food Sovereignty Solutions*. Val David, QC: ETC Group. Available online at: https://www.etcgroup.org/sites/www.etcgroup.org/files/files/blockingthechain_english_web.pdf (accessed March 5, 2021).

MSI Integrity (2020). *Not Fit-for-Purpose: The Grand Experiment of Multi-Stakeholder Initiatives in Corporate Accountability, Human Rights and Global Governance*. Available online at: https://www.msi-integrity.org/wp-content/uploads/2020/07/MSI_Not_Fit_For_Purpose_FORWEBSITE.FINAL_.pdf (accessed March 5, 2021).

Muller, B. (2011). "The elephant in the room: multistakeholder dialogue on agricultural biotechnology in the food and agriculture organization," in *Policy Worlds: Anthropology and the Analysis of Contemporary Power*, eds C. Shore and S. Wright (New York, NY; Oxford: Berghahn Books).

Newell, P., and Taylor, O. (2018). Contested landscapes: the global political economy of climate-smart agriculture. *J. Peasant Stud.* 45, 108–129. doi: 10.1080/03066150.2017.1324426

O'Keefe, E. (2021). *Bill Gates: America's Top Farmland Owner. The Land Report*. Available online at: https://landreport.com/2021/01/bill-gates-americas-top-farmland-owner/ (accessed January 26, 2021).

Patel, R. (2013). The long green revolution. *J. Peasant Stud.* 40, 1–63. doi: 10.1080/03066150.2012.719224

Patel, R., and McMichael, P. (2009). A political economy of the food riot. *Review (Fernand Braudel Center)* 32, 9–35.

Patnaik, P. (2020). *Gavi & Civil Society: Unhappy Engagement*. Geneva Health Files. Available online at: https://genevahealthfiles.substack.com/p/gavi-and-civil-society-unhappy-engagement (accessed March 2, 2021).

Paul, H., and Steinbrecher, R. (2013). *African Agricultural Growth Corridors and the New Alliance for Food Security and Nutrition. Who benefits, who loses?* EcoNexus. Available online at: http://www.econexus.info/sites/econexus/files/African_Agricultural_Growth_Corridors_&_New_Alliance_-_EcoNexus_June_2013.pdf (accessed March 5, 2021).

Pedersen, C. S. (2018). The UN Sustainable Development Goals (SDGs) are a great gift to business! *Procedia CIRP* 69, 21–24. doi: 10.1016/j.procir.2018.01.003

Peters, A. (2012). "Conflict of interest as a cross-cutting problem of governance," in *Conflict of Interest in Global, Public and Corporate Governance*, eds A. Peters and L. Handschin (Cambridge: Cambridge University Press), 3–38. doi: 10.1017/CBO9781139248945.003

Phillips, L., and Ilcan, S. (2003). "A world free from hunger": global imagination and governance in the age of scientific management. *Social. Ruralis* 43, 434–453. doi: 10.1046/j.1467-9523.2003.00254.x

Pigman, G. A. (2007). *World Economic Forum: A Multi-Stakeholder Approach to Global Governance*. New York, NY: Routledge. doi: 10.4324/9780203962756

Ritchie, M. (1993). *Breaking the Deadlock. The United States and Agricultural Policy in the Uruguay Round*. Minneapolis, MN: Institute for Agriculture and Trade Policy, 239.

Schramade, W. (2017). Investing in the UN sustainable development goals: opportunities for companies and investors. *J. Appl. Corpor. Finance* 29, 87–99. doi: 10.1111/jacf.12236

Schwab, K. (2021). *Stakeholder Capitalism: A Global Economy that Works for Progress, People and Planet*. Geneva: John Wiley & Sons.

Schwab, T. (2020). *Bill Gates Gives to the Rich (Including Himself)*. Available online at: https://www.thenation.com/article/society/bill-gates-foundation-philanthropy/ (accessed July 6, 2020).

Seitz, K., and Martens, J. (2017). Philanthrolateralism: private funding and corporate influence in the United Nations. *Glob. Policy* 8, 46–50. doi: 10.1111/1758-5899.12448

Shaw, D. J. (2007). *World Food Security: A History Since 1945*. New York, NY: Palgrave Macmillan.

Swinburn, B. A., Kraak, V. I., Allender, S., Atkins, V. J., Baker, P. I., Bogard, J. R., et al. (2019). The global syndemic of obesity, undernutrition, and climate change: the Lancet Commission report. *Lancet* 393, 791–846. doi: 10.1016/S0140-6736(18)32822-8

Toenniessen, G., Adesina, A., and DeVries, J. (2008). Building an alliance for a green revolution in Africa. *Ann. N. Y. Acad. Sci.* 1136, 233–242. doi: 10.1196/annals.1425.028

Tubiana, L. (1989). "World trade in agricultural products: from global regulation to market fragmentation," in *The International Farm Crisis*, eds D. Goodman and M. Redclift (London: Palgrave Macmillan UK), 23–45. doi: 10.1007/978-1-349-10332-4_2

UNCTAD (2013). *Trade and Environment Review 2013: Wake Up Before It Is Too Late.* Geneva: United Nations Conference on Trade and Development.

UNESCO (2015). *World Heritage Partnerships for Conservation*. Paris: UNESCO World Heritage Centre Available online at: http://whc.unesco.org/document/137223 (accessed March 8, 2020).

Utting, P., and Zammit, A. (2008). United Nations-business partnerships: good intentions and contradictory agendas. *J. Bus. Ethics* 90:39. doi: 10.1007/s10551-008-9917-7

Wise, T. (2020). *Failing Africa's Farmers: An Impact Assessment of the Alliance for a Green Revolution in Africa*. Medford, OR: Tufts University.

Wise, T. (2021). *AGRA Update: Withheld Internal Documents Reveal No Progress for Africa's Farmers*. Washington, DC: Institute for Agriculture & Trade Policy. Available at: https://www.iatp.org/blog/202102/agra-update-withheld-internal-documents-reveal-no-progress-africas-farmers (accessed March 2, 2021).

World Bank (2007). *World Development Report 2008: Agriculture for Development*. Washington, DC: The World Bank.

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A Qualitative Analysis of the Commercial Broiler System, and the Links to Consumers' Nutrition and Health, and to Environmental Sustainability: A South African Case Study

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Food systems face growing challenges to meet targets of Zero Hunger (SDG 2), and South Africa is no exception given its triple burden of malnutrition, foodborne disease outbreaks, and threats of climate change to food production. Broiler meat is South Africa's most affordable meat option, supporting household food and nutrition security. Although considered healthier and less environmentally harmful than ruminant meat, it is not without food safety risks and environmental impacts. This research aimed to present the foremost commercial broiler system narratives in South Africa, around targets of SDG 2, and to discuss key considerations for policymakers. Twenty-nine key informants and stakeholders, purposively selected to cover a wide range of opinions, participated in semi-structured interviews. Transcripts underwent a qualitative framework analysis. Results showed a highly efficient system, dominated by a small number of interlinked large-scale actors, vulnerable to competition from cheaper imports, yet pressurized to maintain high food safety and environmental impact standards, with a price-sensitive consumer base. Existing policies lack integration and enforcement capacity, and are undermined by siloed government departments, and mistrust and power struggles between public and private sectors. We propose removal of silo walls, and trust building through participatory policy development, with collaborative and transformative public-private partnerships that are designed to build capacity to deliver sustainable solutions.

Keywords: food system, food safety, sustainability, broilers, South Africa, Zero Hunger (SDG 2)

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INTRODUCTION

Global food systems face substantial challenges to meet specific targets under the Zero Hunger Sustainable Development Goal (SDG 2), namely to ensure access of all people to safe, nutritious and sufficient food all year, and to build sustainable food production systems (Global Panel, 2020). Food systems in South Africa are particularly challenged, despite the country's substantial socio-economic and political change since the end of apartheid in 1994. Childhood stunting and micronutrient deficiencies persist, whilst obesity prevalence among children and adults grows (Lundeen et al., 2016; NDoH, 2016; Bosire et al., 2020). Food safety surveillance gaps became apparent during the world's largest outbreak of foodborne listeriosis which occurred in South Africa in 2017–18 (Thomas et al., 2020). In the past decade the country's population grew by 17%, however food production is threatened by increasing drought frequency and climate change (Conway et al., 2015; STATS SA, 2018). COVID-19 lockdown restrictions and the pre-existing poverty levels in South Africa, have increased food insecurity risks for the poorest households through job losses, poor access, and unstable (national and international) supply chains (Perez-Escamilla et al., 2020).

South Africa has the highest meat consumption per capita in Africa, with a growing demand for poultry meat, showing an increase of 132% between 1995 and 2015 (DSEA, 2016; Ritchie and Roser, 2019). Broiler meat remains the most affordable meat option and plays an important role in household food and nutrition security, and in the South African food system (GAIN, 2015; McHiza et al., 2015). Whilst considered healthier than red meat by some (Bouvard et al., 2015; Godfray et al., 2018), its impact on consumers' health is complex, with portion sizes and preparation methods playing an important role (Schönfeldt et al., 2014).

The South African commercial[1] poultry (broiler and layer) industry is the single largest contributor to agricultural related GDP, and an exemplar of the country's commercial livestock sector, with its production systems and efficiency comparable with other global intensive production systems (DAFF, 2018; SAPA, 2018b). The broiler value chain is dominated by a small number of large-scale commercial producers, who produce >75% of national production (SAPA, 2018b). The largest are vertically integrated, with formal marketing and distribution networks, involving a few large supermarket chains, and quick-service (fast-food) restaurants, including international franchises (Louw et al., 2017; Ncube, 2018).

Foodborne disease (FBD) presents a greater risk for individuals affected by poverty, malnutrition, reduced immunity (HIV/AIDS), or chronic diseases like tuberculosis (TB), all of which are over-represented in South African society (Lund and O'Brien, 2011; Thomas et al., 2020). Foodborne disease outbreaks in South Africa are commonly associated with *Salmonella* spp., *Clostridium perfringens*, *Bacillus cereus*, *Shigella* spp., *Listeria monocytogenes*, and *Escherichia coli* (Shonhiwa et al., 2018). The main pathogens found on poultry meat include *Staphylococcus aureus*, *Camplylobacter* spp., *Listeria monocytogenes*, and *Salmonella* spp. (Goncalves-Tenorio et al., 2018). South Africa's recent foodborne listeriosis outbreak was traced to a factory producing a low-cost processed meat product containing broiler mechanically deboned meat (MDM) and meat from other livestock sources (Thomas et al., 2020).

Broiler meat is regarded by some as the least environmentally damaging meat option (Willett et al., 2019). However, the rising broiler meat consumption levels brings into question its environmental sustainability. Whilst intensive production has limited direct impacts on land use, it has indirect environmental impacts through its total dependence on cereal based feed (Skunca et al., 2018). Only 11% of South Africa's land area is suitable for cropping, and 3% is used for cereal production (for human and livestock consumption), most of which is rainfall dependent and vulnerable to climate change (Conway et al., 2015; Trading Economics, 2020). Feed costs comprise 65–70% of intensive production costs, and the broiler industry consumes ∼2.8 million tons of feed, made mostly from yellow maize and soybean (SAPA, 2018a). South Africa, whilst generally self-sufficient in maize (outside of drought years), imports 60% of the poultry industry's soybean needs, leaving an environmental impact in the exporting country (SAPA, 2018a). Other environmental impacts of production include water use (in cleaning, and processing), energy use in environmentally controlled housing, and management of waste (Skunca et al., 2018).

Our research forms part of the Sustainable and Healthy Food Systems (SHEFS) programme, which aims to provide policymakers with novel, interdisciplinary evidence to define future food system policies that deliver nutritious and healthy foods, in an environmentally sustainable, and socially equitable manner. The aim is therefore well-aligned with meeting several targets within the SDG of Zero Hunger. To date, many experts have expressed opinions about the unsustainability of food systems, but most have come from distinct and diverse disciplines (Béné et al., 2019). The result has been a range of distinct conceptual frameworks characterized by the links between agriculture and nutrition (Nicholson et al., 2020). However, complex food system challenges call for an interdisciplinary, One health and whole systems approach to gain a better understanding of the system's complexity and interconnectedness (Zhang et al., 2018; Garcia et al., 2020). Consequently, our work is framed within a wider "food systems approach" as described by van Berkum et al. (2018); a theoretical framework which recognizes the various elements within the system and the relationships between them. Preceding this study, we conducted a systems analysis of the livestock-derived food system in South Africa and developed a conceptual system dynamics model, which highlighted the importance of broilers (Queenan et al., 2020). With broiler system as our focus, we used a food systems lens to conduct a qualitative analysis aimed at answering the broad question: How does the commercial broiler system in South Africa contribute to meeting the SDG

[1] "Commercial" is a term used in South Africa to describe privately owned, business orientated large-scale farming operations, with a high level of formal market engagement. These were, but are no longer, exclusively owned by white farmers, but the latter still remain over-represented.

2 targets that relate to consumers' health and nutrition, food safety, and the environment, and what barriers and opportunities exist for change? We present the main narratives based on the perspectives of a wide range of stakeholders and key informants within the broiler system, and discuss challenges and key areas for policymakers' consideration. These results will be used, in part, to develop a system dynamics model of the South African broiler system. This will demonstrate feedbacks, reinforcing and balancing loops, and system archetypes, and will aim to provide evidence for policymakers on the various interrelated outcomes of specific policy scenarios.

METHODS

This qualitative research, using semi-structured interviews, was preceded by our systemic analysis and development of a conceptual system dynamics model of the livestock-derived food system in South Africa. This deepened our understanding of the complexity of livestock-derived food system, the importance of broilers within the agricultural sector, and as the source of the most affordable and commonly consumed meat. This in-depth knowledge was a useful foundation and guide in the formulation of the interview topics and questions (Rabionet, 2011). It also determined our focus on the commercial broiler sector given its contribution to overall production. Research on the small-scale and emerging producers was conducted in parallel and is under review with this journal.

Data Collection

Twenty-two semi-structured interviews were conducted in South Africa with 29 participants (13F, 16M), either individually, or at most in pairs within the same institution. Participants were selected purposively from authors (whose gray and academic literature was reviewed in previous work), professional networks, and online searches. Additional individuals were identified through multiple entry-point snowballing and "horizontal networking" (Geddes et al., 2017). Our selection aimed to represent a wide cross-section from the commercial broiler system, to ensure diversity of perspectives, and to capture common themes within the divergence (Patton, 1999; Creswell, 2014). Participants included those representative of large, medium and small-scale commercial producers, importers, input providers (feeds and medicines), animal health service suppliers (veterinary practitioners, both public and private), human health laboratory specialists, academics and researchers in natural resources, economics, animal health, human health and nutrition, and representatives from the broiler producer association, non-governmental organizations, and government departments and agencies (see **Appendix 1**).

The interview questions were piloted among colleagues experienced in conducting qualitative research to provide an opportunity for feedback, revision and improvement (Turner, 2010). Interviews were conducted jointly by two researchers in English and face-to-face where possible. When people were unavailable or could not be visited, then phone or online virtual meetings were held. One interviewer was South African, which was beneficial to interpret local vernacular and lingua franca expressions (Qu and Dumay, 2011). After outlining the study's aims and explaining data usage and confidentiality, interviewees were given an opportunity to ask questions before providing written consent, which included permission for audio recording.

Open questions were asked that focussed on interviewees' opinions of recent broiler industry trends, the role of the industry in consumers' food security and nutrition, food safety issues, the impact of industry on the environment (and vice versa), and significant past and current policies that impact the industry. Audio recordings were transcribed using an independent South African transcribing service, which allowed for more accurate transcription of local accents.

Ethics approval for this research was gained from the Royal Veterinary College's (University of London) Social Science Ethical Review Board (URN SR2018-1624), and the University of KwaZulu-Natal's Human and Social Sciences Research Ethics Committee (HSS/0235/018D).

Data Analysis

Data was analyzed using a framework analysis, which is an approach specifically designed for the analysis of policy relevant research, where the objectives are commonly established by researchers in advance, and data analysis is informed by a priori reasoning (Pope et al., 2000; Ward et al., 2013; Parkinson et al., 2016). The methodology is also most suited to multidisciplinary research and the thematic analysis of semi-structured interview transcripts, which by nature are less heterogeneous than informal, unstructured interviews (Qu and Dumay, 2011; Gale et al., 2013). This approach also aligned with our research aim, since it addresses a variety and combination of research questions, concerning the context, purpose, evaluation, and future strategies around the subject of interest (Ritchie and Spencer, 1994).

The framework analysis used the five steps as developed by Ritchie and Spencer (1994), and described in Parkinson et al. (2016). These are (i) Familiarization with data: This was accomplished by the interviewing researchers (KQ, SC) reading the transcripts, and discussing emerging categories for the framework. (ii) Identifying framework categories: These were kept within the boundaries of the research questions and interview structure, yet allowed for addition of emerging issues. (iii) Indexing/coding: Transcripts were color coded according to framework categories. (iv) Charting: Coded data were transferred directly into the framework in Microsoft® Excel. Some framework categories were revised and disaggregated further. (v) Mapping and Interpretation: This involved summarizing the categorized framework data, mapping out topics, aligning the data interpretation with the research questions, finding patterns and concepts, and identifying themes. Turner (2010) recommended that interviews be combined with other forms of data collection to fill gaps in the analysis. Therefore, we identified peer-reviewed and gray literature via Google searches, and used them to provide background context to themes, and as methods-triangulation to enhance quality of analysis (Patton, 1999).

RESULTS

Within the boundaries of consumer health, nutrition, and the environmental sustainability of the system, the following themes were developed from the qualitative framework analysis, and are presented with additional background context information. Whilst policy elements are referred to within most themes, a separate policy theme is presented at the end.

Dominance of Integrated and Large-Scale Producers in a Dichotomous System

In 2018, South Africa slaughtered an estimated 18 million locally produced broiler birds per week, yielding 1.8 million tons of broiler meat in the year (SAPA, 2018a). Local production is dominated by two companies that jointly contribute ∼46% of total production in almost equal shares, whilst a further five producers supply 29% (DAFF, 2017). The two largest producers are vertically integrated, controlling their own input supplies (including breeder flocks, feed mills), abattoirs, processing plants, and marketing and wholesale outlets. Integrators also use contract growers to whom they supply chicks, feed, vaccines, advice on production and disease control, and veterinary and laboratory services. The integrator guarantees a market and price for the contractors' grown stock, which is recognized as an advantage by contractors, together with cash-flow savings on the major inputs (feed and chicks).

- We don't have to outlay the food and chicks. And you get a guaranteed market; we don't have to do any marketing. If you've grown 250,000 birds and then have to look for a market; no thank you (190606_001).

At the other extreme, small-scale farmers supply an estimated 20–25% of the broiler meat produced, some through formal market channels, whilst the majority concentrate on the informal live bird market. The middle ground between large and small-scale producers has become increasingly vacant.

- They (medium-scale producers) really didn't have a spot in the whole system. All my (medium-scale) guys are basically packed up and either joined the corporates or changed to different production, from broilers to broiler breeders or things like that. We have seen more smaller guys coming up all over. I think it's at the expense of the mid-sized guys (190618_001).

Local Producers and Importers Fight for Their Market Share

Recent trade agreements (relaxing import tariffs) have resulted in imported poultry supplementing (or competing with) local production. Interviewees specifically referenced the United States (US) African Growth and Opportunity Act (AGOA) from 2000. Other agreements included the EU's Trade, Development and Cooperation Agreement. Tariff relaxations were primarily on bone-in frozen portions, but these were increased again in 2018 in response to the significant increase in imports. In 2018, imports peaked at 566,210 tons, an increase of 44% since 2014 (SAPA, 2019), and ∼95% of this was chicken (almost all was frozen, and of broiler origin). The top three product categories and approximate proportions were, (i) 45% "bone-in portions", (ii) 33.3% mechanically deboned meat (MDM), and (iii) 8.2% clean offal (gizzards, livers, heads, necks, feet, but excluding intestines) (SAPA, 2018c, 2019).

Interviewees within the local production industry claimed that import volumes equate to the presence of a new integrator in the market. Importers disagreed arguing that broiler import figures were not just frozen broiler meat, but included MDM. They stated that MDM should be considered as a separate commodity to broiler meat, and that the import volumes of actual imported broiler meat and offal are significantly less than the 25–30% that is often quoted. Importers also highlighted that cuts used in the exporting countries to produce MDM (necks and backs), are consumed in their original form by South African consumers. As a result, there was little or no local production of MDM, and importers therefore claimed that imported MDM was vital for the local processed meat industry, which provided around 15,000 jobs, and offered a low-priced animal-sourced protein for lower socio-economic status consumers.

- About 15% (of broiler meat) consumption is provided by imports. We (importers) don't include MDM when we do our calculations, because we say, it's not directly competing with chicken in the supermarket or a butchery shelf. MDM, it's sold as polony, or some form of a cooked, smoked sausage. Those products are sold as a competitive product in the market, but it's not chicken, and it's not sold as chicken. It might ultimately land up competing, but it's competing as a different product category against chicken (190517_002).

Unlevel Playing Field for Importers and Local Producers; Winners, and Losers

Before the democratically elected government of 1994, local commercial producers were supported by government subsidies, and protected by import tariffs (Hendriks, 2014). Local industry interviewees were fiercely critical of the lack of support and protection offered by current government, suggesting that the local industry will collapse if imports are not controlled.

- If you look at all the countries in Africa where there aren't local industries anymore, it was decimated by imports. Ghana, Mozambique, Nigeria, Angola. And it's simply, chicken comes in cheap until the local industry is dead, and then chicken prices go up. The countries with no industry, relying on Brazil predominately for imports, it (chicken) is very expensive, the same price as red meat in South Africa (190515_001).

It was reported that government was of the opinion that local production could not meet the increased demand for broiler meat, and they viewed imports as a means to improve food security for the lower socio-economic status consumers. However, local producers claimed they have no incentive to invest and

increase production because they cannot compete with overseas producers that receive subsidies from their own governments.

- We are getting this (imported chicken) from countries where farmers are heavily subsidized, so obviously the South African producer is fighting a battle with somebody who are not coming on equal ground (190624_002).

Breast meat is a consumer-favored and highly profitable cut in high socio-economic markets internationally, whilst the remaining bone-in cuts are less favored, with offal considered a by-product (BFAP, 2016). By contrast, it was reported that almost half of South African consumers prefer bone-in cuts (sold in mixed-portion bags of individually quick frozen (IQF) pieces), and many also enjoy consuming all parts of the bird, including all forms of offal (including intestines). Therefore, importing bone-in cuts and offal products is seen as a market opportunity by importers. Several interviewees recognized that imports challenge the local industry's efficiency, whilst others suggested that local production would not be able to fill the gap left by imports, should tariffs be applied to reduce them.

- It is a local industry that is underperforming. I think it's an opportunity that your importer would see (190517_003).
- Definitely, in terms of food security, it (imported chicken) is a priority. If we raise our tariffs, and then we're going to have shortages, and the SA industry cannot supply enough for the market (190624_001).

Several participants felt that the rise in imports have affected small-scale producers that sell live birds the least. In contrast, they perceived medium-sized producers and emerging commercial farmers as the least able to adapt, and the hardest hit. Integrators have reportedly reacted by taking steps to improve efficiencies, expand or consolidate their market options, or widen or revise their product range. Some integrators reportedly sold off land assets and closed old houses to improve margins, but not without consequent job losses. They opened new, more energy-efficient houses on new, more strategically located sites, closer to the markets, cereal production and feed mills. In addition, they diversified risks, by increasing the proportion of their production delivered through contract growers. High-end quick-service restaurants (QSR) were targeted by integrators as a lucrative and expanding market. An interviewee, with previous experience in QSR chains, reported that imported broiler cuts did not meet their strict traceability requirements and smaller size specifications (for which QSR pay a premium). Local integrators reportedly dominate this QSR market because they were more likely, than small or medium sized independent producers, to consistently meet these requirements.

- (Integrators) want in the QSR and the value-added sector. They don't want whole bird business... So those spec birds are usually birds that have to meet a specific weight and a specific size, specific kind of uniformity… That's where the guys can get more money for their product. (190625_001)

Tension Between Government, Local Producers, and Importers; A Search for Agreement

Evidence of tensions between the local industry and government was noted by several interviewees, with suggestions that the historic race inequality in commercial farm ownership, was an undercurrent for the lack of government support.

- We perceive Government as hostile rather than friendly. Large scale commercial poultry production (in South Africa) is white monopoly capital, and the ANC Government is not in favor of that. So that relationship, there is a certain tension in that, and you are not sure what you are going to get from Government in terms of protection (190520_001).

Interviewees from government ministries, importers, and observers of the industry, offered other perspectives on imports. These included signs of indifference from government.

- Industry players will always have something to complain about. They will say "We are being unfairly outcompeted" by whoever, and "They're dumping their products here" (190624_001).

The complexity of trade agreements around tariffs, specifically those liked to AGOA, was also acknowledged.

- The US uses all sorts of other trade agreements to strong-arm us into accepting their poultry dumping, you know, tariffs on other goods. It's a lot of commodities which are being exchanged between these countries, minerals and things, so it's many different sectors. I think it's a very complex. So, it's a dirty game and I think the government plays it as best they can (190521_001).

In recognition of the market tensions developing, between local and imported products, the "Poultry Masterplan" was agreed and initiated late in 2019. This was a facilitated collaboration between the Departments of Trade and Industry (DTI), of Agriculture, Land Reform and Rural Development (DALRRD) (previously DAFF), the South African Poultry Association (SAPA), and the South African Association of Meat Importers and Exporters (SAAMIE). It was described as "a strategy approach, that brings government and industry and other stakeholders (together) on how to develop and grow an industry" (190726_001), and it aims to invest in local industry growth (including incorporating smaller producers), protect local production from cheap imports and rising feed costs, and improve sanitary requirement for export markets (Details of the masterplan are yet to be released publicly).

Provision of Affordable Broiler-Product Options for Consumers

Despite significant socio-economic progress, South Africa remains one of the most unequal countries in the world (World Bank, 2018). The growth of middle classes and urbanization, typical of growing economies, has driven a rise in meat consumption (specifically poultry meat), however 43% of the population are moderately food insecure (Ritchie and Roser,

2018; FAO, 2020). Several interviewees reported that the bulk of consumers chose chicken-based products largely on price.

- Food security in SA is not about availability of food, it's about the cost of food (190515_001).
- Things like chicken necks, chicken stomachs, chicken livers, chicken hearts, are the only affordable animal protein for many of our population. And I think chicken is the one staple that has kept animal protein on most consumers' plates, even for the poorest consumers (190517_002).

It was stated that price increases would preclude even the low-cost broiler meat options for lowest-income consumers, and that there was little room for value chain actors to increase their prices in response to increased costs, without the risk of their customers switching to cheaper, alternative, non-animal-sourced products.

- I mean when people were battling (economically), they were spending money on potatoes, cabbages, mielie (maize) meal and things like that, and moving away from meat altogether (190618_001).

Food Safety Standards and Surveillance Lack Consistency and Capacity, in a Population With a High Proportion of Individuals Vulnerable to Foodborne Disease

Broiler meat and processed products are linked to many foodborne pathogens such as *Campylobacter* spp., non-typhiodal serotypes of *Salmonella enterica* (NTS), *Listeria monocytogenes*, and Shiga toxin-producing strains of *Escherichia coli* (Heredia and Garcia, 2018). A significant proportion of the South African population is particularly vulnerable to FBD, given the prevalence of TB, HIV/AIDS, malnutrition and poverty (Thomas et al., 2020).

- We also have a huge population that is susceptible, especially for non-typhi Salmonella, in our HIV positive populations, and a lot of under-fives. So, we've got the very highly susceptible populations (190517_001).

Public and veterinary health experts reported that laboratory services are contained within a two-tiered system, of private and government run facilities, and apart from notifiable diseases, there is no obligation for private laboratories to share data. Similarly, although there are ∼260 government run National Health Laboratory Service laboratories, only five process food samples. The majority of food testing is conducted in private laboratories, linked to private food processors and retailers. It was the opinion of a government laboratory interviewee that private laboratories' reluctance to share data, often citing client confidentiality as the reason, potentially delayed the identification of the source of the 2017–2018 listeriosis outbreak. Counter-intuitively, their reluctance to share data, post-listeriosis, reportedly increased rather than decreased.

- Often if you are dealing with outbreaks in the private sector, or when you try to do trace-backs, they use commercial or private food-testing laboratories, and then you can't access that data or isolates. And especially now in the wake of the listeriosis outbreak, the clients, who send their samples to private food laboratories, insist they don't want their data or isolates shared at all, because of litigation (190517_001).

Several participants made the point that public food safety surveillance lacks capacity and integration, and is fragmented across the Department of Health (DoH), DTI, and DALRRD, and their agencies, each with different roles and with some overlap. Integrators and value chain actors involved in animal production, slaughter, and processing of resultant meat products, are regulated by DALRRD. However, the DoH regulates those trading in meat, which includes importers. Whilst the DoH's Food Safety Directorate is responsible for policy, the operational aspects are devolved to municipalities, and the latter's capacity depends on local budgets, which may vary widely.

- The Department of Agriculture (now DALRRD), ourselves (DTI), and also Health, now and then, we talk about what we need is one food agency, so that everything can fall under the food agency. But to get it off the ground is a problem because you have all these people who are doing different things. So, some people might feel that maybe that means that's the end of their jobs (190624_001).
- It's a bit of a mish-mash, right. Department of Health does a lot of the work on the food safety, but Department of Agriculture Forestry and Fishery (now DALRRD) also has that, and they have directorates that are meant to deal with it. But you know, it's always the integration that's an issue, as well as the structures; they inhibit the sort of collaboration (190607_001).

In the broiler system, commercial producers, formal retailers, QSR chains, and large-scale importers have reputational and financial incentives for maintaining high levels of food safety, often setting industry standards above that required by government, and managing their own monitoring systems, using in-house or private laboratories.

- Obviously, they have a huge amount of reputational damage if anything happens. That's what happened with listeriosis, Tiger Foods was massively hammered. I suspect they have all ramped up their food safety protocols since listeriosis (190528_003).

A sub-theme of government distrust, and lack of support felt by large-scale local industry actors, was repeated by several participants. Large-scale actors felt they were overly targeted, whilst small operators went unchecked, and likewise local producers felt that they were under greater scrutiny than importers, and that there was inadequate capacity to police the latter.

- Domestic producers say because they are nearby, it's easy to go and visit them, that the agencies, when it comes to enforcement, they enforce a lot more for them. I guess

sometimes it's just in issue of manpower, that when products are coming in through the ports, maybe there is not enough people to check the containers and the information is not as clearly descriptive of what's contained and all that. So, in some cases, ja (yes), products come in that should have been not in, but ja (yes), it's not so easy (190624_001).
- There are 1,500 abattoirs credited to export here. What should happen is that the importing country (veterinary inspector) visits the particular slaughterhouse, approves the slaughterhouse and the South African government vet signs responsibility over to the exporting country vet, and he must sign off and ensure that they comply with our import regulation. We haven't visited one abattoir in 10 years. So there is no control there, nothing whatsoever (190515_001).

With respect to surveillance integration and data sharing, there is however optimism from relevant stakeholders around the plans to establish the National Public Health Institute of South Africa (NAPHISA), which is "taking a One Health perspective, so hope(fully) it will improve things" (190607_001). It will be benchmarked against the US's Centre for Disease Control and Prevention, and aims to "use formal agreements with public and private health and food testing labs to refer isolates and share data" (190517_001), and thereby provide integrated and coordinated disease surveillance and evaluation of interventions.

Food Safety: A Lower Priority Than Price for Consumers

It was reported that food safety, for consumers of lower socio-economic status, remains a lower priority than price. For some "any food you can get is food and to survive they would eat anything" (190528_003). This is despite the listeriosis outbreak being linked to a processed meat product, commonly bought by lower-income consumers.

- The lower-end consumer, they became very aware of it (food safety) too, which I think probably they wouldn't have been as sensitive, prior to listeriosis, about things like food safety. I think prior to that most people have been fairly blasé about it. I mean, going back not too very long ago, really poor people, people on the edge of poverty and below, were actually digging up poultry mortality pits to consume the mortality (carcass). That's how desperate people have been for food. If you're prepared to do that, you know, food safety is not one of the big items on your radar (190528_003).
- A huge part of the consumer wants the cheapest product. He does not care where it comes from. He does not care if there is an expiry date on it, or what brining it has got. He only looks at the price. He can afford this chicken and that is what is going to go on his table (190515_002).

Whilst the listeriosis outbreak was traced to a product retailed through the formal value chain, there was concern expressed by the stakeholder in foodborne disease surveillance, that food safety in the small-scale and informal value chain is neglected, and needs improvement. Basic knowledge, from animal health and biosecurity, to slaughter and food hygiene, is apparently lacking with many of the informal value chain actors. They are also less able to absorb costs of implementation, and there is little incentive if they are neither monitored, nor experience repercussions. Implementation costs of international food safety standards across all systems, may push smaller actors out of business, or result in costs being transferred to consumers.

- Compliance costs on food safety are high. We do need to look at strengthening our food safety systems and using new technologies; but if we are going to do that, you know it comes at a cost. There is a huge health benefit, but someone would have to bear the costs (190726_001).
- Chicken is a mass product, so at the end of the day, I think the consumer wants something that is safe, however they define it, but at the best possible price (190520_001).

The Industry Is Vulnerable to Climate Change Through the Impacts of Droughts on the Feed Sector, Water Quality, and Avian Influenza Risk

Feed is the greatest variable cost for producers, and as a result, the greatest concerns regarding climate change were the implications of droughts and weather variability on local cereal yields, the need to import raw materials for feed, and the associated fluctuations in feed quality and costs.

- We used to have droughts every 10 years, now we have droughts every 3–4 years, so climate change is having a massive impact; if you compromise on your grain sector then you're in trouble (190726_001).

With only 11% of the land surface in South Africa being suitable for cropping, the total area suitable for maize and soybean is reportedly shrinking due to climate change (Conway et al., 2015; DSEA, 2016).

- Climate change is making a lot of these areas a lot more marginal. I mean Free State and that, have been hammered in recent years with droughts, and you know those predictions (of climate change), it's going to become more of an issue (190607_002).

Droughts also impacted on the quality and reliability of water from municipal and private boreholes sources, with pollution and contamination by raw sewerage being reported. As a result, large scale producers and processors have invested in independent water supplies and in-house purification systems, and have been driven to maximize water efficiencies. Climate change was also mentioned in relation to changing patterns in wild bird migration, and increased risk of avian influenza spill-over into poultry flocks.

- Other impacts of climate change are around the increased incidents of avian influenza. You know, we are seeing certain diseases arriving here that weren't ever present. So we've got no doubt that migratory patterns of birds are changing. All of these things, particularly around climate change, are throwing new challenges (190726_001).

The Industry's Impact on the Environment Is of Less Concern to Them Than the Impact of the Environment on the Industry

The environmental impacts of the industry seem of less concern to the main actors in the commercial system. Some recognition was given to water use, waste management (including bird mortalities), energy use in maintaining stable conditions in environmentally controlled houses, and land use for cereal crops. However, compliance by large-scale producers to the environmental impact assessment (EIA) regulations, as set out in the government's National Environmental Management Act (1989) (DEA, 1998), and Environmental Impact Assessment Regulations (2014) (DEA, 2014), was considered by them to be adequate in mitigating environmental impacts of the industry. They also criticized the EIA process as being costly, bureaucratic, and an example of a comprehensive, yet over-zealous legal framework, with more bureaucracy than enforcement capacity.

- The other thing that will also continue to put pressure on our market, will be the whole approach, the pressure that we have in adhering to certain environmental factors, and the scale of things that we can do, as well as how and when, what has been policed and enforced (190625_001).
- The EIA regulations have become increasingly more bureaucratic, to the point that a lot of farmers will just try to avoid it, either by trying to fall below the threshold or just carrying on and pretending they don't know about it (190607_002).

Waste management was considered by local producers to be less of a concerning issue than in the industrial systems in Europe, due to South Africa's relatively large land space, and dryer climatic conditions. Waste from production houses was seen to have value, commonly used by crop farmers as manure, either directly onto cropland, or composted to reduce nitrogen levels. Disposal of bird mortalities are regulated through environmental legislations, and by DALRRD (with regards to contagious animal diseases like avian influenza), however, some chicken mortalities were reportedly disposed of via captive-crocodile farms that produce crocodile skins and meat.

- We have large land areas and relatively small production. The bulk of manure is used on maize lands, fed to livestock, and yes some of it probably ends up in water causing a bit of water pollution, but because of the larger spaces and much drier climate that Europe, its impact is probably mitigated (190520_001).

Fossil-fuel based heating and ventilation systems are used in environmentally controlled housing. Gas is considered too expensive for heating, and with electricity supplies being unreliable, it was estimated that 80% of producers are dependent on coal for heating. It was also recognized that there is room for improvement, following US production systems that use litter-based, biogas generating facilities, but these were considered currently cost prohibitive in South Africa.

It was recognized by some, that the limited arable land in South Africa, which is constrained primarily by rainfall patterns and water supply, was under competition for use to grow cereals for human consumption, and for animal feeds. Additional conflicts were reported between conservation and agriculture, as pressure increased to convert more natural grasslands into arable land, and also concerns as mining encroached into arable lands.

Policy Environment Is Rich, but Poor in Governance, Integration, and Implementation

A recent review of South African food policies highlighted gaps, contradictions, and poor intersectoral coordination with regards to policy development and implementation (Boatemaa et al., 2018). Governance within South Africa's food system has been criticized for failing to deliver much needed transformative change, primarily due to the siloed nature of government departments, and a tension between the often ambitious objectives and the constraints that exist for those tasked to implement them (Termeer et al., 2018). Furthermore, food system problem-framing has lacked a systems approach, with solutions often favoring a focus on agricultural production and food security (Drimie and Ruysenaar, 2010). Food safety governance and policies (reviewed after the listeriosis outbreak of 2017–2018), were found to be poorly coordinated and fragmented across three government departments, with the lack of implementation capacity being filled by private self-regulation in the formal sector but with gaps remaining in the unregulated informal sector (Boatemaa et al., 2019). Within the commercial broiler system, existing policies were considered by interviewees to be adequate, if not overly detailed and complex. Their main concern was the failing in policy application, and a lack of implementation capacity, which was also noted in the literature (Fourie, 2018; Queenan et al., 2020).

- You could manage within existing policies for instance in South Africa to drive this, but you need the will, and you need the people, the right people with the correct technical know-how as well as the will, you know, the will across the board, with existing industry, with government, you need the right support for the programmes. We write beautiful plans in South Africa; we fail to implement (190517_003).
- What we do is, we put a lot of effort into finding an excellent law, developing it and putting it through parliament, and then we discover that we have no capacity to enforce it or even implement it (190520_001).
- Because, the concept in this country is that we are quite over regulated. We have got a very comprehensive legal framework, but the application and the implementation of it is a real challenge (190607_002).

Some reported that specific policy and regulations were impractical, unenforceable, and needed reviewing. Examples were given concerning government departments' responses to abattoir surveillance findings, regulations around thawing and refreezing imported meat, and thresholds set for requiring an EIA.

- Working with the Department of Agriculture is very challenging, because they don't always come up with rational

policies to be honest. They had a very limited capacity. Poor understanding of the epidemiology. I mean running a poultry abattoir, it's quite a sophisticated operation, and then you have to work with technical people, who have no understanding or clearly very limited understanding of what's at stake. I mean you cannot shut down an abattoir for 2 days, you are going to have X hundred thousand birds all, you know, the system just doesn't allow for that (190520_001).

- If you want to thaw out meat and resell it, the carcass core temperature and the carcass surface temperature is not allowed to go above 7 degrees. That is the law and probably the same law in the US or UK. So it's very difficult to police. You literally need to stand there and wait for the guy to thaw out for 24 h to prove it. So, the legislation is badly written and therefore now they make it difficult to implement, so they've decided not to implement that (190515_001).
- The (EIA) trigger for poultry is the number of birds, but it doesn't really consider where in relation to the sensitive environment or something. A lot of developments in the rural areas do not go through the same processes, and the big corporates and commercial farmers are forced to, they get hammered if they don't follow due process, but it's a kind of free for all in the communal areas (190607_002).

DISCUSSION

This research aimed to investigate the commercial broiler system within the wider food system in South Africa, and its contribution to meeting the targets of SDG 2 that relate to consumers' health and nutrition, food safety, and the environment. We analyzed the perspectives of a wide range of stakeholders within the system, and highlighted several key areas for policymakers to consider, when developing food system policies aimed at the targets of SDG 2. These included the imbalance of power within the system, tension and mistrust between local producers, importers and government, the price sensitivity of consumers, gaps in food safety surveillance, vulnerability to climate change, and the fragmented nature of policy with shortfalls in implementation.

Before specific policy issues within the broiler system are dealt with by policymakers, the lack of trust and imbalance of power between the main government and industry players, which was highlighted by multiple participants, must be addressed. Commercial and larger-scale farming was historically restricted to farmers from the white minority population, supported by British colonial rule, and later by the Nationalist government's policy of apartheid, which ended in 1994 (Tihanyi and Robinson, 2011). The post-apartheid government's agricultural reforms removed parastatal marketing boards and financial structures that supported commercial farmers, and replaced them with Black Economic Empowerment (BEE) policies and land reform, which are ongoing (Tihanyi and Robinson, 2011; O'Laughlin et al., 2013). However, the commercial broiler industry still has notable barriers to entry (primarily prerequisites of substantial capital and technical skill capacity), and has been slow to change from its well-established historic roots (Hall, 2004). This political backdrop is considered by existing commercial producers to influence government policy, which is perceived as unsupportive on several levels. Most notable are policies around import tariffs, and implementation of regulations pertaining to animal health, food safety and environmental impacts, which are perceived as biased against powerful large-scale local producers. Large-scale producers and importers take an approach of self-regulation and self-determination, arguably in response to the government's lack of capacity and support, but potentially contributing to the existing tension and power struggle. Such perceived inequalities by private industry support a vicious cycle of ongoing mistrust and lack of interest in collaboration.

Broiler import tariffs are part of complex international trade deals, which typically involve trade-offs with more valuable commodities. Global power imbalances present additional barriers for South African government negotiators when attempting to meet trade objectives on food and nutrition security (Greenberg et al., 2017). Nevertheless, there is evidence from elsewhere in Africa, that cheap broiler imports outcompete local production on price, eroding local production and the associated feed industries (Dieye et al., 2007; Banson et al., 2015). Import surges also undermine local producer confidence to invest in business expansion (Greenberg et al., 2017). However, downward pressure on prices from imports was reported by some participants as potentially contributing to food and nutrient security, especially to the lower income consumers. Whilst the local industry is calling for more government support and tighter import restrictions, little was said on how capacity to cover shortfalls would be developed. An opportunity exists for the commercial industry to support the marginalized emerging and smaller-scale producers, through mentorship and skills development. Government initiatives to support this would strengthen the delivery of more inclusive agricultural development.

Social inequality persists in South Africa, and racial disparity has arguably been replaced by an economic one, as evidenced by the country's top ranked position in the world for income inequality (World Bank, 2018). Similarly, South African healthcare, historically polarized based on race, is now largely determined by socio-economic status. Approximately 16% of the population use private healthcare, mostly facilitated by private health insurance, whilst the remainder (84%) use public health facilities (Naidoo, 2012). Disparate systems were also noted to exist in surveillance of food safety and foodborne diseases, being either government or privately funded and controlled. Weaknesses and inequalities arising from these systems were unveiled by the listeriosis outbreak, and more recently by the SARS-CoV-2 pandemic (Nwosu and Oyenubi, 2021). Further analysis, as the pandemic unfolds, will provide evidence that can drive accelerated policy reform in this area.

Socio-economic lines also divide provision of veterinary healthcare for livestock. Private veterinarians service the wider commercial farming sector. Integrators go a step further, employing veterinarians to provide in-house health and laboratory services. By contrast, state veterinarians, who rely heavily on animal health technicians, provide capacity-stretched services to the non-commercial sector (Fermet-Quinet et al., 2014). The World Organisation for Animal Health (OIE)

recently stated that, with an ever-increasing demand for national veterinary services to improve livestock productivity and food safety standards, both private and public veterinary services will need to look for opportunities to collaborate and expand capacity (Thevasegayam et al., 2017). Such collaboration is needed in South Africa to address inequalities and capacity gaps in animal health services, and similarly in human healthcare, and food safety surveillance.

Attempts to swiftly resolve the foodborne listeriosis outbreak were reported by some participants to have been undermined by the lack of capacity within, and integration between government departments, and a lack of co-operation between private and public surveillance. More joined-up and consistent policy on food safety and FBD surveillance is needed that encompasses both locally produced and imported boiler products. Solving such complex policy issues requires horizontal collaboration between several government departments and non-governmental stakeholders, but are hampered by the typically narrow-focussed, siloed structures of organizations (Urban, 2018). Therefore, the establishment of an overarching body responsible for food safety is urgently required, along the lines of the European Food Safety Authority or the Canadian Institute of Food Safety, as examples. Improving food safety surveillance and compliance will come at a cost, which according to our interviewees, is unlikely to be absorbed by consumers. Food prices and income are known to strongly affect consumers' food choices (Muhammad et al., 2017). Burger et al. (2015) reported that the lowest quartile of South African households was extremely price sensitive in respect to food choices, especially meat, whilst van Wyk and Dlamini (2018) showed a 1% increase in food prices in South Africa would reduce household welfare by 21.3%, with the greatest impact on household food security of the poor. Underinvestment in food safety and foodborne diseases surveillance is often due to an underestimation of the burden (Grace, 2015). The burden and potential benefits of interventions are best appreciated through a whole-system or One Health lens, which spotlights the links between animal health, productivity and food safety, with environmental sustainability and ecosystem health, and with human health and nutrition (Häsler et al., 2017; Garcia et al., 2020). Policymakers should therefore review the role of both public and private actors in food safety, with the costs associated with improving food safety being positioned alongside public healthcare savings, nutritional benefits, and the cost of reputation loss for private enterprises.

Public-private partnerships (PPP) offer an opportunity to help address the disparities apparent on many levels within the broiler system. They are defined as "a long-term contract between a private party and a government agency, for providing a public asset or service, in which the private party bears significant risk and management responsibility" (World Bank, 2014). South Africa has a strong track record of using PPP, with examples in health, energy, water and waste, and often linked to government's BEE policies (Arimoro, 2018). However, PPP should go beyond the simple procurement or transactional level, and move toward collaborative and transformative models, which involve a joint commitment from all parties to deliver mutually agreed policies, and develop sustainable capacity to deliver durable solutions with business returns (Galiere et al., 2019). Such partnerships could be used to initiate steps toward rebuilding public-private trust, and achieving win-win outcomes (Roehrich et al., 2014).

A topic that interviewees perceived less relevant, yet remains key to reaching SDG 2 targets, was the industry's impact on the environment. A more complete understanding of broiler meat's environmental impact can be gained through a product lifecycle analysis, which considers all elements from farm inputs through to consumer's plate (ISO, 2006). Such an analysis of intensively produced broiler meat showed the environmental impact of feed as the most critical (Skunca et al., 2018). In the South African context, the environmental impact of both imported and locally produced feed should be considered when seeking areas for improvement or mitigation. Broiler waste (and its use as manure) causes ammonia, methane and nitrous oxide emissions, soil acidification, and potential contamination of water sources with phosphates and nitrates through runoff (Belloir et al., 2017). The health implications of nitrate pollution of drinking water through agriculture, is receiving increasing attention of late (Ward et al., 2018). Policy to further mitigate environmental impacts must consider any additional costs to actors in the system, in the light of the already tight margins of producers. With the exception of consumers within the highest income bracket, most South Africans, the bulk of whom prioritized price even before food safety, would similarly be unlikely to pay more for a product's environmental sustainability credentials. In the absence of substantial consumer driven demand for environmental sustainability, government incentives and support will be key in polices aimed at hitting the environmental targets of SDG 2.

The role of low-cost broiler meat and products in obesity was not mentioned by participants during the interviews, with the exception of the nutritionist. Participants instead focussed on broiler meat being an affordable source of animal protein and micronutrients. Although it is also considered healthier than red meat, in terms of non-communicable diseases, the preparation method, and the portion size is crucial when considering its nutritional impact (Schönfeldt et al., 2014). "Big Food" i.e., food distributed through large-scale food companies and retailers, is dominant in the South African food environment (especially for broiler meat) (Igumbor et al., 2012). Whilst a discussion of the drivers of food choice is beyond the scope of this work, Big Food is implicated in driving unhealthy eating habits and obesity through increasing the marketing, affordability and accessibility of more processed and "junk" food, creating a shift from traditional to modern diets (Igumbor et al., 2012). National food consumption data in South Africa requires updating, to help unravel the link between broiler meat and the extremes of over and under-nutrition, before developing policy to address this complex issue. The dominance of Big Food may provide a leverage opportunity to employ wide-reaching change for the better.

Complex food system challenges require a whole system approach, with wide multi-stakeholder representation (Zhang et al., 2018). The latter improves stakeholders' understanding of the system, and their appreciation of others' perspectives, facilitating a shift in their mental models (Ruegg et al., 2018; Zhang et

al., 2018). Our research was restricted by not all invitees being willing to participate (not uncommon for high level actors within large institutions), but despite this, our sample-size exceeded that deemed appropriate in the literature (Guest et al., 2016). Nevertheless, by using a wider food system lens in our approach, our results spotlight the interconnectedness of elements within the broiler system, and how changes would bring about trade-offs and implications elsewhere, with particular reference to balancing imports and local industry growth to maintain food security, and to who bears to the cost of improving food safety and environmental impact mitigation. Future work should aim to be more inclusive, transdisciplinary and participatory when seeking to engage with stakeholders, which could form a foundation on which to begin building trust, a pre-requisite for finding mutually agreeable solutions and engaging in PPP (Roehrich et al., 2014).

Within the diversity of opinions and perspective of participants, it was clear that the commercial broiler system will have a key role to play in reaching SDG 2 targets, given the relative affordability, popularity and increasing consumption rate of broiler meat compared to other meat. In addition, a consistent message from participants was one that called for policy change and refinement; the need for policy to be more pragmatic, and to be backed up sufficient implementation capacity, with even-handed enforcement. Much work remains to address inequalities and mistrust between stakeholders in the broiler system in South Africa, before it can move toward ending malnutrition and ensuring access for all to safe, healthy, nutritious, and sustainably produced food, all year round.

CONCLUSIONS

Our research explored the commercial broiler system as part of the wider food system in South Africa, and analyzed the diverse perspectives of industry stakeholders around topics of consumers' health and nutrition, food safety, and the environment. We identified strong disparate opinions on the role of imports and of local production in meeting the growing demand for broiler meat. We outlined the governance, and policy implications and associated challenges, many of which share commonality with rapidly developing commercial broiler systems elsewhere (e.g., India and Pakistan). Our approach also provides a reference for researchers exploring comparable broiler systems that are experiencing substantial change and similar policy challenges.

A lack of integrated, pragmatic policy, and the capacity to enforce it systemically, echoed throughout this study. Siloed government departments, protection of private business interests, recent political history, and related elements of tension and mistrust, were identified as the main stumbling blocks to change at the level of key system actors. These issues were driven by divergent narratives on imports, perceived bias in enforcing regulations, and a power imbalance between private and public sectors. At the consumer level, their price sensitivity was a barrier to considering issues of quality, safety or socio-environmental externalities of food. Equally, interviewees implied that middle and low-income consumers' price driven choices, and affordability barriers for the lowest income groups, meant a low willingness to pay for higher food safety assurances on broiler meat, and consumers potentially opting for cheaper processed meat products or non-animal sourced foods as alternatives. Although the role of broiler meat in the triple burden of malnutrition received little attention, it needs to be better understood, given the rising consumption levels. Whilst the industry recognized the threat of climate change on feed and profitability, less attention was given to the impact of the broiler system on the environment, both locally and internationally, and this needs to be examined further.

This study highlighted the complexity of the commercial broiler system of South Africa, and revealed the policy and governance challenges within it. We propose the removal of relevant interdepartmental walls in government, and a clearer definition of public roles and responsibilities within the system. Future policy focused research should aim to be participatory and inclusive of stakeholders from across the system. This will allow a greater appreciation of different stakeholders' perspectives, and facilitate the process of trust building, which is a prerequisite to move toward building integrated, inclusive and mutually agreed policies. Once such policies have been developed, collaborative and transformative models of PPP can build the capacity for the delivery of sustainable solutions.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Royal Veterinary College's (University of London) Social Science Ethical Review Board (URN SR2018-1624). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

KQ, SC, and BH worked on the methodology and validation. KQ and SC conducted the investigation and data curation and analysis. KQ wrote the original draft. BH supervised the research. All authors were involved in the conceptualization of the research and contributed to reviewing and editing subsequent drafts.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2021.650469/full#supplementary-material

REFERENCES

Arimoro, A. (2018). An appraisal of the framework for public private partnership in South Africa. *Eur. Procurement Public Priv. Partner. Law Rev.* 13, 214–228. doi: 10.21552/epppl/2018/3/8

Banson, K., Muthusamy, G., and Kondo, E. (2015). The import substituted poultry industry; evidence from Ghana. *Int. J. Agric. For.* 5, 166–175. doi: 10.5923/j.ijaf.20150502.11

Belloir, P., Meda, B., Lambert, W., Corrent, E., Juin, H., Lessire, M., et al. (2017). Reducing the CP content in broiler feeds: impact on animal performance, meat quality and nitrogen utilization. *Animal* 11, 1881–1889. doi: 10.1017/S1751731117000660

Béné, C., Oosterveer, P., Lamotte, L., Brouwer, I. D., de Haan, S., Prager, S. D., et al. (2019). When food systems meet sustainability – current narratives and implications for actions. *World Dev.* 1, 116–130. doi: 10.1016/j.worlddev.2018.08.011

BFAP (2016). *Evaluating the Competitiveness of the South African Broiler Value Chain*. The Bureau for Food and Agricultural Policy (BFAP) and National Agricultural Marketing Council (NAMC).

Boatemaa, S., Barney, M., Drimie, S., Harper, J., Korsten, L., and Pereira, L. (2019). Awakening from the listeriosis crisis: food safety challenges, practices and governance in the food retail sector in South Africa. *Food Control* 104, 333–342. doi: 10.1016/j.foodcont.2019.05.009

Boatemaa, S., Drimie, S., and Pereira, L. (2018). Addressing food and nutrition security in South Africa: a review of policy responses since 2002. *Afr. J. Agric. Resour. Econ.* 13, 264–279. doi: 10.22004/ag.econ.284996

Bosire, E. N., Cohen, E., Erzse, A., Goldstein, S. J., Hofman, K. J., and Norris, S. A. (2020). 'I'd say I'm fat, I'm not obese': obesity normalisation in urban-poor South Africa. *Public Health Nutr.* 23, 1515–1526. doi: 10.1017/S1368980019004440

Bouvard, V., Loomis, D., Guyton, K. Z., Grosse, Y., El Ghissassi, F., Benbrahim-Tallaa, L., et al. (2015). Carcinogenicity of consumption of red and processed meat. *Lancet Oncol.* 16, 1599–1600. doi: 10.1016/S1470-2045(15)00444-1

Burger, R., Coetzee, W., Kreuser, F., and Rankin, N. (2015). *Income and Price Elasticities of Demand in South Africa*. Helsinki: UNU-WIDER.

Conway, D., van Garderen, E. A., Deryng, D., Dorling, S., Krueger, T., Landman, W., et al. (2015). Climate and southern Africa's water–energy–food nexus. *Nat. Clim. Chang.* 5, 837–846. doi: 10.1038/nclimate2735

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 4th Aufl. Lincoln: Sage, University of Nebraska.

DAFF (2017). *A Profile of the South African Broiler Market Value Chain*. Department of Agriculture, Forestry and Fisheries, Arcadia.

DAFF (2018). *Economic Review of South African Agriculture 2017/18*. Pretoria: Department of Agriculture, Forestry and Fisheries, Directorate: Statistics and Economic Analysis, Republic of South Africa.

DEA (1998). *National Environmental Management Act, Act 107, (1998)*. Cape Town: Department of Environmental Affairs.

DEA (2014). *Environmental Impact Assessment Regulations, 2014 (Government Gazette 38282)*. Cape Town: Department of Environmental Affairs.

Dieye, P. N., Duteurtre, G., Cuzon, J.-.R., and Dia, D. (2007). Livestock, liberalization and trade negotiations in West Africa. *Outlook Agric.* 36, 93–99. doi: 10.5367/000000007781159985

Drimie, S., and Ruysenaar, S. (2010). The integrated food security strategy of South Africa: an institutional analysis. *Agrekon* 49, 316–337. doi: 10.1080/03031853.2010.503377

DSEA (2016). *Abstract of Agricultural Statistics, Directorate Statistics and Economic Analysis*. Department of Agriculture, Forestry and Fisheries, Pretoria.

FAO, IFAD, UNICEF, WFP and WHO (2020). *The State of Food Security and Nutrition in the World 2020. Transforming Food Systems for Affordable Healthy Diets*. Rome: FAO.

Fermet-Quinet, E., León, E. A., and Stratton, J. (2014). *PVS Gap Analysis Mission Report, South Africa Paris*. France: World Orgainisation for Animal Health.

Fourie, W. (2018). Aligning South Africa's National Development Plan with the 2030 agenda's sustainable development goals: guidelines from the policy coherence for development movement. *Sustain. Dev.* 26, 765–771. doi: 10.1002/sd.1745

GAIN (2015). *The South African Meat Market*. Global Agricultural Information Network, United States Department of Agricuture; Foreign Agricultural Service.

Gale, N. K., Heath, G., Cameron, E., Rashid, S., and Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Med. Res. Methodol.* 13:117. doi: 10.1186/1471-2288-13-117

Galiere, M., Peyre, M., Munoz, F., Poupaud, M., Dehove, A., Roger, F., et al. (2019). Typological analysis of public-private partnerships in the veterinary domain. *PLoS ONE* 14:e0224079. doi: 10.1371/journal.pone.0224079

Garcia, S. N., Osburn, B. I., and Jay-Russell, M. T. (2020). One health for food safety, food security, and sustainable food production. *Front. Sustain. Food Syst.* 4:1. doi: 10.3389/fsufs.2020.00001

Geddes, A., Parker, C., and Scott, S. (2017). When the snowball fails to roll and the use of 'horizontal' networking in qualitative social research. *Int. J. Soc. Res. Methodol.* 21, 347–358. doi: 10.1080/13645579.2017.1406219

Global Panel (2020). *Future Food Systems: For People, Our Planet, and Prosperity*. London: Global Panel on Agriculture and Food Systems for Nutrition.

Godfray, H. C. J., Aveyard, P., Garnett, T., Hall, J. W., Key, T. J., Lorimer, J., et al. (2018). Meat consumption, health, the environment. *Science* 361:eaam5324. doi: 10.1126/science.aam5324

Goncalves-Tenorio, A., Silva, B. N., Rodrigues, V., Cadavez, V., and Gonzales-Barron, U. (2018). Prevalence of pathogens in poultry meat: a meta-analysis of european published surveys. *Foods* 7:69. doi: 10.3390/foods7050069

Grace, D. (2015). Food safety in low and middle income countries. *Int. J. Environ. Res. Public Health* 12, 10490–10507. doi: 10.3390/ijerph120910490

Greenberg, S., Thow, A. M., and Hara, M. (2017). Trade, food and nutrition security in South Africa: The cases of sugar and poultry. *Working Paper 46*. Cape Town: Institute for Poverty, Land and Agrarian Studies (PLAAS), University of the Western Cape.

Guest, G., Bunce, A., and Johnson, L. (2016). How many interviews are enough? *Field Methods* 18, 59–82. doi: 10.1177/1525822X05279903

Hall, R. (2004). A Political economy of land reform in South Africa. *Rev. Afr. Polit. Econ.* 31, 213–227. doi: 10.1080/0305624042000262257

Häsler, B., Dominguez-Salas, P., Fornace, K., Garza, M., Grace, D., and Rushton, J. (2017). Where food safety meets nutrition outcomes in livestock and fish value chains: a conceptual approach. *Food Secur.* 9, 1001–1017. doi: 10.1007/s12571-017-0710-2

Hendriks, S. (2014). Food security in South Africa: status quo and policy imperatives. *Agrekon* 53, 1–24. doi: 10.1080/03031853.2014.915468

Heredia, N., and Garcia, S. (2018). Animals as sources of food-borne pathogens: a review. *Anim. Nutr.* 4, 250–255. doi: 10.1016/j.aninu.2018.04.006

Igumbor, E. U., Sanders, D., Puoane, T. R., Tsolekile, L., Schwarz, C., Purdy, C., et al. (2012). "Big Food," the consumer food environment, health, and the policy response in South Africa. *PLoS Med.* 9:e1001253. doi: 10.1371/journal.pmed.1001253

ISO (2006). *ISO 14040, 2006 Environmental Management — Life Cycle Assessment — Principles and Framework*. Available online at: https://www.iso.org/standard/37456.html (accessed August 14, 2020).

Louw, M., Davids, T., and Scheltema, N. (2017). Broiler production in South Africa: is there space for smallholders in the commercial chicken coup? *Dev. South. Afr.* 34, 564–574. doi: 10.1080/0376835X.2017.1335593

Lund, B. M., and O'Brien, S. J. (2011). The occurrence and prevention of foodborne disease in vulnerable people. *Foodborne Pathog. Dis.* 8, 961–973. doi: 10.1089/fpd.2011.0860

Lundeen, E. A., Norris, S. A., Adair, L. S., Richter, L. M., and Stein, A. D. (2016). Sex differences in obesity incidence: 20-year prospective cohort in South Africa. *Pediatr. Obes.* 11, 75–80. doi: 10.1111/ijpo.12039

McHiza, Z. J., Steyn, N. P., Hill, J., Kruger, A., Schonfeldt, H., Nel, J., et al. (2015). A review of dietary surveys in the adult South African Population from 2000 to 2015. *Nutrients* 7, 8227–8250. doi: 10.3390/nu7095389

Muhammad, A., D'Souza, A., Meade, B., Micha, R., and Mozaffarian, D. (2017). How income and food prices influence global dietary intakes by age and sex: evidence from 164 countries. *BMJ Glob. Health* 2:e000184. doi: 10.1136/bmjgh-2016-000184

Naidoo, S. (2012). The South African national health insurance: a revolution in health-care delivery! *J. Public Health* 34, 149–150. doi: 10.1093/pubmed/fds008

Ncube, P. (2018). The southern African poultry value chain: corporate strategies, investments and agro-industrial policies. *Dev. South. Afr.* 35, 369–387. doi: 10.1080/0376835X.2018.1426446

NDoH (2016). *South Africa Demographic and Health Survey; Key indicators*. South African Medical Research Council (SAMRC) and ICF Stats SA, Pretoria: Rockville, MD.

Nicholson, C. F., Kopainsky, B., Stephens, E. C., Parsons, D., Jones AD, Garrett, J., and Phillips, E. L. (2020). Conceptual frameworks linking agriculture and food security. *Nature Food* 1, 541–551 doi: 10.1038/s43016-020-00142-3

Nwosu, C. O., and Oyenubi, A. (2021). Income-related Health inequalities associated the coronavirus pandemic in South Africa: A decomposition analysis. *Int. J. Equity Health*. 20:21 doi: 10.1186/s12939-020-01361-7

O'Laughlin, B., Bernstein, H., Cousins, B., and Peters, P. E. (2013). Introduction: agrarian change, rural poverty and land reform in South Africa since 1994. *J. Agr. Change* 13, 1–15. doi: 10.1111/joac.12010

Parkinson, S., Eatough, V., Holmes, J., Stapley, E., and Midgley, N. (2016). Framework analysis: a worked example of a study exploring young people's experiences of depression. *Qual. Res. Psychol.* 13, 109–129. doi: 10.1080/14780887.2015.1119228

Patton, Q. M. (1999). Enhancing the quality and credibility of qualitative analysis. *Health Serv. Res.* 34(Pt. 2), 1189–1208.

Perez-Escamilla, R., Cunningham, K., and Moran, V. H. (2020). COVID-19 and maternal and child food and nutrition insecurity: a complex syndemic. *Matern. Child Nutr.* 16:e13036. doi: 10.1111/mcn.13036

Pope, C., Ziebland, S., and Mays, N. (2000). Analysing quali data. *BMJ* 320:114. doi: 10.1136/bmj.320.7227.114

Qu, S. Q., and Dumay, J. (2011). The qualitative research interview. *Qual. Res. Account. Manage.* 8, 238–264. doi: 10.1108/11766091111162070

Queenan, K., Sobratee, N., Davids, R., Mabhaudhi, T., Chimonyo, M., Slotow, R., et al. (2020). A systems analysis and conceptual system dynamics model of the livestock-derived food system in South Africa: a tool for policy guidance. *J. Agric. Food Syst. Commun. Dev*. 9, 275–298. doi: 10.5304/jafscd.2020.094.021

Rabionet, E. S. (2011). How I learned to design and conduct semi-structured interviews: an ongoing and continuous journey. *Qual. Rep.* 16, 563–566. doi: 10.46743/2160-3715/2009.2850

Ritchie, H., and Roser, M. (2018). *Meat and Seafood Production and Consumption*. Available online at: https://ourworldindata.org/meat-and-seafood-production-consumption. (Accessed October 05, 2018).

Ritchie, H., and Roser, M. (2019). *Meat and Dairy Production.* Available online at: https://ourworldindata.org/meat-production#meat-production-by-type (accessed March 25, 2020).

Ritchie, J., and Spencer, L. (1994). "Qualitative data analysis for applied policy research," in *Analysing Qualitative Data*, eds A. Bryman and R. G. Burgess (London: Routledge), 173–194.

Roehrich, J. K., Lewis, M. A., and George, G. (2014). Are public-private partnerships a healthy option? A systematic literature review. *Soc. Sci. Med.* 113, 110–119. doi: 10.1016/j.socscimed.2014.03.037

Ruegg, S. R., Nielsen, L. R., Buttigieg, S. C., Santa, M., and Aragrande, M., Canali M, Ehlinger, T., et al. (2018). A systems approach to evaluate one health initiatives. *Front. Vet. Sci.* 5:23. doi: 10.3389/fvets.2018.00023

SAPA (2018a). *Broiler Industry Production Report: September 2018.* South African Poultry *Association*.

SAPA (2018b). *South African Poultry Association: 2018 Industry Profile*. South African Poultry Association.

SAPA (2018c). *Key Market Signals in the Broiler Industry: For the fourth quarter of 2018*. South African Poultry Association.

SAPA (2019). *Annual Report 2019.* South African Poultry Association.

Schönfeldt, H. C., Pretorius, B., and Hall, N. (2014). The impact of animal source food products on human nutrition and health. *S. Afr. J. Anim. Sci.* 43:394. doi: 10.4314/sajas.v43i3.11

Shonhiwa, A. M., Ntshoe, G., Essel, V., Thomas, J., and McCarthy, K. (2018). *A Review of Foodborne Disease Outbreaks Reported to the Outbreak Response Unit, National Institute for Comminicable Diseases. South Africa, 2013 – 2017 in NICD Bulletin*: NICD.

Skunca, D., Tomasevic, I., Nastasijevic, I., Tomovic, V., and Djekic, I. (2018). Life cycle assessment of the chicken meat chain. *J. Clean. Prod.* 184, 440–450. doi: 10.1016/j.jclepro.2018.02.274

STATS SA (2018). *Mid-year Population Estimates, July 2018: Statistics South Africa*. Pretoria.

Termeer, C. J. A. M., Drimie, S., Ingram, J., Pereira, L., and Whittingham, M. J. (2018). A diagnostic framework for food system governance arrangements: the case of South Africa. *NJAS Wageningen J. Life Sci.* 84, 85–93. doi: 10.1016/j.njas.2017.08.001

Thevasegayam, S., Dieuzy-Labaye, I., and Tagliaro, E. (2017). Public-private partnerships: expectations of private sector partners for international animal health and livestock sector development programmes. *Paper Presented at the 85th General Session, World Assembly*. (Paris).

Thomas, J., Govender, N., McCarthy, K. M., Erasmus, L. K., and Doyle, T. J., Allam M, Ismail, A., et al. (2020). Outbreak of Listeriosis in South Africa associated with processed meat. *N. Engl. J. Med* 382, 632–643. doi: 10.1056/NEJMoa1907462

Tihanyi, K., and Robinson, K. (2011). "Chapter 1-Setting the scene," in *Case Studies of Emerging Farmers and Agribusinesses in South Africa*, eds E. Mabaya, K. Tihanyi, M. Karaan, and J. van Rooyen (Stellenbosch: Sun Press), 1–25.

Trading Economics (2020). *South Africa - Land Area*. Available online at: https://tradingeconomics.com/south-africa/land-area-sq-km-wb-data.html (accessed May 18, 2020).

Turner, W. D. (2010). Qualitative interview design: a practical guide for novice investigators. *Qual. Rep.* 15, 754–760. doi: 10.46743/2160-3715/2010.1178

Urban, M. C. (2018). *Abandoning Silos: How Innovatove Governments are Collaborating Horizontally to Solve Complex Problems*. Mowat Research. Toronto, ON: Mowat Centre, Munk School of Global Affairs and Public Policy.

van Berkum, S., Dengerink, J., and Ruben, R. (2018). *The Food Systems Approach: Sustainable Solutions for a Sufficient Supply of Healthy Food*. Wageningen: Wageningen Economic Research.

van Wyk, R. B., and Dlamini, C. S. (2018). The impact of food prices on the welfare of households in South Africa. *South Afr. J. Econ. Manage. Sci.* 21:a1979. doi: 10.4102/sajems.v21i1.1979

Ward, D. J., Furber, C., Tierney, S., and Swallow, V. (2013). Using framework analysis in nursing research: a worked example. *J. Adv. Nurs.* 69, 2423–2431. doi: 10.1111/jan.12127

Ward, M. H., Jones, R. R., Brender, J. D., de Kok, T. M., Weyer, P. J., Nolan, B. T., et al. (2018). Drinking water nitrate and human health: an updated review. *Int. J. Environ. Res. Public Health* 15:1557. doi: 10.3390/ijerph15071557

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, A., et al. (2019). Food in the anthropocene: the EAT–lancet Commission on healthy diets from sustainable food systems. *Lancet* 393, 447–492. doi: 10.1016/S0140-6736(18)31788-4

World Bank (2014). *Public-Private Partnerships: Reference Guide, Version 2.0*. Washington, DC: World Bank.

World Bank (2018). *Overcoming Poverty and Inequality in South Africa: An Assessment of Drivers, Constraints and Opportunities.* The World Bank, Washington, DC.

Zhang, W., Gowdy, J., Bassi, A. M., Santamaria, M., DeClerck, F., Adegboyega, A., et al. (2018). Systems Thinking: An Approach for Understanding 'Eco-Agri-Food Systems'. TEEB for Agriculture and Food: Scientific and Economic Foundations; United Nations Environment, Geneva.

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REVIEW
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The Paths to Connectedness: A Review of the Antecedents of Connectedness to Nature

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Although many philosophers and environmental psychologists agree that progress toward a more ecologically conscious society depends upon individuals developing a sense of connectedness to nature, such agreement is of limited use if we do not understand how connectedness forms. The purpose of this review is to delineate the state of the psychological literature concerning the antecedents of connectedness to nature. The literature review is organized into three main sections: (1) situational contexts that influence connectedness; (2) individual difference predictors, such as demographic group membership, personality, or beliefs; and (3) internal psychological states that may explain psychological processes that result in connectedness. Major critiques of the extant literature and future directions are presented in a discussion following the body of the review. The primary implications highlighted by the review are a greater need for theories delineating the formation of connectedness, a greater focus on process, and increased differentiation between similar antecedents of connectedness.

Keywords: connectedness to nature, contact with nature, self, antecedents, literature review

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INTRODUCTION

Philosophers, environmentalists, and psychologists alike contend that a critical step in the progression toward a more environmentally responsible society is coming to include nature within our sphere of concern. That is, people must make nature a part of what or who they deem important enough to be deserving of concern and protection (Leopold, 1949; Naess, 1987; Stern et al., 1999; Schultz, 2002; Crimston et al., 2016). For Leopold (1949), this meant including nature in our ethical frameworks, like we would a traditional community member. Naess (1987), in particular, goes further by noting the value of including nature in our self, and our self in nature, a view notably consistent with that adopted by psychologists (e.g., Schultz, 2002). Supporting the contentions of philosophers and psychologists, individuals who feel more connected to nature—that is, who include nature in their sense of self—are more pro-environmentally disposed (e.g., Davis et al., 2011) and tend to have better psychological wellbeing (e.g., Mayer et al., 2009). Thus, connectedness to nature is of particular interest because it may simultaneously promote the health of both the planet and people.

The purpose of this review is to delineate the state of the psychological literature concerning the antecedents of connectedness to nature in hopes of moving the field toward the development of theory. Although philosophers and environmental psychologists agree upon the importance of connectedness, such agreement is of limited use if we do not understand how a sense of

connectedness forms and, consequently, can be fostered. Thus, a call for increased connectedness to nature begs the question of how this sense of connection might develop. We first define connectedness to nature. Then, we describe the literature review and findings. Last, we consider implications of the reviewed findings for areas future research.

Definitions of Connectedness to Nature

Definitions of connectedness to nature (connectedness hereafter) found in the psychological literature emphasize a merging of self and nature (Schultz, 2002) and a sense of oneness or unity with nature (Mayer and Frantz, 2004). Both the merging of self and nature and the sense of oneness align with individuals' explanation of what connectedness means to them (Unsworth et al., 2016). These two points of emphasis are also consistent with viewing connectedness as a form of self-transcendence (Lengieza et al., 2021). Specifically, self-transcendence is characterized by "decreased salience of the self, accompanied by a softening or complete dissolution of the conceptual boundaries between self and others, involving a sense of oneness with others and one's surroundings" (Lengieza et al., 2021, p. 5; see also Yaden et al., 2017). Given these considerations, we define connectedness as psychological joining of nature and the self which manifests as a sense of oneness with nature.[1]

LITERATURE REVIEW

The purpose of the review is to identify the general state of the psychological literature on the causes of connectedness to identify the key concepts that predict and help explain the development of connectedness and provide future directions for research. While thorough, the review is not meant to be exhaustive but instead is meant to capture the most prominent trends in the psychological literature on connectedness to nature.

Method

First, a search of peer-reviewed empirical articles in PsychINFO and PsychArticles, conducted *via* ProQuest was used to focus on empirical studies that would provide evidence of psychological predictors of connectedness. The search terms used were: "connectedness," "connection to nature," "connectedness with nature," "connection with nature," "nature relatedness," "nature connectedness," "environmental identity," "Inclusion of nature in the self," "Inclusion of nature in self," "nature connectivity," "connectivity to nature," "connectivity with nature," "disposition to connect with nature," "disposition to connect to nature," "emotional affinity to nature," "emotional affinity with nature," and "love and care for nature" appearing anywhere in the abstract up to and including the year 2019. These search terms were informed by the first author's experience with the literature and, more specifically, the constructs included in Tam (2013) paper investigating the overlap between constructs used to study connectedness. The breadth of search terms was selected to ensure that relevant articles were not blindly excluded from the review. The noted search terms returned 323 articles.

The first author read the abstracts of the 323 articles to determine which articles warranted further reading. First, papers that did not mention connectedness as an observed construct or made it clear that they measured environmental*ist* identity were excluded ($n = 170$) reducing the number of articles to 153. Second, articles were *pragmatically* excluded—based upon the abstract—based on treating connectedness as predictor, and not an outcome were excluded ($n = 68$), which reduced the number of articles to 85.[2] It is important to note that, since this step was motivated by pragmatism, sources that the first author had previously read and were already known to be relevant to the review but otherwise would have been excluded at this step were ultimately included in the narrowed pool referenced below. The articles from the narrowed pool ($N = 85$) were then read to determine the general themes in the literature. **Table 1** presents the sources included in the review and in which of the sections they appear. The table also notes the subthemes that are covered in detail in the qualitative review of these studies.

FINDINGS

The body of the review is organized according to the three emergent themes identified in the literature: (1) situational contexts associated with connectedness; (2) individual difference predictors, such as demographic group membership, personality, and beliefs; and (3) internal psychological states that may explain psychological processes that result in. Each section ends with a summary of the findings outlined in that section. After detailing findings from the review, in the discussion, we highlight gaps and future directions for the study of the antecedents of connectedness that emerge when considering the body of literature as a whole. **Table 2** presents the number of studies appearing in each section broken down by relevant attributes.

The situational contexts section outlines the ways in which contact with nature, in a variety of forms and doing various activities during contact, promote or suppress connectedness. The individual differences section touches on the influence that demographic characteristics, personality, and worldviews have on connectedness. The psychological states section details how connectedness is impacted by psychological states related to mindfulness, the self, and affect.

[1]This definition treats connectedness as distinct from what is most aptly referred to as environmental*ist* identity which instead focuses on whether one views themselves as a person who engages in various forms of pro-environmental behavior, or outright views themselves as an environmentalist (e.g., Kashima et al., 2014).

[2]The reason for this step was that many papers treating connectedness as a predictor include other variables as predictors within the same equation which taints our ability to draw conclusions about the association between the Y variable in the equation and connectedness to nature itself. The article pool was simply too large to allow us to read every single paper, therefore, we chose to exclude these papers since they had a high probability of being unusable for statistical reasons since this paper was focused on the antecedents of connectedness to nature.

TABLE 1 | Sources included in the review and the location of their appearances.

Citation by paper	Year	Study	Situational contexts			Individual differences			Psychological factors		
			Contact	Mediat.	Activ.	Demo.	Pers.	World.	Mindf.	Self	Affect
Ahn et al.	2016	1		X						X	
		2		X						X	
		3		X						X	
Aspy and Proeve	2017	1			X						
Barbaro and Pickett	2016	1							X		
		2							X		
Barton et al.	2016	1	X			X					
Beery	2013	1	X		X	X					
Braun and Dierkes	2017	1	X		X	X					
Brick and Lewis	2014	1					X	X			
Brown	2017	1	X			X		X			
Bruni and Schultz	2010	1	X			X		X			
		2	X			X		X			
		3	X		X	X		X			
Bruni et al.	2008	1	X			X					
Bruni et al.	2017	1			X						
		2	X								
		3		X							
Burbach et al.	2012	1	X		X	X					
Capaldi et al.	2014	1				X					X
Capaldi et al.	2017	1						X			X
		2						X			X
Cheng and Monroe	2012	1	X					X			
Cho and Lee	2018	1			X						
Clayton et al.	2011	1	X		X			X			
Crawford et al.	2017	1			X	X		X			X
Crimston et al.	2016	3						X			
Davis and Stroink	2016a	1				X		X			
Davis and Stroink	2016b	1				X		X		X	
Davis et al.	2011	1						X			
DiFabio and Bucci	2016	1					X	X			
Di Fabio and Kenny	2018	1					X	X			
Diessner et al.	2018	1				X		X			
Dopko et al.	2019	1			X						X
Dopko et al.	2014	1		X							X
		2		X							
Duffy and Verges	2010	1	X					X			
Dutcher et al.	2007	1				X		X			
Ernst and Theimer	2011	1			X						
Forstmann and Sagioglou	2017	1			X		X				
Frantz et al.	2005	1				X		X		X	
		2				X		X		X	
Hanley et al.	2017	1							X		
Hanley et al.	2016	1	X			X					
Hedlund-de Witt	2014	1						X			X
Hinds and Sparks	2009	1	X								X
Howell et al.	2011	1							X		X
		2							X		X
Hughes et al.	2019	1				X					
Johnson-Pynn et al.	2014	1			X						
Kals et al.	1999	1	X								
Lankenau	2018	1			X						
Larson et al.	2018	1	X			X					
Lee et al.	2015	1					X	X			
Lengieza and Swim	2021	1	X							X	
Lengieza et al.	2021	1			X						X
Liefländer et al.	2013	1				X					
		2			X	X					
Liu et al.	2019	3			X	X					

(Continued)

TABLE 1 | Continued

Citation by paper	Year	Study	Situational contexts			Individual differences			Psychological factors		
			Contact	Mediat.	Activ.	Demo.	Pers.	World.	Mindf.	Self	Affect
Lumber et al.	2017	1	X					X			
		2	X					X			
		3	X					X			
Lyons and Carhart-Harris	2018	1			X						
Mayer and Frantz	2004	1	X			X		X			
		2				X		X			
		3			X						
		4						X			
		5						X			
Mayer et al.	2009	1	X			X				X	X
		2	X	X		X				X	X
		3	X	X		X				X	X
Nisbet and Zelenski	2011	1	X								X
		2	X								X
Nisbet et al.	2019	1	X		X						X
Nisbet et al.	2009	1	X				X	X			
		2	X				X				
Nisbet et al.	2011	1									X
		2									X
		3									X
Nour et al.	2017	1			X	X	X	X		X	
Otto and Pensini	2017	1			X						
Passmore and Holder	2017	1			X						
Pensini et al.	2016	2	X			X					
Poon et al.	2015	1									X
		3									X
Richardson and Sheffield	2015	1							X	X	
		2					X		X	X	
		3		X					X	X	
Richardson et al.	2016	1	X								X
Rosa et al.	2018	1	X								
Sanguinetti	2014	1			X	X		X			
Schultz and Tabanico	2007	1						X			
		2	X					X			
		3	X			X					
		4	X			X					
		5	X								X
Schutte and Malouff	2018	1				X			X		
Scott	2010	1	X					X		X	
		2	X					X		X	
		3		X						X	
Sellmann and Bogner	2013	1			X			X			
Soliman et al.	2017	1		X							
Spendrup et al.	2016	1	X			X					
Swami et al.	2016	1	X			X				X	
Tam	2013	1					X	X			
		2	X								
Tam et al.	2013	2			X						
		3			X						
Unsworth et al.	2016	1				X			X		
		2	X		X	X			X		
Vess et al.	2012	1						X			
		2						X			
		3						X			
Walters et al.	2014	1	X			X					
Wang et al.	2019	1			X						
Wang et al.	2016	1			X						

(Continued)

TABLE 1 | Continued

Citation by paper	Year	Study	Situational contexts			Individual differences			Psychological factors		
			Contact	Mediat.	Activ.	Demo.	Pers.	World.	Mindf.	Self	Affect
Weinstein et al.	2009	2		X		X					
		3		X		X					
		4	X			X					
Wheaton et al.	2016	1	X								
Whitburn et al.	2019	1			X	X		X			
Wyles et al.	2019	1	X		X	X					
Yang et al.	2018	2									X
		3									X
Zelenski et al.	2015	1		X							
		3		X							
Zhang et al.	2014b	1				X	X	X			
		2				X		X		X	
Column totals			47	15	32	46	11	45	11	19	36

Situational Contexts That Influence Connectedness

Several of the known antecedents to connectedness can be broadly characterized as "situational contexts." These situational contexts can involve (a) experiences with nature that occur through different mediums, such as contact with actual nature and contact with virtual nature, and can involve (b) different activities, such as participating in environmental education programs (e.g., Liefländer et al., 2013) or meditation (e.g., Nisbet et al., 2019). Knowing what kinds of situational contexts tend to result in connectedness reveals where and when connectedness tends to flourish and where and when it tends to struggle. These insights can both help to select ideal contexts upon which to focus efforts to promote connectedness and help identify other perhaps not-so-obvious, but theoretically relevant, contexts that may also increase connectedness. In other words, the type of research reviewed in this section will help identify where (in which contexts) and when (during which activities) to target efforts to promote connectedness.

Experiences With Nature

One of the most studied predictors of connectedness is contact with nature. The mediums of contact that have been studied range from actual, first-hand contact, most of which is in the form of spending time out in nature (e.g., Mayer et al., 2009), to mediated contact, often in the form of viewing pictures (e.g., Richardson and Sheffield, 2015) or watching videos of nature (e.g., Soliman et al., 2017), but increasingly includes more immersive experiences provided by virtual reality (e.g., Ahn et al., 2016).

Actual Contact With Nature

Many studies converge on the value of studying contact as a predictor of connectedness, demonstrating that contact (e.g., Kals et al., 1999; Mayer and Frantz, 2004, S1; Schultz and Tabanico, 2007, S3–5; Nisbet et al., 2009; Beery, 2013; Tam, 2013; Braun and Dierkes, 2017; Lumber et al., 2017), in a variety of forms, improves connectedness—whether it be contact with nature through nature-based tourism (Burbach et al., 2012; Wheaton et al., 2016) wilderness expeditions (Barton et al., 2016; Richardson et al., 2016), or contact *via* walking in nature (Mayer et al., 2009; Nisbet and Zelenski, 2011; Nisbet et al., 2019). In addition to contact with relatively organic forms of nature, contact with contrived nature, such as zoos, can foster a sense of connectedness (e.g., Schultz and Tabanico, 2007; Bruni et al., 2008). There is also substantial evidence that living closer to nature (e.g., Cheng and Monroe, 2012), living in a rural environment (e.g., Hinds and Sparks, 2009; Harvey et al., 2016) and more frequent exposure to nature (e.g., Kals et al.,1999; Mayer and Frantz, 2004, S1; Schultz and Tabanico, 2007, S5; Hinds and Sparks, 2009; Nisbet et al., 2009; Scott, 2010, S1–2; Tam, 2013, S2; Pensini et al., 2016; Richardson et al., 2016; Swami et al., 2016; Larson et al., 2018; Rosa et al., 2018) are associated with higher levels of connectedness. Contact with nature can even be as subtle as exposure to plants in a lab space (Weinstein et al., 2009). There is also some evidence to suggest that literal contact with nature may facilitate connectedness: one study found that comfort level walking barefoot is associated with increased connectedness; however, the causal direction of this relationship remains subject to interpretation and in need of further research (Harvey et al., 2016). Ultimately, many studies investigating the effect of contact with actual nature on connectedness conclude that it has a positive effect.

Characteristics of the Situation. The characteristics of the situation—the presence of certain attributes (e.g., greenery, water, etc.) as well as other situational elements of the nature experience (e.g., weather, immersion, etc.)—appear to influence the effect of contact on connectedness. Higher-quality natural areas (i.e., protected areas) are more effective in promoting connectedness than are lower-quality natural areas (Wyles et al., 2019). Additionally, rural green spaces seem to result in more connectedness compared to coastal blue spaces (e.g., oceans; Wyles et al., 2019). The importance of different features of nature on one's sense of connectedness is consistent with research in biophilia which argues that

TABLE 2 | Counts of studies appearing in each section broken out by relevant attributes.

Section	Total	Measure						Gender composition[1]			Sample age		
		INS	CNS	NR	IAT	Combo	Other	≥55% W	Equal	≥55% M	Child	College	Other
Situational	84	18	20	9	9	14	13	46	20	7	15	36	32
Individual	72	10	29	8	6	9	10	44	19	5	10	30	32
Psychological	44	10	19	4	1	4	6	27	9	5	2	28	14

Total reflects the number of studies, not papers. Rows are not mutually exclusive; columns within an attribute category are. [1]*Some studies did not report their sample gender composition.*

people prefer environments that include features that improved human survival, including water (aka, the "blue effect"), landscapes that improve people's ability to see long distances (prospect) or hide from predators (refuge; Dosen and Ostwald, 2016). Additionally, more global factors such as weather and season may influence connectedness. As the reader might suspect, connectedness is lower in the winter compared to autumn and spring and lower on rainy days compared to non-rainy days (Duffy and Verges, 2010). It may also be the case that variation in intensity of contact influences whether or not studies find an effect. For example, individuals report feeling more connectedness with longer contact with nature (Wyles et al., 2019). Further, the effects of exposure to plants on connectedness depends upon participants level of immersion. Participants who were immersed in a nature condition felt greater connectedness, whereas in a non-nature condition, the opposite was true (Weinstein et al., 2009), which would suggest that being more absorbed in natural environments facilitates connectedness, whereas being absorbed by non-nature environments may diminish connectedness.

The sizeable body of studies identifying contact with nature as a predictor of connectedness notwithstanding, a few studies fail to find an effect of contact with nature on connectedness (e.g., Bruni and Schultz, 2010; Clayton et al., 2011; Unsworth et al., 2016, S2; Bruni et al., 2017, S2; Lumber et al., 2017; Lengieza and Swim, 2021). For the most part, the reason for these null findings is unclear. On the one hand, the lack of effect may be attributable to mundane limitations, such as self-selection (e.g., Unsworth et al., 2016). Yet, the lack of effect may be meaningful. For example, studies may be more likely to find an effect when using comparison conditions that are more distinct from each other, such as comparing walking outside to walking inside (Nisbet and Zelenski, 2011), whereas those that use more similar conditions (dense vs. sparse nature, Lengieza and Swim, 2021) may not be as likely to detect an effect. If such a comparison were made within a study, rather than across separate studies, it might more readily reveal theoretically valuable insights about what *type* of contact is necessary to promote connectedness; in the case of this example, perhaps all that is important is having participants walk outside.

Childhood Contact With Nature. The above research focused on adult experiences in nature; however, several studies have also looked at the importance of childhood contact with nature. Like the trend noted above, these often-retrospective studies generally conclude that childhood contact with nature is a determinant of connectedness (Hinds and Sparks, 2009; Cheng and Monroe, 2012; Beery, 2013; Tam, 2013; Pensini et al., 2016; Rosa et al., 2018). However, some studies suggest that the primary avenue through which childhood contact exerts its influence on connectedness is through its influence on subsequent adult contact with nature (Pensini et al., 2016; Rosa et al., 2018). Still, much more can be learned about contact across the lifespan. Contact may be more potent at different stages in one's life, perhaps being more

integral to the development of the self at early stages in one's life or being more impactful during transitional periods. What is more, some forms of contact might turn out to be more important than others at different periods of one's life.

Mediated Contact With Nature

Pictures and Videos as Contact With Nature. Like the evidence that actual, first-hand contact with nature results in increased connectedness, several studies conclude that mediated contact with nature increases connectedness. Studies suggest that viewing pictures of nature (e.g., Scott, 2010, S3; Richardson and Sheffield, 2015) or videos of nature (Mayer et al., 2009, S2–3; Zelenski et al., 2015, S3; Soliman et al., 2017) can lead to increased connectedness, though, as with exposure to actual nature such as plants, this may depend on immersion (e.g., Weinstein et al., 2009; but also see Soliman et al., 2017).[3] Though viewing nature in the form of videos and pictures has been identified as a predictor of connectedness, it is important to acknowledge that some studies report no effect of viewing pictures (Dopko et al., 2014, S1–2) or videos of nature (Zelenski et al., 2015, S1). Additionally, while pictures and videos of nature appear to promote connectedness, the effect of videos—and likely the effect of pictures as well—may fall short of spending time in actual nature (e.g., Mayer et al., 2009, S2–3).

Virtual Reality as Contact With Nature. Between full-fledged contact with actual nature and viewing videos or pictures of nature is exposure to nature *via* virtual reality (VR). Due to its infancy, a clear picture has yet to emerge from this line of research and there are not studies comparing VR to actual contact with nature. At present, however, two studies (i.e., Ahn et al., 2016, S1–2) demonstrate that VR is better than ordinary video. In contrast, two studies (i.e., Ahn et al., 2016, S3; Soliman et al., 2017) suggest that VR has no benefit (vs. video) and a third study with children suggests that levels of connectedness were no different before and after a virtual hike (Bruni et al., 2017, S3).

Infancy and ambiguity aside, the research on VR does point to one potentially valuable theoretical insight. Namely that one of the mechanisms through which VR may have its influence on connectedness is body transference (the perception of owning the body of the experienced avatar, something likely unique to VR; Ahn et al., 2016). This highlights that VR may operate through different mechanisms than other forms of contact with nature. Despite this interesting possibility, ultimately, the only conclusion to be drawn from the literature on VR at present is that we simply do not know whether VR consistently enhances connectedness.

[3]The discrepancy between these two findings is likely because in one study immersion was manipulated *via* a mental imagery script (Weinstein et al., 2009), whereas in the other immersion was manipulated in the form of the technology used (e.g., video vs. VR; Soliman et al., 2017).

Summary and Critique of Research on Contact With Nature

Contact with nature, both as child (e.g., Tam, 2013) and as an adult, is perhaps the most well documented antecedent of connectedness; research has consistently shown that spending time around or in nature (e.g., Mayer et al., 2009), viewing nature (e.g., videos; Richardson and Sheffield, 2015), or otherwise experiencing nature (e.g., VR; Ahn et al., 2016) can foster a sense of connectedness. Despite this consistency, there are several areas for advancement.

As noted above, while much research has been dedicated to understanding *if* contact with nature can increase connectedness, little, if any, research has adequately addressed the question of when and why contact with nature might not increase connectedness—cases where contact with nature may simply not have an effect, cases where some feature of the experience inhibits the normally positive effect, or, most importantly, cases where something about the situation actively *diminishes* connectedness. There are several studies in which contact with nature did not seem to affect connectedness (e.g., Lumber et al., 2017). Yet, we do not have a framework to understand why some studies find these null effects of contact with nature (e.g., Lengieza and Swim, 2021) in order to determine which null effects are theoretically meaningful and which are most likely methodological flukes. For example, one study investigated whether nature sounds would increase connectedness but found no evidence to support this notion (Spendrup et al., 2016). It might be easy to explain these findings by assuming that the manipulation may not have been sufficiently salient to be effective. However, to illustrate, these findings might have important theoretical implications; it may be that at a certain point, some contact is superficial or insufficiently meaningful to alter our mental landscape or, perhaps more importantly for theory, it may potentially be that nature sounds are not an important part of the effect of contact on connectedness. Ultimately, more attention should be paid to understanding when contact does not increase connectedness to disentangle methodological limitations from theoretically meaningful boundary conditions.

Moreover, we do not have a framework to predict when contact with nature should be expected to diminish connectedness. That is, there is virtually no research about conditions when contact with nature results in decreased connectedness. For example, contact with the "bugs and mud" of nature might create an aversive experience that counteracts the usually positive effect of nature, perhaps because such exposure feels threatening (see research on negative affect in later sections). The two studies appearing in this review closest to answering such questions investigated the how connectedness is affected by exposure to natural disasters—by all accounts a less than positive encounter with nature (e.g., Walters et al., 2014; Brown, 2017). While the results paint opposing pictures—in one study exposure to natural disasters was associated with increased connectedness (Walters et al., 2014) and in the other the opposite was true (Brown, 2017)—the research questions themselves are emblematic of an interest in the negative side of contact with nature. Notably, this interest in the potential

negative side of contact with nature in terms of its effect on connectedness is similar to research on biophobia (Zhang et al., 2014a); however, research specifically focusing on the extent to which contact with aversive elements of nature promotes or undermines including nature in our sense of self or feeling a sense of oneness with nature is still needed.

Both a framework for explaining null effects and predictions about when contact with nature might have a negative effect are important for the development of theories describing the formation of connectedness. Future research can provide answers to these types of questions, and, subsequently, a better theoretical understanding of the different forms of contact with nature. However, it will require a shift from primarily looking for *whether* contact with nature promotes connectedness to explicitly examining instances in which contact with nature either does not promote connectedness or actively diminishes it as well as a focus on developing theories to explain null and/or negative effects.

Additionally, this section highlights that there are unanswered questions concerning comparisons between types of contact with nature. The presence of research showing that features of the environment matter when it comes to connectedness (e.g., Duffy and Verges, 2010; Wyles et al., 2019) indicates that contact with nature is likely a heterogenous category which may contribute to variability in the degree to which contact with different types of nature will affect connectedness (c.f., Duffy and Verges, 2010). If fostering connectedness is a goal, it is important to understand what features of the environment influence the degree to which contact with nature influences connectedness. Though the effects of actual first-hand contact with nature have received considerable attention more research is needed to know whether certain types of contact with actual nature have differential effects on connectedness—for example, blue spaces vs. rural green spaces or urban green spaces (c.f., Wyles et al., 2019). We also see few studies comparing videos of nature to actual nature (c.f., Mayer et al., 2009, S2–3) and none comparing VR and actual nature.

Last, despite research on contact with nature focusing on both adults and children, we do not know during which period of life contact with nature is *most* important. Although current evidence, noted above, suggests that adult contact is more important than childhood contact (e.g., Rosa et al., 2018), asking which type of contact—child or adult—begs the question of whether the distinction is meaningful.

In sum, research investigating the effects of contact with nature on connectedness should take the next steps and begin to explore (1) the heterogeneity of contact with nature (2) across the lifespan as well as begin focusing on (3) when—and subsequently why—contact with nature fails to promote, or actively suppresses, connectedness.

Activities

A handful of activities promote connectedness. These include activities where people are in direct contact with nature such as outdoor pastimes done for pleasure (e.g., Beery, 2013). Others include those which can potentially occur with only indirect exposure to nature, such as environmental educational programs (e.g., Liefländer et al., 2013). Yet others—including meditation (e.g., Aspy and Proeve, 2017) and the use of psychedelics (e.g., Nour et al., 2017)—can occur without any contact with nature at all.

Activities as More Than Contact With Nature

Activities that involve some degree of contact with nature—such as gardening (e.g., Beery, 2013; Sanguinetti, 2014), planting trees (e.g., Whitburn et al., 2019), walking dogs (Beery, 2013; Wyles et al., 2019), having picnics in nature, studying plants and animals (Beery, 2013) depicting nature artistically (Bruni et al., 2017), or receiving interpretation while touring nature parks (Burbach et al., 2012)—are positively associated with connectedness. For many of these activities it is unclear if the relations exist merely because these activities bring the individual into contact with nature. The alternative possibility is that the activities in some way enhance, or work independent of, the incidental contact with nature. Unfortunately, the extant literature does little to help dissociate these possibilities. One study, however, suggests that noticing nature increases connectedness and this effect seems to be above and beyond contact with nature; even though all participants spent equal time in nature, compared to business as usual, participants instructed to notice nature experienced increased connectedness (Passmore and Holder, 2017). This study, as an example, highlights the possibility that activities that *involve* contact with nature might be more than *just* contact with nature.

Just as not all contact with nature enhances connectedness, not all activities that involve contact with nature increase connectedness. Indeed, some activities, such as going to the beach and playing on a playground were not correlated with connectedness (Bruni and Schultz, 2010, S3) and other activities such as waterskiing and wake boarding (Beery, 2013), as well as exercising or playing in nature (Wyles et al., 2019) have been reported to be negatively correlated with connectedness. One possibility is that these activities involve treating nature as merely an arena in which to engage in the activity which could potentially result in nature becoming a non-salient background element of the experience or may even result in viewing nature from an entirely different perspective, where nature is objectified as a means to an end. Regardless, that these activities—which involve contact with nature—still seem to decrease connectedness suggests that activities can have an effect that is independent of the effect of contact with nature.

Environmental education is one commonly studied activity appearing in the connectedness literature. The majority of evidence appearing in this review suggests that participation in environmental education programs—which does not necessarily entail direct physical contact with nature (e.g., Lankenau, 2018)—is associated with increases in connectedness (Mayer and Frantz, 2004; Clayton et al., 2011; Liefländer et al., 2013; Sellmann and Bogner, 2013; Johnson-Pynn et al., 2014; Braun and Dierkes, 2017; Crawford et al., 2017; Otto and Pensini, 2017; Cho and Lee, 2018; Lankenau, 2018; Dopko et al., 2019). However, as with contact with nature,

there are exceptions, with some studies showing no effect of participation in environmental education (e.g., Ernst and Theimer, 2011). And, again, as with contact with nature, the reasons for these disparities are not well outlined in the literature. We do not know what kinds of programs—classroom vs. field, broad verses specific, etc.—are most likely to increase connectedness. There is some evidence, however, that longer programs are more effective at fostering connectedness (e.g., Johnson-Pynn et al., 2014; Braun and Dierkes, 2017). This effect may be attributable to several things such as more impactful content, more immersion, or some other element that differs between longer and shorter programs, but the exact reason for this effect requires further research.

Activities Without Contact With Nature

There are also other activities which can promote connectedness that have both the potential to influence how we think about nature and do not necessarily involve actual contact with nature.

Meditation. Meditation, which alters how we think (c.f., Lutz et al., 2007), is one activity that can increase connectedness without actually being in nature. Formally, the western understanding of meditation is that it is a set of practices generally designed to cultivate particular mental qualities through repeated induction of a mental state (Lutz et al., 2007). A commonly known form of meditation is mindfulness meditation; however, there are other kinds of meditation and meditative practices that do not focus on mindfulness.

Indeed, meditation (Beery, 2013; Unsworth et al., 2016; Nisbet et al., 2019) and yoga (Beery, 2013) may enhance the effects of spending time in nature on connectedness; individuals who spent time meditating in nature felt greater connectedness than individuals who just spent time in nature (Unsworth et al., 2016; Nisbet et al., 2019). The effect of meditation, however, might not require contact with nature. For example, compared to progressive muscle relaxation mindfulness meditation and loving kindness meditation have been associated with connectedness without any contact with nature at all (Aspy and Proeve, 2017). This suggests that meditative practices likely have effects entirely separate from contact with nature. Similar to meditation, Langerian (see Langer, 2000) mindful learning—which is explicitly aimed at fostering a more flexible and open mindset (Tang et al., 2017) as well as at shifting thinking patterns (Wang et al., 2016)—has been associated with higher levels of connectedness compared to other forms of learning (Wang et al., 2016, 2019).

Reflection. In the abstract, meditation has a great deal to do with reflective modes of thinking, and, as stated at the outset of this paragraph, focuses on altering how we think. Meditation, however, is not the only way of altering the way we think nor is it the only way of engaging in reflection. Importantly, there is evidence that the way in which we reflect upon past experiences (e.g., eudaimonic vs. hedonic reflection vs. mundane recollection) may influence our sense of connectedness (Lengieza et al., 2021). This suggests that other forms of reflective or contemplative practices beyond meditation may also impact our feelings of connectedness. Additionally, there are more explicit ways to alter how we think in the moment; in some cases, we can consciously choose to think about nature in a different light. For example, anthropomorphizing nature is associated with increased connectedness, an effect corroborated experimentally (Tam et al., 2013; Liu et al., 2019). Thus, there is a growing body of evidence that altering the way we think (e.g., meditation, mindful learning) and what we think about (e.g., the content of reflections, anthropomorphized nature) has the potential to increase connectedness.

Psychedelics. Last, recent research suggests that lifetime use of psychedelics—known for their capacity to alter ways of thinking about the world (Pollan, 2018)—is associated with increased connectedness (Forstmann and Sagioglou, 2017; Nour et al., 2017). Further, a preliminary experimental study—with an admittedly small sample—demonstrated that connectedness increased following a guided psilocybin therapy session (Lyons and Carhart-Harris, 2018). Yet, other common recreational drugs have either not shown an association with connectedness (e.g., Forstmann and Sagioglou, 2017), or have been negatively associated with connectedness (e.g., cocaine and alcohol use, Nour et al., 2017), suggesting that the positive effect is possibly specific to psychedelics.

Summary and Critique of Research on Activities

There is evidence that a variety of activities enhance connectedness. This includes activities such as gardening or planting trees (e.g., Whitburn et al., 2019), participating in environmental education (e.g., Lankenau, 2018), as well as meditating (e.g., Aspy and Proeve, 2017) and certain recreational drug use (Forstmann and Sagioglou, 2017).

In addition to replicating findings and experimentally confirming correlational relationships, future research should address the question, already noted in this section, of whether the activities that involve contact with nature reviewed in this section have an effect above and beyond the effect of having contact with nature and if so, why. While some of these activities can involve varying degrees of contact with nature, it seems unlikely that they can be boiled down to simply be about being in nature. Instead, it is likely that they enhance the contact with nature that happens to be involved in that activity. For example, gardening (c.f., Beery, 2013) also includes a component of taking care of or nurturing nature. Does this additional facet of caring for nature bring something new to the table or can it really be reduced to being in contact with nature? The need to understand whether nature-based activities have affects above and beyond contact with nature is also particularly apparent for activities that seem to suppress connectedness despite involving contact with nature such as exercising or playing in nature (Wyles et al., 2019) or waterskiing and wake boarding (Beery, 2013). Research is needed to

understand why these activities overshadow the effects of contact with nature.

Finally, there may be moderators of the relationship between various activities or experiences and connectedness. For example, age may moderate the effect of regular participation in outdoor activities and connectedness; regular participation—vs. non-regular participation—may only matter for older age groups (Beery, 2013). As illustrated in the next section, age is only one of many individual differences that may be worthy of consideration. Few studies, though, have investigated the possibility of factors that moderate the relationship between connectedness and the experiences and activities listed above. Therefore, research on the effect of various activities on connectedness should pay attention to potential moderators.

Individual Differences That Influence Connectedness

Several individual differences are associated with connectedness. Some of these individual differences, such as age, gender, race, and socioeconomic status, are generally considered demographics. Others fall neatly into the category of personality. The remaining individual differences considered here are best characterized as various types of worldviews. While less practically manipulable compared to other antecedents identified in this review, it is still valuable to consider the associations between individual differences and connectedness because they illuminate for whom certain experiences might differentially affect connectedness and they may also stimulate discussions about which psychological processes might be informative to study. More specifically, these individual differences may provide insight into the influence of social processes on connectedness, such as self-selection into contact with nature or socialization which encourages developing a connection to nature. Further, although individual differences do not lend themselves to direct intervention, it is probable that some of them moderate the influence of other antecedents of connectedness, making them of practical interest.

Demographics

Demographics, as antecedents to connectedness, are important to consider because they can provide boundary conditions for findings and can potentially provide insights into self-selection into experiences that would influence contact with nature, for example.

Age

Research on age suggests that our sense of connectedness might be influenced by where we are in our lifespan. Several studies with adults indicate that age is positively associated with connectedness (Burbach et al., 2012; Beery, 2013; Sanguinetti, 2014; Zhang et al., 2014b, S1–2; Harvey et al., 2016; Lumber et al., 2017; Nour et al., 2017; Diessner et al., 2018). However, a sizeable number of studies with adults suggest no relationship (Mayer and Frantz, 2004; Dutcher et al., 2007; Bruni et al., 2008; Weinstein et al., 2009, S1–3; Walters et al., 2014; Unsworth et al., 2016, S1–2; Swami et al., 2016; Brown, 2017; Whitburn et al., 2019). In contrast, studies examining school-aged children indicate that age has the opposite effect amongst children; younger children tend to feel greater connectedness than older children (Liefländer et al., 2013; Braun and Dierkes, 2017; Crawford et al., 2017; Larson et al., 2018). These opposing patterns suggest a curvilinear effect whereby children temporarily grow-out of their connection to nature, so to speak, until at some point they begin to reformulate their connection to nature. At present, this pattern has been supported by one study specifically seeking to sample a range of ages to address the question of age's impact on connectedness more comprehensively (Hughes et al., 2019).

Gender

When gender differences in connectedness are found, they appear to more often conclude that women feel greater connectedness than men (Schultz and Tabanico, 2007, S3–4; Mayer et al., 2009, S2; Bruni and Schultz, 2010, S3; Beery, 2013; Sanguinetti, 2014; Zhang et al., 2014b, S1; Pensini et al., 2016; Spendrup et al., 2016; Swami et al., 2016; Crawford et al., 2017; Nour et al., 2017; Hughes et al., 2019) than they report that men feel more connectedness than women (Larson et al., 2018; Wyles et al., 2019). However, a number of studies that provide information about the associations between gender and connectedness report no effect (Mayer and Frantz, 2004, S1–2; Frantz et al., 2005; Bruni et al., 2008; Mayer et al., 2009, S1 and S3; Weinstein et al., 2009, S1–3; Bruni and Schultz, 2010, S1–2; Duffy and Verges, 2010; Vess et al., 2012; Zhang et al., 2014b, S2; Barton et al., 2016; Davis and Stroink, 2016a,b; Harvey et al., 2016; Unsworth et al., 2016, S1–2; Lumber et al., 2017; Di Fabio and Kenny, 2018; Diessner et al., 2018; Liu et al., 2019; Whitburn et al., 2019). Additionally, there is no evidence that gender moderates any effects in any of the studies reporting on gender and connectedness (e.g., Mayer et al., 2009; Duffy and Verges, 2010; Vess et al., 2012; Capaldi et al., 2014). Thus, the conclusion to be drawn from the literature is that, if gender has an effect at all—a tenuous association at best—women may feel greater connectedness than men.

Other

There are three understudied demographics—education, race, and socioeconomic status—which may be worth further attention. Several studies have found that level of education does not have an effect on connectedness (Mayer and Frantz, 2004, S1; Dutcher et al., 2007; Beery, 2013; Walters et al., 2014; Nour et al., 2017; Whitburn et al., 2019); however, other studies have found higher education to be associated with lower connectedness (Sanguinetti, 2014; Brown, 2017). Similarly, a small number of studies have found no relationship between race and connectedness (Weinstein et al., 2009, S1–3; Whitburn et al., 2019), while one found that white participants report a sense of connectedness more so than non-white participants (Larson et al., 2018). And, again similarly, while studies have suggested no relationship between connectedness and socioeconomic status (Wyles et al., 2019) or income

(Mayer and Frantz, 2004; Dutcher et al., 2007; Beery, 2013; Walters et al., 2014), yearly income and home ownership have been associated with decreased connectedness (Whitburn et al., 2019). Thus, based solely on the literature appearing in this review, it would be premature to draw conclusions about the effect of level of education, race, and socioeconomic status on connectedness.

Personality

Certain facets of personality appear to exert an influence on connectedness. The most frequently reported relation is a positive association between openness to experience and connectedness (Nisbet et al., 2009; Tam, 2013; Brick and Lewis, 2014; Zhang et al., 2014b, S1; Lee et al., 2015; Richardson and Sheffield, 2015; Di Fabio and Bucci, 2016; Forstmann and Sagioglou, 2017; Nour et al., 2017). Additionally, openness is the only personality facet shown to correlate with connectedness when using observer reports of personality (Lee et al., 2015). There is also strong evidence that agreeableness (Nisbet et al., 2009; Tam, 2013; Brick and Lewis, 2014; Zhang et al., 2014b, S1; Di Fabio and Bucci, 2016) and conscientiousness (Nisbet et al., 2009; Tam, 2013; Brick and Lewis, 2014; Zhang et al., 2014b, S1; Di Fabio and Bucci, 2016; Forstmann and Sagioglou, 2017) are positively associated with connectedness. While the other facets of personality—specifically, humility (Brick and Lewis, 2014; Lee et al., 2015), emotionality (Tam, 2013; Brick and Lewis, 2014), extraversion (Nisbet et al., 2009, S1; Tam, 2013; Zhang et al., 2014b, S1) and (less) neuroticism (Zhang et al., 2014b, S1)—have shown positive correlations with connectedness, the evidence is not as overwhelming (i.e., only one or two studies showing significant associations per personality attribute).

Worldviews

Worldviews—which encompass beliefs, attitudes, orientations, and values (Clayton and Myers, 2015)—are associated with connectedness. While demographics and personality are determined at an early age and are largely immutable, worldviews develop over time and consequently have a greater degree of mutability. Therefore, worldviews may be additional targets for efforts to enhance connectedness. Research in this domain is important because, as noted in the preceding sections, it can help us identify potential moderators of other antecedents of connectedness. This type of research may also inform theoretical accounts of connectedness. For example, if connectedness consistently covaries with a particular class of constructs, such as those associated with self-transcendence, then we can more confidently conceptualize connectedness as a form of self-transcendence and make predictions based on that view.

Common Worldviews and Connectedness

As might be expected, people who hold more positive environmental beliefs feel greater connectedness (Mayer and Frantz, 2004, S1–2; Frantz et al., 2005; Nisbet et al., 2009, S1; Bruni and Schultz, 2010; Clayton et al., 2011, S1; Davis et al., 2011; Brick and Lewis, 2014; Lee et al., 2015; Davis and Stroink, 2016a,b; Whitburn et al., 2019). Additionally, higher levels of connectedness are found among individuals who tend to appreciate natural beauty (Zhang et al., 2014b, S1–2; Capaldi et al., 2017, S1–2; Lumber et al., 2017; Diessner et al., 2018), are more politically liberal (Dutcher et al., 2007; Nour et al., 2017), and are more empathic (Mayer and Frantz, 2004, S2 and S4; Di Fabio and Bucci, 2016; Di Fabio and Kenny, 2018). Lower levels of connectedness are found among those who are more politically conservative (Brick and Lewis, 2014) more authoritarian (Nour et al., 2017), more oriented toward consumerism (Mayer and Frantz, 2004, S4) or materialism (Hedlund-de Witt et al., 2014), and who ascribe to the feminine beauty ideal (Scott, 2010, S1–2). In general, individual's values seem to be associated with connectedness (Sellmann and Bogner, 2013; Lumber et al., 2017), an effect which may be initially derived from parent's values (Cheng and Monroe, 2012). There is also evidence that religious fundamentalism is negatively associated with connectedness; however, this was only under conditions of mortality salience (Vess et al., 2012), whereas more general religiosity or spirituality may have either no (Vess et al., 2012, S1–3, but see Brown, 2017) or a positive effect on connectedness (Hedlund-de Witt et al., 2014).

Self-Transcendent Worldviews and Connectedness

Connectedness also shows positive associations with constructs that support the perspective that connectedness reflects a form of self-transcendence. Specifically, connectedness is positively associated with self-transcendent values and negatively associated with self-enhancement values (Tam, 2013). Further, connectedness is positively associated with constructs involving connecting to something greater, such as connectedness to community (Sanguinetti, 2014) and even to humanity as a whole (Lee et al., 2015; Lengieza et al., 2021), as well as with greater moral expansiveness (Crimston et al., 2016) and more altruism (Nisbet et al., 2009, S1). Moreover, connectedness is positively associated with non-self-interested concern for nature (e.g., biospheric concern; Mayer and Frantz, 2004, S4–5; Davis and Stroink, 2016a,b; although this effect is sometimes not found, e.g., Schultz and Tabanico, 2007, S2; Duffy and Verges, 2010) whereas, at best, connectedness is simply not associated with self-interested concern for the environment (e.g., egoistic concern; Mayer and Frantz, 2004, S4; Schultz and Tabanico, 2007, S1–2; Duffy and Verges, 2010; Davis and Stroink, 2016a,b) and, at worst, may be negatively associated with such self-centered concern (Mayer and Frantz, 2004, S5; Schultz and Tabanico, 2007, S1). Lastly, individuals who think more in terms of systems—which is related to seeing oneself as part of a set of interrelated parts and suggestive of self-transcendence (c.f., Lengieza et al., 2021)—tend to report higher levels of connectedness (Davis and Stroink, 2016a). Thus, there is evidence that constructs consistent with self-transcendence (e.g., self-transcendence values; Tam, 2013) are associated with connectedness which supports the contention that connectedness reflects a form of self-transcendence (e.g., Lengieza et al., 2021).

Summary and Critique of Research on Individual Differences

Who we are and how we view the world influences our sense of connectedness. The apparent consensus is that age is associated with connectedness; however, this effect is likely curvilinear (see Hughes et al., 2019). Gender on the other hand, may or may not be related to connectedness, at least directly, as many studies reported no gender related effects. Still, a non-negligible number of studies have reported that women feel greater connectedness than men, suggesting that there may be an effect of gender, though one that is likely small. In both cases, however, a more systematic investigation into the effects of age and gender seems warranted at this juncture. Individual's personality also influences connectedness, most notably their degree of openness to experience (e.g., Lee et al., 2015) as well as agreeableness and conscientiousness are associated with connectedness (e.g., Brick and Lewis, 2014). Lastly, there are a multitude of worldviews which are associated with connectedness (e.g., Crimston et al., 2016), several of which are consistent with viewing connectedness as a form of self-transcendence (e.g., Lengieza et al., 2021).

It is not necessarily surprising that certain types of individuals, those from certain backgrounds, and those who hold certain views more (or less) easily develop a connection to the natural world than others. For the most part, however, it is unclear exactly *why* various demographic characteristics and facets of personality would influence connectedness, largely because of a lack of theory. There are several potential reasons that demographics might be theoretically important. Demographics memberships might serve as proxies for likelihood of having contact with nature, for example. That is, certain individuals may be more or less likely to have contact with nature, and therefore, end up feeling lower connectedness. Alternatively, potential differences between demographic groups could be a matter of socialization and what is culturally valued by one's peers. Perhaps in some socio-demographic contexts individuals are encouraged to connect with nature—or at least encouraged to pay attention to their relationship with nature—whereas in others, individuals do not receive such encouragement. To empirically test these possibilities, however, researchers will need to begin considering the mediating process through which these variables influence connectedness. To date, one study suggests that part of the reason agreeableness and openness might be associated with connectedness is *via* empathy (Di Fabio and Kenny, 2018). However, empathy is unlikely to be the only pathway between personality and connectedness and, thus, more research is undoubtedly warranted. Further investigation into why these relationships exist—to the extent that they do—is theoretically helpful because it may shed light on potential social processes that influence connectedness and may also inspire investigations into other individual differences that might influence connectedness.

Additionally, individual differences are likely candidates for moderators of other antecedents of connectedness. For example, as noted in a previous section, age potentially influences the importance of participation in outdoor activities with activities being more important for older adults than younger adults (Beery, 2013) and, additionally, one meta-analysis suggests the effect of mindfulness on connectedness is larger in samples with older participants (Schutte and Malouff, 2018). More generally, certain individuals may tend to experience the same activity differently. Practically, these considerations could influence how one might construct interventions to increase connectedness. For example, individual differences in appreciating natural beauty might influence the effect of engaging with nature artistically (c.f., Bruni et al., 2017). Thus, if one were to design an intervention meant to enhance connectedness through artistic engagement with nature, it might make sense to first focus on fostering an appreciation of natural beauty prior to the core focus of the intervention.

Psychological States That Influence Connectedness

Contrasting with relatively stable individual differences noted above, some studies identify more malleable and transitory underlying psychological states that may promote connectedness. Ultimately, research on these states provides insight into the psychological processes through which other antecedents of connectedness may have their effect. To the extent that we understand the process that unfolds behind a given antecedent, such as contact with nature, we can better activate that process to make the experience, or other antecedent, as impactful as possible. Thus, research on psychological states that promote connectedness will inform what to leverage in efforts to increase connectedness. Additionally, as was noted in the worldviews section, this research may help form theoretical accounts of connectedness. Similar to worldviews, if certain classes of psychological states, such as states involving the self, tend to consistently covary with connectedness then we can more confidently conceptualize connectedness as a phenomenon involving the self. The states reviewed in this section can be categorized as being related to mindfulness, the self, and affect.

Mindfulness

While meditation, as an activity, was mentioned earlier in this review, not all meditative practices are aimed at increasing mindfulness (e.g., loving-kindness meditation). Therefore, conflating meditation and mindfulness should be avoided. Additionally, there is a great deal that meditation might change even when it is aimed at increasing mindfulness. Thus, simply because meditation influences connectedness does not necessarily mean that mindfulness, as psychological quality of mind, influences connectedness. For example, meditation may simply increase individuals' ability to introspect—which is not the same as mindfulness—and this increase in introspection might be the true cause of some hypothetical increase in connectedness (c.f., Richardson and Sheffield, 2015). Research solely examining the practice of meditation also cannot illuminate which facets of mindfulness are associated with connectedness. It is, therefore, necessary to also measure mindfulness to determine whether, and how, mindfulness as a psychological quality impacts connectedness.

Several studies demonstrate a positive link between mindfulness and connectedness (see Schutte and Malouff, 2018, for a meta-analysis). Given the meta-analysis on the subject, it seems unnecessarily redundant to outline all of the individual findings related to the mindfulness–connectedness association; however, it is worth noting one important trend. While mindfulness in general has been associated with higher levels of connectedness (e.g., Howell et al., 2011; Richardson and Sheffield, 2015, S1–2; Unsworth et al., 2016, S1; Schutte and Malouff, 2018), certain facets seem to be more related to connectedness than others. Specifically, the "observing" (Barbaro and Pickett, 2016, S1–2; Hanley et al., 2017), "nonreactivity" (Barbaro and Pickett, 2016, S1–2; Hanley et al., 2017), and "describing" (Barbaro and Pickett, 2016, S1–2) facets of mindfulness have been associated with connectedness, whereas the "nonjudging" (Barbaro and Pickett, 2016, S1–2; Hanley et al., 2017) and "acting" (Barbaro and Pickett, 2016, S1; Hanley et al., 2017) facets have not.

Summary and Critique of Research on Mindfulness

The obvious consensus in the literature—largely informed by the results of the meta-analysis (i.e., Schutte and Malouff, 2018)—is that the psychological experience of mindfulness is associated with increased connectedness. This association in conjunction with the evidence that meditation also increases connectedness, seems to suggest that changes in mindfulness would mediate the relationship between meditation and connectedness. To date, however, this process of mediation has not been empirically tested. Thus, future research should attempt to document the process through which meditation increases connectedness. Such an endeavor will entail paying greater attention to various facets of mindfulness to fully understand the relations between meditation, mindfulness, and connectedness.

It is also possible that mindfulness is not the only path through which meditation increases connectedness; perhaps meditation also influences connectedness through an effect on the way we think about the self (c.f., Hanley et al., 2017) through an effect on affective experiences (c.f., Jazaieri et al., 2013), or simply through increased reflective or introspective propensity (c.f., Richardson and Sheffield, 2015; see ensuing sections for elaboration). Consequently, research investigating the process through which meditation has its effect should consider alternative mechanisms in addition to mindfulness.

Psychological States Related to the Self

Connectedness is defined as including nature in the self, and, therefore, it is reasonable to expect that psychological states associated with the self would influence connectedness (Lengieza and Swim, 2021). Thus, to support the assertion that connectedness does involve including nature in the self, it is important to study if, and how, self-related psychological phenomena impact connectedness.

Negative Impacts of the Self on Connectedness

Self-awareness, with its different facets, is one such self-related phenomena that affects connectedness. Studies suggest that taking oneself as the object of awareness might negatively impact connectedness. In one study, self-objectification—taking the critical perspective of an observer when considering the self—was negatively associated with connectedness across three samples of women (Scott, 2010). Another study demonstrated that being seated in front of a mirror—which theoretically increases objective self-awareness—diminished connectedness (Frantz et al., 2005). This suggests that objective self-awareness may interfere with connectedness.[4]

Other studies corroborate the findings from research on objective self-awareness. Evidence suggests that being publicly self-aware—being more aware of how you appear to others—is negatively associated with connectedness (Mayer et al., 2009). In line with the negative association with public self-awareness, rumination—which was defined as anxious, or preoccupied, attention that is focused on the self and is concerned with self-worth or failure (making it similar to public self-awareness)—was negatively correlated with connectedness (Richardson and Sheffield, 2015). Further, research suggests that decreases in public self-awareness may be the mechanism through which contact with nature increases connectedness (Lengieza and Swim, 2021). Thus, being overly focused on oneself from a third-person perspective seems to have a negative impact on connectedness.

In addition to research on self-awareness, other evidence implies that diminishing overly self-focused attention may be important for facilitating connectedness. First, some studies investigating mindfulness implicate the self as an important determinant of connectedness; one of the reasons that mindfulness may influence connectedness is because of its effect on decentering (Hanley et al., 2017; see also Nisbet et al., 2019). Specifically, decentering has been argued to be linked with self-transcendence and to a blurring of the self–other dichotomy (Hanley et al., 2018). Thus, the link between decentering and connectedness is consistent with the defining connectedness as a form of self-transcendence (Lengieza et al., 2021). Second, one of the reasons that psilocybin increases connectedness may be because of the effect it has on individual's sense of self; ego dissolution—a pharmacologically induced state of selflessness associated with psychedelics—during individuals' most significant experience with psilocybin was associated with increased connectedness (Nour et al., 2017). Thus, this evidence would loosely suggest that diminishing attention to the self might promote connectedness.

Positive Influences of the Self on Connectedness

There is other evidence that which implicate the self in the formation of connectedness and also suggests that the self might not always be an obstacle in the way of forming a connection with nature. In contrast to objective self-awareness and public self-awareness, private self-awareness—being aware

[4]This effect was primarily true for individuals who held less positive environmental attitudes; individuals with highly positive environmental attitudes experienced similar levels of connectedness in either condition (Frantz et al., 2005) which may be reflective of a ceiling effect for connectedness among individuals who already hold strong proenvironmental attitudes.

of one's inner experience, effectively synonymous with introspection—may enhance connectedness (Mayer et al., 2009). Consistent with this finding, reflective self-attention was found to be a better predictor of connectedness than mindful attention (Richardson and Sheffield, 2015, S1–2) and moderated the effect of exposure to nature, with higher levels of reflective self-attention strengthening the effects of contact with nature on connectedness (Richardson and Sheffield, 2015, S3). Additionally, as noted above, one of the mechanisms through which VR might increase connectedness may be body transference (Ahn et al., 2016, S1–3); in other words, a transfer of our corporeal sense of self seems to influence connectedness. Fourth, the ways in which we construe the self (e.g., interdependent, independent, etc.) seem to influence connectedness (Davis and Stroink, 2016b) as does the way that we feel about ourselves (i.e., self-esteem; Zhang et al., 2014b, S2; Swami et al., 2016). Thus, there is growing evidence that self-related phenomena are, at the very least, an important part of the formation of connectedness.

Summary and Critique of Research on Psychological States Related to the Self

The above evidence concludes that self-related phenomena play a critical role in the formation of connectedness. Specifically, both the way in which we attend to the self (e.g., Richardson and Sheffield, 2015) and the way we subjectively experience the self (e.g., Hanley et al., 2017; Nour et al., 2017) influence connectedness, though there is still much of this story left to untangle.

This means, however, that there are many exciting directions for future research in this area. First, there are several additional phenomena related to the self that may impact individuals' sense of connectedness such as goal-related content (e.g., actual, ideal and ought selves; Higgins, 1987) temporal reflections (e.g., past, present and future selves; Markus and Nurius, 1986) and structure of the self (e.g., self-schemas, Markus, 1977). The growing evidence that the self influences connectedness in multiple ways suggests that the unstudied associations between these facets of the self and connectedness warrants future investigation.

Second, there are opportunities to further differentiate already-studied phenomena (c.f., public vs. private self-awareness) to create more nuanced accounts of how self-related psychological states are expected to impact connectedness. As an example, the observation of a positive association between connectedness and private self-awareness in contrast to the negative association with public self-awareness suggests that these two types of self-awareness should be differentiated. Moreover, these specific opposing relations raise two interrelated points. (A) These opposing effects emphasize that more research is necessary to understand when focusing on the self diminishes connectedness and when it might benefit it. (B) It seems to tentatively suggest that what gets in the way of connecting to nature is a disproportionate (e.g., Lengieza and Swim, 2021) and preoccupied (e.g., Richardson and Sheffield, 2015) focus on the self—as opposed to an introspective or proportionate focus on the self (e.g., Richardson and Sheffield, 2015). In other words, in the context of its relation to connectedness, there may be such a thing as a healthy and unhealthy focus on the self.

Third, there is the opportunity to use research on the self to inform research on the antecedents of connectedness. For example, it is worth considering how self-related psychological states might mediate relations described in earlier sections. One could test, as suggested above, whether decentering—which tentatively links mindfulness to connectedness (e.g., Hanley et al., 2017)—is one of the avenues through which meditation affects connectedness. Further, it is also worth considering how other, yet-studied, situations or interventions that are believed to influence the self might be related to changes in connectedness. For example, body scan meditation has been shown to induce a blurring of the self-other boundary (Dambrun, 2016), thus studying the effect on connectedness that this type of intervention has might warranted solely on the basis that it influences the self.

Affect and Motivation

Affective states have an impact on individuals' sense of connectedness. A meta-analysis suggests that, on the whole, positive affect as well as wellbeing are positively correlated with connectedness (Capaldi et al., 2014) and research has consistently concluded that positive affect promotes connectedness (e.g., Mayer et al., 2009, S1–3; Howell et al., 2011, S2; Nisbet et al., 2011, 2019, S1–3; Nisbet and Zelenski, 2011, S1–2; Capaldi et al., 2014, 2017, S1; Dopko et al., 2014, 2019, S1; Crawford et al., 2017). In fact, increased positive affect may be one of the psychological mechanisms through which contact with nature increases connectedness (Nisbet et al., 2011), although not all studies find significant relationships between affect and connectedness (e.g., Schultz and Tabanico, 2007, S5; Howell et al., 2011, S1; Vess et al., 2012).

Research also suggest that it is useful to delineate different types of positive affect; specific forms of positive affect, such as awe (Yang et al., 2018; Nisbet et al., 2019) or similar types of emotions such as elevating experiences (Capaldi et al., 2017, S1; Lengieza et al., 2021) have been positively associated with connectedness. Moreover, meaning and purpose, a form of eudemonic affect, is positively correlated with connectedness (Hinds and Sparks, 2009; Howell et al., 2011, S1–2; Nisbet et al., 2011, S1 and S3; Capaldi et al., 2017, S1) as are other forms of more general wellbeing (Capaldi et al., 2014, 2017, S1–2; Richardson et al., 2016; Nisbet et al., 2019) whereas hedonic affect was no longer associated with connectedness after controlling for eudaimonic affect (Lengieza et al., 2021).

In addition to focusing on positive affect, a few studies have also shown that negative affect is negatively correlated with connectedness (Mayer et al., 2009, S2; Nisbet et al., 2011; Nisbet and Zelenski, 2011, S4; Dopko et al., 2019). As noted in the above sections, there are open questions about whether "the bugs and mud" of nature negatively impacts connectedness. To the extent that "bugs and mud" elicits negative affect, it would be reasonable to expect them to negatively impact connectedness.

Motivational factors may also influence connectedness. One study found that after experiencing or recalling ostracism

individuals reported a stronger disposition to connect with nature (Poon et al., 2015, S1 and S3), suggesting our more universal needs for relatedness (Ryan and Deci, 2000) might be a potential determinant of connectedness. Another study, referenced above, found connectedness was lower among individuals for whom thoughts about death were more accessible, suggesting that our purported motivation to avoid our own mortality may hinder connectedness (Vess et al., 2012).

Summary and Critique of Research on Affect

Affect may be an important determinant of connectedness. Positive affect has been shown to (e.g., Nisbet and Zelenski, 2011) promote connectedness, whereas negative affect appears to suppress it (e.g., Nisbet et al., 2011). For the most part, however, few studies consider affect and emotions with increased granularity. That is, most studies treat positive affective states and negative affective states as cohesive groups. Affective states, however, differ on more than just valence (e.g., approach–avoidance; Harmon-Jones et al., 2017) and it may be worthwhile to understand how certain classes of emotions affect connectedness (e.g., awe as a type of self-transcendent emotions; Stellar et al., 2017) as there is evidence that different types of positive affect differentially predict connectedness (Lengieza et al., 2021).

DISCUSSION

The purpose of this review was to provide an overview of the literature on the psychological antecedents of connectedness. At present, many studies point to the importance of actual and mediated contact with nature as well as to the importance of the activities that one does as antecedents of connectedness. People also seem to vary in connectedness based on individual differences which suggests that different life experiences or ways of engaging with the world may be influential factors that affect connectedness. Prime examples of these individual differences are age, openness to experience, as well as worldviews that reflect attitudes toward nature and self-transcendence. Other research has illuminated potential psychological processes that may explain other effects outlined in the review. For example, decreased public self-awareness (Lengieza and Swim, 2021) and increased positive affect (Nisbet and Zelenski, 2011) may mediate the effect of contact with nature on connectedness.

Broader Critiques of The Literature

This review, however, highlights broader critiques of the literature, in addition to those raised in the summary sections throughout the paper. First, there appears to be a lack of theoretical frameworks detailing how connectedness forms. Development of such theories will help guide the generation of novel research questions and will also help guide the selection of potential moderators worthy of investigation. Theories are also important because they will help outline when effects are and are not expected to occur. Thus, such theories will consequently help provide frameworks to understand and interpret null findings—a point which is especially important for research on contact with nature. Additionally, theories are important to help unify seemingly disparate findings, such as the loose collection of work outlined in the worldviews section.

Second, the ability to develop such theories would greatly benefit from greater inquiries into the process through which known antecedents have their effects. While there are several antecedents believed to impact connectedness, we often do not know *why* these antecedents have their effect. For example, despite many studies testing whether contact with nature increases connectedness, only two studies have attempted to document the process through which this effect occurs (Nisbet and Zelenski, 2011; Lengieza and Swim, 2021). Understanding the process through which an effect occurs is not only scientifically interesting in its own right—being critically important for the development of theories—but also important for designing effective interventions for practical use. To illustrate the latter point, to the extent that the reason contact with nature has an effect on connectedness is, in part, because it decreases public self-awareness (Lengieza and Swim, 2021), then this would suggest an intervention in which individuals are taken to a natural area among a group of strangers might be less effective than individual excursions into nature because being surrounded by strangers would likely *increase* concerns about how one appears to others (i.e., public self-awareness).

Specific Future Directions

There are several subfields within this body of research that are developed enough to warrant more nuanced investigations. The research on the mindfulness–connectedness association is a good example of why more nuanced accounts of a particular construct's impact on connectedness is theoretically and practically valuable.

Nuances of the Mindfulness–Connectedness Relationship

There is substantial research that has demonstrated a link between mindfulness and connectedness, and we can be fairly confident that, generally speaking, mindfulness increases connectedness (Schutte and Malouff, 2018). A few researchers have taken the step toward a more nuanced account and investigated which of the many facets of mindfulness might be most responsible for this association (e.g., Barbaro and Pickett, 2016); the preliminary indication being that not all facets of mindfulness affect connectedness (e.g., Barbaro and Pickett, 2016). This is an important observation for both (a) theoretical accounts of the formation of connectedness and (b) for the design of effective interventions. Regarding the former, this is important because, if one can identify something common between the factors of mindfulness that are related to connectedness, it would be a step toward creating a parsimonious account of the influence of mindfulness on connectedness. Regarding the latter, there are a variety of interventions that one could employ to increase mindfulness, and they might not influence all facets of mindfulness in the same way. Thus, a given mindfulness intervention might not

target one of the facets believed to impact connectedness. For example, sitting meditation seems to primarily increase the non-judging facet of mindfulness (Sauer-Zavala et al., 2013), which has not been correlated with connectedness (e.g., Barbaro and Pickett, 2016), whereas both body scan meditation and yoga seem to primarily increase the describing facet of mindfulness (Sauer-Zavala et al., 2013), which has been correlated with connectedness (e.g., Barbaro and Pickett, 2016). Therefore, an intervention using sitting meditation might not be the more effective means of promoting connectedness *via* mindfulness, at least compared to yoga or body scan meditation. Such an insight would be lost without this more nuanced view of mindfulness.

Other Areas in Need of Nuance

There are other sub-areas that would benefit from nuanced accounts of effect that their phenomena of interest have on connectedness: contact with nature, self-awareness, and affect.

Nuances of the Contact–Connectedness Relationship

While contact with nature seems to be an important determinant of connectedness only one study appeared in this review that compared different types of contact with nature within the same study (e.g., Wyles et al., 2019). There are a number of dimensions on which nature can vary—from manicured to wild, from green to blue to gray, from novel to familiar, etc.—and it would be valuable to know, for the same general reasons listed in the preceding mindfulness example, if and how these dimensions might matter.

Nuances of the Self-Awareness–Connectedness Relationship

Research on self-awareness would also benefit from increased consideration of the nuances between types of self-awareness. Specifically, it seems that public and private self-awareness have opposing effects on connectedness (e.g., Mayer et al., 2009), suggesting that there may be a type of focus on the self that is beneficial and a type of focus on the self that is not. However, at present, no research has truly addressed this question systematically.

Nuances of the Affect–Connectedness Relationship

Research on affect and connectedness may also benefit from differentiating between various forms of affect. As the literature currently stands, positive affect promotes, whereas negative affect diminishes, connectedness (e.g., Nisbet et al., 2011). There is reason to believe, however, that not all positive affect will affect connectedness in the same way; (e.g., eudaimonic vs. hedonic affect; Lengieza et al., 2021). Thus, it may be worthwhile to consider more nuanced distinctions between similar types of emotions.

Cultural Contexts

Finally, it may be appropriate, at this stage in the field, to begin considering these effects with an explicit cross-cultural lens. For example, the trend in connectedness across ages (Hughes et al., 2019) may not adhere to the same pattern for interdependent and independent cultures (Markus and Kitayama, 1991) to the extent that these age-related differences stem from differences in social pressures at different points in individuals' lives. Additionally, as another example, thinking about or focusing on the self might not activate the same set of processes across cultures and therefore may impact connectedness differently (c.f., Zhu et al., 2007). Therefore, the relationship between connectedness and self-awareness (e.g., Lengieza and Swim, 2021) may differ between cultural contexts. Consequently, future research might want to consider if and how certain cultural contexts might affect connectedness directly, as well as might moderate the effect of other antecedents.

Preliminary Theoretical Considerations

The sheer number of studies reporting the effect of contact with nature on connectedness may give the impression that contact with nature is *the* way to promote connectedness. However, there are several key findings that occur in contexts in the absence of contact with nature. Specifically, both loving-kindness and mindfulness meditation in the absence of contact with nature seem to promote connectedness (Aspy and Proeve, 2017). Additionally, lab-based manipulations of self-awareness affect connectedness in the absence of nature (Frantz et al., 2005). Further, mindful learning seems to increase connectedness *without* requiring contact with nature (e.g., Wang et al., 2019).

Upon closer inspection, these findings seem to support the tentative theoretical perspective that the default tendency is for people to develop a sense of connectedness. One can think of meditation, specifically mindfulness meditation, as being specifically aimed at minimizing problematic ways of thinking which ultimately create unnecessary pressures in our everyday lives (i.e., "clinging" and "aversion"). According to theories of self-awareness, public self-awareness should increase the influence of external standards whereas private self-awareness should increase the influence of internal standards (Govern and Marsch, 2001; Carver, 2012). Thus, the former seeming to inhibit connectedness and the latter seeming to promote it, suggests that—at least in in a psychological vacuum—the default tendency may be toward increasing connectedness. This would be consistent with the biophilia hypothesis (see Wilson, 1984; Kahn Jr, 1997) which proposes that we have an innate affinity other forms of life and for nature broadly. Further, the fact that connectedness appears to decrease heading into adolescence—a period of time during which self-construals appear to more heavily rely on external pressures (i.e., other's impressions; e.g., Pfeifer et al., 2009), at least in the western context—and steadily increases afterward, is consistent with the view that connectedness thrives in the absence of counter self-preoccupied pressures. Thus, our tentative suggestion is that people innately develop connectedness and that other pressures—which are presumably common in modern-day life—may often work against that innate tendency. Indeed, it may be that contact with nature simply represents a return to that which feels normal, a brief reprieve from all the concerns and external pressures of everyday life that keep us disconnected from nature (c.f., Lengieza and Swim, 2021).

This view is also consistent with other perspectives found in psychology more broadly. Specifically, the need for relatedness (Ryan and Deci, 2000) or belonging (Baumeister and Leary, 1995) and the need for self-expansion (Aron and Aron, 1986; Aron et al., 2013) are both believed to be fundamental motives that drive human experience and behavior. Connectedness may fulfil both needs (e.g., Mayer and Frantz, 2004) which would be consistent with viewing greater connectedness as the default trajectory in the absence of competing forces. Future theoretical accounts of the formation of connectedness should consider whether connectedness simply reflects another form of either self-expansion or fulfilment of the need for relatedness—and, therefore, can be accounted for by existing theories—or if there is something unique that is not captured by existing frameworks.

CONCLUSION

The literature on the psychological antecedents to connectedness is in a good place. There are associations of which we can be confident, such as the association between contact with nature and connectedness and between mindfulness and connectedness. There are, however, clear directions for future research. The priority should be placed on developing theories that help one understand the process through which known effects occur as well as on differentiating between different facets or types of a particular class of antecedents to better account for the heterogeneity identified in several of the antecedents. As the literature on the antecedents to connectedness continues to grow, and theories emerge, we will be better situated to leverage connectedness as a means of creating a more sustainably inclined society.

AUTHOR CONTRIBUTIONS

ML reviewed the literature and wrote the manuscript. JS provided input on the framing, organization, and presentation of the information in the manuscript as well as edits. All authors contributed to the article and approved the submitted version.

REFERENCES

Ahn, S. J. G., Bostick, J., Ogle, E., Nowak, K. L., McGillicuddy, K. T., and Bailenson, J. N. (2016). Experiencing nature: embodying animals in immersive virtual environments increases inclusion of nature in self and involvement with nature. *J. Comput.-Mediat. Commun.* 21, 399–419. doi: 10.1111/jcc4.12173

Aron, A., and Aron, E. N. (1986). *Love and the Expansion of Self: Understanding Attraction and Satisfaction*. New York: Hemisphere Publishing Corp/Harper & Row Publishers.

Aron, A., Lewandowski Jr, G. W., Mashek, D., and Aron, E. N. (2013). "The self-expansion model of motivation and cognition in close relationships," in *The Oxford Handbook of Close Relationships*. eds. J. A. Simpson and L. Campbell (Oxford: Oxford University Press), 90–115.

Aspy, D. J., and Proeve, M. (2017). Mindfulness and loving-kindness meditation: effects on connectedness to humanity and to the natural world. *Psychol. Rep.* 120, 102–117. doi: 10.1177/0033294116685867

Barbaro, N., and Pickett, S. M. (2016). Mindfully green: examining the effect of connectedness to nature on the relationship between mindfulness and engagement in pro-environmental behavior. *Personal. Individ. Differ.* 93, 137–142. doi: 10.1016/j.paid.2015.05.026

Barton, J., Bragg, R., Pretty, J., Roberts, J., and Woody, C. (2016). The wilderness expedition: an effective life course intervention to improve young people's well-being and connectedness to nature. *J. Exp. Educ.* 39, 59–72. doi: 10.1177/1053825915626933

Baumeister, R. F., and Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychol. Bull.* 117, 497–529. doi: 10.1037/0033-2909.117.3.497

Beery, T. H. (2013). Nordic in nature: friluftsliv and environmental connectedness. *Environ. Educ. Res.* 19, 94–117. doi: 10.1080/13504622.2012.688799

Braun, T., and Dierkes, P. (2017). Connecting students to nature-how intensity of nature experience and student age influence the success of outdoor education programs. *Environ. Educ. Res.* 23, 937–949. doi: 10.1080/13504622.2016.1214866

Brick, C., and Lewis, G. J. (2014). Unearthing the "green" personality: core traits predict environmentally friendly behavior. *Environ. Behav.* 48, 635–658. doi: 10.1177/0013916514554695

Brown, J. S. (2017). Predicting connectedness with nature among survivors of the Joplin tornado. *Ecopsychology* 9, 193–198. doi: 10.1089/eco.2017.0007

Bruni, C. M., Fraser, J., and Schultz, P. W. (2008). The value of zoo experiences for connecting people with nature. *Vis. Stud.* 11, 139–150. doi: 10.1080/10645570802355489

Bruni, C. M., and Schultz, P. W. (2010). Implicit beliefs about self and nature: evidence from an IAT game. *J. Environ. Psychol.* 30, 95–102. doi: 10.1016/j.jenvp.2009.10.004

Bruni, C. M., Winter, P. L., Schultz, P. W., Omoto, A. M., and Tabanico, J. J. (2017). Getting to know nature: evaluating the effects of the get to know program on children's connectedness with nature. *Environ. Educ. Res.* 23, 43–62. doi: 10.1080/13504622.2015.1074659

Burbach, M. E., Pennisi, L., West, C. D., and Ziegler-Chong, S. (2012). The impact of environmental interpretation in developing a connection to nature in park visitors. *LARNet - The Cyber Journal of Applied Leisure and Recreation Research* 15, 13–30.

Capaldi, C. A., Dopko, R. L., and Zelenski, J. M. (2014). The relationship between nature connectedness and happiness: a meta-analysis. *Front. Psychol.* 5:976. doi: 10.3389/fpsyg.2014.00976

Capaldi, C. A., Passmore, H. A., Ishii, R., Chistopolskaya, K. A., Vowinckel, J., Nikolaev, E. L., et al. (2017). Engaging with natural beauty may be related to well-being because it connects people to nature: evidence from three cultures. *Ecopsychology* 9, 199–211. doi: 10.1089/eco.2017.0008

Carver, C. S. (2012). "Self-awareness," in *Handbook of Self and Identity*. eds. M. R. Leary and J. P. Tangney (New York, NY, US: The Guilford Press), 50–68.

Cheng, J. C. H., and Monroe, M. C. (2012). Connection to nature: children's affective attitude toward nature. *Environ. Behav.* 44, 31–49. doi: 10.1177/0013916510385082

Cho, Y., and Lee, D. (2018). 'Love honey, hate honey bees': reviving biophilia of elementary school students through environmental education program. *Environ. Educ. Res.* 24, 445–460. doi: 10.1080/13504622.2017.1279277

Clayton, S., Fraser, J., and Burgess, C. (2011). The role of zoos in fostering environmental identity. *Ecopsychology* 3, 87–96. doi: 10.1089/eco.2010.0079

Clayton, S., and Myers, G. (2015). *Conservation Psychology: Understanding and Promoting Human Care for Nature*. John Wiley & Sons, Hoboken, NJ.

Crawford, M. R., Holder, M. D., and O'Connor, B. P. (2017). Using mobile technology to engage children with nature. *Environ. Behav.* 49, 959–984. doi: 10.1177/0013916516673870

Crimston, D., Bain, P. G., Hornsey, M. J., and Bastian, B. (2016). Moral expansiveness: examining variability in the extension of the moral world. *J. Pers. Soc. Psychol.* 111:636. doi: 10.1037/pspp0000086

Dambrun, M. (2016). When the dissolution of perceived body boundaries elicits happiness: the effect of selflessness induced by a body scan meditation. *Conscious. Cogn.* 46, 89–98. doi: 10.1016/j.concog.2016.09.013

Davis, J. L., Le, B., and Coy, A. E. (2011). Building a model of commitment to the natural environment to predict ecological behavior and willingness to sacrifice. *J. Environ. Psychol.* 31, 257–265. doi: 10.1016/j.jenvp.2011.01.004

Davis, A. C., and Stroink, M. L. (2016a). The relationship between systems thinking and the new ecological paradigm. *Syst. Res. Behav. Sci.* 33, 575–586. doi: 10.1002/sres.2371

Davis, A. C., and Stroink, M. L. (2016b). Within-culture differences in self-construal, environmental concern, and proenvironmental behavior. *Ecopsychology* 8, 64–73. doi: 10.1089/eco.2015.0061

Di Fabio, A., and Bucci, O. (2016). Green positive guidance and green positive life counseling for decent work and decent lives: some empirical results. *Front. Psychol.* 7:261. doi: 10.3389/fpsyg.2016.00261

Di Fabio, A., and Kenny, M. E. (2018). Connectedness to nature, personality traits and empathy from a sustainability perspective. *Curr. Psychol.* 1095–1106. doi: 10.1007/s12144-018-0031-4

Diessner, R., Genthôs, R., Praest, K., and Pohling, R. (2018). Identifying with nature mediates the influence of valuing Nature's beauty on Proenvironmental Behaviors. *Ecopsychology* 10, 97–105. doi: 10.1089/eco.2017.0040

Dopko, R. L., Capaldi, C. A., and Zelenski, J. M. (2019). The psychological and social benefits of a nature experience for children: a preliminary investigation. *J. Environ. Psychol.* 63, 134–138. doi: 10.1016/j.jenvp.2019.05.002

Dopko, R. L., Zelenski, J. M., and Nisbet, E. K. (2014). Nature salience increases judgments of environmental satisfaction. *Ecopsychology* 6, 207–217. doi: 10.1089/eco.2014.0042

Dosen, A. S., and Ostwald, M. J. (2016). Evidence for prospect-refuge theory: a meta-analysis of the findings of environmental preference research. *City, Territ. Archit.* 3:4. doi: 10.1186/s40410-016-0033-1

Duffy, S., and Verges, M. (2010). Forces of nature affect implicit connections with nature. *Environ. Behav.* 42, 723–739. doi: 10.1177/0013916509338552

Dutcher, D. D., Finley, J. C., Luloff, A. E., and Johnson, J. B. (2007). Connectivity with nature as a measure of environmental values. *Environ. Behav.* 39, 474–493. doi: 10.1177/0013916506298794

Ernst, J., and Theimer, S. (2011). Evaluating the effects of environmental education programming on connectedness to nature. *Environ. Educ. Res.* 17, 577–598. doi: 10.1080/13504622.2011.565119

Forstmann, M., and Sagioglou, C. (2017). Lifetime experience with (classic) psychedelics predicts pro-environmental behavior through an increase in nature relatedness. *J. Psychopharmacol.* 31, 975–988. doi: 10.1177/0269881117714049

Frantz, C., Mayer, F. S., Norton, C., and Rock, M. (2005). There is no "I" in nature: the influence of self-awareness on connectedness to nature. *J. Environ. Psychol.* 25, 427–436. doi: 10.1016/j.jenvp.2005.10.002

Govern, J. M., and Marsch, L. A. (2001). Development and validation of the situational self-awareness scale. *Conscious. Cogn.* 10, 366–378. doi: 10.1006/ccog.2001.0506

Hanley, A. W., Derringer, S. A., and Hanley, R. T. (2017). Dispositional mindfulness may be associated with deeper connections with nature. *Ecopsychology* 9, 225–231. doi: 10.1089/eco.2017.0018

Hanley, A. W., Nakamura, Y., and Garland, E. L. (2018). The nondual awareness dimensional assessment (NADA): new tools to assess nondual traits and states of consciousness occurring within and beyond the context of meditation. *Psychol. Assess.* 30:1625. doi: 10.1037/pas0000615

Harmon-Jones, E., Harmon-Jones, C., and Summerell, E. (2017). On the importance of both dimensional and discrete models of emotion. *Behav. Sci.* 7:66. doi: 10.3390/bs7040066

Harvey, M. L., Oskins, J. D., McCarter, K. N., and Baker, J. R. (2016). Direct earth contact: barefootedness and nature connection. *Ecopsychology* 8, 96–106. doi: 10.1089/eco.2015.0075

Hedlund-de Witt, A., De Boer, J., and Boersema, J. J. (2014). Exploring inner and outer worlds: a quantitative study of worldviews, environmental attitudes, and sustainable lifestyles. *J. Environ. Psychol.* 37, 40–54. doi: 10.1016/j.jenvp.2013.11.005

Higgins, E. T. (1987). Self-discrepancy: a theory relating self and affect. *Psychol. Rev.* 94:319. doi: 10.1037/0033-295X.94.3.319

Hinds, J., and Sparks, P. (2009). Investigating environmental identity, well-being, and meaning. *Ecopsychology* 1, 181–186. doi: 10.1089/eco.2009.0026

Howell, A. J., Dopko, R. L., Passmore, H. A., and Buro, K. (2011). Nature connectedness: associations with well-being and mindfulness. *Personal. Individ. Differ.* 51, 166–171. doi: 10.1016/j.paid.2011.03.037

Hughes, J., Rogerson, M., Barton, J., and Bragg, R. (2019). Age and connection to nature: when is engagement critical? *Front. Ecol. Environ.* 17, 265–269. doi: 10.1002/fee.2035

Jazaieri, H., McGonigal, K., Jinpa, T., Doty, J. R., Gross, J. J., and Golden, P. R. (2013). A randomized controlled trial of compassion cultivation training: effects on mindfulness, affect, and emotion regulation. *Motiv. Emot.* 38, 23–35. doi: 10.1007/s11031-013-9368-z

Johnson-Pynn, J. S., Johnson, L. R., Kityo, R., and Lugumya, D. (2014). Students and scientists connect with nature in Uganda, East Africa. *Int. J. Environ. Sci. Educ.* 9, 311–327. doi: 10.12973/ijese.2014.217a

Kahn, P. H. Jr. (1997). Developmental psychology and the biophilia hypothesis: children's affiliation with nature. *Dev. Rev.* 17, 1–61. doi: 10.1006/drev.1996.0430

Kals, E., Schumacher, D., and Montada, L. (1999). Emotional affinity toward nature as a motivational basis to protect nature. *Environ. Behav.* 31, 178–202. doi: 10.1177/00139169921972056

Kashima, Y., Paladino, A., and Margetts, E. A. (2014). Environmentalist identity and environmental striving. *J. Environ. Psychol.* 38, 64–75. doi: 10.1016/j.jenvp.2013.12.014

Langer, E. J. (2000). Mindful learning. *Curr. Dir. Psychol. Sci.* 9, 220–223. doi: 10.1111/1467-8721.00099

Lankenau, G. R. (2018). Fostering connectedness to nature in higher education. *Environ. Educ. Res.* 24, 230–244. doi: 10.1080/13504622.2016.1225674

Larson, L. R., Szczytko, R., Bowers, E. P., Stephens, L. E., Stevenson, K. T., and Floyd, M. F. (2018). Outdoor time, screen time, and connection to nature: troubling trends Among rural youth? *Environ. Behav.* 966–991. doi: 10.1177/0013916518806686

Lee, K., Ashton, M. C., Choi, J., and Zachariassen, K. (2015). Connectedness to nature and to humanity: their association and personality correlates. *Front. Psychol.* 6:1003. doi: 10.3389/fpsyg.2015.01003

Lengieza, M. L., and Swim, J. K. (2021). Diminished public self-awareness in nature contributes to the positive effects of contact with nature on connectedness to nature. *Ecopsychology* 210–218. doi: 10.1089/eco.2020.0047

Lengieza, M. L., Swim, J. K., and Hunt, C. A. (2021). Effects of post-trip eudaimonic reflections on affect, self-transcendence and philanthropy. *Serv. Ind. J.* 41, 285–306. doi: 10.1080/02642069.2019.1636966

Leopold, A. (1949). "The land ethic," in *A Sand County Almanac: And Sketches Here and There* (London: Oxford University Press), 201–226.

Liefländer, A. K., Fröhlich, G., Bogner, F. X., and Schultz, P. W. (2013). Promoting connectedness with nature through environmental education. *Environ. Educ. Res.* 19, 370–384. doi: 10.1080/13504622.2012.697545

Liu, T., Geng, L., Ye, L., and Zhou, K. (2019). "Mother nature" enhances connectedness to nature and pro-environmental behavior. *J. Environ. Psychol.* 61, 37–45. doi: 10.1016/j.jenvp.2018.12.003

Lumber, R., Richardson, M., and Sheffield, D. (2017). Beyond knowing nature: contact, emotion, compassion, meaning, and beauty are pathways to nature connection. *PLoS One* 12:e0177186. doi: 10.1371/journal.pone.0177186

Lutz, A., Dunne, J. D., and Davidson, R. J. (2007). "Meditation and the neuroscience of consciousness: an introduction," in *Cambridge Handbook of Consciousness*. eds. P. Zelazo, M. Moscovitch, and E. Thompson. (Cambridge: Cambridge University Press), 499–551.

Lyons, T., and Carhart-Harris, R. L. (2018). Increased nature relatedness and decreased authoritarian political views after psilocybin for treatment-resistant depression. *J. Psychopharmacol.* 32, 811–819. doi: 10.1177/0269881117748902

Markus, H. (1977). Self-schemata and processing information about the self. *J. Pers. Soc. Psychol.* 35:63. doi: 10.1037/0022-3514.35.2.63

Markus, H. R., and Kitayama, S. (1991). Culture and the self: implications for cognition, emotion, and motivation. *Psychol. Rev.* 98:224. doi: 10.1037/0033-295X.98.2.224

Markus, H., and Nurius, P. (1986). Possible selves. *Am. Psychol.* 41:954. doi: 10.1037/0003-066X.41.9.954

Mayer, F. S., and Frantz, C. M. (2004). The connectedness to nature scale: a measure of individuals' feeling in community with nature. *J. Environ. Psychol.* 24, 503–515. doi: 10.1016/j.jenvp.2004.10.001

Mayer, F. S., Frantz, C. M. P., Bruehlman-Senecal, E., and Dolliver, K. (2009). Why is nature beneficial?: The role of connectedness to nature. *Environ. Behav.* 41, 607–643. doi: 10.1177/0013916508319745

Naess, A. (1987). Self-realization: an ecological approach to being in the world. *Trumpeter* 4, 35–42.

Nisbet, E. K., and Zelenski, J. M. (2011). Underestimating nearby nature: affective forecasting errors obscure the happy path to sustainability. *Psychol. Sci.* 22, 1101–1106. doi: 10.1177/0956797611418527

Nisbet, E. K., Zelenski, J. M., and Grandpierre, Z. (2019). Mindfulness in nature enhances connectedness and mood. *Ecopsychology* 11, 81–91. doi: 10.1089/eco.2018.0061

Nisbet, E. K., Zelenski, J. M., and Murphy, S. A. (2009). The nature relatedness scale: linking individuals' connection with nature to environmental concern and behavior. *Environ. Behav.* 41, 715–740. doi: 10.1177/0013916508318748

Nisbet, E. K., Zelenski, J. M., and Murphy, S. A. (2011). Happiness is in our nature: exploring nature relatedness as a contributor to subjective well-being. *J. Happiness Stud.* 13, 303–322. doi: 10.1007/s10902-010-9197-7

Nour, M. M., Evans, L., and Carhart-Harris, R. L. (2017). Psychedelics, personality and political perspectives. *J. Psychoactive Drugs* 49, 182–191. doi: 10.1080/02791072.2017.1312643

Otto, S., and Pensini, P. (2017). Nature-based environmental education of children: environmental knowledge and connectedness to nature, together, are related to ecological behaviour. *Glob. Environ. Chang.* 47, 88–94. doi: 10.1016/j.gloenvcha.2017.09.009

Passmore, H. A., and Holder, M. D. (2017). Noticing nature: individual and social benefits of a two-week intervention. *J. Posit. Psychol.* 12, 537–546. doi: 10.1080/17439760.2016.1221126

Pensini, P., Horn, E., and Caltabiano, N. J. (2016). An exploration of the relationships between adults' childhood and current nature exposure and their mental well-being. *Child. Youth Environ.* 26, 125–147. doi: 10.7721/chilyoutenvi.26.1.0125

Pfeifer, J. H., Masten, C. L., Borofsky, L. A., Dapretto, M., Fuligni, A. J., and Lieberman, M. D. (2009). Neural correlates of direct and reflected self-appraisals in adolescents and adults: when social perspective-taking informs self-perception. *Child Dev.* 80, 1016–1038. doi: 10.1111/j.1467-8624.2009.01314.x

Pollan, M. (2018). *How to Change Your Mind: The New Science of Psychedelics*, Penguin Press, New York.

Poon, K. T., Teng, F., Chow, J. T., and Chen, Z. (2015). Desiring to connect to nature: the effect of ostracism on ecological behavior. *J. Environ. Psychol.* 42, 116–122. doi: 10.1016/j.jenvp.2015.03.003

Richardson, M., Cormack, A., McRobert, L., and Underhill, R. (2016). 30 days wild: development and evaluation of a large-scale nature engagement campaign to improve well-being. *PLoS One* 11:e0149777. doi: 10.1371/journal.pone.0149777

Richardson, M., and Sheffield, D. (2015). Reflective self-attention: a more stable predictor of connection to nature than mindful attention. *Ecopsychology* 7, 166–175. doi: 10.1089/eco.2015.0010

Rosa, C. D., Profice, C. C., and Collado, S. (2018). Nature experiences and adults' self-reported pro-environmental behaviors: the role of connectedness to nature and childhood nature experiences. *Front. Psychol.* 9:1055. doi: 10.3389/fpsyg.2018.01055

Ryan, R. M., and Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am. Psychol.* 55:68. doi: 10.1037/0003-066X.55.1.68

Sanguinetti, A. (2014). Transformational practices in cohousing: Enhancing residents' connection to community and nature. *J. Environ. Psychol.* 40, 86–96. doi: 10.1016/j.jenvp.2014.05.003

Sauer-Zavala, S. E., Walsh, E. C., Eisenlohr-Moul, T. A., and Lykins, E. L. (2013). Comparing mindfulness-based intervention strategies: differential effects of sitting meditation, body scan, and mindful yoga. *Mindfulness* 4, 383–388. doi: 10.1007/s12671-012-0139-9

Schultz, P. W. (2002). "Inclusion with nature: the psychology of human-nature relations," in *Psychology of Sustainable Development*. eds. P. Schmuck and W. P. Schultz (Boston, MA: Springer), 61–78.

Schultz, P. W., and Tabanico, J. (2007). Self, identity, and the natural environment: exploring implicit connections with nature. *J. Appl. Soc. Psychol.* 37, 1219–1247. doi: 10.1111/j.1559-1816.2007.00210.x

Schutte, N. S., and Malouff, J. M. (2018). Mindfulness and connectedness to nature: a meta-analytic investigation. *Personal. Individ. Differ.* 127, 10–14. doi: 10.1016/j.paid.2018.01.034

Scott, B. A. (2010). Babes and the woods: women's objectification and the feminine beauty ideal as ecological hazards. *Ecopsychology* 2, 147–158. doi: 10.1089/eco.2010.0030

Sellmann, D., and Bogner, F. X. (2013). Effects of a 1-day environmental education intervention on environmental attitudes and connectedness with nature. *Eur. J. Psychol. Educ.* 28, 1077–1086. doi: 10.1007/s10212-012-0155-0

Soliman, M., Peetz, J., and Davydenko, M. (2017). The impact of immersive technology on nature relatedness and pro-environmental behavior. *J. Media Psychol.* 29, 8–17. doi: 10.1027/1864-1105/a000213

Spendrup, S., Hunter, E., and Isgren, E. (2016). Exploring the relationship between nature sounds, connectedness to nature, mood and willingness to buy sustainable food: a retail field experiment. *Appetite* 100, 133–141. doi: 10.1016/j.appet.2016.02.007

Stellar, J. E., Gordon, A. M., Piff, P. K., Cordaro, D., Anderson, C. L., Bai, Y., et al. (2017). Self-transcendent emotions and their social functions: compassion, gratitude, and awe bind us to others through prosociality. *Emot. Rev.* 9, 200–207. doi: 10.1177/1754073916684557

Stern, P. C., Dietz, T., Abel, T., Guagnano, G. A., and Kalof, L. (1999). A value-belief-norm theory of support for social movements: the case of environmentalism. *Hum. Ecol. Rev.* 6, 81–97.

Swami, V., Barron, D., Weis, L., and Furnham, A. (2016). Bodies in nature: Associations between exposure to nature, connectedness to nature, and body image in US adults. *Body Image* 18, 153–161. doi: 10.1016/j.bodyim.2016.07.002

Tam, K. P. (2013). Concepts and measures related to connection to nature: similarities and differences. *J. Environ. Psychol.* 34, 64–78. doi: 10.1016/j.jenvp.2013.01.004

Tam, K. P., Lee, S. L., and Chao, M. M. (2013). Saving Mr. nature: anthropomorphism enhances connectedness to and protectiveness toward nature. *J. Exp. Soc. Psychol.* 49, 514–521. doi: 10.1016/j.jesp.2013.02.001

Tang, Y., Geng, L., Schultz, P. W., Zhou, K., and Xiang, P. (2017). The effects of mindful learning on pro-environmental behavior: A self-expansion perspective. *Conscious. Cogn.* 51, 140–148. doi: 10.1016/j.concog.2017.03.005

Unsworth, S., Palicki, S. K., and Lustig, J. (2016). The impact of mindful meditation in nature on self-nature interconnectedness. *Mindfulness* 7, 1052–1060. doi: 10.1007/s12671-016-0542-8

Vess, M., Arndt, J., and Cox, C. R. (2012). Faith and nature: the effect of death-relevant cognitions on the relationship Between religious fundamentalism and connectedness to nature. *Soc. Psychol. Personal. Sci.* 3, 333–340. doi: 10.1177/1948550611420303

Walters, A. B., Drescher, C. F., Baczwaski, B. J., Aiena, B. J., Darden, M. C., Johnson, L. R., et al. (2014). Getting active in the gulf: environmental attitudes and action following two Mississippi coastal disasters. *Soc. Indic. Res.* 118, 919–936. doi: 10.1007/s11205-013-0428-2

Wang, J., Geng, L., Schultz, P. W., and Zhou, K. (2019). Mindfulness increases the belief in climate change: the mediating role of connectedness With nature. *Environ. Behav.* 51, 3–23. doi: 10.1177/0013916517738036

Wang, X., Geng, L., Zhou, K., Ye, L., and Ma, Y. (2016). Mindful learning can promote connectedness to nature: implicit and explicit evidence. *Conscious. Cogn.* 44, 1–7. doi: 10.1016/j.concog.2016.06.006

Weinstein, N., Przybylski, A. K., and Ryan, R. M. (2009). Can nature make us more caring? Effects of immersion in nature on intrinsic aspirations and generosity. *Personal. Soc. Psychol. Bull.* 35, 1315–1329. doi: 10.1177/0146167209341649

Wheaton, M., Ardoin, N. M., Hunt, C., Schuh, J. S., Kresse, M., Menke, C., et al. (2016). Using web and mobile technology to motivate pro-environmental action after a nature-based tourism experience. *J. Sustain. Tour.* 24, 594–615. doi: 10.1080/09669582.2015.1081600

Whitburn, J., Linklater, W. L., and Milfont, T. L. (2019). Exposure to urban nature and tree planting are related to pro-environmental behavior via connection to nature, the use of nature for psychological restoration, and environmental attitudes. *Environ. Behav.* 51, 787–810. doi: 10.1177/0013916517751009

Wilson, E. O. (1984). *Biophilia*. Cambridge, MA: Harvard University Press.

Wyles, K. J., White, M. P., Hattam, C., Pahl, S., King, H., and Austen, M. (2019). Are Some natural environments more psychologically beneficial Than others? The importance of type and quality on connectedness to nature and psychological restoration. *Environ. Behav.* 51, 111–143. doi: 10.1177/0013916517738312

Yaden, D. B., Haidt, J., Hood, R. W. Jr., Vago, D. R., and Newberg, A. B. (2017). The varieties of self-transcendent experience. *Rev. Gen. Psychol.* 21, 143–160. doi: 10.1037/gpr0000102

Yang, Y., Hu, J., Jing, F., and Nguyen, B. (2018). From awe to ecological behavior: the mediating role of connectedness to nature. *Sustainability* 10:2477. doi: 10.3390/su10072477

Zelenski, J. M., Dopko, R. L., and Capaldi, C. A. (2015). Cooperation is in our nature: nature exposure may promote cooperative and environmentally sustainable behavior. *J. Environ. Psychol.* 42, 24–31. doi: 10.1016/j.jenvp.2015.01.005

Zhang, W., Goodale, E., and Chen, J. (2014a). How contact with nature affects children's biophilia, biophobia and conservation attitude in China. *Biol. Conserv.* 177, 109–116. doi: 10.1016/j.biocon.2014.06.011

Zhang, J. W., Howell, R. T., and Iyer, R. (2014b). Engagement with natural beauty moderates the positive relation between connectedness with nature and psychological well-being. *J. Environ. Psychol.* 38, 55–63. doi: 10.1016/j.jenvp.2013.12.013

Zhu, Y., Zhang, L., Fan, J., and Han, S. (2007). Neural basis of cultural influence on self-representation. *NeuroImage* 34, 1310–1316. doi: 10.1016/j.neuroimage.2006.08.047

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Public Policies for Agricultural Diversification: Implications for Gender Equity

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Gender equity is recognized as central to sustainable development, but women still face significant constraints in accessing and controlling productive resources important for agricultural livelihoods. Identifying mechanisms (e.g., policies and interventions) in agriculture that enhance women's empowerment—a critical aspect of gender equity—is of paramount importance for sustainable development. In this study, we investigate how Brazil's flagship targeted public food procurement program, the National School Feeding Program (PNAE), influences women's empowerment in southern Brazil. We conducted household surveys on farm characteristics and practices, women's empowerment (e.g., participation in farm decision-making and control over income), and women's participation in social movements, with farmers ($n = 75$) who do and do not participate in the PNAE. We found that women were more empowered in households participating in the PNAE, and that this empowerment was associated with diversified farming systems. When women had greater levels of participation in farm management decisions, agrobiodiversity and use of agroecological practices were higher. We also show that women's participation in agroecological social movements was associated with significantly higher empowerment (both in control over income and greater participation in decision-making). This study identifies targeted public food procurement as a promising policy instrument with potential to link cross-sectoral Sustainable Development Goals (SDGs) to sustainably increase food production (SDG 2), provide economic opportunities for small-scale farmers (SDG 1), and create an economic space that women in agriculture can more easily access (SDG 5).

Keywords: agrobiodiversity, agroecology, school meal programs, social movements, public procurement, women's empowerment, sustainable development goals

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INTRODUCTION

Gender equity is an important human right and sustainable development goal, as well as a fundamental pre-condition for achieving other development objectives including improved food security, child nutrition and education, poverty reduction, and women's health (Quisumbing, 2003; Kabeer, 2010; World Bank, 2011; Gates, 2014; Cunningham et al., 2015; Malapit and Quisumbing, 2015). A critical aspect of promoting gender equity—that is, the equal enjoyment of rights, responsibilities, opportunities, and well-being between men, women, and non-binary people—is the empowerment of

women. Empowerment describes the extent to which women are agents who can formulate choices, control resources, and enact decisions that affect important life outcomes (Kabeer, 1999; Malhotra and Schuler, 2005; Johnson et al., 2018), ultimately allowing women and men to fully participate as equal partners in productive and reproductive life.

However, women face significant challenges in their ability to access and control productive resources and opportunities that are important for agricultural livelihoods, although the nature and extent of gender inequity vary across countries, communities, and regions (FAO, 2011; Alkire et al., 2013; Agarwal, 2014; Kilic et al., 2015). In developing countries, women, on average, comprise 43% of the agricultural labor force (FAO, 2020), but are less likely than men to own land or livestock, adopt new technologies, use credit or other financial services, or receive education or agricultural extension services. Women often play a limited role in household decision-making, including about how household income is used (Head et al., 2014). Women's work in agriculture is often unpaid and focuses on the cultivation of crops for household consumption, such as in home gardens (FAO, 2020). Furthermore, when agriculture is mechanized, women's work tends to be excluded from productive activities (Kawarazuka et al., 2019).

Empowerment, broadly, often increases with participation in social mobilization that gives people a voice to demand change. In agriculture, social movements include formal and informal groups organized and led by small-scale farmers to protect their rights and further their opportunities (Martínez-Torres and Rosset, 2010; Rosset and Martínez-Torres, 2012; Blesh and Wittman, 2015). Scholarship on gender in agriculture has highlighted women's exclusion from material and political processes (Allen and Sachs, 2007); in response, while not all rural and agrarian movements are feminist in orientation, the agroecology movement, particularly in Latin America, has increasingly prioritized feminist struggles in social movement formation processes (Trevilla Espinal et al., 2021), including by demanding greater recognition in agroecological spaces of praxis, science, and political formation (Prévost, 2019). For example, in the Brazilian context, it wasn't until the 1980s that some agrarian movements started adopting feminist viewpoints in their agendas (Siliprandi, 2015b). Programs and policies have emerged globally supporting women to participate in agricultural programs and access critical resources, such as land and credit (Oliver, 2016; Johnson et al., 2018). For example, social movements championing food sovereignty in Latin America have made significant gains in strengthening women's formal rights to land access (Deere, 2003, 2017).

Research has found a positive feedback between widely accepted indicators of women's empowerment—namely, decision-making and control over income—and diversified farming systems, particularly those applying agroecological practices (Hall and Mogyorody, 2007; Rosset et al., 2011; Bezner Kerr et al., 2018). Agroecological practices involve the intentional management of plant and animal diversity to support ecosystem functioning, which may eliminate or reduce the need for synthetic inputs and increase environmental sustainability (Wezel et al., 2014). Agroecological systems can improve women's position in agriculture by valuing activities traditionally managed by female farmers such as horticulture, and presenting income opportunities through venues such as farmers' markets (Siliprandi, 2015a). For example, as farms transition from conventional monocultures to diversified agroecological farming, Rosset et al. (2011) observed changes in the structure, roles and power relations within farming families, which led to greater participation and income opportunities for women and other family members. Previous work has also shown that when women make production decisions, they tend to have a positive effect on agrobiodiversity by favoring diverse food crops to support household nutrition (Oakley and Momsen, 2005; Hall and Mogyorody, 2007; Rosset et al., 2011; Bezner Kerr et al., 2018).

Although gender equity is recognized as central to increasing resilience of farms and the food system, a recent review reported that <6% of food security publications in the previous 25 years included the topic of gender (Schipanski et al., 2016). There is a need, then, to identify mechanisms by which policies and interventions in agriculture can enhance women's empowerment (Johnson et al., 2018), and ultimately gender equity. Particularly promising are targeted public food procurement programs, which shift resources to (i.e., target) family farmers and create "structured demand"—that is, a significant and predictable demand—for locally-produced fruits, vegetables, legumes, dairy and other food products. Given their focus on diverse food items, targeted public food procurement programs can enable family farms to transition from intensive monocultures to diversified farming systems (Valencia et al., 2019). However, public food procurement remains an underexplored topic, including its relationships with farming practices and women's empowerment (Swensson et al., 2021).

This study focuses on targeted public food procurement programs that support farm diversification (Valencia et al., 2019) to investigate how public procurement may also serve as a policy mechanism to enhance women's empowerment. Our two key hypotheses are that (1) public procurement programs create an enabling social context that bolsters positive feedbacks between women's empowerment and crop diversification on farms; and, (2) this enabling context is amplified by social movements that both support agroecological farming and champion women's rights (**Figure 1**). Female farmers may benefit from public procurement policies that increase the economic viability of horticultural production, which otherwise represents unpaid labor to support household food consumption. By increasing the economic viability of diversified farming systems, particularly in regions where markets favor a small number of commodities and staple grains, targeted public food procurement can restructure markets to support agricultural activities in which female farmers actively participate.

We tested this framework (**Figure 1**) by analyzing the implementation of Brazil's National School Feeding Program (*Programa Nacional de Alimentação Escolar*, or PNAE, by its Portuguese acronym). The PNAE's main objective is to feed school children a healthy diet while directing at least 30% of its budget to source diversified food products from family farmers. We conducted this research in the state of Santa

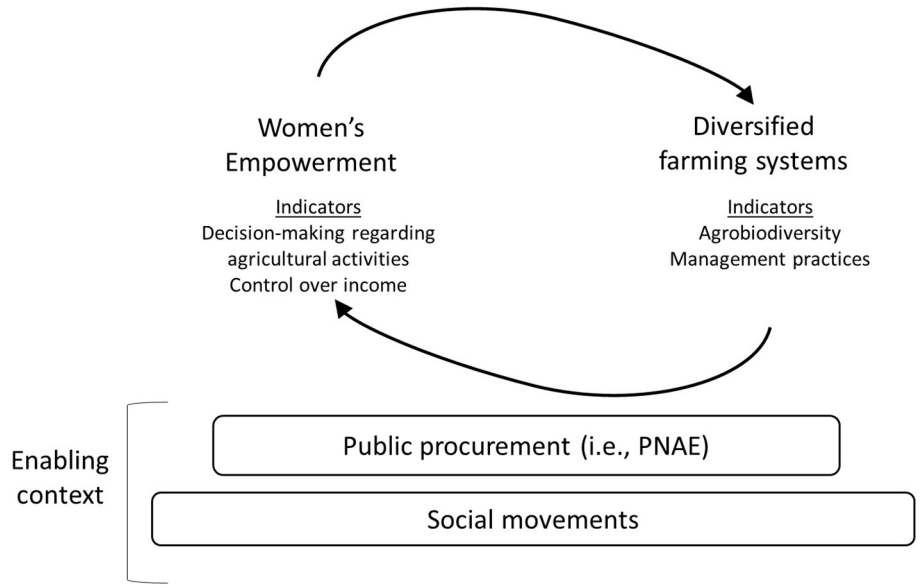

FIGURE 1 | Focusing on targeted public food procurement programs that support farm diversification, we hypothesize that public procurement programs create an enabling social context that bolsters positive feedbacks between women's empowerment and crop diversification on farms; and that this enabling context is amplified by social movements.

Catarina in southern Brazil, where the regional implementation of PNAE has been particularly successful in meeting its food procurement goals compared to other regions of Brazil (FAO, 2014; Schneider et al., 2016). Analyzing a case study in this region allowed us to explore the potential of public procurement programs to enhance the links between women's empowerment and farm diversification. In the following sections, we discuss how we conceptualized and measured women's empowerment; we elaborate on the conceptual linkages between public food procurement and sustainable development; and describe the evolution of the PNAE program in Brazil over the last decade.

Women's Empowerment

Empowerment is defined as increasing the capacity for people to make choices and transform them into desired outcomes (Kabeer, 1999). Specifically, empowerment spans three key dimensions: *resources* (material, human, and social resources which enhance the ability to make choices), *agency* (the ability to define one's goals and act upon them, often operationalized as decision-making) and *achievements* (well-being outcomes) (Kabeer, 1999). The process of empowerment, in which an individual accesses resources and applies them to achieve a meaningful outcome, is critical for achieving gender equity. Although the terms equality and equity are often used interchangeably, they are distinct (Leach et al., 2018). Equality means that resources and opportunities are evenly distributed (i.e., equal treatment), whereas equity involves shifting resources to account for inequality, and better incorporates the concept of justice. We use the term equity in this paper, in part because we focus on a "targeted" policy program that seeks to shift resources and opportunities to increase fairness and improve well-being of marginalized groups.

Empowerment of individuals is influenced both by agency and by the "opportunity structure" of a society; that is, the social and institutional context, including policies, cultural norms, and markets, which also shape access to resources (Narayan, 2005; Ibrahim and Alkire, 2007). Example opportunity structures that influence women's empowerment include family systems, policy conditions and infrastructure, gender ideologies, and regional or local market processes (Malhotra and Schuler, 2005). Structural conditions define the parameters within which different actors can pursue their ambitions, inhibiting the agency of some while promoting that of others. Structural inequities constrain women's ability to make strategic life choices, while institutional changes that are inclusive of women may increase empowerment.

Women's empowerment thus often depends on collective action to change the structures that perpetuate unequal power relations (Narayan, 2005), and women's organizations and social movements have played an important role in creating conditions for change and in facilitating the agency of individuals (Kabeer, 1999). In Latin America, social movements have been crucial for women to attain formal land rights, both in constitutional reforms and in practice. In the late 1990s in Brazil, participation of women within social movements was key for more women to benefit from land reforms (Deere, 2003). Social movements such as the Landless Workers' Movement (*Movimento dos Trabalhadores sem Terra*) began to more explicitly address gender concerns as part of their political strategy, arguing that a failure to recognize women's land rights was detrimental to attaining the movement's goals

(Deere, 2003). In Brazil specifically, women's and gender rights mobilizations were rooted in the spread of rural feminism (Butto, 2019), and engaged with the state in developing new institutions, including the National Council for Food and Nutrition (Conselho Nacional de Segurança Alimentar e Nutricional, CONSEA). Mobilizations by the MST, the Peasant Women's Movement (*Movimento das Mulheres Camponeses, MMC),* and other movements associated with La Vía Campesina led to the development of specific rural credit programs for women (PRONAF), as well as incentives for women's participation in public procurement programs such as the Food Acquisition Program (Programa de Aquisição de Alimentos, PAA) and the PNAE, which increased support for the marketing of food products that tend to predominantly involve–and make visible–women's labor, including horticulture and processed foods (Grisa and Isopo Porto, 2015; Siliprandi and Cintrao, 2015).

In this study, we focus on women's empowerment in farming households in Brazil within the broader context of two key institutions, the PNAE and social movements. We draw from the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI), which is a survey-based tool designed to measure the empowerment, agency, and inclusion of women in the agricultural sector (Malapit et al., 2015). The A-WEAI includes five domains, each with its corresponding indicator, which reflect aspects of empowerment found in the literature: (1) decisions about agricultural production, (2) access to and decision-making power about productive resources, (3) control of use of income, (4) leadership in the community, and (5) time allocation (Alkire et al., 2013). We focus on domains 1 and 3 because we are particularly interested in how women's decision-making regarding agricultural production and control over use of income impact agrobiodiversity and agricultural practices. Moreover, the first domain directly follows from definitions of empowerment as the ability to make choices (Kabeer, 1999; Alsop et al., 2006), in this case about agricultural production. Control over income is key for exercising agency and reflects whether an individual is able to benefit from their efforts. We also consider domain 4 (leadership in the community) with respect to groups that support agroecology because we are interested in the role of social movements in supporting a transformation toward sustainable food systems.

Public Procurement and Sustainable Development

Public procurement constitutes a powerful policy mechanism for sustainable development by leveraging the purchasing power of the state to restructure production and consumption patterns. Estimates suggest that public procurement comprises up to 16% of the GDP in the European Union, while in OECD countries it ranges between 5 and 20% (Brammer and Walker, 2011; OECD, 2017). The potential of targeted public procurement to promote sustainable development is recognized in SDG 12 "Sustainable Consumption and Production Patterns," particularly in target 12.7 to "promote public procurement practices that are sustainable."

Targeted public food procurement establishes what types of food will be purchased (e.g., local, diverse), from whom it will be purchased (e.g., local farmers, women), and the production systems from which it will be purchased (e.g., organic systems) (Swensson et al., 2021). Depending on how these choices are made, governments can tailor public food procurement to policy and social welfare objectives and pursue outcomes, from localizing food systems to supporting the participation of marginalized groups. We suggest, as a theory of change, that public procurement can improve sustainability in food systems by offering:

(1) *A large, predictable, and reliable demand* for agricultural products that reduces risks and uncertainties associated with commodity markets;
(2) A reliable source of *income generation* through the creation of favorable market conditions, particularly for family farmers;
(3) *Price stabilization* through establishment and negotiation of prices;
(4) *Incentives or requirements for meeting voluntary sustainability standards* in production (e.g., organic) and value chain governance (e.g., Fair Trade);
(5) A demand for *diversified food products* (e.g., vegetables, legumes, dairy).

Points 1–3 characterize structured demand (Sumberg and Sabates-Wheeler, 2011; Commandeur and Casey, 2016; Nehring et al., 2017). By creating reliable demand for products grown by smallholder or family farmers, structured demand programs in theory improve food systems by reducing market risk and increasing production and supply chain quality (Coles, 2013). Sources of structured demand include schools, hospitals, the military, and food aid programs. In this form of market, the state mediates supply and demand relationships to drive systemic changes needed to increase market access for smallholder farmers (Wittman and Blesh, 2017). Through government intervention, markets are redesigned to be more "socially efficient" and fair, particularly for supporting food security and other basic social welfare needs (Rocha, 2007). The result is a more accessible, less risky, and more profitable market for farmers to produce food for local and regional consumers (Sumberg and Sabates-Wheeler, 2011).

The National School Feeding Program (PNAE)

Brazil's long-standing National School Feeding Program (PNAE) was redesigned in 2009 to link objectives in food security, education, and rural development, as part of a broader food security strategy based on the creation of new markets driven by public procurement (Schneider et al., 2016). School feeding programs based on targeted procurement, such as PNAE, aim to increase children's consumption of locally and regionally procured food. The focus on *locally* produced food reflects increasing understanding of the potential benefits to farmers, traders, and consumers of localized procurement strategies

(Sumberg and Sabates-Wheeler, 2011). The PNAE is a decentralized program operating at the municipal level.

Since 2009, the PNAE has included a budget benchmark of at least 30% for purchasing food from family farmers within a school's municipality, recognizing the importance of family farmers for meeting national food security needs. Even more relevant to expanding the presence of diversified farming systems, the Brazilian government provides direct incentives for certified organic and agroecological food products through this program (Law No. 12.512, 2012; Resolution No. 26, 2013). PNAE provides up to a 30% price premium for certified organic and agroecological products and prioritizes contracts for certified production (Sidaner et al., 2013). Participatory certification programs that allow peer-to-peer certification and monitoring of practices within farmer networks have been key in supporting the expansion of agroecological practices (Abreu et al., 2012; Guerra et al., 2017). These certification schemes have lower barriers to entry for family farmers (Abreu et al., 2012; Barrett et al., 2012; Guerra et al., 2017) and support practices such as reducing or eliminating chemical fertilizers, preserving native forest, increasing biodiversity, and planting organic seeds (Guerra et al., 2017). Through these innovative mechanisms, PNAE has created a unique market for family farmers to sell diversified food and agricultural products (Wittman and Blesh, 2017; Valencia et al., 2019).

Political mobilization by social movements played a central role in triggering the redesign of PNAE to also benefit family farmers, and especially women farmers. Until the 1990s, public policies in the agricultural sector were largely focused on supporting medium and large export-oriented farms by, for example, offering subsidized credits and capital investment projects (Medina et al., 2015). These credit instruments were practically inaccessible to family farmers. In the 1980s and 1990s, family farmers and landless workers started to emerge as a political force playing an important role in the democratization of Brazil (Wolford, 2010; Grisa and Schneider, 2014). In the 1980s, the Landless Workers Movement mobilized government support for land distribution, while in the 1990s, rural and social movements began a joint campaign demanding government action in response to increasing levels of hunger and malnutrition (Mendonça Leão and Maluf, 2003; Schneider et al., 2010; Rocha et al., 2012). This resulted in a series of programs and policies, such as PNAE, based on the creation of institutional markets aimed at food security and environmental sustainability (Grisa and Schneider, 2014).

Political will was also fundamental to modifying the legal framework to enable innovations in public procurement in Brazil. Typical public procurement procedures follow a bidding process to ensure transparency and reduce discrimination and corruption in government spending. However, the bidding process presents a legal obstacle to family farmers, who cannot easily compete with larger producers due to its formality, complexity, and technical requirements (Müller et al., 2007; Takagi et al., 2014). To facilitate participation of family farmers, it was necessary to adapt the procurement procedure to suit the capabilities and characteristics of family farmers by waiving the bidding process to create a direct procurement mechanism (Swensson, 2015).

MATERIALS AND METHODS

Study Area

The study took place in 2016 in the municipalities of Curitibanos, Correa Pinto, and São Jose do Cerrito in the plateau region of Santa Catarina state in southern Brazil. The study municipalities include a range of farming systems that span soybean, garlic, bean, and corn monocultures; livestock production (e.g., chickens, pigs, dairies); and diversified horticultural crops for both household and market purposes. Markets for soybean, garlic, beans, and corn include regional, national, and international markets, while corn is often produced to feed farmers' own livestock. Typical markets for horticulture crops include local markets such as PNAE, restaurants, and farmers' markets. In Santa Catarina, family farmers comprise 85% of farming establishments with an average farm size of 28.8 hectares (IBGE, 2006). By family farmers, we refer to a farming property that preferentially employs family members and whose income is derived predominantly from farming. This is in line with Brazil's legal definition of family farmers, which is based on four criteria: a maximum land tenure defined regionally; a predominant recourse to non-wage family labor; an income mainly originating from the farming activity; and a farm operated by the family. Santa Catarina ranks highest in the Human Development Index (HDI) after Brazil's Federal District and the state of São Paolo (UNDP., 2016), a level higher than most Latin American countries and corresponding to one of the highest levels of education and literacy in Brazil (IBGE, 2013; SEBRAE, 2013). As in other southern Brazilian states, the racial and gender inequity in wages, education, and occupation is smaller relative to the North of the country (Lovell, 2000). This region is also characterized by more favorable conditions for agriculture compared to other regions of Brazil, including greater access to agricultural credit and infrastructure (Medina et al., 2015).

Santa Catarina is one of the states where PNAE has most successfully met its food procurement objectives. Based on data obtained from FNDE (2018), we calculated that across municipalities in Santa Catarina, on average, 50% of school meal funding was invested in acquisitions from family farmers, thereby exceeding the minimum 30% commitment required by law. In contrast, for all of Brazil, we calculated that only 49% of municipalities meet the minimum (30%) requirement. The other half may not meet this requirement because there are not enough family farmers in the municipality to supply demand, or due to other barriers that prevent participation, such as long distances between farms and food purchasing centers, or poor road infrastructure. The success of PNAE in Santa Catarina is recognized by the United Nations Food and Agriculture Organization, who used this case as a model informing the design and implementation of feeding programs based on targeted public food procurement (FAO, 2014). Focusing this study on a region with robust PNAE policy implementation allowed us

to explore the potential of public procurement in supporting women's empowerment.

Data Collection

To develop the case study, we interviewed members of 20 family farms in our study region who were participating in PNAE. This sample came from a total group of ∼25 family farms enrolled in PNAE in the three municipalities, which we identified via interviews with key informants at local government agencies in each municipality, and farmers' organizations who had official lists of farmers participating in PNAE. Although more than 25 individuals were officially registered in PNAE in the study area, occasionally multiple members of the same household were registered in the program but were associated with the same farming unit. In those cases, we did not "double count" those farmers, but included them in the final sample of 20 family farm households participating in PNAE. We also interviewed members of 55 family farms not participating in PNAE, which were selected to represent the diversity of cropping systems in the region while also minimizing variation in other factors across farms (e.g., soil and climate conditions). We identified non-PNAE family farms with recommendations from key informants combined with snowball sampling.

Surveys to assess women's empowerment and participation in social groups that promote the use of agroecology were directed to the female farmer head of household for all 75 farms. Female farmers were interviewed by female interviewers to help ensure that respondents felt comfortable answering questions related to empowerment. Surveys on management and farm characteristics were directed to the head of household responsible for management. Although management surveys were primarily answered by the male farmer head of household, female farmers were also present and contributed information. Management surveys collected data on farm management, including agrobiodiversity; use agrochemicals and other inputs; extent of mechanization; agroecological certification status, and markets where each product was sold, including PNAE. At the end of each interview, we conducted visual inspection of farms alongside with farmers to corroborate responses on farm agrobiodiversity and management practices; on a few occasions, observed crops had been omitted by respondents during interviews and these were added to the list by the interviewer.

We also conducted key informant interviews with seven female community leaders to gain in-depth understanding of the links between PNAE, social movements, women's empowerment, and farm diversification. Specifically, we discussed the role of female farmers in decision-making about farm diversification in response to market demands created by PNAE, and the role that social movements played in this process. In addition to community leaders in the study site, key informant interviews also included leaders of the Movement of Rural Women (*Movimento de Mulheres Camponesas*) in their offices in Western Santa Catarina; although outside of the study site, these interviews provided valuable contextual information. Key informant interviews were open-ended conversations that lasted between 60 and 120 min. Key informant interviews were conducted by the primary author; surveys were conducted by the primary author and a team of six trained enumerators.

Women's Empowerment

We used the questionnaire developed for the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) to collect data to calculate indicators for two key dimensions of empowerment: (i) female farmers' participation in decisions about agricultural production and (ii) control over use of income (Malapit et al., 2015). We also used the questionnaire developed by A-WEAI to assess leadership in the community, with a specific focus on female farmers' participation in social groups that support knowledge sharing and promotion of agroecological practices.

The A-WEAI was developed and calibrated with data from pilot studies in countries such as Bangladesh and Uganda. At the time of this study, the thresholds of empowerment for these indicators had not been calibrated for middle income countries characterized by higher development metrics (e.g., literacy rates, Human Development Index), such as our study area. We therefore used the A-WEAI survey instrument without applying the proposed thresholds for empowerment. Furthermore, in the original A-WEAI survey, when asked questions about who makes decisions, respondents may only choose "self," "spouse," "other household member," or "other non-household member." Yet based on observations during pilot testing, we noted that joint decision-making between male and female heads of household was a common decision-making strategy in our study region. Consequently, we added another option for respondents: "both my spouse and me." Other studies have also identified joint-decision making as important to farming households (Acosta et al., 2019).

We assessed female farmers' participation in decision-making, and control over use of income, for horticultural plots on the farm—regardless of whether production was for home-consumption or markets—and for the primary agricultural activity as defined by household members, if different from horticulture (e.g., soybean, garlic, dairy). The questionnaire collected the following data from the female farmers who indicated actively participating in a given agricultural activity: who was in charge of decision-making (i.e., "self," "spouse," "self and spouse," "other household member," or "other non-household member"); and how much the female farmer participated in decision-making (i.e., not at all to very little; in some decisions; in most decisions; no decisions were taken). Finally, regarding control over income, we asked how much the female farmer contributed to decision-making on the use of the income generated by the agricultural activity in question (i.e., not at all to very little; in some decisions; in almost all decisions; no decisions were taken).

Agrobiodiversity

We calculated food species (plants and livestock combined) richness for the entire farm and plant species richness for the horticulture plot. Crop species and varieties included fruit trees, vegetables, tubers, and legume grains; livestock species included cows, pigs, chickens, turkeys, rabbits, and other animals. We used

the package Biodiversity.R in the statistical software R to calculate richness metrics (Kindt and Coe, 2005).

Agroecological Practices

As a proxy for application of agroecological practices, we developed an external input intensity indicator following Garibaldi et al. (2016), and applied in Valencia et al. (2019). The indicator was constructed by adding +1 for each input purchased or acquired from off the farm; −1 for each input or organic amendment (e.g., compost, legume cover crops) acquired from the farm based on farmers' own resources; and −0.5 for amendments or pest control products made from both internally and externally acquired ingredients. This indicator captures the goal of agroecological practices to reduce use of off-farm inputs by managing plant diversity (e.g., cover crops or intercrops), or integrated crop-livestock systems for greater ecological function. The indicator values ranged from −5 to +7, where more negative values (i.e., lower input use intensity) reflect greater use of on-farm resources and agroecological management. The indicator was calculated both at the field level (e.g., horticulture plot) and whole farm level by weighting each field's indicator by the farm's total cropped area.

ANALYSES

Institutional Demand for Diversified Food Products and Women's Empowerment

We assessed how PNAE's demand for diversified foods affects women's empowerment. We compared households enrolled and not enrolled in PNAE to investigate the association with two domains of women's empowerment: female farmers' participation in decision-making about agricultural activities, and control over use of income. We used Fisher's exact test to assess if differences between PNAE and non-PNAE were statistically significant, followed by a pairwise comparison by using the Benjamini and Hochberg (1995) correction. All statistical analysis were conducted in the statistical software R (Kindt and Coe, 2005). Values are reported as significant at p-values < 0.05.

Women's Empowerment, Agrobiodiversity, and Agroecological Practices

We examined how female farmers' participation in decision-making about agricultural activities affected agrobiodiversity and agroecological practices. We applied ANOVAs followed by Tukey's HSD to test if agrobiodiversity (measured by richness in both the entire farm and horticulture plots) and the external input intensity indicator were related to: whether female farmers participated (yes or no) in decision-making about the main agricultural activity or horticulture plot (regardless of whether horticulture was the main agricultural activity, or primarily for household consumption); degree of female participation (limited, moderate, or considerable) in decision-making about the main agricultural activity or horticulture; and the person in charge (female, male, or both) of decision-making about the main agricultural activity or horticulture plot. We also conducted a linear regression in which richness in the horticulture plot was the dependent variable, and as explanatory variables we included the primary person in charge of the horticulture plot (female, male, or both), and whether the household was part of PNAE, while controlling for the size of the horticulture plot.

The Role of Social Movements

We tested the role of social movements in enabling: (1) farmers' participation in public programs such as PNAE and (2) women's empowerment. For (1), we compared female farmers' participation in social movements between households enrolled and not enrolled in PNAE by conducting a Welch two-sample t-test and two-sample Wilcoxon tests when data did not meet the assumptions of normality. We checked for normality using the Shapiro-Wilk test. For (2), we conducted Fischer's exact tests to compare whether participating (or not) in social movements was associated with: who was in charge of decision-making; to what extent the female farmer participated in decision-making; and, how much the female farmer contributed to decision-making about the use of income generated by the main agricultural activity. For contingency tables of 2×3, we conducted *post-hoc* multiple pairwise comparisons and adjusted p-values by using the Benjamini and Hochberg (1995) correction.

Qualitative Analysis

Following a mixed methods approach, during each key informant interview, the primary author took detailed notes. Notes were then transferred into summary sheets, from which we summarized the main findings and key themes of each interview. Summary sheets were analyzed to identify recurrent explanations and themes. The qualitative analysis was used to generate contextual information to help interpret statistical results (Blesh and Wittman, 2015).

RESULTS

Institutional Demand for Diversified Food Products and Women's Empowerment

Key informant interviews with female community leaders suggested that female farmers played a mediating role in the process of farm diversification in households enrolled in PNAE. That is, female farmers supported the transition of a household's primary focus from grains or other monoculture systems to diversified farming systems (i.e., horticulture), primarily managed without mechanization. This was because women, who were typically in charge of cultivating home gardens to support a household's self-provisioning, perceived PNAE as a market opportunity from which they could generate an income. The alternative markets for horticultural products primarily included restaurants and small local farmers' markets, which are highly variable in terms of size and stability of demand. Key informants also explained that because the expansion of horticultural production implied a shift of resources (e.g., labor, inputs, time) from the primary activity (often corn and bean monocultures) to horticulture, female farmers played a role in overcoming their household's resistance and anxiety vis-à-vis engaging with a new market. As recounted in multiple interviews, female farmers needed to persuade the male head of household to

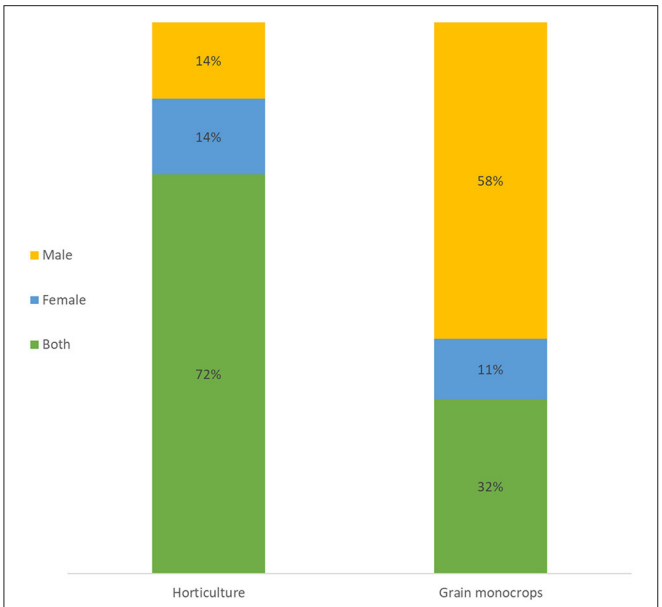

FIGURE 2 | Decision-making by farming system type (horticulture vs. grain monocrops), comparing whether male farmers, female farmers, or both (joint management) were the primary decision makers. The proportion of primary decision makers who were either male farmers or "both" male and female farmers was significantly different between horticulture and grain monocrops (p-value < 0.05).

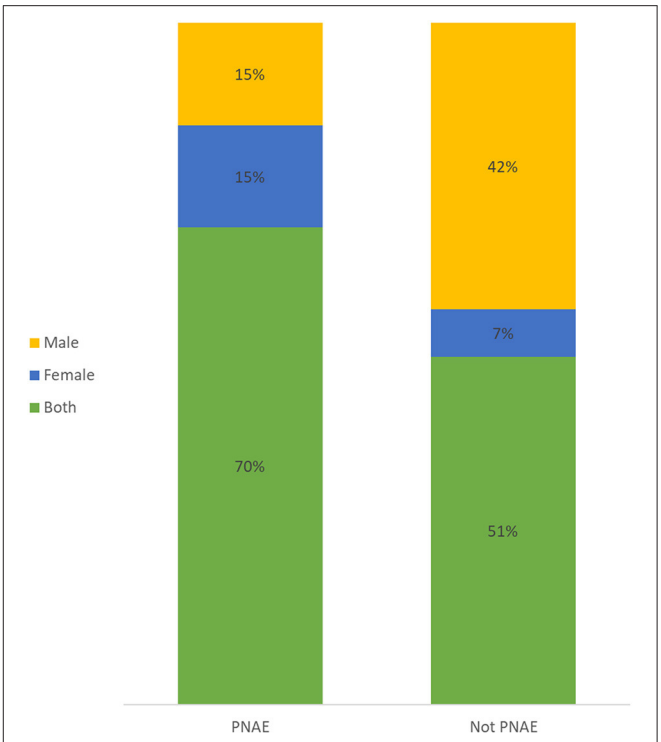

FIGURE 3 | Decision-making by households participating, and not participating, in PNAE, comparing whether male farmers, female farmers, or both (joint management) were the primary decision makers. The overall difference between PNAE and non-PNAE was marginally significant (p-value $=$ 0.06).

support expanding the horticulture plot from a home garden to a larger, market-oriented field capable of meeting PNAE's demands for vegetables, tubers, legumes, and other products.

Expanding horticultural production to participate in PNAE also shifted women's role from previously tending a home garden, or small plot for household consumption, to involvement in decision-making for a market-oriented plot, which in many cases became the main agricultural activity of the household. Female farmers' participation in production decisions in households with horticulture as the main agricultural activity was significantly higher than in households where grains dominated because male farmers typically managed grain cropping systems (p-value < 0.05). The difference was primarily evident in the higher proportion of women involved in "joint" decision-making (72 vs. 32%, p-value < 0.05), and in the lower proportion of men (14 vs. 58%, p-value < 0.05) as the sole decision-makers in horticulture vs. grain monocrop households (**Figure 2**).

All female farmers in the PNAE group reported actively participating in the main agricultural activity, compared to 80% of non-PNAE female farmers (p-value < 0.05). Among female farmers who actively participated in the main agricultural activity, there was a marginally significant difference between the PNAE and control group regarding who made decisions concerning that activity (p-value $= 0.06$) (**Figure 3**), but there were no significant differences regarding control over income. Specifically, for PNAE farmers, most decisions (70%) were made jointly by males and females, while for non-PNAE farmers joint decision making occurred in half the cases (51%). For non-PNAE farmers, 42% of primary decision-makers were male farmers, whereas this only rarely occurred (15%) among male farmers in PNAE. In both groups, female farmers were the primary decision-makers in just a few cases (15% in PNAE; 7 % control group).

Women's Empowerment, Agrobiodiversity, and Agroecological Practices

Results from ANOVA models (**Table 1**) indicated that when female farmers did not participate in decision-making for horticulture crops, whether as the main activity or a plot for home consumption, horticulture richness was halved (p-value < 0.01). The same effect was detected on richness for the entire farm, although it was only marginally significant (p-value $= 0.05$). We also found that when the horticulture plot was managed by both the male and female farmers, crop richness, on average, was 50% greater (p-value < 0.05) compared to when it was just managed by either one alone (see **Table 1**). Furthermore, when only the female farmer, or both the male and female farmers, managed the main agricultural activity, the external input intensity indicator was significantly lower than when only the male farmer managed in isolation (p-value < 0.0001).

Results of linear regression showed that participation in PNAE was the strongest, positive predictor of horticulture richness (p-value < 0.0001) and of total farm richness (p-value < 0.05).

TABLE 1 | Relationship between agrobiodiversity and indicators of women's empowerment. Reported values are means followed by standard deviation in parenthesis.

		Female participation in decision-making for main activity			Female participation in decision-making in horticulture plot			Who is primarily in charge of horticulture plot		
Indicator	Level	Yes ($n = 64$)	No ($n = 11$)	*P*-value	Yes ($n = 66$)	No ($n = 9$)	*P*-value	Both ($n = 38$)	Female ($n = 20$)	Male ($n = 17$)
Richness	Horticulture plot	6.8 (3.8)	2.5 (2.2)	***	6.6 (3.9)	3.2 (1.6)	**	7.5 (4.0)[b]	4.7 (3.1)[a]	5.1 (3.5)[a]
	Farm	19.4 (5.7)	15.8 (4)	•	19.0 (5.8)	17.1 (3.8)	N.S.	19.5 (6.2)[a]	20.6 (5.2)[a]	17.2 (4.4)[a]
External input intensity	Horticulture plot	−2.0 (1.3)	−0.4 (2.1)	**	−1.8 (1.6)	−1.7 (0.7)	N.S.	−1.9[a]	−1.7[a]	−1.5[a]
	Farm	−0.6 (3.1)	2.7 (2.0)	**	−0.26 (3.1)	2.7 (2.9)	*	−1.3[a]	−1.2[a]	1.7[b]

For multiple comparisons, mean values in rows with the same letter do not differ significantly (p-value < 0.05).
****p-value < 0.001.*
***p-value < 0.01.*
**p-value < 0.05.*
•p-value = 0.05.
N.S. p-value > 0.05.

Management by the female or male farmer alone was a negative predictor of horticulture richness (p-value < 0.05) compared to joint management, which tended to have a positive, but not statistically significant, relationship in linear regression.

The Role of Social Movements

Our analysis of the role of social movements identified two key groups that promoted agroecological practices in the region (henceforth "agroecological social movements"). One group was a local NGO actively engaged in particular communities in the study region, which leads programs to support the dissemination of knowledge about agroecological practices, and helps family farmers attain and retain certification for organic production. Women were actively encouraged by the NGO to participate in trainings and workshops; 23% of the women farmers interviewed for the study participated in activities led by this group, but not all interviewed farmers knew of its existence or participated. The second group was the Movement of Rural Women (MCC); about a third of female farmers in the study sample were engaged with the movement. Other groups in the region supported agroecological practices, but not exclusively; that is, they also provided technical assistance for other types of farming (e.g., garlic, corn, and soy monocultures). For example, the cooperative-based rural bank and the state's extension agency both played a role in supporting agroecological farmers, but also provided technical assistance and financial support for conventional management systems. These other groups were not included in the category "agroecological social movements" in our analysis.

We found that 65% of PNAE households participated in agroecological social movements compared to 40% of non-PNAE farmers (marginally significant difference, p-value $= 0.06$). Additionally, households in which female farmers participated in agricultural programs led by the local NGO were ∼7 times more likely to be enrolled in PNAE than those not participating in these NGO programs (odds ratio $= 6.63$; 95% CI: 1.8, 26.4; p-value < 0.001).

Across the entire sample (both PNAE and non-PNAE participants), most women (85%) actively participated in the main agricultural activity; among these women, half (47%) also participated in agroecological social movements while the other half (53%) did not participate. When we compared these latter two groups, we found greater participation in decision-making regarding main agricultural activities (p-value < 0.01) and a higher control over income (p-value < 0.01) for the women who participated in agroecological social movements.

DISCUSSION

To understand how public policies that increase farm diversification can also support women's empowerment in agriculture, we evaluated links between targeted public food procurement and gender dynamics. The PNAE public food procurement program targets family farmers and other marginalized social groups by creating a large and reliable (i.e., "structured") demand for diversified food products. The structural changes facilitated by PNAE modified the parameters within which women participate in agricultural activities and farm household decision-making. In supporting the process of farm diversification, PNAE benefited women's empowerment by creating the conditions for women to pursue productive activities, such as growing food products for PNAE, and make strategic choices including decision-making regarding productive activities and control over income.

The changes brought by PNAE would have been difficult to achieve without the social movements that prompted its redesign in the 2000s. By institutionalizing a guaranteed right to a market for family farmers, PNAE massified the efforts of social movements to support the family farming sector in Brazil (Grisa and Schneider, 2014). Women's empowerment was also bolstered by collective solidarity created by social groups, which had been supporting conditions for social change even before PNAE was redesigned. In our study, women who participated in social movements were more empowered and their households were more likely to participate in PNAE, possibly because participation in social movements increased their self-confidence, self-determination, and ability to pursue

activities they value (Ibrahim and Alkire, 2007; Alkire, 2008). For instance, social movements focused on agroecological knowledge may contribute to women's empowerment by supporting peer-to-peer knowledge sharing, training and workshops, thereby supporting women's confidence on their own knowledge base (Sumner and Llewelyn, 2011). However, it must be noted that agroecological social movements have not always been consciously feminist. Reaching the point in which some of these social movements embraced a feminist agenda is the result of long endured struggles and efforts of women within these movements (Butto, 2017).

PNAE enabled households to transition from input-intensive monocultures to diversified farming systems (e.g., horticulture) and to increase the size of horticulture plots (Valencia et al., 2019). These two key changes shifted women's role from tending a home garden for household consumption to involvement in a primary household economic activity. Other studies in Brazil have shown that a similar targeted public food procurement program—*Programa de Aquisição de Alimentos*, or the Program for Food Acquisition—also enabled female farmers to pursue and achieve economic autonomy (dos Santos et al., 2018). These outcomes are key for women's contribution to family income, although often within a context of subordination and a well-defined gender division of labor (Lopes Barbosa, 2017). Despite evidence for women's higher participation in, and decision-making about, productive activities in households involved in programs such as PNAE, registration data suggests that women's participation in such programs is low. This is likely because male heads of household are the ones who officially register for these programs (Siliprandi and Cintrão, 2011).

Our findings are consistent with other studies reporting that agroecological farming can more equitably distribute power and labor between men and women (Hall and Mogyorody, 2007; Bodapati and Chander, 2011; Sumner and Llewelyn, 2011). Gendered knowledge may help explain why women's participation is higher in diversified production systems, particularly those managed with agroecological practices. Knowledge about production systems and their management may differ between men and women due to gendered roles, a result of the division of household tasks and sometimes farming separate plots. In conventional agriculture, which is often mechanized and dominated by low diversity cultivation of cash crops, men tend to control both productive knowledge and decision-making (Momsen, 2004; Kawarazuka et al., 2019). Dividing resources and responsibilities in this way reflects gendered power relations in the use and control of resources (Rocheleau et al., 1996; Rocheleau, 2005).

PNAE supports a process of farm diversification (Valencia et al., 2019), for which women's empowerment played a crucial part. Across all farms, we found that when women were absent from decision-making, agrobiodiversity was lower and farmers relied less on agroecological practices. On the other hand, when both men and women were involved in decision-making, they jointly managed higher levels of agrobiodiversity while increasing use of agroecological practices. This may be because the complexity of management systems increases as agrobiodiversity increases, as does the knowledge required about ecological interactions among crop species and between crop and wild species (Kremen et al., 2012; Pauli et al., 2012). When men and women have complementary, rather than redundant, knowledge about agricultural production, joint decision-making may allow the household to manage more complex, knowledge-intensive systems. Higher complexity may also translate to higher labor demands, which requires the involvement of more family members. Joint decision-making demonstrates that a transition toward agroecology requires the integration of experiences and knowledge from different family members who manage different plots, thereby breaking the "management monopoly" that men often hold (Siliprandi, 2015a). While joint decision-making implies equal say between spouses, Acosta et al. (2019) caution against assuming that joint decision-making is equally balanced. In their study, they found that women reported joint decision-making more often than men in the same households. While denoting a certain level of perceived agency, this result also signals conflicting perceptions of participation and power dynamics. Although we cannot eliminate this possibility from our own study, based on field observations and key informant interviews, we are confident that joint decision-making in this study accurately captured women's bargaining power in an intrahousehold process of negotiation.

Gender dynamics related to technology were reflected in our study in the differences in women's participation in decision-making between horticulture and grain monocropping. Agricultural mechanization—the adoption of labor-saving machines and tools for agriculture—has been shown to alienate women from agricultural activities (Jellison, 1993; Niskanen, 2001; Hall and Mogyorody, 2007). Technology may accentuate gender inequities by introducing machines, such as tractors, that result in men gaining power both materially and symbolically. Often, labor saving technologies, such as plowing, harrowing, and weeding machines, are only used by men because both men and women perceive those machines as physically too heavy for women, or too difficult or dangerous to handle (Kawarazuka et al., 2019). This is partly because technological innovations are often proposed or developed by male researchers in response to priorities identified by male farmers, resulting in the production and reproduction of male-oriented technology (Kline and Pinch, 1996; Kawarazuka et al., 2019). In this way, technology influences, and is influenced by, gender relations (Wajcman, 2010). From a normative perspective, women's decision-making and capacity to participate in productive decisions should not be constrained by commodity and grain markets. Kawarazuka et al. (2019) argues that rather than trying to increase women's acess to existing male-oriented technologies, agricultural development interventions need to identify the needs of women and other marginalized groups (e.g., ethnic minorities) and (re)design tehcnologies with these groups' needs as priorities. Consulting women in the design process and adjusting technologies to their needs and priorities can ensure higher adoption of time-saving technologies by both men and women (Kawarazuka et al., 2018). This may reduce the amplifying effect that some forms of technological innovation can have on gender inequity and power imbalances.

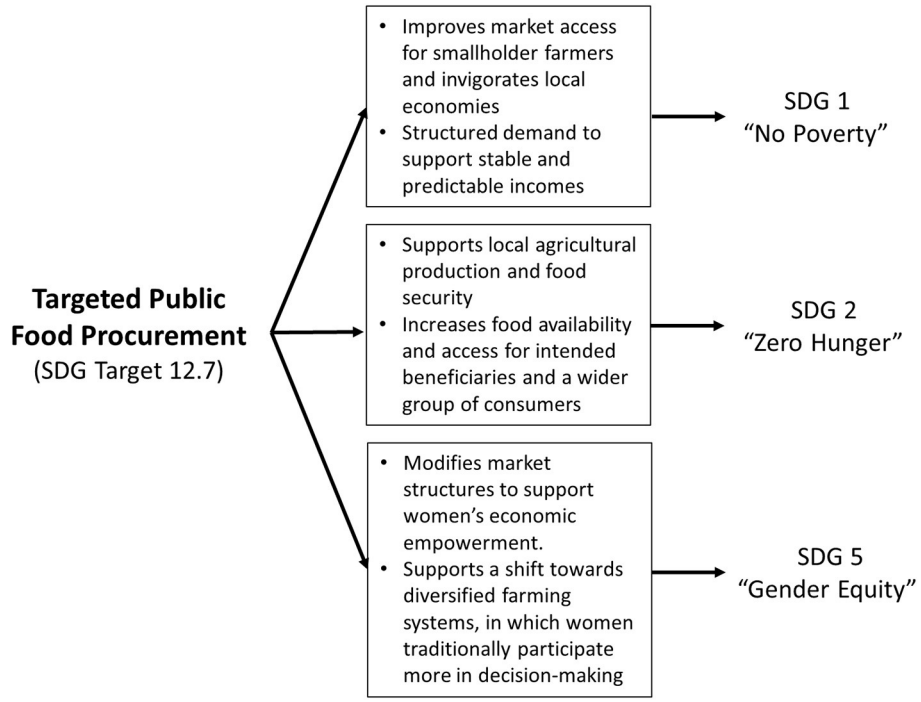

FIGURE 4 | Targeted public food procurement programs, such as Brazil's National School Feeding Program, may contribute to sustainable consumption and production patterns (SDG 12, target 12.7). Targeted public food procurement may also support other Sustainable Development Goals, particularly SDG 1 "No Poverty," SDG 2 "Zero Hunger," and SDG 5 "Gender Equality".

Women's higher level of participation in productive activities, although a positive indicator of empowerment, may have negative implications on women's time allocation. We did not apply the A-WEAI module on time allocation, which would have allowed us to examine whether changes in women's roles in productive activities in agriculture resulted in more total working hours. Increasing the number of hours worked in the field does not necessarily release women from their usual household work, which means that they may experience a double workday (Allen and Sachs, 2007; Brumer, 2008). Although women's empowerment is often associated with improved maternal and child health (van den Bold et al., 2013; Cunningham et al., 2015; Pratley, 2016), an increased involvement in productive activities may come at a trade off with time spent on care practices, such as breastfeeding, negatively affecting child nutrition (Barrios and Hoffman, 2012; Jones, 2014; Cunningham et al., 2015). Furthermore, studies that have also found higher levels of household decision-making and control over income among women who participate in social movements, reported that these benefits are offset by time poverty, as women continue to bear a disproportionate share of domestic labor obligations (Lyon et al., 2017). Therefore, development interventions and programs such as PNAE should take into account the demands on women's time from the responsibilities of income-generating activities and other duties such as child rearing and household work (Koehler, 2016). Although our results suggest that women in households participating in PNAE are more empowered, the implications of potential changes in time allocation on their work burden and in other aspects of women's lives in the study sample require further study.

Policy Implications

Public procurement programs, such as PNAE, may support SDG 1 "No Poverty," SDG 2 "Zero Hunger," and SDG 5 "Gender Equality" while also providing a tangible pathway for implementing SDG 12, target 12.7, which promotes sustainable public procurement, but which is only vaguely phrased and does not provide effective guidance for implementation (Bengtsson et al., 2018; **Figure 4**). Realizing the full potential of public procurement will require a conducive regulatory framework to translate broader sustainability and development objectives into procurement rules and practices (Swensson and Tartanac, 2020).

By design, public procurement programs based on structured demand have the potential to serve broad development objectives, including supporting local and more sustainable agricultural production and increasing food security thereby addressing SDG 2 "Zero Hunger." These programs may influence the structural determinants of food security by reducing food price volatility (an issue for both urban consumers and rural producers) and maintaining dynamic domestic food supply chains (Ashe and Sonnino, 2013)., Targeted public food procurement may indirectly benefit food security by increasing food availability and access for a wider group of consumers, including farmers themselves and the local community (Coles, 2013; FAO, 2018). For example, by focusing on diversified food products, these programs contribute to achieving "Zero

Hunger" among program beneficiaries, while also creating positive spillover effects in communities by increasing the local and regional supply of diversified food products (Valencia et al., 2019).

Public procurement programs may also help address SDG 1 "No Poverty" by improving market access for disadvantaged groups and invigorating local economies. Because they are targeted programs, they reduce barriers to entry and transaction costs for the targeted disadvantaged groups (e.g., smallholder farmers) (Sumberg and Sabates-Wheeler, 2010), and thus reduce the risks of market participation. For instance, Brazil adapted its legal frameworks to allow public procurement calls to favor local, small-scale farmers (Swensson, 2015). Structured demand may also support the process of economic localization by linking local producers (family farmers) with local consumers (e.g., procurement beneficiaries).

Finally, public procurement could directly address SDG 5 "Gender Equality" by enacting "gender-responsive procurement," defined by UN Women—the UN organization dedicated to gender equity—as "the selection of goods, civil works or services that take into account their impact on gender equality and women's empowerment" (U. N. Women, 2020). Public procurement may also support women's economic empowerment by creating more inclusive access to supply chains and increasing their participation in labor markets (Harris Rimmer, 2017). One way of removing barriers for women to participate in public procurement is to preferentially engage enterprises owned by women (Chin, 2017). For example, Brazil's Food Acquisition Program, established in 2011, requires that at least 40% of purchases come from female farmers in order to strengthen gender equity and address the "invisibility" of women in public procurement policies (dos Santos et al., 2018).

CONCLUSION

Gender equity is now recognized as central to sustainable development, as highlighted in SDG 5 in the United Nations Agenda 2030. However, women still face significant constraints in accessing and controlling productive resources important for agricultural livelihoods. In this study, we showed that public procurement is a promising policy mechanism for enhancing women's empowerment in agriculture, in combination with social movements that are inclusive of women. Procurement programs such as PNAE, which target family farmers, may support women's empowerment by creating local markets for a wide range of food products, thereby valuing diversified production systems which are more inclusive of women. By supporting women's empowerment at the household level, the interplay between PNAE and social movements has the potential for positive feedbacks that increase gender equity, indicating that interactions between grassroots movements and government institutions can create more equitable and sustainable food systems.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Michigan IRB. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

VV: conceptualization, methodology, investigation, data curation, formal analysis, visualization, and writing—original draft. HW and AJ: writing—reviewing and editing. JB: conceptualization, methodology, writing—reviewing and editing, funding acquisition, and supervision. All authors contributed to the article and approved the submitted version.

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REFERENCES

Abreu, L. S., Bellon, S., Brandenburg, A., Ollivier, G., Lamine, C., Darolt, M. R., et al. (2012). Relações entre agricultura orgânica e agroecologia: desafios atuais em torno dos princípios da agroecologia. *Desenvolv. e Meio Ambient.* 26, 143–160. doi: 10.5380/dma.v26i0.26865

Acosta, M., van Wessel, M., van Bommel, S., Ampaire, E. L., Twyman, J., Jassogne, L., et al. (2019). What does it mean to make a 'Joint' decision? unpacking intra-household decision making in agriculture: implications for policy and practice. *J. Dev. Stud.* 56, 1210–1229. doi: 10.1080/00220388.2019.1650169

Agarwal, B. (2014). Food sovereignty, food security and democratic choice: critical contradictions, difficult conciliations. *J. Peasant Stud.* 41, 1247–1268. doi: 10.1080/03066150.2013.876996

Alkire, S. (2008). *Concepts and Measures of Agency*. OPHI Working Paper 9, Oxford: University of Oxford. doi: 10.1093/acprof:oso/9780199239115.003.0025

Alkire, S., Meinzen-Dick, R., Peterman, A., Quisumbing, A., Seymour, G., and Vaz, A. (2013). The women's empowerment in agriculture index. *World Dev.* 52, 71–91. doi: 10.1016/j.worlddev.2013.06.007

Allen, P., and Sachs, C. (2007). Women and food chains 1 : the gendered politics of food. *Int. J. Sociol. Food Agric.* 15, 1–23. Available online at: https://doi.org/10.48416/ijsaf.v15i1.424

Alsop, R., Bertelsen, M., and Holland, J. (2006). *Empowerment in Practice From Analysis to Implementation*. Washington, DC: World Bank. doi: 10.1596/978-0-8213-6450-5

Ashe, L. M., and Sonnino, R. (2013). At the crossroads: new paradigms of food security, public health nutrition and school food. *Public Health Nutr.* 16, 1020–1027. doi: 10.1017/S1368980012004326

Barrett, H. R., Browne, A. W., Harris, P. J. C., and Cadoret, K. (2012). Smallholder farmers and organic certification: accessing the eu market from the developing world. *Biol. Agric. Horicult.* 19, 183–199. doi: 10.1080/01448765.2001.9754920

Barrios, P. L., and Hoffman, D. J. (2012). *Relationship Between Household Strcture, Maternal Autonomy and Undernutrition in Brazilian Children* (dissertation). New Brunswick, NJ: The State University of New Jersey. doi: 10.1096/fasebj.27.1_supplement.618.7

Bengtsson, M., Alfredsson, E., Cohen, M., Lorek, S., and Schroeder, P. (2018). Transforming systems of consumption and production for achieving the sustainable development goals: moving beyond efficiency. *Sustain. Sci.* 13, 1533–1547. doi: 10.1007/s11625-018-0582-1

Benjamini, Y., and Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *J. R. Stat. Soc. Ser. B* 57, 289–300. doi: 10.1111/j.2517-6161.1995.tb02031.x

Bezner Kerr, R., Hickey, C., Lupafya, E., and Dakishoni, L. (2018). Repairing rifts or reproducing inequalities? Agroecology, food sovereignty, and gender justice in Malawi. *J. Peasant Stud.* 6150, 1499–1518. doi: 10.1080/03066150.2018.1547897

Blesh, J., and Wittman, H. (2015). "Brasilience:" assessing resilience in land reform settlements in the Brazilian Cerrado. *Hum. Ecol.* 43, 531–546. doi: 10.1007/s10745-015-9770-0

Bodapati, S., and Chander, M. (2011). Organic agriculture: a way forward to achieve gender equality in India. *J. Org. Syst.* 6, 13–19.

Brammer, S., and Walker, H. (2011). Sustainable procurement in the public sector: an international comparative study. *Int. J. Oper. Prod. Manag.* 31, 452–476. doi: 10.1108/01443571111119551

Brumer, A. (2008). Gender relations in family-farm agriculture and rural-urban migration in Brazil. *Lat. Am. Perspect.* 35, 11–28. doi: 10.1177/0094582X08326012

Butto, A. (2017). *Movimentos Sociais De Mulheres Rurais No Brasil : A Construção Do Sujeito Feminista* (dissertation). Recife: Universidade Federal de Pernambuco.

Butto, A. (2019). "March of the daisies: subject, agriculture, and the state," in *State Capitalism Under Neoliberalism: The Case of Agriculture and Food in Brazil*, eds A. Bonanno and J. S. Barbosa Cavalcant (Lanham, MD: The Rowman & Littlefield), 1–113.

Chin, K. (2017). *The Power of Procurement: How to Source from Women-Owned Businesses*. New York, NY: UN Women.

Coles, C. (2013). *What is Known About the Impact of Structured Demand Activities on Resilient Food Systems?*. London: Overseas Development Institute. Available online at: https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8618.pdf (accessed May 20, 2020).

Commandeur, D., and Casey, K. (2016). *Structured Demand Markets and Smallholder Farmers: Relevance and Access*. SNV. Available online at: https://agriknowledge.org/downloads/zp38wc67w (accessed September 20, 2020).

Cunningham, K., Ruel, M., Ferguson, E., and Uauy, R. (2015). Women's empowerment and child nutritional status in South Asia: a synthesis of the literature. *Matern. Child Nutr.* 11, 1–19. doi: 10.1111/mcn.12125

Deere, C. D. (2003). Women's land rights and rural social movements in the Brazilian agrarian reform. *J. Agrar. Chang.* 3, 257–288. doi: 10.1111/1471-0366.00056

Deere, C. D. (2017). Women's land rights, rural social movements, and the state in the 21st-century Latin American agrarian reforms. *J. Agrar. Chang.* 17, 258–278. doi: 10.1111/joac.12208

dos Santos, Á. O., Wagner Silva, D., and Quaresma, E. S. (2018). "Women farmers and the PAA: participation in the productive process and commercialization," in *3rd International Conference "Agriculture and food in an urbanizing society"* (Porto Alegre, Brazil: Universidade Federal do Rio Grande do Sul), 1–8.

FAO. (2011). *Women in Agriculture: Closing the Gender Gap for Development*. Rome: FAO Available online at: http://files/4686/FAO-2011-Women/inagriculture/closing/thegender/gapfor/d.pdf (accessed October 31, 2020).

FAO. (2014). Scaling *Up the Brazilian School Feeding model: Using South–South Cooperation to Share Brazil's Experience of School Feeding in Latin America and the Caribbean*. Rome: Food and Agriculture Organization. Available online at: http://www.fao.org/3/a-h0050e.pdf (accessed September 20, 2020).

FAO. (2018). *Strengthening Sector policies for Better Food Security and Nutrition Results: Public Food Procurement. Policy Guidance Note*. Rome. Available online at: http://www.wipo.int/amc/en/mediation/rules (accessed April 11, 2019).

FAO. (2020). *The Female Face of Farming*. Rome. Available online at: http://www.fao.org/gender/resources/infographics/the-female-face-of-farming/en/ (accessed January 17, 2020).

Fundo Nacional de Desenvolvimento da Educacao (FNDE) (2018) *Dados da Agricultura Familiar*. Available online at: https://www.fnde.gov.br/programas/pnae/pnae-consultas/pnae-dados-da-agricultura-familiar

Garibaldi, L. A., Carvalheiro, L. G., Vaissière, B. E., Gemmill-Herren, B., Hipólito, J., Freitas, B. M., et al. (2016). Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. *Science* 351, 388–391. doi: 10.1126/science.aac7287

Gates, M. F. (2014). Putting women and girls at the center of development. *Science* 345, 1273–1275. doi: 10.1126/science.1258882

Grisa, C., and Isopo Porto, S. (2015). "Dez anos de PAA: As contribuições e os desafios para o desenvolvimento rural," in *Políticas Públicas de Desenvolvimento Rural NO BRASIL*, eds. C. Grisa, and S. Schneider (Porto Alegre, Brazil: Editora da UFRGS), 155–180.

Grisa, C., and Schneider, S. (2014). Três gerações de políticas públicas para a agricultura familiar e formas de interação entre sociedade e estado no Brasil. *Rev. Econ. e Sociol. Rural* 52, 125–146. doi: 10.1590/S0103-20032014000600007

Guerra, J., Blesh, J., Schmitt, A., and Wittman, H. (2017). Pathways to agroecological management through mediated markets in Santa Catarina, Brazil. *Elem. Sci. Anth.* 5, 1–16. doi: 10.1525/elementa.248

Hall, A., and Mogyorody, V. (2007). Organic farming, gender, and the labor process. *Rural Sociol.* 72, 289–316. doi: 10.1526/003601107781170035

Harris Rimmer, S. (2017). *Gender-Smart Procurement Policies for Driving Change*. London: Chatham House.

Head, S., Zweimueller, S., Marchena, C., and Hoel, E. (2014). *Women's Lives and Challenges : Equality and Empowerment Since 2000*. Maryland, USA. Available online at: www.dhsprogram.com (accessed September 22, 2020).

Ibrahim, S., and Alkire, S. (2007). Agency and empowerment: a proposal for internationally comparable indicators. *Oxford Dev. Stud.* 35, 379–403. doi: 10.1080/13600810701701897

Instituto Brasileiro de Geografia e Estadisticas (IBGE) (2006). *Censo Agropecuario*, Available online at: http://www.sidra.ibge.gov.br/bda/acervo/acervo2.asp?ti=1&tf=99999&e=v&p=CA&z=t&o=11

Instituto Brasileiro de Geografia e Estadísticas (IBGE) (2013). Segurança Alimentar. Report. Available online at: http://www.ibge.gov.br/home/presidencia/noticias/imprensa/ppts/00000020112412112014 2_43818986695.pdf

Jellison, K. (1993). *Entitled to Power: Farm Women and Technology, 1913-1963*. North Carolina: University of North Carolina Press.

Johnson, N., Balagamwala, M., Pinkstaff, C., Theis, S., and Meinzen-dick, R. (2018). How do agricultural development projects empower women? *Link. Strat. Expect. Outcomes*. 3, 1–19.

Jones, A. D. (2014). The production diversity of subsistence farms in the Bolivian Andes is associated with the quality of child feeding practices as measured by a validated summary feeding index. *Public Health Nutr.* 18, 329–342. doi: 10.1017/S1368980014000123

Kabeer, N. (1999). Resources, agency, achievements: reflections on the measurement of women's empowerment. *Dev. Change* 30, 435–464. doi: 10.1111/1467-7660.00125

Kabeer, N. (2010). Women's empowerment, development interventions and the management of information flows. *IDS Bull.* 41, 105–113. doi: 10.1111/j.1759-5436.2010.00188.x

Kawarazuka, N., Anh, N. T. H. I. V. A. N., Thai, V. U. X., and Thuong, P. H. U. U. (2019). "A Bird Locked in a Cage": Hmong young women's lives after marriage in northern Vietnam. *Gender Agric. Agrar. Transform. Chang. Relations Afr. Lat. Am. Asia* 111–126. doi: 10.4324/9780429427381-7

Kawarazuka, N., Prain, G., Forsythe, L., Mayanja, S., Mudege, N. N., Babini, C., et al. (2018). *Gender in Agricultural Mechanization: Key Guiding Questions*. Lima, Peru. Available online at: http://www.vedcouganda.org (accessed April 13, 2020).

Kilic, T., Winters, P., and Carletto, C. (2015). Gender and agriculture in sub-Saharan Africa: introduction to the special issue. *Agric. Econ.* 46, 281–284. doi: 10.1111/agec.12165

Kindt, R., and Coe, R. (2005). *Tree Diversity Analysis. A Manual and Software for Common Statistical Methods for Ecological and Biodiversity Studies*. Nairobi: World Agroforestry Centre (ICRAF).

Kline, R., and Pinch, T. (1996). Users as agents of technological change: the social construction of the automobile in the rural United States. *Technol. Cult.* 37, 763–795. doi: 10.2307/3107097

Koehler, G. (2016). Tapping the Sustainable Development Goals for progressive gender equity and equality policy? *Dender Dev*. 24, 53–68. doi: 10.1080/13552074.2016.1142217

Kremen, C., Iles, A., and Bacon, C. (2012). Diversified farming systems: an agroecological, systems-based alternative to modern industrial agriculture. *Ecol. Soc.* 17, 288–306. doi: 10.5751/ES-05103-170444

Leach et al., Leach, M., Reyers, B., Bai, X., Brondizio, E. S., Cook, C., Díaz, S., et al. (2018). Equity and sustainability in the anthropocene: a social-ecological systems perspective on their intertwined futures. *Glob. Sustain.* 1, 1–13. doi: 10.1017/sus.2018.12

Lopes Barbosa, T. (2017). *The Process of Empowerment of Rural Women and the Programa Nacional de Alimentação Escolar (PNAE): the Case of Viçosa-MG*. (Master's thesis). Viçosa, Minas Gerais: Universidade Federal de Viçosa.

Lovell, P. A. (2000). Race, gender and regional labor market inequalities in Brazil. *Rev. Soc. Econ.* 58, 277–293. doi: 10.1080/00346760050132337

Lyon, S., Mutersbaugh, T., and Worthen, H. (2017). The triple burden: the impact of time poverty on women's participation in coffee producer organizational governance in Mexico. *Agric. Human Values* 34, 317–331. doi: 10.1007/s10460-016-9716-1

Malapit, H., Kovarik, C., Sproule, K., Meinzen-Dick, R., and Quisumbing, A. (2015). *Instructional Guide on the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI)*. International Food Policy Research Institute. Available online at: http://files/4692/Malapit et al. - Instructional Guide on the Abbreviated Women's Emp.pdf

Malapit, H., and Quisumbing, A. (2015). What dimensions of women's empowerment in agriculture matter for nutrition in Ghana? *Food Policy* 52, 54–63. doi: 10.1016/j.foodpol.2015.02.003

Malhotra, A., and Schuler, S. (2005). "Chapter 3 women's empowerment as a variable in international development," in *Measuring Empowerment Cross-Disciplinary Perspectives*, ed. Narayan (Washington, DC: World Bank), 1–496.

Martínez-Torres, M. E., and Rosset, P. (2010). La Vía Campesina: the birth and evolution of a transnational social movement. *J. Peasant Stud.* 37, 149–175. doi: 10.1080/03066150903498804

Medina, G., Almeida, C., Novaes, E., Godar, J., and Pokorny, B. (2015). Development conditions for family farming: lessons from Brazil. *World Dev.* 74, 386–396. doi: 10.1016/j.worlddev.2015.05.023

Mendonça Leão, M., and Maluf, R. S. (2003). *Effective Public Policies and Active Citizenship: Brazil's Experience of Building a Food and Nutrition Security System*. Brasilia: Abrandh and Oxfam.

Momsen, J. H. (2004). "Gender and development," in *Gender and Developmen* (London; New York, NY: Routledge).

Müller, A. L., Fialho, M. A. V., and Schneider, S. (2007). A inovação institucional e a atuação dos atores locais na implementação do Programa de Aquisição de Alimentos no Rio Grande do Sul. *Soc. e Desenvolv. Rural.* 1, 1–21.

Narayan, D., ed. (2005). *Measuring Empowerment: Cross-Disciplinary Perspectives*. Washington, DC: World Bank. doi: 10.1037/e597202012-001

Nehring, R., Miranda, A., and Howe, A. (2017). Making the case for institutional demand: supporting smallholders through procurement and food assistance programmes. *Glob. Food Sec.* 12, 96–102. doi: 10.1016/j.gfs.2016.09.003

Niskanen, K. (2001). Gender economics in action: rural women's economic citizenship in Finland during the twentieth century. *J. Womens. Hist.* 13, 132–152. doi: 10.1353/jowh.2001.0054

Oakley, E., and Momsen, J. H. (2005). Gender and agrobiodiversity: a case study from Bangladesh. *Geogr. J.* 171, 195–208. doi: 10.1111/j.1475-4959.2005.00160.x

OECD (2017). *"Size of public procurement," in Government at a Glance 2017* (Paris).

Oliver, B. (2016). "The Earth Gives Us So Much": agroecology and rural women's leadership in Uruguay. *Cult. Agric. Food Environ.* 38, 38–47. doi: 10.1111/cuag.12064

Pauli, N., Barrios, E., Conacher, A. J., and Oberthür, T. (2012). Farmer knowledge of the relationships among soil macrofauna, soil quality and tree species in a smallholder agroforestry system of western Honduras. *Geoderma* 189–190, 186–198. doi: 10.1016/j.geoderma.2012.05.027

Pratley, P. (2016). Associations between quantitative measures of women's empowerment and access to care and health status for mothers and their children: a systematic review of evidence from the developing world. *Soc. Sci. Med.* 169, 119–131. doi: 10.1016/j.socscimed.2016.08.001

Prévost, H. (2019). Agroecologia, uma ciência 'norma(l)cho'? sob as escrituras científicas, o androcentrismo. *Rev. Cad. Ciências Sociais da UFRPE.* 2, 25–52.

Quisumbing, A. (2003). *Household Decisions, Gender, and Development: A Synthesis of Recent Research*. Available online at: http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129647 (accessed October 8, 2019).

Rocha, C. (2007). Food insecurity as market failure: a contribution from economics. *J. Hunger Environ. Nutr.* 1, 5–22. doi: 10.1300/J477v01n04_02

Rocha, C., Burlandy, L., and Maluf, R. (2012). Small farms and sustainable rural development for food security: the Brazilian experience. *Dev. South. Afr.* 29, 519–529. doi: 10.1080/0376835X.2012.715438

Rocheleau, D. (2005). *Gender, Environment and Development*. London; New York, NY: Routledge.

Rocheleau, D., Thomas-Slayter, B., and Wangari, E., eds. (1996). *Feminist Political Ecology: Global Issues and Local Experiences*. London: Routledge.

Rosset, P., and Martínez-Torres, M. E. (2012). Rural social movements and agroecology: context, theory, and process. *Ecol. Soc.* 17:17. doi: 10.5751/ES-05000-170317

Rosset, P., Sosa, B. M., Jaime, A. M. R., and Lozano, D. R. Á. (2011). The Campesino-to-Campesino agroecology movement of ANAP in Cuba: social process methodology in the construction of sustainable peasant agriculture and food sovereignty. *J. Peasant Stud.* 38, 161–191. doi: 10.1080/03066150.2010.538584

Schipanski, M. E., MacDonald, G. K., Rosenzweig, S., Chappell, M. J., Bennett, E. M., Bezner Kerr, R., et al. (2016). Realizing resilient food systems. *Bioscience* 66, 600–610. doi: 10.1093/biosci/biw052

Schneider, S., Shiki, S., and Belik, W. (2010). Rural development in Brazil: overcoming inequalities and building new markets. *Riv. di Econ. Agrar.* 65, 225–259.

Schneider, S., Thies, V., Grisa, C., and Belik, W. (2016). "Potential of public purchases as markets for family farming," in *Advances in Food Security and Sustainability*, ed. D. Barling (Burlington: Academic Press), 69–95. Available at: https://www.researchgate.net/publication/309710349_Potential_of_Public_Purchases_as_Markets_for_Family_Farming (accessed September 22, 2020). doi: 10.1016/bs.af2s.2016.09.003

SEBRAE (2013). *Santa Catarina em Números*. Florianópolis, SC. Available online at: https://www.sebrae.com.br/Sebrae/Portal%20Sebrae/Anexos/Relatorio%20Estadual.pdf

Sidaner, E., Balaban, D., and Burlandy, L. (2013). The Brazilian school feeding programme: an example of an integrated programme in support of food and nutrition security. *Public Health Nutr.* 16, 989–994. doi: 10.1017/S1368980012005101

Siliprandi, E. (2015a). "A AGROECOLOGIA E O PROTAGONISMO DAS AGRICULTORAS E dos AGRICULTORES," in *Mulheres e Agroecologia: Transformando o Campo, as Florestas e as Pessoas* (Rio de Janeiro: Universidade Federal do Rio de Janeiro), 81–110.

Siliprandi, E. (2015b). "As mulheres no movimento agroecologico Brasilieiro," in *Mulheres e Agroecologia: Transformando o Campo, as Florestas e as Pessoas* (Rio de Janeiro: Universidade Federal do Rio de Janeiro), 111–184.

Siliprandi, E., and Cintrao, R. (2015). "Mulheres rurais e políticas públicas no Brasil: abrindo espaços para o seu reconhecimento como cidadãs," in *Políticas Públicas de Desenvolvimento Rural No Brasil*, eds. C. Grisa, and S. Schneider (Porto Alegre: UFRGS Editora) 571–594.

Siliprandi, E., and Cintrão, R. P. (2011). As mulheres agricultoras no Programa de Aquisição de Alimentos (PAA). *Segurança Aliment. e Nutr.* 18, 12–32. doi: 10.20396/san.v18i2.8634675

Sumberg, J., and Sabates-Wheeler, R. (2010). *Working Paper Linking Agricultural Development to School Feeding*. Brighton: Institute of Development Studies. Available online at: http://files/4463/Sumberg and Sabates-wheeler - 2010 - Working Paper Linking Agricultural Development to.pdf.

Sumberg, J., and Sabates-Wheeler, R. (2011). Linking agricultural development to school feeding in sub-Saharan Africa: theoretical perspectives. *Food Policy* 36, 341–349. doi: 10.1016/j.foodpol.2011.03.001

Sumner, J., and Llewelyn, S. (2011). Organic solutions? Gender and organic farming in the age of industrial agriculture. *Capital. Nat. Soc.* 22, 100–118. doi: 10.1080/10455752.2010.546659

Swensson, L. (2015). *Institutional Procurement of Food From Smallholder Farmers: The Case of Brazil.* Food and Agriculture Organization. Available online at: http://files/4503/a-bc569e.pdf (accessed December 11, 2020).

Swensson, L., and Tartanac, F. (2020). Public food procurement for sustainable diets and food systems: the role of the regulatory framework. *Glob. Food Sec.* 25:100366. doi: 10.1016/j.gfs.2020.100366

Swensson, L. F. J., Hunter, D., Schneider, S., and Tartanac, F. (2021). Public food procurement as a game changer for food system transformation. *Lancet Planet. Heal.* 5, e495–e496. doi: 10.1016/S2542-5196(21)00176-5

Takagi, M., Sanches, A., and da Silva, J. G. (2014). *Programa de Aquisição de Alimentos: um Embaixador do Brasil Contra a Fome. PAA: 10 Anos de Aquisição de Alimentos*. Brasilia: Ministerio do Desenvolvimento Social e Combate à Fome.

Trevilla Espinal, D. L., Soto Pinto, M. L., Morales, H., and Estrada-Lugo, E. I. J. (2021). Feminist agroecology: analyzing power relationships in food systems. *Agroecol. Sustain. Food Syst.* 45, 1029–1049. doi: 10.1080/21683565.2021.1888842

UNDP. (2016). *ANÁLISE GERAL DA TENDÊNCIA DE EVOLUÇÃO DO IDHM NO BRASIL*. UNDP. Available online at: http://atlasbrasil.org.br/2013/data/rawData/RadarIDHM_Analise.pdf

U. N. Women. (2020). *Procurement: Gender-Responsive Procurement*. Available online at: https://www.unwomen.org/en/about-us/procurement/gender-responsive-procurement (accessed November 1, 2019).

Valencia, V., Wittman, H., and Blesh, J. (2019). Structuring markets for resilient farming systems. *Agron. Sustain. Dev.* 39:25. doi: 10.1007/s13593-019-0572-4

van den Bold, M., Quisumbing, A., and Gillespie, S. (2013). *Women's Empowerment and Nutrition: An Evidence Review*. Available online at: https://books.google.nl/books?hl=en&lr=&id=GbDvAQAAQBAJ&oi=fnd&pg=PR5&dq=women$+$empowerment$+$nutrition$+$health&ots=jisYubN7yI&sig=uqSRmUYhFaUM9n-ly1KldRlvBsk&redir_esc=y#v=onepage&q=women empowerment nutrition health&f=false (accessed March 20, 2020). doi: 10.2139/ssrn.2343160

Wajcman, J. (2010). Feminist theories of technology. *Cambridge J. Econ.* 34, 143–152. doi: 10.1093/cje/ben057

Wezel, A., Casagrande, M., Celette, F., Vian, J.-F., Ferrer, A., and Peigné, J. (2014). Agroecological practices for sustainable agriculture. A review. *Agron. Sustain. Dev.* 34, 1–20. doi: 10.1007/s13593-013-0180-7

Wittman, H., and Blesh, J. (2017). Food sovereignty and fome zero: connecting public food procurement programmes to sustainable rural development in Brazil. *J. Agrar. Chang.* 17, 81–105. doi: 10.1111/joac.12131

Wolford, W. (2010). *This Land Is Ours Now: Social Mobilization and the Meanings of Land in Brazie.* North Carolina: Duke University Press. doi: 10.1515/9780822391074

World Bank. (2011). *Gender Equality and Development*. Washington, DC: World Bank

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University Wellness Program—A Pedagogic Innovation to Nudge Wellness and Sustainability Among Students

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Anthropocentric activities have induced climate change, threatened planetary health, and harmed human health and wellness. The changing lifestyles, dietary patterns and digital obsession have affected the mental and physical health, particularly of the youth. University campuses reflect the challenges faced by the society at large and therefore make for an ideal ecosystem to initiate positive changes toward wellness and sustainability. The energy of ∼200 million university students globally is largely unleveraged for facing these challenges. Values of empathy and sustainable living are crucial to be inculcated, alongside technical and managerial skills for leading the mass transformation. This article describes a novel pedagogic approach called the University Wellness Program (UWP). The aim of UWP is to equip students with technical and leadership skills to achieve wellness and campus sustainability. That is, UWP is a platform that facilitates the students to design and implement multi-disciplinary projects that address campus related challenges. In the process, they acquire the necessary soft and technical skills to solve real-life problems. The durability of UWP is secured since the projects and activities are explicitly linked to existing curricula and evaluation system of the university. The strategy and framework adopted, and the early experiences of implementing UWP are shared. UWP is amenable for replication globally and has the potential to create change-makers.

Keywords: university, wellness, campus sustainability, pedagogy, future preparedness

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INTRODUCTION

Human wellbeing is an outcome of complex, interrelated factors involving the individual, society, and the planet (1). These are captured to a large extent by the UN Sustainable Development Goals (SDGs). Achieving the SDGs requires a holistic approach and presumes values that cut across the goals, but which are not clearly listed. For example, the requirement of an eco-centric mind-set (as opposed to ego-centric), value for the planet, organizational abilities, the vision and leadership qualities etc. are assumed in SDGs. SDGs provide targets and broad guidelines expecting each country to strategize its own plans, monitor and execute them. This would require teams of change-makers including critical thinkers, technical experts, innovators, leaders, and managers for action.

Anthropocentricity and the Human Wellbeing Challenge

Anthropocentric activities have adversely impacted biotic and abiotic environments, leading to unprecedented changes to climate (2). The latest (Sixth Report) of the Intergovernmental Panel on Climate Change (IPCC) categorically concluded that human activities induced Climate Change and Global Warming, will lead to discernible changes within the next 20 years (3). Frequent outbreaks of zoonotic diseases in recent times including Zika, Ebola and several others are attributed to environmental degradation (49). The ongoing COVID-19 pandemic has reminded us about the interconnectedness of humans with each other, the environment, and other beings on this planet, albeit in an adverse way (4). The COVID-19 pandemic has also negatively impacted the mental health status, exacerbating stress, anxiety, depression, and suicidal ideation, and increased substance abuse (5). There has been a set-back of health and SDG indicators of all countries during the last 1.5 years, due to the COVID- 19 pandemic (6).

Human lifestyle and dietary changes over the last 3–4 decades have seen a steady drop in mental wellbeing and an increase in respiratory and metabolic diseases, cancer, and injuries (7, 8). An analysis of the surveillance data from 105 countries indicates that one fourth of the youth do not follow the public health guidelines for physical activity (9). According to the current figures of the World Health Organization (10), 14% of global burden of diseases is due to mental health disorders and substance abuse, with ∼800,000 deaths every year (11). Rising levels of anxiety (42%), depression (36%), suicide ideation (16%) and self-injury (∼9%) are growing among university students, in particular (12). A survey on 37,500 university students from 140 universities in the UK found that 1 in 5 students had a mental health issue, and 1 in 3 felt they needed psychological help (13). There could be direct and indirect factors that exacerbate loneliness, stress, depression etc. among young students in university campuses, leading to untoward behavior including substance abuse and suicidal tendencies (14). In the Indian scenario, the stigma associated with seeking professional help for psychological issues, lack of public awareness, and an acute shortage of trained manpower lead to neglect and marginalization of the affected (15). The Mental Healthcare Act (16) of the Government of India was an attempt to mainstream mental health under the National Health Mission in order to ensure better care through the health systems. However, a lot can and needs to be done at the family and educational institutions level to offer the emotional support that the youth require.

Other man-made challenges that threaten the future of mankind largely stem from inequity (49). These include conflicts, war, political marginalization, and migration. Mitigating these challenges require innovative global and local actions in parallel. Leading healthy lifestyles requires learning to "live and let live" and sustainable consumption behaviors. A groundswell of people with awareness, empathy, values, and skills, is required to bring about the transformation. The UN Environment Program has warned of a shortage of skills and manpower for achieving a green and sustainable economy (17). Engaging the youth in influential spaces, not just brings energy and innovation but is crucial, considering they will bear the brunt of the impact of the anthropocentric activities in the future (18).

Universities-Mini Societies

Around 3.5 billion young adults (<30 years of age) live in this world, which amounts to almost 50% of the total global population (19). Of these ∼207 million, a staggering number, are university students (20), whose power is yet to be tapped for addressing serious issues faced by humanity today, concerning climate change, public and planetary health. Ways of constructive engagement with youth are being explored to involve them in decision-making (21). In 2010, the UN General Assembly resolved to involve youth in decision-making and action for a sustainable future (22). The UN recognizes that the youth need to play a significant role in the realization of Sustainable Development Goals (SDGs) as critical thinkers, change makers, innovators, and communicators (23). In 2019, the UN conducted its first Youth Summit in New York to discuss Climate Change and youth participation to achieve SDGs. The SDG Students program, an initiative of the Sustainable Development Solutions Network (SDSN). Youth was launched by the UN SDSN in 2012. This network aims to engage university students globally to achieve the 2030 SDGs agenda as well as to empower them with the knowledge, skills, and pathways to action to be effective change agents (24).

The concept of Health Promoting Universities and a framework for integrating health in curriculum and university system was proposed in 1998 by academicians in the UK (25). The Okanagan Charter proposed a transformative vision for Health Promoting Universities and Colleges in Canada, to strengthen communities and contribute to wellbeing of people and plan (26). The sustainability of these initiatives requires conceptualizing and customizing strategies that integrate contextual research and action programs for wellness and planetary health *within the academic systems* of universities. The University Wellness Program (UWP) is one such pedagogic innovation that evolved independently within the *milieu* of a typical Indian university. This article describes the UWP concept, genesis, the pedagogical framework and the process adopted. It shares the initial experiences and challenges faced.

UNIVERSITY WELLNESS PROGRAM

University Wellness Program (UWP) is an experiential learning platform that encourages students to think, design and implement multi-disciplinary projects for the benefit of the university community. The twin goals of UWP are (i) to achieve wellness and campus sustainability and (ii) to equip students with technical and leadership skills. The vision of UWP is ambitious and its durability is addressed by explicitly linking all its projects/activities *to existing curricula and evaluation system* of the academic programs in the university. UWP provides the scope for empathy, inclusiveness, reflection, ideation, collaboration, and leadership. Over time it is expected to create an ecosystem of empathy, equity, and value for fellow beings and the planetary resources. The students also become equipped with the necessary

practical skills and competencies to tackle real-life problems when they graduate and become future global citizens.

Genesis of UWP

There were three main thought processes that led to the genesis of UWP during 2019 (**Figure 1**).

Mental Wellbeing

The National Crime Records Bureau (NCRB) reported that young adults in the age group of 18–30 years was the most vulnerable, contributing to >35% of suicides in India. It was very disturbing to note that every hour one university student succumbed to suicide in India (27, 28). Globally, suicide was the second leading cause of death among 15–29-year-old, next to road accidents (10). The American College Health Association reported that 26% of the students surveyed were feeling so depressed that they could not carry out their normal functions (29). The world over, the Happiness Index had decreased in >50% of the countries surveyed (30), with mental health becoming a significant concern. These scenarios, wherein young adults and students were succumbing to poor mental wellness, indicate a deep-rooted malaise in our societies. The fundamental reasons for this need to be explored and addressed. Students are critical to the progress of any nation and the future of mankind, and their wellbeing is the collective responsibility of all concerned.

University freshers struggle to adjust to academic challenges, new environments, and relationships. Facing these challenges requires a positive mental framework and resilience. Moeller et al., point out that emotional and social quotients (EQ and SQ) play an equal role as the intelligent quotient (IQ) in a student's academic performance (31). EQ and SQ help them in understanding, expressing and managing emotions appropriately (31).

Wellness and Sustainability

Tens of thousands of people move around in a typical university campus every day. For example, there is a footfall of ∼100,000 people including faculty, staff, patients in university hospitals, vendors and ∼50,000 students mill through a typical multi-disciplinary university campus in India (32). Therefore, universities are strategic places to begin the wellness drive and to "walk the talk" about wellness and sustainability. Several universities are already actively engaged with achieving SDGs through management action, organizing events, student projects etc. Green metrics and recognition of universities through awards have been instituted to rank the universities globally (33). These initiatives do bring about awareness and positive changes on campus (34), but since they are top-down approaches and external to the campus, they tend to be addressed in a non-strategic and *ad hoc* manner and become yet another indicator in the university ranking system. For any effort to become embedded in the system and to change the mindset and behavior of the stakeholders, requires a parallel, contextual, bottom-up approach as well, involving the key stakeholders, along with programmatic interventions that are sustainable by design (35).

Learning Life-Skills

A significant trigger for the genesis of UWP was the question as to whether the graduates are future-ready (not just job-ready). The graduating students need to also be prepared to face the global challenges of climate change, conflicts, and disasters. While being sensitive and empathetic to societal issues, the graduates need to develop the technical and leadership skills to address these challenges. It was reported that almost every other university graduate from Indian universities in 2018 did not have the necessary skills (36). Practical, evidence-based solutions that are appropriate to the community/environmental contexts need to be developed. Acquiring soft skills of communication, collaboration, and negotiation, will prepare them to navigate systems. This requires the teachers and the university management to be clued-in to contemporary global and local issues like climate change and conflicts. It also requires a pedagogy that has adaptable teaching and evaluation system that not just assesses the technical skills but also the students' critical thinking and ability to apply theoretical knowledge for practical solutions for contemporary issues.

Higher education is not just for better jobs and pay packages for the graduates but also to create thought leaders and change makers for human development and a sustainable future (37). A study by Entwistle and Peterson reports that students in higher education who seek deeper meaning tend to perform better than those who see it as instruments for better jobs (38). However, majority of the students are not trained in critical thinking or skilled for solving real-life, complex problems (39).

Thus, with enough complex issues on campus, a university would be an ideal place to implement UWP.

UWP- Why a "Wellness" and Not "Health" Program?

The commonly accepted definition of Health is that of WHO. Health is a "state of complete physical, mental and social wellbeing and not merely the absence of disease and infirmity" (10). In the context of UWP, "wellness" refers to *individual's perception* of being well. The feeling of "being well" is important for carrying out routine functions and in living life to the fullest. One can clinically be perfectly "healthy" but still not feel "well", while another who has serious health problems can still "feel" well, enthusiastic, and active. Wellness is dynamic and dependent on individual mind-set and the ability to bounce back from any obstacle.

The Global Wellness Institute defines wellness as "the active pursuit of activities, choices and lifestyles that lead to a state of holistic health". That is, wellness can be aimed for and actively pursued (40). Wellness is captured succinctly in Indian health traditions by the Sanskrit term *Svasthya* (*sva*-individual, *sthya*-stability). That is, the state of being in harmony with one-self. This state would vary with person and context. It was felt that "wellness" may be a better terminology to be used in a university context than "health" or "healthy". Therefore, the **University Wellness Program** or **UWP** was coined.

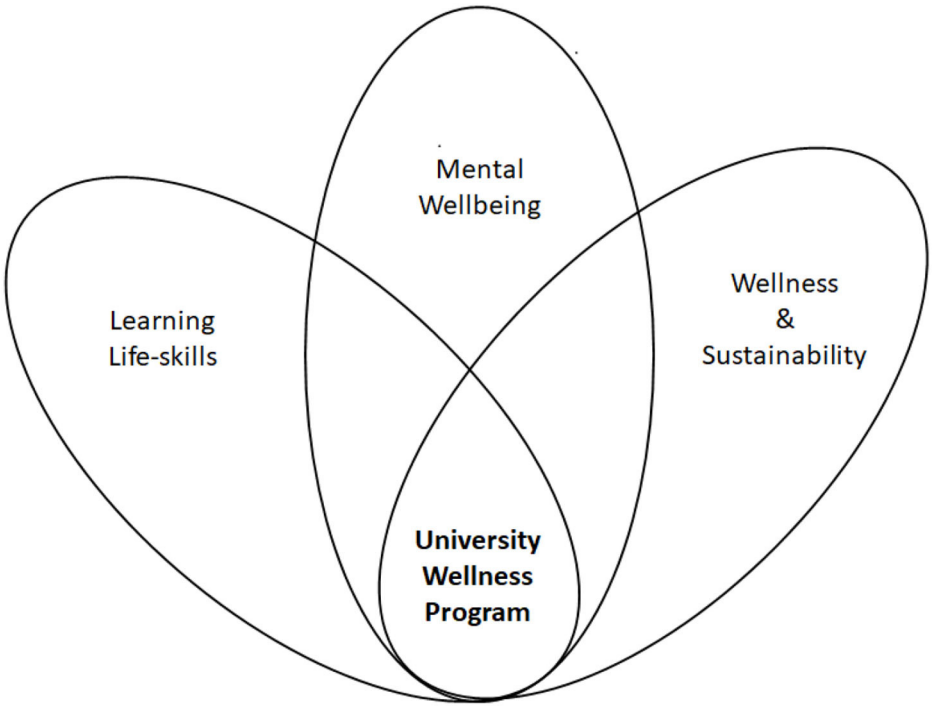

FIGURE 1 | Genesis of UWP.

PEDAGOGICAL FORMAT

UWP being a new concept to Indian universities, the challenge was to create processes that aims to achieve wellness and campus sustainability through student learning and doing. The challenge was also to integrate UWP within the university system for better programmatic sustainability. UWP kick-started with an evolving strategy, following four broad steps as given in **Figure 2**.

Almost all university academic programs have structured syllabi comprising of both theory and practicals/ practicum which usually have a one-to-one correlation, with the practicals strengthening theoretical learning. For example, a Chemistry student gets exposed to the theory of acids and bases during lectures, and learns better by performing acid-base titrations during practicals. These are absolutely essential and should continue. However, they are typically stand-alone, mono-disciplinary learning methods that most often are not linked to real-life, multi-disciplinary issues. The mainstream model of education at best produces students who learn, recall and predominantly practice mono-disciplines post their graduation. Schön (50) describes the much needed "reflection-in-action" method, to provide scope for student learning and practicing on real-life issues, while on campus.

One of the ways a broader application of theoretical learning can happen is by making UWP an integral part of existing curricula of the various academic programs. The methodology is iterative involving discussions with key stakeholders. The framework adopted to initiate UWP and early experiences have been shared in the following sections.

Buy-In From Stakeholders

Freeman's simple definition of "stakeholder" as "any group or individual that is affected by or can affect the achievement of an organization" is applicable in a university setting (51). University stakeholders can be of two kinds, direct or indirect stakeholders (**Figure 3**). Direct stakeholders in a university campus include students, teaching, non-teaching and administrative staff, the management, housekeeping, other service providers, and the immediate communities outside the university campus etc. whereas indirect stakeholders include those who may not be visible on a daily basis or be present on campus but yet influence campus wellness and sustainability. The latter include the institutional, local and other governing bodies, parents/family of students, other universities, businesses and the public at large. In today's times, the social media and network play important roles as virtual "stakeholder" group, especially in a student's life (41, 42).

Without the buy-in from key stakeholders, any new program can run into multiple roadblocks during implementation. Therefore, one of the essential steps to be taken before initiating any program is to obtain the buy-in from key stakeholders, particularly from the top management during the initial stages (43).

In the case of UWP, sharing the vision, objectives, and scope helped gauge the readiness of the different stakeholder groups to adopt the program and to enthuse their participation. It also helped garner the necessary administrative, financial, and human resource support from the management to initiate the program. Meetings with the faculty and heads of departments provided an

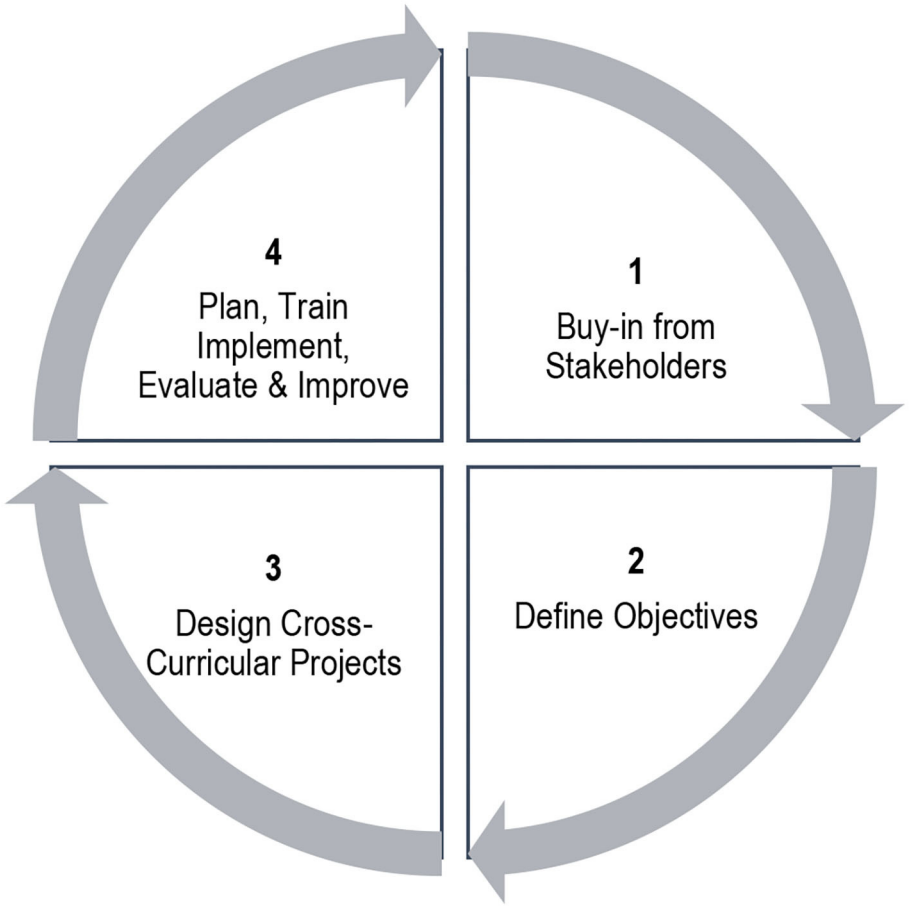

FIGURE 2 | Framework to initiate University Wellness Program.

opportunity to brainstorm ideas, learn about ongoing initiatives on sustainability and wellness, and the major implementation challenges faced. Interactions with student groups were useful in providing insights into the kind and intensity of issues on campus and assessing the capacities and interest of students. The faculty and students at the School of Public Health (SPH) were the immediate stakeholders, who in turn carried the UWP agenda forward.

Define Objectives

Defining the objectives and setting targets is crucial for the success of any project because it brings clarity and transparency to all. Drucker in his 1954 book, "Practice of Management" coined the term *Management by Objectives* that describes the importance of all stakeholders to participate in defining the objectives for a program's viability and durability (44). Goal-setting guides projects and provides the scope for monitoring performance and measuring success. It also is a motivational lever for the team (45).

The Postgraduate (PG) and Undergraduate (UG) academic programs at the University run on a semester basis and therefore it was decided to set semester-wise (5 months) objectives. Brainstorming meetings with the management, faculty and students were held before crystallizing the objectives for UWP for the first semester. Two mini projects were undertaken by the students and faculty of SPH, for the first semester (August–December 2019):

Mini Project #1: Launch of UWP

In order to announce UWP, it was decided to hold a formal event inviting high profile individuals, the top management, heads of departments, faculty and students on campus. It was also decided to invite the media and press for giving the event good visibility.

Mini Project #2: Identification of key student issues

Students were the largest (∼60–70%) stakeholders on university campus. Hence it was decided to identify issues of this group, to begin with. It was important to know the status of wellness of the students, the key issues faced by them and the coping methods.

The framework and processes were crystallized and documented for initiating the two mini- projects during this period.

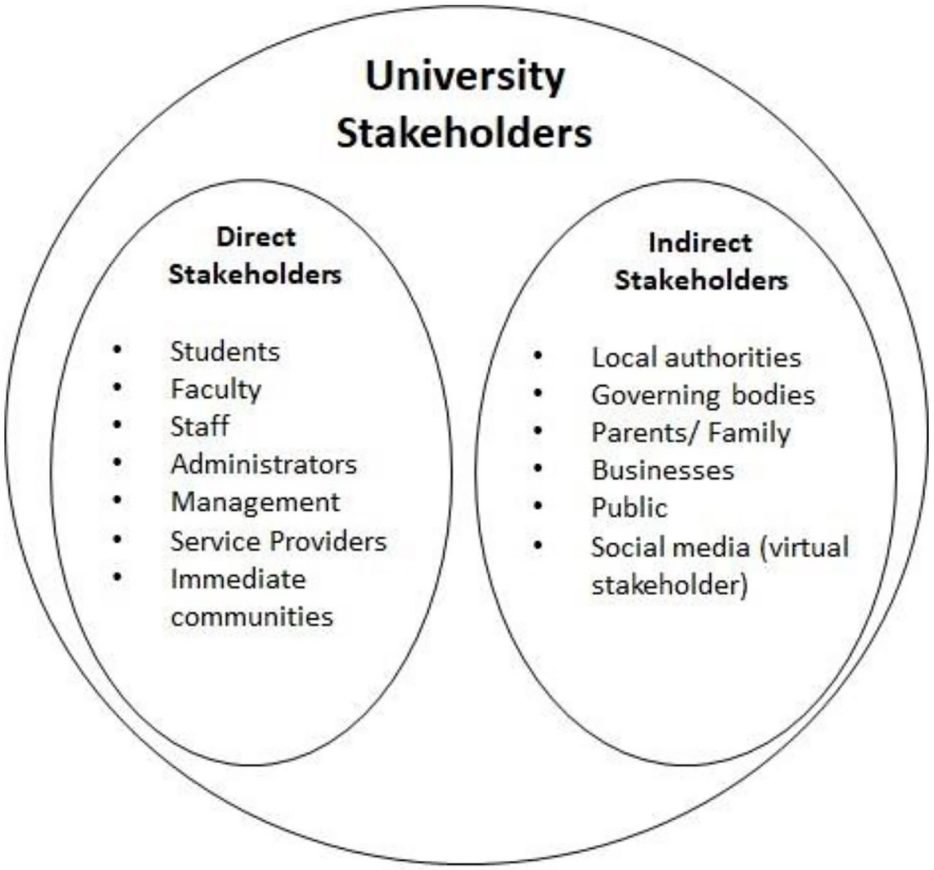

FIGURE 3 | Typical stakeholders in a university/HEI.

Design Cross-Curricular Projects Linked to Curriculum

Practice-based learning is an essential part of the pedagogy of professional academic programs. For example, a student training to be a doctor, dentist or a nurse is exposed to patients on a regular basis, so that they learn how to treat patients when they become full-fledged practitioners. This is not the norm in other disciplines and the students are rarely exposed to wellness or sustainability concepts and actions.

The UWP idea is to encourage students to look inward, within the campus and their immediate environments including the communities, to identify and address the issues, leveraging their respective domain skills. For example, a Visual Communication student from the Humanities and Sciences College, who learns the skills in photo/video-graphy, drawing, computer graphics, recording etc. and a public health student from the Health Sciences College, who learns health promotion, communication, nutrition, and research methods etc. as a part of their respective academic syllabi, can work together to identify the nutritional status of students on campus and to create effective health promotional materials. This collaboration would bring about a better researched audiovisual and there would be a cross-fertilization of ideas. Thus, the practical application of theoretical learning will be for achieving overall campus wellness.

Once the aim is stated, designing the UWP projects three main steps were involved (**Table 1**):

(i) *Detail the activities*: Once the objective(s) of the project were set, the broad activities that would be required for fulfilling the objectives were delineated. For example, we wanted to create and inaugurate a logo for UWP during the UWP launch event, which meant designing the logo was one of the UWP activities under Mini-project #1.

(ii) *State the Learning Outcomes:* Identify the technical and other skills that are required to achieve the project learning outcomes. For example, knowledge about effective communication and branding, and skills to design a logo are some of the expected learning outcomes from Mini Project #1.

(iii) *Map and Select Modules*: Select those modules from the syllabus whose learning objectives match with those of the UWP project outcomes. Leverage modules that provide the space to learn hands-on technical skills and/or soft skills required to achieve the targets (**Table 1**). The module should also have the scope for assessing the students' performance as a part of the regular evaluation system.

TABLE 1 | Mapping of modules and skills and competencies to achieve the targets.

Define the objectives	Detail the activities	State the learning outcomes from the project (technical and soft skills)	Map the modules (pertinent to the listed skills/competencies)	
Official launch of UWP (Mini-Project #1)	• Design UWP logo • Plan, monitor and execute the launch event • Archive the project outputs	**Technical** • Designing UWP logo • Planning, execution, monitoring and management of event	**Module name** • Social and behavior change, effective communication in healthcare • Health management: management principles and practices	**Expected learning outcomes of modules** • Application of concepts of strategic communication in Public Health • Planning and management • Public health leadership
		Soft skills • Leadership, teamship • Interpersonal and communication skills	• Communication skills	• Public speaking, writing, inter-personal skills
Identification of key student issues (Mini Project #2)	Conduct research to identify • student wellness (physical, mental) • key issues faced on campus • coping methods and • recommendations	**Technical** • Research skills and aptitude • Planning, monitoring; execution and management of project	• Principles of research methods	• Knowledge and practice of types of research methods • Protocol design and ethical process • Data collection, analysis and interpretation • Research communication skills
		Soft skills • Leadership, teamship, interpersonal and communication skills	• Communication skills	• Public speaking, scientific presentation, inter-personal skills

Broadly, the skills and competencies required for implementing the Mini-projects were *explicitly spelt out* as "learning" outcomes and tagged to pertinent module(s), and the students were formally evaluated for the same. Sometimes when the targets set required multi-disciplinary efforts, it was important that departments within or outside the college collaborate to achieve them.

Plan, Train, Implement, Monitor, Evaluate, and Improve

Plan

While Mini Project #1, namely the UWP launch, was an event that required branding, networking and managerial skills, Mini Project #2 (Identification of key issues) required mainly research skills. In consultation with the SPH team of faculty and students, plans were developed.

The groups, the milestones, end points, timelines and responsibilities to implement the two mini projects, were written down and shared with all. The PG and UG students across all years and programs, were vertically grouped. That is, a I year UG student who was freshly out of high school got to observe and learn from the final year senior PG students, and the seniors in turn learnt empathy and tolerance. The students selected one leader/representative from each group and one faculty volunteered to drive each of the UWP projects (**Figure 4**). The main responsibility of the faculty-in-charge and the student leaders was to drive and monitor progress. Wednesdays were set aside as UWP days when all the students (∼130 nos.) and faculty came together to review the progress of the two mini-projects and change strategies as required.

Train

Students were trained and guided on the technical skills and competencies required to execute the activities. The faculty handling the module(s) has the liberty of selecting the aspect(s) for which training is required and this would depend on the set objectives and activities. It may or may not be the regular training provided. For example, as a part of the 'Social and Behavioral Change and Effective Communication' module, a professional creative designer was especially brought in to conduct a workshop on the importance of brand building. The students learnt the essential features of branding for public health. Creating a logo for UWP was given as an assignment for which they were evaluated and the team which designed the best logo for UWP was to be rewarded by show-casing it at the UWP launch event. It was declared that in recognition of the students' participation, certificates for leadership and contribution would be distributed.

The theoretical aspects of the principles of Research Methods (types—qualitative, quantitative, and mixed-methods), protocol design, ethics, data collection, analysis and interpretation etc are taught as a part of the regular teaching of the module. However, practical training was also provided on qualitative research including performing Free Listing, Focus Group Discussions (FGDs) and analysis of qualitative responses, which were essential skills to fulfill Mini-Project #2.

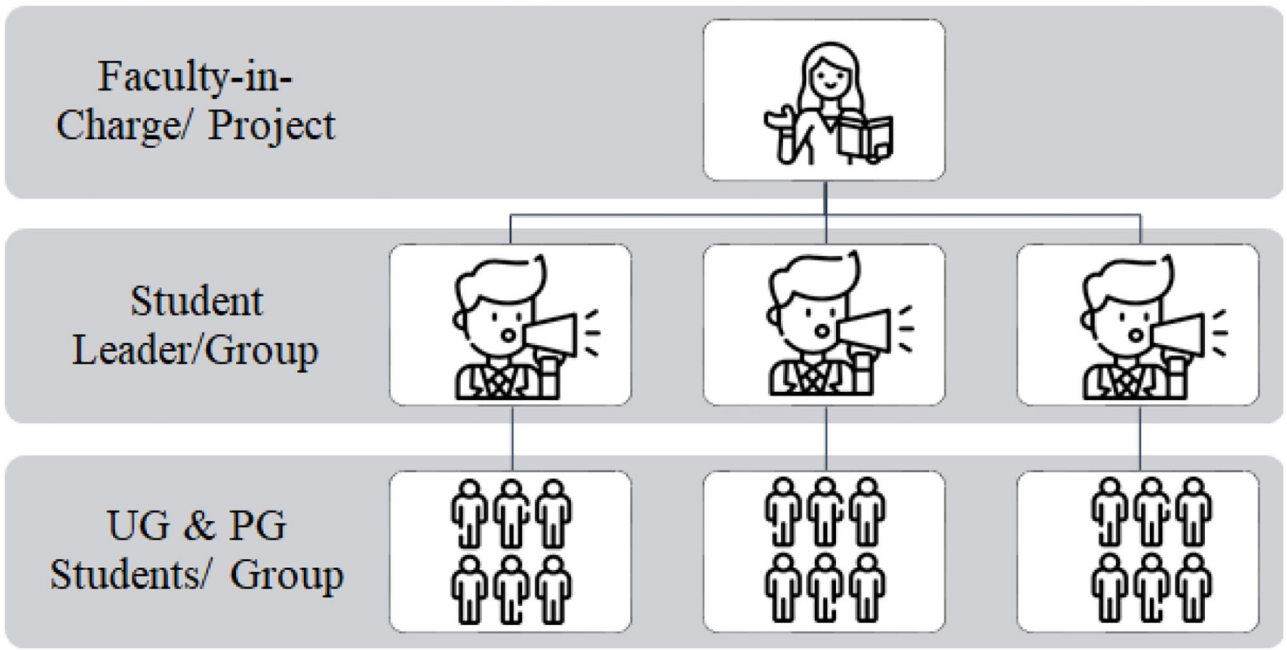

FIGURE 4 | Grouping of students for UWP projects.

Students were oriented in soft skills including listening, team work, tolerance and public speaking as a part of the "Social and behavior change, effective communication in healthcare" module. They were nudged to reflect on the process and recommend next steps.

Thus, over and above the regular teaching, special training was given depending on the skills and competencies required for fulfilling the project. It may vary depending on the project requirement.

Monitoring and Evaluation

For durability of UWP it is important to leverage existing university evaluation system and integrate the student projects within its scope. For example, in our university system 40% of marks is toward continuous internal assessment and 60% allocated for end-semester examination. The internal assessment system provided adequate scope for evaluating the practical learning of the students in the UWP projects. Normally, assignments, presentations and cycle tests on theoretical learning are evaluated in internal assessment. For UWP, execution of project activities and deliverables became part of the existing continuous, monitoring and internal assessment system of the module(s).

Students were evaluated for individual as well as group contributions for the fulfillment of two projects. Soft skills such as leadership qualities, communication skills, empathy, inclusivity and teamship were encouraged and assessed based on class interactions and presentations during the semester. The projects themselves were evaluated by the success of fulfilling the objectives, namely UWP launch event and prioirtization of key issues faced by the students. We are in the process of creating the framework for evaluating UWP at the university level. Five year goals, roadmap and key success indicators are being developed.

UWP Project/Activity Criteria

Research and action projects, events and activities are a regular part of any univerisity. However, keeping in mind the UWP objectives and durability, a set of criteria were developed by us. Only those projects/activities that fulfilled these criteria were qualified as a UWP project/activity.

(i) **the purpose/objective** has to be clearly spelt out and should contribute to wellness and/or campus sustainability
(ii) **the expected outputs/outcomes stated**- these could include products/service/events etc. Other practical/soft skills learnt need to also be indicated
(iii) **the student academic program/modules and evaluation methods** that will be leveraged need to be mentioned
(iv) **the faculty in-charge** who will drive the project/activity, needs to be named
(v) **name the student leader and team(s)** who will execute the project, need to be named
(vi) **the skeletal plan** of execution needs to be secured

A project was considered successful if the set objectives and learning outcomes were achieved, fulfilling the above criteria.

INITIAL EXPERIENCE

Mini Project #1: UWP Launch

UWP was successfully launched at an official event organized on November 12th, 2019, and the best logo for UWP that was designed by students was unveiled at the event (**Figure 5**).

FIGURE 5 | UWP logo. MPH students designed the logo and learnt the importance of branding during the "social and behavior change, effective communication in healthcare".

The group which designed the best logo got an opportunity to describe the logo and the tagline at the event. The bright orange shade in the logo represents positive energy, youth and action. The tagline "University Wellness. Universal Wellness" indicates the vision that a small change in university can lead to changes at the global level and the reach of the universities. The UWP launch event was planned and managed by the students. Dr. Kasturirangan, Chairman of New Education Policy Committee (2019), Government of India presided over the function. It received good coverage in social media and press. The aim of launching UWP, designing the logo and to do it through students as a part of existing academic evaluation system, was achieved.

Mini Project #2: Identification of Student Issues

The students received hands-on experience in conducting qualitative research under the Research Methodology module (**Table 1**). They learnt to perform free-listing, FGDs, coding and categorization of qualitative responses. Four key themes emerged from the student responses with important sub-themes (**Table 2**).

- Mental Wellbeing—stress, anxiety, depression and suicidal ideation thoughts etc emerged as important emotions that affected the students daily performance. Girl students specifically mentioned pre-menstrual syndrome (PMS) as an issue
- Lifestyle behavior—social media time, mobile usage, substance abuse, food intake, sedantary lifestyle, indisciplined sleep pattern etc. were ackmolwledged as significant aspects of student life on campus
- Water, Sanitation and Hygiene (WASH)—campus WASH facilities were mentioned as being important. Frequent cleaning of toilets was expressed as important during busy times. The girl students mentioned that better and accessible facilities can be provided, to help during menstruation
- Global Warming—It was important to note that global warming, in general, came up in the FGDs as an important issue that the students were concerned about. These included pollution, food wastage, transport, use of plastics and paper, within and outside the campus. The FGDs strongly highlighted that the students realized the negative impact of human (anthropocentric) activities on the health of communities and the planet. There was a will to contribute and make a difference

TABLE 2 | Themes and sub-themes of key student issues that emerged through free-listing and FGDs.

Themes	Sub-themes
Mental health	Stress, anxiety, depression and suicidal thoughts, Pre-Menstrual Syndrome among girls
Lifestyle behavior	Social media time, mobile usage, substance abuse, food intake, sedantary lifestyle, sleep pattern etc
WASH	Frequency of cleaning of toilets, better facilities for girl students
Global warming	Pollution, food wastage, transport, use of plastics and paper, within and outside the campus

The presentation of the research findings of the key issues faced by the university students at the UWP launch (i.e., Mini-project #1) was a highlight of the event and was much appreciated by the management and audience.

Going forward, prioritization of projects and activities to be taken up needs to be worked out. This would depend on the urgency, resources available, and the interest of the students, faculty and management.

DISCUSSION

The Okanagan Charter started the Canadian Health Promoting Campuses Network in 2015 that called for embedding health in all aspects of campus culture (26). The UK Healthy Universities Network promoted a similar concept (46). The UWP idea emerged independently in 2019, within the academic, socio-cultural and political context of a typical Indian private university.

This article has introduced a new pedagogic concept called the University Wellness Program (UWP), which enables students to work toward achieving wellness and campus sustainability. Through the implementation of the two Mini projects, a methodology/framework has been delineated to demonstrate how UWP can be embedded in university learning and evaluation system. One project was to formally launch UWP and the other was to identify and prioritize key issues faced by students on campus.

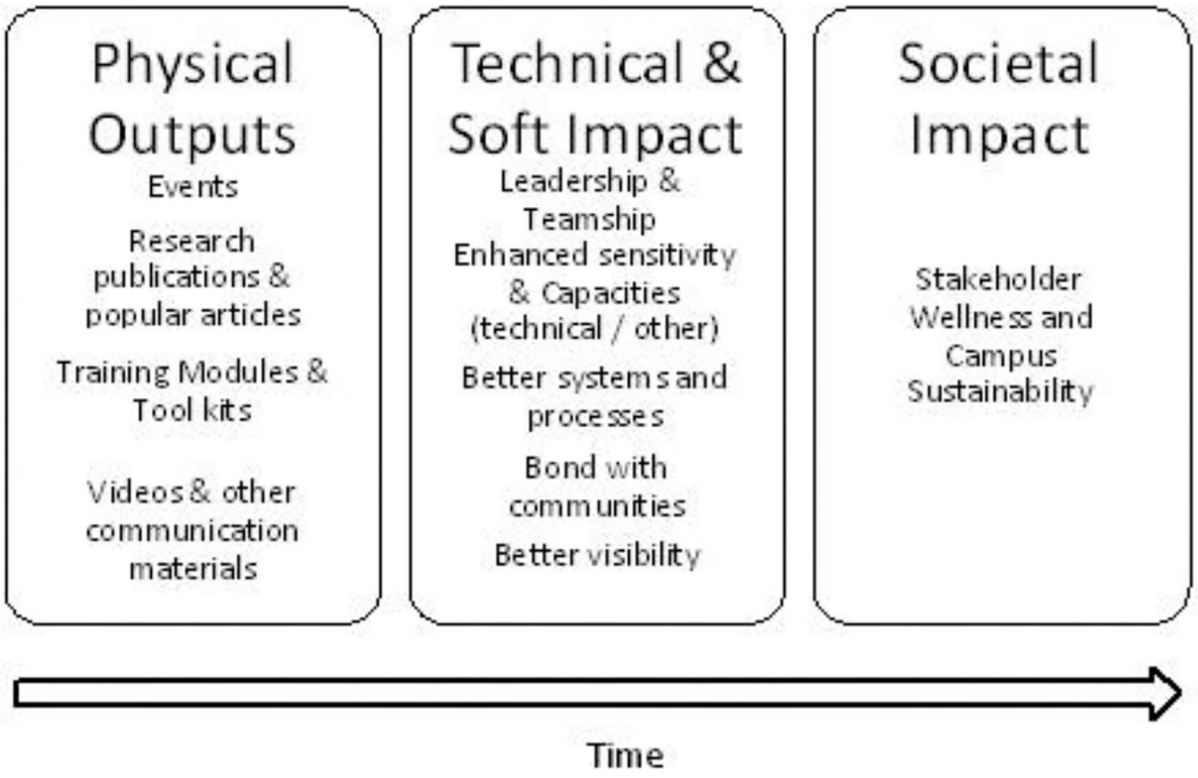

FIGURE 6 | Expected outputs from UWP over time.

The UWP Mini-Projects provided the students hands-on technical skills, managerial, leadership and other soft skills to implement the projects. Over and above the technical skills required in implementing the projects, the students learnt listening skills, empathy, ability to think critically, leadership and team-ship, public speaking and effective communication. These qualitative aspects were monitored and assessed on a weekly basis by faculty. All teams and presented their work at the final project presentation, as college seminar. The best teams got opportunity to present at the UWP launch event.

We expect that the impact created by UWP *per se* will become evident only over a period of time, say 5 years. A system for longitudinal research is being set up with the current cohort of students. A database is planned to be created for capturing every student's wellness at the university level. We have also established a core UWP committee consisting of experts and student representatives from different departments across the university to look at the various UWP aspects, including research/action/fund mobilization/management/communication related. The committee members are the drivers to keep UWP going. A 5 year roadmap for UWP is being created, with goals and key success indicators. Faculty and students of SPH and the Department of Computer Science & Engineering are creating a digital platform and a dashboard to capture the UWP projects and progress. This in itself was taken up as a UWP project. These are some of the work in progress beyond 2019.

The expected outcomes from UWP over time can be classified as physical outputs, technical and soft impact, and societal impact (**Figure 6**). UWP would provide opportunities for students to have a more rounded development.

Challenges Faced

The seven factors identified by Valaitis et al., that influence the success of new or existing programs are very relevant for the durability of UWP (47). The factors include (i) clear mandates, vision and goals (ii) strategic coordination and communication mechanisms (iii) formal organizational leaders as collaborative champions (vi) collaborative organizational culture (v) optimal use of resources (vi) optimal use of human resources and (vii) collaborative approaches to programs and services delivery.

The challenges faced in UWP implementation were mainly faculty and program implementation related. Initially, convincing the faculty about the idea took some time. The main reasons for this were (i) resistance to new ideas; as is usual in any pre-existing group (ii) lack of clear-cut methodology to integrate UWP in existing teaching and evaluation system in the early stages of UWP (iii) faculty perception as additional burden to already hectic academic and research schedules (vi) fear of failure and (v) indifference and hesitancy in ownership.

UWP uses practice/problem-based learning (PBL) approach for achieving wellness and sustainability on university campus. PBL has the advantage of imparting capacities among students at the conceptual, practical and attitudinal levels but it presents

challenges to the teachers. Loss of control over their teaching styles, selection of topics of students interest, unpredictability of outcomes, fear of exposure of their knowledge gaps and need for more time investment were some of the perceptions of teachers about PBL (48). These issues/fears will need to be addressed to obtain faculty participation, along with training them in the new pedagogy.

Recruitment of a new Teaching Associate who is dedicated for UWP coordination helped immensely in reducing the faculty burden. The faculty buy-in was achieved through frequent meetings and interactions, setting objectives, drawing up clear plans of execution and engagement. Discussing the potential advantages, and outcomes motivated them a great deal.

Identifying topics that were pertinent to key stakeholder issues, campus wellness and sustainability and designing research or action-oriented projects that leveraged existing academic programs required asking fundamental questions. For example, what are the key issues faced by students and the status of wellness of students? What needs to be done and how to crystallize them requires individual and group brainstorming. These were difficult to achieve in an already packed teaching-learning-evaluation university system. We solved these to a large extent by setting aside 1 day in a week for UWP related activities. Explicit linkage of objectives to ongoing modules and the freedom to assign practical work, can enhance the quality of teaching and learning. Also, a campus wellness/sustainability related issue gets addressed in the process.

UWP members become potential stewards and change-makers in university campuses. The activities can also become part of regular clubs, roping-in students and faculty from departments and universities. New academic programs and PhDs could stem from the UWP projects. Toolkits and online/offline training programs can be developed for sharing with other universities. UWP is work in progress and the strategy would need to be modified depending on context.

CONCLUSION

The article introduces University Wellness Program (UWP), a novel pedagogical concept to focus on wellness and sustainability issues that face us today. It provides the scope for practice-based learning for students, by leveraging existing academic modules and evaluation system. Our strategy demonstrates the feasibility of UWP. Faculty interest and leadership are probably the biggest assumptions for UWP's durability.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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REFERENCES

1. Prescott SL, Logan AC. Planetary health: from the wellspring of holistic medicine to personal and public health imperative. *Explore.* (2019) 15:98–106. doi: 10.1016/j.explore.2018.09.002
2. Whitmee S, Haines A, Beyrer C, Boltz F, Capon AG, Dias BF, et al. Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation–Lancet Commission on planetary health. *Lancet.* (2015) 386:1973–2028. doi: 10.1016/S0140-6736(15)60901-1
3. Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, et al. *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press (2021).
4. Amuasi JH, Winkler AS. One health or planetary health for pandemic prevention? – Authors' reply. *Lancet.* (2020) 396:1882–3. doi: 10.1016/S0140-6736(20)32392-8
5. Czeisler MÉ, Lane RI, Petrosky E, Wiley JF, Christensen A, Njai R, et al. Mental health, substance use, and suicidal ideation during the COVID-19 pandemic — United States, June 24–30, 2020. *MMWR Morb Mortal Wkly Rep.* (2020) 69:1049–57. doi: 10.15585/mmwr.mm6932a1
6. United Nations. *The Sustainable Development Goals Report 2020*. New York, NY: United Nations Publications (2020).
7. Friel S, Butler C, McMichael AJ. Climate change and health: Risks and Inequities. In: : Benatar S, Brock G, editors. *Global Health and Global Health Ethics*, Cambridge: Cambridge University Press (2011). P. 198–209.
8. Erskine HE, Moffitt TE, Copeland WE, Costello EJ, Ferrari AJ, Patton G, et al. A heavy burden on young minds: the global burden of mental and substance use disorders in children and youth. *Psychol Med.* (2015) 45:1551–63. doi: 10.1017/S0033291714002888
9. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet.* (2012) 380:247–57. doi: 10.1016/S0140-6736(12)60646-1
10. WHO. *Suicide.* (2021). Available online at: https://www.who.int/news-room/fact-sheets/detail/suicide (accessed Ocober 25, 2021).
11. Bilsen J. Suicide and youth: risk factors. *Front Psychiatry.* (2018) 9:540. doi: 10.3389/fpsyt.2018.00540
12. Mistler BJ, Services H, Reetz DR, Services C, Krylowicz B, Services C, et al. *The Association for University and College Counseling Center Directors Annual Survey.* (2012). Available online at: https://files.cmcglobal.com/Monograph_2012_AUCCCD_Public.pdf (accessed December 27, 2021).
13. Pereira S, Reay K, Walker L, Dzikiti C, Platt C, Goodrham C. University Student Mental Health Survey 2018- A large scale study into the prevalence of student mental illness within UK universities. Insight Network and

Digin. (2019). Available online at: https://uploads-ssl.webflow.com/561110743bc7e45e78292140/5c7d4b5d314d163fecdc3706_Mental%20Health%20Report%202018.pdf (accessed December 27, 2020).
14. Esmaeelzadeh S, Moraros J, Thorpe L, Bird Y. Examining the association and directionality between mental health disorders and substance use among adolescents and young adults in the U.S. and Canada-a systematic review and meta-analysis. *J Clin Med.* (2018) 7:543. doi: 10.3390/jcm7120543
15. National Mental Health Survey (2015–2016). Available online at: https://nhm.gov.in/images/pdf/National_Health_Mental_Policy.pdf (accessed February 16, 2022).
16. The Mental Healthcare Act (2017). Available online at: https://egazette.nic.in/WriteReadData/2017/175248.pdf (accessed February 16, 2022).
17. UNEP (2008). *UNEP Annual Report*. Available online at: https://wedocs.unep.org/handle/20.500.11822/7742 (accessed October 26, 2021).
18. Asian Development Bank and Plan International UK (2018). Available online at: https://www.adb.org/sites/default/files/publication/466811/youth-engagement-sdgs.pdf (accessed November 3, 2021).
19. Euromonitor International. *Special Report: The World's Youngest Populations*. Euromonitor (2012). Available online at: https://www.euromonitor.com/article/special-report-the-worlds-youngest-populations
20. UNESCO. *Education for People and Planet: Creating Sustainable Futures for All, Global Education Monitoring report- UNESCO Digital Library*. (2016). Available online at: https://unesdoc.unesco.org/ark:/48223/pf0000245752 (accessed October 26, 2021).
21. Spajic L, Behrens G, Gralak S, Moseley G, Linholm D. Beyond tokenism: meaningful youth engagement in planetary health. *Lancet Planetary Health.* (2019) 3:e373–5. doi: 10.1016/S2542-5196(19)30172-X
22. United Nations. General Assembly (2010). February 3–7. Available online at: https://undocs.org/A/RES/64/130 (accessed December 27, 2021).
23. United Nations. *THE 17 GOALS -Sustainable Development.* (2021). Available online at: https://sdgs.un.org/goals
24. SDSN Australia/Pacific. *Getting Started With the SDGs in Universities- A Guide for Universities, Higher Education Institutions, and the Academic Sector*. Australia, New Zealand and Pacific Edition. Sustainable Development Solutions Network – Australia/Pacific, Melbourne (2017). Available online at: https://ap-unsdsn.org/wp-content/uploads/University-SDG-Guide_web.pdf
25. Tsouros AD, Dowding G, Thompson J, Dooris M. *Health Promoting Universities- Concept, Experience and Framework for Action.* (1998). Available online at: https://www.euro.who.int/__data/assets/pdf_file/0012/101640/E60163.pdf (accessed December 27, 2021).
26. The Okanagan Charter. *Canadian Health Promoting Campuses- Okanagan Charter.* (2015). Available online at: https://wellbeing.ubc.ca/okanagan-charter (accessed October 25, 2021).
27. NCRB. *Suicides in India*. National Crime Records Bureau (2019). Available online at: https://ncrb.gov.in/sites/default/files/Chapter-2-Suicides_2019.pdf (accessed November 3, 2021).
28. NCRB. *Accidental Deaths and Suicides in India*. National Crime Records Bureau (2020). Available online at: https://ncrb.gov.in/en/accidental-deaths-suicides-in-india (accessed October 25, 2021).
29. ACHA. *National College Health Assessment II: Reference Group Executive Summary Spring 2019*. Silver Spring, MD: American College Health Association (2019). Available online at: https://www.acha.org/documents/ncha/NCHA-II_SPRING_2019_US_REFERENCE_GROUP_EXECUTIVE_SUMMARY.pdf (accessed November 3, 2021).
30. Helliwell J, Layard R, Sachs J. *World Happiness Report 2019*. New York: Sustainable Development Solutions Network (2019).
31. Moeller RW, Seehuus M, Peisch V. Emotional intelligence, belongingness, and mental health in college students. *Front Psychol.* (2020) 11:93. doi: 10.3389/fpsyg.2020.00093
32. Ministry of Power. *Annual Report 2016-17.* (2016). Available online at: https://powermin.gov.in/sites/default/files/uploads/MOP_Annual_Report_2016-17.pdf (accessed December 27, 2021).
33. UI GreenMetric (2021). Available online at: http://greenmetric.ui.ac.id/about/methodology/ (accessed October 25, 2021).
34. Ragazzi M, Ghidini F. Environmental sustainability of universities: critical analysis of a green ranking. *Energy Procedia.* (2017) 119:111–20. doi: 10.1016/j.egypro.2017.07.054
35. Walugembe DR, Sibbald S, Le Ber MJ, Kothari A. Sustainability of public health interventions: where are the gaps? *Health Res Policy Syst.* (2019) 17:8. doi: 10.1186/s12961-018-0405-y
36. India Skills Report. *Future Skills Future Jobs.* (2018). Available online at: https://wheebox.com/static/wheebox_pdf/india-skills-report-2018.pdf
37. Kromydas T. Rethinking higher education and its relationship with social inequalities: past knowledge, present state and future potential. *Palgrave Commun.* (2017) 3:1–12. doi: 10.1057/s41599-017-0001-8
38. Entwistle NJ, Peterson ER. Conceptions of learning and knowledge in higher education: relationships with study behaviour and influences of learning environments. *Int J Educ Res.* (2004) 41:407–28. doi: 10.1016/j.ijer.2005.08.009
39. Arum R, Roksa J. *Academically Adrift: Limited Learning on College Campuses*. Chicago, IL: University of Chicago Press (2011). P. xi, 259.
40. Ophelia yeung and Katherine Johnston. *Resetting the World with Wellness*. Global Wellness Institute (2020). Available online at: https://static1.squarespace.com/static/5f3f345272d5a76e6b281123/t/6018f1fbd4aab87fb9ba5519/1612247548058/GWI2020_White_Paper_Series_Resetting_the_world_with_Wellness_Revised.pdf
41. Zachos G, Paraskevopoulou-Kollia E-A, Anagnostopoulos I. Social media use in higher education: a review. *Educ Sci.* (2018) 8:194. doi: 10.3390/educsci8040194
42. Keles B, McCrae N, Grealish A. A systematic review: the influence of social media on depression, anxiety and psychological distress in adolescents. *Int J Adolesc Youth.* (2020) 25:79–93. doi: 10.1080/02673843.2019.1590851
43. Felekoglu B, Moultrie J. Top management involvement in new product development: a review and synthesis. *J Product Innovat Manage.* (2014) 31:159–75. doi: 10.1111/jpim.12086
44. Drucker PF. *The Practice of Management*. New York: Harper & Row (1954).
45. Van der Hoek M, Groeneveld S, Kuipers B. Goal setting in teams: goal clarity and team performance in the public sector. *Rev Public Personnel Adm.* (2018) 38:472–93. doi: 10.1177/0734371X16682815
46. Holt M, Powell S. Healthy Universities: a guiding framework for universities to examine the distinctive health needs of its own student population. *Perspect Public Health.* (2016) 137:53–8. doi: 10.1177/1757913916659095
47. Valaitis R, Meagher-Stewart D, Martin-Misener R, Wong S, MacDonald M, O'Mara L. Organizational factors influencing successful primary care and public health collaboration. *BMC Health Services Res.* (2018) 18:420. doi: 10.1186/s12913-018-3194-7
48. Ribeiro LRC. *Journal of University Teaching & Learning Practice,* Vol. 8, Article 4 (2011). Available online at: http://ro.uow.edu.au/jutlp/vol8/iss1/4 (accessed February 13, 2022).
49. Romanello M, McGushin A, Napoli CD, Drummond P, Hughes N, Jamart L. The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. Lancet (2021) 398:1619–62. doi: 10.1016/S0140-6736(21)01787-6
50. Schön DA. Educating the Reflective Practitioner: Toward a New Design for Teaching and Learning in the Professions. Jossey-Bass (1987).
51. Freeman RE, McVea J. A stakeholder approach to strategic management. In: Hitt M, Freeman E, Harrison J, editors. Handbook of Strategic Mangement. Oxford: Blackwell Publishing (2001). doi: 10.2139/ssrn.263511f

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Learning from the past to deal with the future: Using different knowledges to ensure food security in the Tsá Tué biosphere reserve (Northwest Territories, Canada)

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The community of Dél̨ı̨nę̨, located in the UNESCO Tsá Tué Biosphere Reserve, is experiencing the impacts of climate change on the lands surrounding Great Bear Lake, in Northwest Territories, Canada. These impacts are limiting the community's ability to access the land to support their food system, which depends on harvesting traditional foods. This article details a participatory action research approach, driven by the community, that used on-the-land activities, workshops, community meetings and interviews to develop a community food security action plan to deal with the uncertainties of a changing climate on the food system. Data was analyzed using the Community Capitals Framework (CCF) to describe the complex nature of the community's food system in terms of available or depleting capitals, as well as how the impacts of climate change affect these capitals, and the needs identified by the community to aid in adaptation. For Dél̨ı̨nę̨, the theme of self-sufficiency emerged out of concerns that climate change is negatively impacting supplies from the south and that building and maintaining both social and cultural capital are key to achieving food security in an uncertain future. Learning from the past and sharing Traditional Knowledge[1] was a key element of food security planning. However, other types of knowledge, such as research and monitoring of the health of the land, and building capacity of the community through training, were important aspects of adaptation planning in the community. This knowledge, in its many forms, may assist the community in determining its own direction for achieving food security, and offers a glimpse into food sovereignty in Northern regions.

KEYWORDS

climate change adaptation, food systems, indigenous, North, food security, traditional knowledge

[1]**There is no universally accepted definition of Traditional Knowledge but it is used here to describe the collective knowledge of traditions used by Indigenous people to sustain themselves and the environment over time, which is unique to communities and rooted in the rich culture of its peoples (Assembly of First Nations, 2009).**

Introduction

Food security has emerged as a growing concern in communities across northern Canada. Individuals face multiple, and often complex barriers, to achieving food security, where rates of food insecurity can range from 24 to 48–69% more remote areas, dramatically higher than the national average of 15.9%[2] (Rosol et al., 2011; Council of Canadian Academies, 2014; Tarasuk et al., 2016, 2022). Indigenous communities have faced decades of social, cultural, and political changes, on multiple scales that have had negative impacts of community health and well-being (Power, 2008; Council of Canadian Academies, 2014). As a result of these impacts, Indigenous communities in the North, and across the globe, have shifted away from traditional food systems, that relied on hunting, fishing and harvesting foods from the land, toward a reliance on food purchased from stores where the high cost and transportation of goods to remote locations leads to the lack of affordable, nutritious (Kuhnlein et al., 2004; Damman et al., 2008; Council of Canadian Academies, 2014). However, as many communities strive to maintain cultural and traditional practices inherent in the traditional food system, northern regions are now being profoundly impacted by global climate change. The region as seen an increase in temperature of roughly 4 to 5 times greater than the global average (IPCC, 2018). Impacts such as decreased sea ice thickness, permafrost thaw, changing migratory patterns of animals, and the increased intensity and frequency of weather events are affecting the access to and availability of traditional food sources, which are the staple of food systems in northern communities (Ford et al., 2006a, 2008, 2010; Guyot et al., 2006; Nickels and Furgal, 2006; Pearce T. et al., 2009; Andrachuk and Smit, 2012; Spring et al., 2018). As Indigenous Peoples have a deep connection to the land and depend on it for their food, health and cultural and spiritual well-being; they therefore are vulnerable to the impacts of changes to the ecosystem (Smit and Wandel, 2006; Costello et al., 2009; Cunsolo-Willox et al., 2012). Understanding and adapting to the impacts of climate change is essential for the long-term sustainability of northern communities.

To better understand the vulnerabilities and issues behind food insecurity in northern communities, there is a need to examine food systems through a different lens, one that accounts for the complexities, uncertainties, but also strengths in the community (Wesche et al., 2016). In this research the Community Capital Framework (CCF) is used to define the food system in a remote Indigenous community in the NWT. Developed by Flora et al. (2004), the CCF illustrates the interactions of seven types of capital contained within a community, including: natural, social, cultural, political, built, financial, and human. This framework has already been modified to describe northern food systems (Spring et al., 2018). The CCF is based on the Sustainable Livelihoods (SL) (Scoones, 2009) but is used here to describing the food systems of communities in the North. This framework complements other emerging definitions of food systems, including complex adaptive systems (Stroink and Nelson, 2013) and systems-of-systems approaches (Hipel et al., 2010; Blay-Palmer et al., 2015). Systems approaches are important for addressing issues of resilience, the ability to recover from a shock or stress, that are key to the sustainability in the face of climate change (Gunderson and Holling, 2002; Olsson et al., 2004; Walker et al., 2004; Folke, 2006). The CCF can be appropriate for food systems in the North as Indigenous communities have a diverse set of economies, and therefore capitals, accessed to maintain their way of life, including the social, traditional and wage-based economies (Usher et al., 2003; Abele, 2009; Dombrowski et al., 2013; Harnum et al., 2014; Simmons et al., 2015). The Dene Way of Life describes the close relationship to the land, being on and living off the land but also includes elements of self-governance, practicing cultural and spiritual traditions the social network and support of families and the community (Bartlett, 2005; Parlee et al., 2007)—again describing many of the capitals present in the CCF, including natural, cultural, social and political capitals. The addition of financial and built capitals reflect the needs for tools, equipment and infrastructure required to access the land, and support community services including food purchased at the stores (Council of Canadian Academies, 2014).

The research presented in this paper draws on a project, initiated at the invitation of the community of Dél̨ı̨nę, in Northwest Territories (NWT), Canada, which is a part of the recently designated Tsá Tué Biosphere Reserve. Dél̨ı̨nę is a small of community of ∼600 people, the majority of which are Dene, it is the only settlement on Great Bear Lake, the largest lake entirely within Canada and eighth largest in the world (Figure 1). The Sahtúot'ine Dene, or Bear Lake People enjoy a close relationship with the lake and the surrounding landscape and rely upon it for their health and spiritual well-being. Hunting, fishing, trapping and gathering remain important activities and the basis of the community's food system and livelihood. In 2016, the community work to recognize the lake and its watershed for its unique ecological and cultural heritage was achieved through a designation by United Nations Educational, Scientific and Cultural Organization (UNESCO). Biosphere Reserve designation show a commitment by local organizations to sustainably manage the resources in these areas and showcase these living laboratories to the world. However, this region, as with much of the northern regions of Canada, is under threat from the impacts of climate change and the community of Dél̨ı̨nę is concerned about how changes to the ecosystem will affect food security and well-being in the community. These issues have become increasingly pressing with the significant and

2 National average updated using Tarasuk et al. (2022), however, this report does not contain data for the territories.

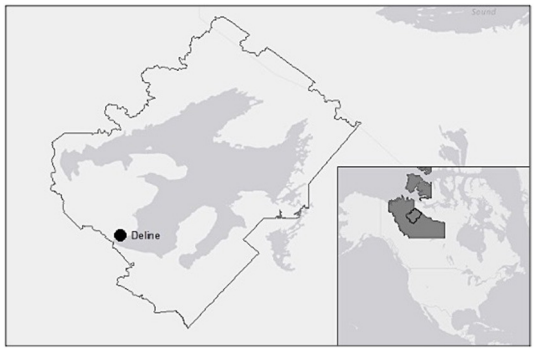

FIGURE 1
The community of Dél̨ı̨ne is located in the UNESCO Tsá Tué Biosphere Reserve, which encompasses the watershed of Great Bear Lake in Northwest Territories, Canada.

rapid decline of the Bluenose East caribou herd (Adamczewski et al., 2012; Boulanger et al., 2014) which the community has relied on as an important source of food. The community faces the prospect of reduced caribou harvesting and may face other uncertainties due to the impact of climate change such as access and availability of other traditionally harvested species. However, the impacts of climate change on the community's food systems needs to be put in a broader context of food system transition. Like many northern communities, Délı̨nę is remote and accessible only by air, boat, and winter road. Therefore, the majority of supplies, including fuel, food and other materials are shipped into the community during the window of winter road operation, typically from mid-January to late March. Fresh food stuffs and other necessary supplies are delivered to the community on a weekly basis through air cargo flights. The supply of food and other goods to communities like Délı̨nę is vulnerable to the impacts of climate change as the reliability of winter and ice roads and infrastructure will be affected (Prowse et al., 2009). A community plan was needed to build a more resilient food system. The purpose of this research was to: (1) understand the role of traditional foods and practices in the community's food system; (2) understand impacts of climate change on the availability of capitals of traditional foods system; and (3) identify capitals required to develop a food security adaptation strategies and programs to ensure food security and community self-sufficiency for the future.

Methods

This research details a collaborative Participatory Action Research (PAR) approach used to explore climate change vulnerability and adaptation strategies for the community of Délı̨nę in the Tsá Tué Biosphere Reserve. Community members were concerned about the impact that climate change is having on their most important food source, caribou. This concern triggered a broad discussion about climate change, health and well-being, and food security in the community. University researchers were engaged in 2014 to help secure project funding and help facilitate and document the discussion with community members to develop a plan. This ensured that the research would be community driven, is responsive to the needs of the community stakeholders and furthers the goals of social science through co-learning and building a collaboration of researcher and community (Gilmore et al., 1986; McTaggart, 1999). As community members in Délı̨nę have experience with social science studies, the community-based organizations that were partners in this research, including the Sahtú Renewable Resources Board (SRRB) have their own protocols. Much of the research methodology builds on existing frameworks to foster community collaboration, engagement, and trust building throughout the process (outlined in Caine et al., 2007; McGregor et al., 2010; Tondu et al., 2014; Simmons et al., 2015). This approach has origins in community empowerment, social action and community health and development (McTaggart, 1999; Altrichter et al., 2002).

A key principle of the approach was to encourage as much opportunity for community engagement and participation as possible (Minkler and Wallerstein, 2011). Throughout the process of developing the proposal for this project in 2014, information was sent, via emails or letters, to various decision-making bodies, organizations, and the broader community to raise awareness of the project. This was done to help solicit support, interest, and input from the community for the project. Community partners identified and recruited a diverse group of participants to take part in planning meetings, including Elders, youth, and active harvesters, who were able to share their knowledge of the changes observed on the land. This group became informally known as the steering committee and was involved in all aspects of the research planning, including meetings and conference calls that were aimed at making committee members familiar with the research process and the researchers themselves, approve research questions and approaches, and help foster broader community engagement. These meetings served as a valuable opportunity to share insights into the research and develop community-relevant questions and methodologies that reflected how the community wanted to be involved in the project. These actions served to build trust and foster open and transparent communication between all parties (Pearce T.D. et al., 2009; Tondu et al., 2014; Spring et al., 2018, 2020).

Other integral aspects of the project were two on-the-land camps that were planned to coincide with the fall and spring research visits. These camps were planned to help facilitate meaningful opportunities for community members, particularly youth, to be on-the-land learning skills from their Elders and harvesting foods to bring back to others in the community. Furthermore, this learning environment allowed the researchers

to gain a deeper understanding of the culture and traditions of the community (McGregor et al., 2010; Bartlett et al., 2012; Simmons et al., 2015). These opportunities also facilitated informal discussion around research topics and the building of trust and relationships (Tondu et al., 2014) and embody the spirit of PAR as these experiences can achieve both research and community goals. The camps, however, proved difficult to facilitate, with weather and dangerous conditions limiting the success of the fall camp, and planning and timing issues impacting the spring camp. As such, research process was delayed many times throughout the process. This experience highlights the ongoing evolution of community-based research in the North. The process of building trust and spending time and sharing experiences in the community is valuable, as is a highly flexible and patient approach to the research. Sometimes, the pressures between data collection, funding and reporting deadlines, community commitments, and the weather do not always come together. But building good relationships with community partners and good communication with research participants, helped to modify plans to accommodate for last minute changes. PAR was, therefore, the goal and the spirit of the research conducted in the community and may eventually be achieved through ongoing collaboration and communication with community members.

In all, 13 community members participated in semi-structured interviews with each interview taking ∼1 h and conducted in the language of their preference (North Slavey or English). As most people in Délı̨nę are fluent in both languages, English was predominantly used, but an interpreter was available to consecutively translate both questions and responses when needed. Interviews were mostly conducted in the Délı̨nę Land Corporation offices, but some were conducted in other locations if this was the preference of the participant. Interviews were structured around questions on health, food, changes witnessed over time to the land, and what solutions participants would they like to see to ensure access to food for future generations. The questions were open-ended to further explore specific experiences and expertise of the participant (Hay, 2000). All interviews were digitally recorded, and participants were reimbursed for their time, as per community protocol. Interviews were transcribed and shared with participants for their approval, and to ensure their accuracy. The data were thematically coded using the capitals of the CCF as a structure of the community's food system. This enabled the results to tell the story of the impacts of climate change on the food system, and what capitals can be used, or are needed to adapt to these impacts. A results workshop was held in 2017 after the data was analyzed and was open to all members of the community. This workshop allowed for the opportunity to discuss the project, validate key themes and observations that emerged from the interviews, and begin the planning of the community's food security action plan. Follow up conference calls and community visits were conducted between 2017 and 2019 to further validate findings of the study and plan and propose future projects as determined by the study results. A community report and action plan called *Dene béré belarewílé: Ensuring food security for future generations in Délı̨nę* were given to community leadership and served as the basis for future work in the community. This research approach and methodology was approved under Research Ethics Board of Wilfrid Laurier University and through the Aurora Research Institute (License number 15746), the research licensing organization for the NWT.

Results and discussion

The capitals of Délı̨nę's food system

In Délı̨nę, like many other communities in the North, health and well-being are linked to the health of the ecosystem—the land, animals and water but also access to traditional foods (Parlee et al., 2007; Loring and Gerlach, 2009; Parlee and Furgal, 2012; Spring et al., 2018). In general, participants described how they feel that Délı̨nę is a healthy community because the relationship to the land remains strong, as many people depend on the land for their livelihoods and their diets are maintained by traditional foods.

"Health in Deline, well, from knowing from way back from our grandparents, they lived on the land and had traditional food and they were always healthy. And you could see that, they were always up early every day, going, working, they were always energized...Health is going out on the land, having that fresh air, being with nature. Living off the land and taking care of your water and the animals, and that's health." ∼Joey Dillon

The land, waters and surrounding ecosystem play an important role in the lives of the community and is fundamental in their identity and sense of place, and food system. Due to the location of Délı̨nę, on the shores of Great Bear Lake, water became a common theme throughout the interviews. The lake was identified as the most important asset in the community; it is what makes Délı̨nę the place where people want to live and plays an important role in their lives, physically, mentally and spiritually. The lake is also woven into stories and prophesies told in the community, making it important, not only to natural capital, but also to cultural capital. It is the main method of transportation in all seasons to harvest food but is also the source of much of the community's food supply, as fish is an important staple. Many participants commented on how easy it is to just get in a boat (an important, but expensive tool for harvesters), get onto the lake and go catch fish, and the escape the lake provides to life in town.

> "The water is gold to Délı̨nę people. The Elders say is our freezer, Great Bear Lake, with all those fish in there" ∼Bertha Kenny

Having access to traditional foods is perceived as the basis of the community's preferred food system. However, there is a concern amongst participants that the community is not as reliant on traditional food as it once was, and that is having an impact on peoples' health. Participants discussed the many changes that have occurred during recent decades that have influenced health in the community, including the changing relationship with the land and water. Transition into permanent housing, water delivery, fuel heating, the need for jobs, moving away from dog teams to skidoos and the dependence on food from the store all play a role in changing the way the community members maintain their livelihoods.

> "That's when everything changed, when they brought up all this government housing, in 1968. I know, they left everything. Everyone left their dogs, and their bush life. Everything." ~George Kenny

The changing relationship with the land that has happened over time is illustrated now through concerns for the future of food in the community. The younger generation, generally, do not have the same relationship to the land, know the language nor possess the skills and experiences needed to survive on the land or bring back food for the community. There are concerns about where their food is going to come from if there is a lack of skills needed to maintain traditional foods as part of their livelihood in the future. Global and societal changes are having an impact on Dél̨ı̨nę, particularly their food system.

The capitals influencing Dél̨ı̨nę's food system (both positively and negatively) are outlined in Table 1 and were determined through interviews, conversations, and other background descriptions of the community. In Dél̨ı̨nę, the social economy is strong, and the community has done a great deal to maintain and build cultural capital though community-based programming and food sharing networks (Harnum et al., 2014; Simmons et al., 2015). Natural capital is abundant, with a pristine environment providing access to traditional food sources. These capitals are the drivers of the food system, where Traditional Knowledge and social practices allow community members to access food from the natural capital. But, as discussed, the ongoing social and cultural changes in the community may serve to limit the replenishment of these capitals over time, which is the cause for concern regarding the lack of skills for the next generation of harvesters. Financial capital is now needed to pay for gas, equipment and supplies to access food from the land and required for the increased reliance on food from the store. As financial capital may not be available for some individuals, the pursuit of employment to pay for supplies or other costs of living can take away from time in the community and on the land, further limiting social and cultural capitals. Human capital is now required to service modern harvesting tools, such as skidoos and small engines, and is not always accessible in the community, especially when technological advances in such equipment requires new skills and more technical equipment to service. The community's food system also relies on winter roads and weekly airplane food deliveries (built capital) to bring fresh food supplies, as well as other goods into the community. Dél̨ı̨nę does possess a great deal of political capital, achieved through the Comprehensive Land Claim and advanced through many community-led initiatives, and now as a self-governed community. This community power and influence over management of natural resources is currently being tested in ongoing discussions regarding caribou conservation, land use planning and protected area strategies. Although a brief snapshot of the community's food system, one can see the levels of complexity and interactions between the capitals, and the reliance on certain capitals and infrastructure to maintain the food system. Now, and maybe most importantly, the pressures of climate change on community's natural capital, and impacts on other capitals, will add more pressure on that food system.

Climate change impacts on the community capitals

Climate change is having a noticeable impact on the ecosystem; through interviews, participants described how these changes to the land are impacting the community. Community members spoke of changes in temperature, noting that it is not as cold as it has been in the past; they have also seen a change in the temperature of the lake, particularly in the past few years. People notice that the fish they catch in their nets spoils much faster than before. As one interviewee commented:

> "Way back, people set their net and they could go check it two days later and all the fish would be still fresh. But now, the old people have been mentioning it for a few years now, that if you don't check your net you get some spoiled fish on there because the water's getting warmer." ~Freddie Vitale

Therefore, adaptation in this case means more trips on the lake to check the nets and taking more resources in the form of human and financial capital to harvest similar amounts of food. Lower water levels on the lake and surrounding rivers were also noted as an area of concern as was a change in the availability of some fish species. Some species of fish have declined in numbers and are no longer available in some of the locations where they were traditionally found.

> "[Some fish] go someplace else but all the big trout they all go there, but they're all gone now. There used to be lots of fish there. The herring, I don't know where they moved." ~George Kenny

TABLE 1 Summary of the community's food system based on capitals, and how key findings, as identified through interviews and background research, either add to (+) or deplete (–) these capitals.

Capital	Key findings
Social	(+) Strong social economy (e.g., food sharing)
	(+) Close-knit community
	(+) Experience with networks outside of community
	(–) Social change due to global pressures
Cultural	(+) Reliance on traditional foods
	(+) Maintaining traditional practices and activities
	(+) Many are fluent in their traditional language
	(–) Language as barrier to transfer of Traditional Knowledge
	(–) Some youth not as engaged in traditional foods and activities
	(–) Changes to relationship with land
Natural	(+) Abundant sources of country food (fish, moose, and others)
	(+) Great Bear Lake
	(–) Declining caribou herds
Financial	(+) Access to community funding and government grants
	(+) Comprehensive land claim
	(–) Limited availability of jobs in community
	(–) High cost of living (food, gas, and supplies)
Political	(+) Multiple layers of government
	(+) Comprehensive land claim
	(+) Self-government
	(+) Co-management of resources
	(+) UNESCO biosphere reserve designation
Human	
	(+) Engaged community
	(+) Educational opportunities in community
	(+) Employ consultants to fill capacity voids
Built	(+) Community services (water, wastewater, and health)
	(+) Access to stores
	(–) Fly-in community (winter road access only)

Furthermore, some people have noticed changes in fish health, including parasites and changes in taste. Key informants also shared their observations that travel on the lake has also become more unpredictable. The wind can change rapidly, bringing waves and unsafe conditions that can have severe implications on travel plans, as experienced by the research participants as travel to the fall on-the-land camp was postponed several times due to the sudden, and dangerous, change in conditions. Although rapidly changing weather has always been a risk associated with travel on such a big lake at certain times of the year, members of the community reported that it is now more difficult to predict.

> "It is riskier, especially in the fall and spring when the wind starts picking up and it gets cold and freezes. It's way more dangerous to travel on the lake." ~Ted Mackenzo

There are many stories and experiences by community members of being delayed or stuck on the land due to weather. One story involved an Elder that was stranded on the lake due to a mechanical breakdown. He survived through severe weather, drifting on the lake, and ultimately fashioning a sail to make his way to land. In this more extreme example, it was through the years of experience and the combination of having the right tools and quick thinking that led to his survival. Participants remarked that if it had happened to anyone else, it might not have ended as well, again underlining the importance of learning a diversity of skills and spending time on the land in all types of conditions. The community is aware of the dangers of travel, especially during lake freeze-up and break-up, where travel plans may not go as expected. Bringing extra supplies, traveling with small groups, and being more cautious when traveling are some of the adaptations used to enhance safety, but these are not necessarily practiced by all community members.

The overall changes in weather observed by the community, including rain events in December and difference in timing of freeze/thaw cycles in the fall and spring is limiting access to the land. These changes are known to impact animal foraging, particularly in caribou, vegetation, and human activities in other regions (Bokhorst et al., 2016). Although significant changes to the landscape through the impacts of permafrost thaw are minimal, the community did report instances of slumping of some riverbanks and hillsides around the lake as well as changes in the freezing of muskeg, increasing the risk associated with travel in certain areas. Most importantly for the community are the changes they have witnessed in animals, particularly species that are important food sources to the community, including caribou. The community has seen the numbers of caribou decline and commented on how far they need to travel in search of caribou now.

> "There was a lot of caribou across the North shore. They don't come here. This time of year there were lots out there, but now they're all gone." ~George Kenny

Their accounts, paired with reports regarding the significant decline of Bathurst East caribou herd, as well as other barren-ground herds in the NWT (Adamczewski et al., 2012; Boulanger et al., 2014), have led to a deep concern in the community as to what to do to help the caribou. At this point, the research intersected with the community's caribou conservation plan, known as *Belare wile Gots'ę ʔekwę –Caribou for All Time* (Dél̨nę ʔekwę Working Group, 2016) which was being developed

concurrently to this research. The community's plan proposed to limit the harvest of caribou for the next 3 years to ceremonial purposes only, outlined key approaches to conservation based on Traditional Knowledge and relationship with the caribou, and enforced their decision-making and monitoring rights as outlined in the Comprehensive Land Claim Agreement (Dél̨nę ʔekwę́ Working Group, 2016). This synergy, between the food security and the caribou plan, offered an interesting insight into community conversations about the importance of caribou, and the difficult decision to restrict the harvest of caribou, a right outlined in the land claim agreement and a polarizing issue within the community and amongst the other communities and regions that depend on that resource.

Making the difficult decision to limit the caribou harvest is an example of the community using its political capital to determine its own food system and offers a unique insight into food sovereignty in the North. Food sovereignty is a concept where communities define their own food system, and is largely based on the right to food (Patel, 2009, 2012). While the right to food, in this case subsistence food resources, is granted through the Sahtú Dene and Métis Comprehensive Land Claim Agreement, the community is invoking the right as stewards of the land to protect this important resource for future generations. Although this may have short term consequences on food availability in the community, the long-term health of the caribou and other animals, is in the best interest of everyone, including future generations.

> "[If we] hunt all the caribou or fish out the lake, then what would happen to this unborn generation? How they survive but all these things disappear? And the trapping, no one's going to teach them how to do it. So what I'm looking at is to try to save as much as we can for the next generation. ∼Paul Modeste

What emerged during discussions with participants was the language of self-sufficiency, where the community would not have to rely so heavily on goods, particularly food, being transported from the south. Although many community members admitted that they will still need that link for many commodities (fuel and some food for example), they also observed that links to the south would not be as reliable due to the impacts of climate change in the future. This point was highlighted during the research visit in February 2016 where the condition of the ice road was so poor that it had yet to open to heavy truck traffic. This was a major delay from previous years and led to an increased sense of anxiety in the community about whether supplies would reach the community that year. A week later, the road was opened to heavy truck traffic and a fuel truck fell through the ice on its crossing of the lake (CBC News, 2016). Although the fuel was safely removed and the truck was lifted out of the ice, it was a stark reminder of the need to promote the solutions that community members wanted to see to build a more sustainable food system for the future.

Adaptations based on past experiences

Making changes to the community's food systems involved two key themes that emerged during interviews: learning from the past and gaining new knowledge from outside the community. Learning from the past involved sharing Traditional Knowledge and skills within the community and thereby strengthening the social and cultural capitals within the community. This also encompasses how the community has adapted to past events, such as fluctuations in climate (Ford et al., 2006b) or, in the case of Dél̨nę, changes in food availability. For example, the current situation with the Bluenose East caribou herd and the limits to harvesting that species is not unlike a situation the community experienced in the past. During interviews Elders shared stories of the time there were no barren-ground caribou around Dél̨nę for the community to harvest for 30 years. When asked how the community coped with the loss of caribou, Elders highlighted a variety of other animals that the community used for food sources and the importance of sharing food.

> "Moose, lots of moose…and fish, trout, whitefish… the other caribou, woodland…." ∼Charlie Neyelle

Elders acknowledged that it was not an easy time for the community, but they worked together, shared food, and adapted by being flexible in what was harvested. Fast forward to today, there is a concern regarding the community's dependency on caribou and the lack of variety of species harvested. And that knowledge of when and where other food sources were traditionally harvested in and around the area is not readily available. It is therefore a priority of the community to document and map these important locations with Elders, and ultimately share this knowledge with community members and harvesters. This will ensure a more sustainable harvest of traditional food sources by increasing the variety of both species and locations, but also by visiting sites they have not returned to in years and even returning to species they have not harvested in years as well. This will help to increase self-reliance and available food for the community, and hopefully lead to less reliance on food from the store. This shift to a broader range of locations and species does come at a cost, of both fuel and supplies and time (predominantly human and financial capitals) (Brinkman et al., 2014). Although the local agency, the DRRC, will help with some of the financial burden by providing gas to land claim beneficiaries for the harvest and sharing of food with the community, it will take a more coordinated effort to shift harvesting practices back to those used in the past. This

shift toward traditional harvesting timing and location is also not without risk. Traveling to places farther away from the community adds costs and makes harvesters more vulnerable to the risks associated with the changes in climate described earlier. Furthermore, as some of these locations have not been visited for years, it is unknown what the health of the land or species availability might be in these areas. Families that harvested at these locations in the past also maintained cabins and spent a great deal of time in those areas and knew those areas well. Recapturing that information from past experiences and revisiting and assessing these harvesting locations will be important for the future of the food supply in the community.

What is also important, then, is that community members have the knowledge to properly harvest and respect a variety of animals along with safety and survival skills. With the new challenges and risks associated with the changing climate, harvester safety and being respectful of cultural traditions on the land are paramount as the community chooses to continue to utilize traditional foods as the basis of their food system. Young harvesters must be provided with the opportunity to learn and practice skills on the land, under the guidance of community Elders and knowledge holders, and be encouraged to become harvesters, trappers, food providers and positive role models in the community.

> "We have to start teaching our young people to live off the land by themselves. Like in the old days, people used to make their own homes, tents with spruce, and even how to make fire out there on the land. That's what we need to teach our young people" ~Leon Modeste

There was interest in integrating on-the-land learning into the school and creating more opportunities for the youth to learn the language. Getting youth interested in cultural practices and activities was seen as important to do at an early age, but many participants highlighted barriers to implementing some of these changes. Young children do not, generally, speak the language. Although there are some language programs at the school, it is not being taught or spoken at home. It seems that young parents with young children do not generally speak the language as they were brought up in schools that taught in English only. Providing community members experience on the land as families or large groups was seen as the ideal way to learn skills and reestablish bonds with each other and the land as well as reconnecting with the language. Language is the key to understanding Traditional Knowledge and skills.

> "They have to learn their language, then they'll know everything." ~George Kenny

Language was a key component of the community's approach to self-government and caribou conservation. And participants wanted to see programming aimed at incorporating language education and Traditional Knowledge and skills into programming, either through the school or through another organization in the community. The possibility that self-government may provide a vehicle to deliver a more culturally appropriate education in the community was raised as part of several interviews. In Dél̨ı̨nę, perhaps, political capital may be the key to building and maintaining cultural capital, and the community appears to be allocating other capitals within the community to achieve this goal. Learning and sharing Traditional Knowledge from within the community also requires bonding social capital to support the maintenance of cultural capital and therefore, the food system of the community, something the community has been working on through their vision of self-governance as well (Bayha and Spring, 2020).

Adaptations through creation of new knowledge

Although community priorities for adaptation relied on the building of capitals through strengthening of community bonds (social capital), sharing of Traditional Knowledge (cultural capital) and through their political capital, there was also an emphasis on bringing new knowledge into the community to help build a more sustainable food system. And sometimes the combination of the two were seen as solutions for the community. Through interviews, growing food was identified as a key way forward for Dél̨ı̨nę to become more self-sufficient and food secure in the future as well as for decreasing their dependence on expensive store food.

> "Because everything here is so expensive. If we do our own garden, if people want some stuff they can just get some. Share." ~Bertha Kenny

Potatoes were a key food source that people wanted to see grown in the community, but many cited the lack of knowledge around gardening in the community amongst the Dene people. Although gardening has been done in the community, most of it has been through people from outside the community who grow food for a while and then leave, taking the skills needed with them. The current garden is operated behind the community's nursing station and provides food to a small portion of the community. There are Sahtúot'ine currently involved and even more are interested, so scaling up the existing community garden, while working to build capacity, knowledge, and interest in the community around growing food, is important. If the capacity to grow food already exists in the community, creating more opportunities to learn and share this information within the community may be a way forward. Local food production is a key adaptation that many communities across the North are investigating (Spring et al., 2018; Chen and Natcher, 2019)

so there are opportunities to learn and share information with others.

Building the food system to be more self-sufficient also does not always have to rely on new skills and knowledge either. Many community members mentioned that muskox are now present, and even plentiful, in the area but are unsure of the viability of the species as a substitute for caribou in the community diet. Often muskox were described negatively, as competition for caribou for food and space on the land, or the fact that caribou dislike and avoid musk-ox, a story supported in other NWT communities (Wesche and Chan, 2010). However, there was some interest in trying it, mainly if it would help the caribou. As one participant noted:

> "I have a buddy from Nunavut and says the meats the same. But if I get a chance I'll try to get a calf there. The meat should be nice and tender, just to try it. There are lots of people saying that they're all over." ~Freddie Vital

Although there are examples of climate change creating opportunities for other species to become important food sources for communities in the North, these cases have involved harvesting more of a traditionally less-harvested species (Ford et al., 2006a; Wenzel, 2009). Muskox, in particular, has not been harvested much, if at all, in Dél̨ı̨nę in the past, so there was concern that there was a lack of skills to properly harvest them, or if it was appropriate to do so, since the community had no experience with this species. Food substitutions, therefore, may not be culturally acceptable for some communities. However, the community was interested in learning more, with the possibility of talking to other communities and harvesters to bring in this knowledge. In a sense, it would be sharing Traditional Knowledge from other communities to aid in adaptation: communities learning from other communities. The community will have to decide if this is an appropriate substitution for them[3].

Many of the solutions proposed by the community involved monitoring the lake and the resources around the lake to ensure the entire ecosystem is healthy and protected. The basis for this is not only the dependence on the lake for their livelihoods, but the role that Great Bear Lake plays in community beliefs and culture. Monitoring, it was felt, gave the community the voice as the protectors of the lake, and the ability to assert their rights to the land and fulfill their wish to be stewards of the lake. However, much of the monitoring, of water quality for example, was done by outside institutions, and participants noted that much of the findings are not shared with the community. Community members indicated the need for more participation in ongoing monitoring initiatives but highlighted the importance for better communication of results to the community.

> "Non-Dene researchers and scientists, we need to work together and help each other learn about the land, learn about the animals. We know for a fact that right now the caribou is in decline. And we have to deal with it, we have to work with it. Not only that, but we know for a fact that the water level is also low. So those kind of things we need people, scientists that are knowledgeable about that to come and work with us, and share information with us." ~Leon Modeste, Elder

Making the scientific knowledge more available would help community members better understand the changes on the land and the health of the ecosystem, and aid in adaptation and decision making (Armitage et al., 2011; McCarthy et al., 2011). With increasing uncertainty around the impacts of climate change on species, such as caribou, and the realization that some Traditional Knowledge may no longer be applicable in the changing climate, the need to supplement traditional ways of knowing with evidence-based decision-making through scientific knowledge becomes critical. Participants wanted to see scientific knowledge and studies focus on important issues for the community and wanted to see the community also contribute to, if not lead, this research. Research in with the Tsá Tué Biosphere Reserve is now focusing on building stronger relationships with researchers to support a research and monitoring network to align with the community's vision of protecting Great Bear Lake.

Building a food system that is resilient to the impacts of climate change will be a challenge to all northern communities. By examining the food system in Dél̨ı̨nę, one can see that multiple stresses, including climate change and other social and cultural changes, are impacting the capitals of the food system. The community, however, is actively adapting their food systems in the face of climate change and has a vision for building a more resilient food system through the building of capitals that support the community. A detailed list of the capitals required to build a more sustainable food system are given in Table 2. For Dél̨ı̨nę, the emphasis has been put on building social and cultural capitals through promoting intergenerational knowledge transfer and emphasizing quality time together on the land. The building of bridging and bonding social capital and the sharing of knowledge across scales can help in the formations of new linkages and opportunities for the food system (Levkoe, 2011; Blay-Palmer et al., 2015). As witnessed in this research, adding new knowledge was vital to moving these community-defined projects forward to meet the vision of the community's food system. Equally, there was a focus to relearn, rediscover and share information already present in the community,

3 A food processing workshop was held in 2019 to showcase different ways of preparing and preserving different types of food. Muskox meat was harvested and made into burgers and sausages for a community event and proved a popular food choice. Follow up discussion are ongoing as to how food processing infrastructure can make foods more available in the community.

TABLE 2 Community capitals required to build a sustainable food system in Dél̨ı̨nę̨.

Capital	Adaptations
Social	More community hunts (involving families) and time together on the land Increase communications amongst harvesters to report conditions on the land Create relationships (outside of the community) to bring in new knowledge
Cultural	Learn from past experiences and share Traditional Knowledge Language programming Promote on-the-land camps/events when possible Engage youth and create mentorship opportunities
Natural	Increased research and monitoring
Financial	Resources needed to fund community-defined programs Self-government able to allocate funding to community initiatives
Political	Continue to build through self-government and Biosphere Reserve Monitoring lands
Human	Skills and training needed for initiatives (gardening, mapping, etc.) Promote harvester safety
Built	Infrastructure and tools required programs and initiatives (gardens, etc.)

allowing the reemergence of a sustainable food system used in the past. This does involve strengthening relationships within the community, but also requires harnessing the community's cultural capital as key elements of a more sustainable food system lie in the Traditional Knowledge of the community. Accessing stored cultural capital to learn from the past should be the basis for culturally acceptable adaptations (Adger et al., 2009, 2012; Pearce et al., 2015). As communities define their food system based on place and local circumstance (Marsden, 2012; Blay-Palmer et al., 2015), in the context of the CCF, it emerges out of the capitals that are available to the community. It is, however, cultural capital that emerges as a defining capital in the food system in northern Canada. Cultural customs, practices and Traditional Knowledge play a major role in these food systems as well as in their sense of place and identity (Wilson, 2003; Cunsolo-Willox et al., 2012) and is becoming the focus of adaptation strategies in the region (Crane, 2010; Pearce et al., 2015; Spring et al., 2018). The importance of cultural capital is what makes the food systems here unique and is captured within the CCF as a lens to examine the system of food systems in Dél̨ı̨nę̨.

While this study represents the beginning of a participatory action research relationship between researchers and the community, there are limitations to this study and its findings. First, funding timelines meant that data collection needed to start in the initial phases of community engagement. With no previous relationship in the community, lack of trust and familiarity with researchers may have limited responses to questions and overall engagement. Although the broader research team did consist of regional and community representatives, researchers were ultimately limited in how much time they could spend in the community during the course of the project. Finalizing community reports and recommendations also felt rushed due to these time constraints. Second, our relatively small sample size means we may not have captured enough community voices on the impacts and adaptions. Building relationships with the community has been the focus of the researchers over the past few years and so continuing the discussion about food security and climate change adaptation with more community members and continuing to validate and implement this work has occurred. However, much of the progress of this academic publication has been slowed by the implementation of self-government in the community of Dél̨ı̨nę̨, as well as by the pandemic. The research team has worked closely with the community to ensure that the impacts and actions presented in this study are still relative today.

Conclusion

Climate change is a reality for northern communities and brings changes to the land, water and animals communities depend upon. Through a dialog with community members this research highlighted the needs for different types of knowledge to flow within and into the community to enhance adaptation and secure food for the future. As traditional foods are the basis of the preferred food system for Dél̨ı̨nę̨, knowledge to support the harvesting and gathering of these foods is central to the community's plan moving forward. A community vision of self-sufficiency also emerged as part of this research. Self-sufficiency, as described by participants, involves not having to rely on goods coming from the South, but also focusing on building capacity in the community for people to feed themselves from the land as they have done in the past and through new skills such as growing food. By maintaining traditional foods as the foundation of the community's food system and increasing local production or gathering of other foods, the community envisions a future with continued access to safe, affordable and culturally appropriate foods, meeting the criteria of community food security (Hamm and Bellows, 2003). To achieve this goal, however, relies on building and strengthening capitals as part of the food system. Key to building capitals is the transfer of knowledge, both in terms of traditional skills and knowledge from within the community (social and cultural capitals) as well as other types of knowledge, including education, skills, as well as monitoring and science, from outside the community.

In the UNESCO Tsá Tué Biosphere Reserve, there is the opportunity to watch food sovereignty unfold. Due to the presence of such high amounts of political capital in the community, and thanks to self-government and the comprehensive land claim agreement. The community is reimagining their food system as one rooted in both their cultural values and Traditional Knowledge and new knowledge from outside the community. As another example of the food politics of the possible (Blay-Palmer et al., 2015), this community has the opportunity to shape their food system to be based upon cultural capital and the Traditional Knowledge systems of the people. Utilizing the CCF, this research has identified community strengths, as well as gaps in the food system and offered insights into how to develop capitals to build resilience into the food system. Recent work continues to examine how the community's high level of political capital, that is still changing with the recent implementation of self-government, shapes the food system as issues concerning rights to lands, resource development and food sovereignty continue to evolve in Canada and globally. More recent community-led research in Tsá Tué has involved youth engagement through supporting cultural and language programming (Bayha and Spring, 2020) as well as assisting in the community's vision to protect Great Bear Lake for all time through protected area legislation, Indigenous Guardians initiatives and research and monitoring programs. It is hoped that through this process, the Tsá Tué Biosphere Reserve will offer a unique case study in both northern-specific, and contemporary food studies to share with the world.

Data availability statement

The datasets presented in this article are not readily available because Data is owned by the Indigenous community involved in the project. Requests to access the datasets should be directed to aspring@wlu.ca.

Ethics statement

The studies involving human participants were reviewed and approved by Wilfrid Laurier University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

AS: writing, methodology, data collection, and validation. DS, MN, and WB: methodology, community engagement, data collection, and validation. AB-P: supervision, review, and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Abele, F. (2009). The state and the northern social economy : research prospects. *Northern Rev.* 30, 37–56.

Adamczewski, J., Boulanger, J., Croft, B., Davison, T. M., Sayine-Crawford, H., and Tracz, B. (2012). *A Comparison of Calving and Post-Calving Photo-Surveys for the Bluenose-East Herd of Barren-Ground Caribou in the Northwest Territories, Canada in 2010*. Yellowknife, NT: Environment and Natural Resources, Government of Northwest Territories. Manuscript Report 244.

Adger, W. N., Barnett, J., Brown, K., Marshall, N., and O'brien, K. (2012). Cultural dimensions of climate change impacts and adaptation. *Nat. Clim. Chang.* 3, 112–117. doi: 10.1038/nclimate1666

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., et al. (2009). Are there social limits to adaptation to climate change? *Clim. Change* 93, 335–354. doi: 10.1007/s10584-008-9520-z

Altrichter, H., Kemmis, S., McTaggart, R., and Zuber-Skerritt, O. (2002). The concept of action research. *Learn. Organ.* 9, 125–131. doi: 10.1108/09696470210428840

Andrachuk, M., and Smit, B. (2012). Community-based vulnerability assessment of Tuktoyaktuk, NWT, Canada to environmental and socio-economic changes. *Reg. Environ. Change* 12, 867–885. doi: 10.1007/s10113-012-0299-0

Armitage, D., Berkes, F., Dale, A., Kocho-Schellenberg, E., and Patton, E. (2011). Co-management and the co-production of knowledge : learning to adapt in Canada's Arctic. *Glob. Environ. Change* 21, 995–1004. doi: 10.1016/j.gloenvcha.2011.04.006

Assembly of First Nations. (2009). *First Nations Ethics Guide on Research and Aboriginal Traditional Knowledge*. Assembly of First Nations. Available online at: https://www.afn.ca/uploads/files/fn_ethics_guide_on_research_and_atk.pdf.

Bartlett, C., Marshall, M., and Marshall, A. (2012). Two-eyed seeing and other lessons learned within a co-learning journey of bringing together Indigenous and mainstream knowledges and ways of knowing. *J. Environ. Stud.* 2, 331–340. doi: 10.1007/s13412-012-0086-8

Bartlett, J. G. (2005). Health and well-being for Métis women in Manitoba. *Can. J. Public Health* 96, S22–S27. doi: 10.1007/BF03405312

Bayha, M., and Spring, A. (2020). Response to COVID in Déline, NT: reconnecting with our community, our culture and our past after the pandemic. *Agric. Human Values* 37, 597–598. doi: 10.1007/s10460-020-10059-z

Blay-Palmer, A., Sonnino, R., and Custot, J. (2015). A food politics of the possible? Growing sustainable food systems through networks of knowledge. *Agric. Hum. Values* 33, 27–43. doi: 10.1007/s10460-015-9592-0

Bokhorst, S., Pedersen, S. H., Brucker, L., Anisimov, O., Bjerke, J. W., Brown, R. D., et al. (2016). Changing Arctic snow cover: a review of recent developments and assessment of future needs for observations, modelling, and impacts. *Ambio* 45, 516–537. doi: 10.1007/s13280-016-0770-0

Boulanger, J., Croft, B., and Adamczewski, J. (2014). *An Estimate of Breeding Females and Analyses of Demographic Indicators From the Bathurst Herd 2012 Calving Ground Photographic Survey*. Yellowknife, NT: Northwest territories environment and natural resource.

Brinkman, T., Maracle, K. T. B., Kelly, J., Vandyke, M., Firmin, A., and Springsteen, A. (2014). Impact of fuel costs on high-latitude subsistence activities. *Ecol. Soc.* 19, 27. doi: 10.5751/ES-06861-190418

Caine, K. J., Salomons, M. J., and Simmons, D. (2007). Partnerships for social change in the Canadian North : revisiting the insider – outsider dialectic. *Dev. Change* 38, 447–471. doi: 10.1111/j.1467-7660.2007.00419.x,

CBC News (2016). *Fuel Tanker Plunges Through Deline, N.W.T., ice road*. Available online at: http://www.cbc.ca/news/canada/north/truck-plunges-deline-ice-road-1.3477869 (accessed November 1, 2017).

Chen, A., and Natcher, D. (2019). Greening Canada's Arctic food system: local food procurement strategies for combating food insecurity. *Can. Food Stud.* 6, 140–154. doi: 10.15353/cfs-rcea.v6i1.301

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., et al. (2009). Managing the health effects of climate change. *Lancet* 373, 1693–1733. doi: 10.1016/S0140-6736(09)60935-1

Council of Canadian Academies (2014). *Aboriginal Food Security in Northern Canada: An Assessment of the State of Knowledge*. Ottawa, ON: Council of Canadian Academies.

Crane, T. A. (2010). Of models and meanings : cultural resilience in social – ecological systems. *Ecol. Soc.* 15, 19. doi: 10.5751/ES-03683-150419

Cunsolo-Willox, A., Harper, S. L., Ford, J. D., Landman, K., Houle, K., and Edge, V. L. (2012). "From this place and of this place:" climate change, sense of place, and health in Nunatsiavut, Canada. *Soc. Sci. Med.* 75, 538–547. doi: 10.1016/j.socscimed.2012.03.043

Damman, S., Eide, W. B., and Kuhnlein, H. V. (2008). Indigenous peoples' nutrition transition in a right to food perspective. *Food Policy* 33, 135–155. doi: 10.1016/j.foodpol.2007.08.002

Dél̨nę ʔekwę́ Working Group (2016). *Belarewile Gots'ę́ ʔekwę́ Deline Caribou Conservation: A Deline Plan of Action*.

Dombrowski, K., Channell, E., Khan, B., Moses, J., and Misshula, E. (2013). Out on the land: income, subsistence activities, and food sharing networks in Nain, Labrador. *J. Anthropol.* 2013, 1–11. doi: 10.1155/2013/185048

Flora, C., Flora, J., and Fey, S. (2004). *Rural Communities: Legacy and Change*. 2nd Edn. Boulder, CO: Westview Press.

Folke, C. (2006). Resilience: the emergence of a perspective for social–ecological systems analyses. *Glob. Environ. Change* 16, 253–267. doi: 10.1016/j.gloenvcha.2006.04.002

Ford, J. D., Pearce, T., Duerden, F., Furgal, C., and Smit, B. (2010). Climate change policy responses for Canada's Inuit population : the importance of and opportunities for adaptation. *Glob. Environ. Change* 20, 177–191. doi: 10.1016/j.gloenvcha.2009.10.008

Ford, J. D., Smit, B., and Wandel, J. (2006a). Vulnerability to climate change in the Arctic: a case study from Arctic Bay, Canada. *Glob. Environ. Change* 16, 145–160. doi: 10.1016/j.gloenvcha.2005.11.007

Ford, J. D., Smit, B., Wandel, J., Allurut, M., Shappa, K., Ittusarjuat, H., et al. (2008). Climate change in the Arctic: current and future vulnerability in two Inuit communities in Canada. *Geogr. J.* 174, 45–62. doi: 10.1111/j.1475-4959.2007.00249.x

Ford, J. D., Smit, B., Wandel, J., and MacDonald, J. (2006b). Vulnerability to climate change in Igloolik, Nunavut: what we can learn from the past and present. *Polar Rec.* 42, 127. doi: 10.1017/S0032247406005122

Gilmore, T., Krantz, J., and Ramirez, R. (1986). Action based modes of inquiry and the host-researcher relationship. *Consultation* 5, 160–176.

Gunderson, L. H., and Holling, C. S. (2002). *Panarchy: Understanding Transformations in Systems of Humans and Nature*. Washington, DC: Island Press.

Guyot, M., Dickson, C., Paci, C., Furgal, C., and Chan, H. M. (2006). Local observations of climate change and impacts on traditional food security in two northern Aboriginal communities. *Int. J. Circumpolar Health* 65, 403–415. doi: 10.3402/ijch.v65i5.18135

Hamm, M. W., and Bellows, A. C. (2003). Community food security and nutrition educators. *J. Nutr. Educ. Behav.* 35, 37–43. doi: 10.1016/S1499-4046(06)60325-4

Harnum, B., Hanlon, J., Lim, T., Modeste, J., Simmons, D., and Spring, A. (2014). Best of Both *Worlds: Depending on the Land in the Sahtu Region*. Tulita, NT: Sahtu renewable resources board.

Hay, I. (2000). *Qualitative Research Methods in Human Geography*. Don Mills: Oxford University Press.

Hipel, K. W., Fang, L., and Heng, M. (2010). System of systems approach to policy development for global food security. *J. Syst. Sci. Syst. Eng.* 19, 1–21. doi: 10.1007/s11518-010-5122-1

IPCC (2018). *Global Warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change.*

Kuhnlein, H. V., Receveur, O., Soueida, R., and Egeland, G. M. (2004). Community and international nutrition arctic indigenous peoples experience the nutrition transition with changing dietary patterns and obesity. *J. Nutr.* 1447–1453. doi: 10.1093/jn/134.6.1447

Levkoe, C. Z. (2011). Towards a transformative food politics. *Local Environ.* 16, 687–705. doi: 10.1080/13549839.2011.592182

Loring, P. A., and Gerlach, S. C. (2009). Food, culture, and human health in Alaska: an integrative health approach to food security. *Environ. Sci. Policy* 12, 466–478. doi: 10.1016/j.envsci.2008.10.006

Marsden, T. (2012). "Food systems under pressure: regulatory instabilities and the challenge of sustainable development," in *Food Practices in Transition: Changing Food Consumption, Retail and Production in the Age of Reflexive Modernity*, Eds G. Spaargaren, P. Oosterveer, and A. Loeber (New York, NY: Routledge), 311–31.

McCarthy, D. D. P., Crandall, D. D., Whitelaw, G. S., General, Z., and Tsuji, L. J. (2011). A critical systems approach to social learning: building adaptive capacity in social, ecological, epistemological (SEE) systems. *Ecol. Soc.* 16, 18. doi: 10.5751/ES-04255-160318

McGregor, D., Bayha, W., and Simmons, D. (2010). "Our Responsibility to Keep the Land Alive": voices of northern indigenous researchers. *Pimatisiwin J. Aborig. Indigen. Commun. Health* 8, 101–124.

McTaggart, R. (1999). Reflection on the purposes of research, action, and scholarship: a case of cross-cultural participatory action research. *Syst. Pract. Action Res.* 12, 493–511. doi: 10.1023/A:1022417623393

Minkler, M., and Wallerstein, N. (Eds.). (2011). *Community-Based Participatory Research for Health: From Process to Outcomes*. San Francisco, CA: John Wiley and Sons.

Nickels, S., and Furgal, C. (2006). *Unikkaaqatigiit—Putting the Human Face on Climate Change: Perspectives From Inuit in Canada*. Ottawa, ON: Inuit Tapiriit Kanatami, Nasivvik Centre for Inuit Health and Changing Environments at Universite Laval; Ajunnginiq Centre, National Aboriginal Health Organization.

Olsson, P., Folke, C., and Berkes, F. (2004). Adaptive comanagement for building resilience in social-ecological systems. *Environ. Manage.* 34, 75–90. doi: 10.1007/s00267-003-0101-7

Parlee, B., and Furgal, C. (2012). Well-being and environmental change in the arctic: a synthesis of selected research from Canada's International Polar Year program. *Clim. Change* 115, 13–34. doi: 10.1007/s10584-012-0588-0

Parlee, B., Neil, J. O., and Lutsel K'e Dene First Nation (2007). "The Dene Way of Life": perspectives on health from Canada's North. *J. Can. Stud.* 41, 112–133. doi: 10.3138/jcs.41.3.112

Patel, R. (2009). Food sovereignty. *J. Peas. Stud.* 36, 663–706. doi: 10.1080/03066150903143079

Patel, R. C. (2012). Food sovereignty: power, gender, and the right to food. *PLoS Med.* 9, 2. doi: 10.1371/journal.pmed.1001223

Pearce, T., Ford, J., Willox, A. C., and Smit, B. (2015). Inuit Traditional Ecological Knowledge (TEK), subsistence hunting and adaptation to climate change in the Canadian Arctic. *Arctic* 68, 233–245. doi: 10.14430/arctic4475

Pearce, T., Smit, B., Duerden, F., Ford, J. D., Goose, A., and Kataoyak, F. (2009). Inuit vulnerability and adaptive capacity to climate change in Ulukhaktok, Northwest Territories, Canada. *Polar Rec.* 46, 157. doi: 10.1017/S0032247409008602

Pearce, T. D., Ford, J. D., Laidler, G. J., Smit, B., Duerden, F., and Allarut, M. (2009). Community collaboration and climate change research in the Canadian Arctic. *Polar Res.* 28, 10–27. doi: 10.1111/j.1751-8369.2008.00094.x

Power, E. M. (2008). Conceptualizing food security for Aboriginal people in Canada. *Can. J. Public Health* 99, 95–97. doi: 10.1007/BF03405452

Prowse, T. D., Furgal, C., Chouinard, R., Melling, H., Milburn, D., and Smith, S. L. (2009). Implications of climate change for economic development in northern Canada: energy, resource, and transportation sectors. *Ambio* 38, 272–281. doi: 10.1579/0044-7447-38.5.272

Rosol, R., Huet, C., Wood, M., Lennie, C., Osborne, G., and Egeland, G. M. (2011). Prevalence of affirmative responses to questions of food insecurity: International Polar Year Inuit Health Survey, 2007-2008. *Int. J. Circumpolar Health* 70, 488–497. doi: 10.3402/ijch.v70i5.17862

Scoones, I. (2009). Livelihoods perspectives and rural development. *J. Peas. Stud.* 36, 171–196. doi: 10.1080/03066150902820503

Simmons, D., Bayha, W., Fink, I., Gordon, S., Rice, K., and Taneton, D. (2015). "Gúlú Agot'T'á Kə Gotsúha Gha (Learning about Changes): rethinking Indigenous Social Economy in Déline, Northwest Territories," in *Northern Communities Working Together: The Social Economy of Canada's North*, Ed C. Southcott (Toronto, ON: University of Toronto Press), 253.

Smit, B., and Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Glob. Environ. Change* 16, 282–292. doi: 10.1016/j.gloenvcha.2006.03.008

Spring, A., Carter, B., and Blay-Palmer, A. (2018). Climate change, community capitals, and food security: building a more sustainable food system in a northern Canadian boreal community. *Can. Food Stud.* 5, 111–141. doi: 10.15353/cfs-rcea.v5i2.199

Spring, A., Skinner, K., Wesche, S., Fresque-Baxter, J., Brockington, M., Bayha, G., et al. (2020). Building community-university research partnerships to enhance capacity for climate change and food security action in the NWT. *Northern Public Affairs*. Available online at: http://www.northernpublicaffairs.ca/index/volume-6-special-issue-3-special-issue-on-hotii-tseeda-working-together-for-good-health/building-community-university-research-partnerships-to-enhance-capacity-for-climate-change-and-food-security-action-in-the-nwt/ (accessed October 15, 2020).

Stroink, M. L., and Nelson, C. H. (2013). Complexity and food hubs: five case studies from Northern Ontario. *Local Environ.* 18, 620–635. doi: 10.1080/13549839.2013.798635

Tarasuk, V., Li, T., and Fafard St-Germain, A. (2022). *Household Food Insecurity in Canada, 2021*. Toronto, ON: Research to identify policy options to reduce food insecurity (PROOF). Available online at: https://proof.utoronto.ca/.

Tarasuk, V., Mitchell, A., and Dachner, N. (2016). *Household Food Insecurity in Canada, 2014*. Toronto, ON. Available online at: http://proof.utoronto.ca/ (accessed August 27, 2016).

Tondu, J. M. E., Balasubramaniam, A. M., Chavarie, L., Gantner, N., Knopp, J. A., Provencher, J. F., et al. (2014). Working with Northern Communities to build collaborative research partnerships: perspectives from early career researchers. *Arctic* 67, 419–429. doi: 10.14430/arctic4416

Usher, P. J., Duhaime, G., and Searles, E. (2003). The household as an economic unit in arctic aboriginal communities, and its measurement by means of a comprehensive survey. *Soc. Indic. Res.* 61, 175–202. doi: 10.1023/A:1021344707027

Walker, B., Holling, C. S., Carpenter, S. R., and Kinzig, A. (2004). Resilience, adaptability and transformability in social-ecological systems. *Ecol. Soc.* 9, 5. doi: 10.5751/ES-00650-090205

Wenzel, G. W. (2009). Canadian Inuit subsistence and ecological instability - if the climate changes, must the Inuit?. *Polar Res.* 28, 89–99. doi: 10.1111/j.1751-8369.2009.00098.x

Wesche, S. D., and Chan, H. M. (2010). Adapting to the impacts of climate change on food security among Inuit in the Western Canadian Arctic. *Ecohealth* 7, 361–373. doi: 10.1007/s10393-010-0344-8

Wesche, S. D., Hare-gordon, M. A. F. O., and Robidoux, M. A. (2016). Land-based programs in the Northwest Territories : building Indigenous food security and well-being from the ground up. *Can. Food Stud.* 3, 23–48. doi: 10.15353/cfs-rcea.v3i2.161

Wilson, K. (2003). Therapeutic landscapes and First Nations peoples: an exploration of culture, health and place. *Health Place* 9, 83–93. doi: 10.1016/S1353-8292(02)00016-3

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Taboos, food avoidances, and diseases: Local epistemologies of health among Coastal Endenese in Eastern Indonesia

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To advance interventions targeting malnutrition among small-scale fishing societies, knowledge on the role played by taboos and dietary avoidances on the consumption of fish related products becomes crucial. The article builds upon ethnographic fieldwork (participant observation, focus groups and interviews), dietary questionnaires (n: 112), and archival research among Coastal Endenese in Eastern Indonesia to understand the role played by taboos and dietary preferences in regulating intake of marine products. Moving beyond binary notions of "good" and "bad" when considering the food-system implications of taboos, it explores how local beliefs about illness and food shape dietary practices that can have concrete consequences for an individual's health. Endenese consider fish as having originated from terrestrial creatures, creating a continuous cycle of movement from land to sea and back. Within this cosmology, food is seen as a medium that can bring about healthy outcomes but also disease. Results emphasize the need to understand taboos and food avoidances within the larger cosmological and religious system but also underscore the changing nature of dietary preferences and values due to market integration processes which may have long-term repercussions on health. This information is key to the design of culturally sensitive dietary strategies and alternative livelihoods approaches that seek to minimize poverty.

KEYWORDS

food, fisheries, nutrition, traditional societies, Indonesia

Introduction

Widely spread throughout the Indo-Pacific, taboos, nutritional prohibitions, and avoidances, constitute essential elements of Indigenous cosmologies. Whether informal or formal, dietary restrictions embody cultural institutions that regulate social interactions and delimit what is considered normal or desirable (Forth, 2020). Food prohibitions are mostly family based and associated with gender, with the large majority of taboos imposed on women (Vasilevski and Carolan-Olah, 2016). Passed down from generations, taboos shape behaviors and preferences that may have long-term consequences for the health of a population. Studied by anthropologists, religious experts, ecologists, and public health specialists, diverse explanations have been proposed to account for their existence (Begossi and Braga, 1992; Meyer-Rochow, 2009; Foale et al., 2011).

For example, according to social anthropologists, taboos can have protective purposes. By curtailing the consumption of food items associated with cultural and societal norms, they prevent illness and disasters stemming from disruptions of the cosmological order (Malinowski, 1918; Douglas, 2002; Alaszewski, 2018). To scholars of religion and symbolism, taboos, a subsection of ritualized prohibitions, are part of value-based avoidances that characterize religious belief systems. These institutions reflect the complex relations between

humans and the natural world (Durkheim and Mauss, 1967; Levi-Strauss, 1971; Valeri, 2000). Among environmental scientists and ecologists, because prescriptions prevent individuals from extracting and consuming specific food items, taboos have been associated with biodiversity conservation goals (Alvard, 1998; Colding and Folke, 2001; Singhal et al., 2021).

Within public health and medical fields, taboos are considered potential sources of malnutrition and dietary insufficiency (Ogbeide, 1974; Ekwochi et al., 2016; Köhler et al., 2018). Numerous studies in Africa and Asia have shown that observing food taboos during pregnancy can lead to significant health impacts for the mother and the baby (Triratnawati et al., 2016; Vasilevski and Carolan-Olah, 2016; Köhler et al., 2019). Affecting the intake of key animal and vegetable protein and micronutrient sources, prohibitions have long-term consequences for the cognitive development, growth, and immunological system of children, and can increase the risks of a dangerous delivery for the mother (Iradukunda, 2020). In some cultures, the extent of restrictions concerns entire groups of foods such as red meat, raising questions about the rationale behind such practices and the ultimate benefits associated with taboos (Vasilevski and Carolan-Olah, 2016). To some extent, public health and biomedical perspectives echo classic anthropological debates regarding the study of food preferences and the utility of taboos. Case studies within societies in India, Papua New Guinea, Brazil, and Iran (Harris et al., 1966; Rappaport, 1968; Sahlins, 1985; Begossi et al., 2004), have tried to shed light on the more concrete consequences from avoidances, the potential advantage or ecological/material cause for their existence, and their connection to symbolic and religious beliefs. Failing to coalesce into a single explanation, these studies have demonstrated that diets may manifest more than one motivation and confound both cultural and utilitarian reasons. Because taboos, avoidances, and prohibitions are deeply embedded in belief systems with direct consequences for the environment a population lives in, scholars have questioned the value of separating between different kinds of explanation (Meyer-Rochow, 2009).

While the relationship between taboos, health, and malnutrition continues to be a topic of interest (Köhler et al., 2018, 2019), the systematic study of dietary avoidances, food preferences and of their nutritional consequences among traditional societies, and especially, on coastal groups, remains somewhat limited (but see Begossi et al., 2004; Gibson et al., 2020, 2021). Over the past decades, attention has grown toward the challenges faced by Indigenous fisheries (Charles, 2012; Chuenpagdee et al., 2013). Due to their high reliance on subsistence fishing, small-scale coastal communities are highly vulnerable to disturbances in their food systems that may endanger their wellbeing (Arthur et al., 2022). Recent exposure to climate change, extreme events, overfishing, and urban development have further implications for the survival of millions of people that rely on fish as their main source of nourishment (Loring et al., 2019). In fact, fish diets have been shown to provide important amounts of animal protein, vitamins, and key micronutrients that can significantly contribute to food security and health (Béné et al., 2016; Hicks et al., 2019).

To advance interventions targeting malnutrition among these societies, knowledge on the role played by taboos and dietary avoidances on the consumption of fish related products becomes crucial. Lack of information on how decisions are made within fishing households in terms of diets, as well as their symbolic connections to disease and ill health, poses an interesting obstacle (Gibson et al., 2020, 2021). This article proposes as its main goal to explore how different types of prescriptions and beliefs about the spiritual world regarding the consumption of maritime and coastal items shape dietary practices within a small-scale fishery in Ende, Eastern Indonesia. Experiencing some of the highest rates of poverty, stunting, and nutritional pathologies in Indonesia, Endenese rely heavily on subsistence fishing for their livelihood (Anonymous, 2016; Ramenzoni, 2017; Matondang 2017). By eliciting prohibitions and common prescriptions observed by this society, the article emphasizes the need to understand taboos and dietary avoidances within the larger cosmological and religious system. As such, food-based institutions are parts of a local epistemology of health where illnesses and maladies constitute disruptions to a normal cosmological and societal order. Failure to apprehend the interconnections between dietary prohibitions, illness, and the spiritual world giving shape to a complex etiology of disease may affect the efficacy of behavioral interventions (Triratnawati et al., 2016). Indicating the widespread practice of food avoidance, the article also underscores the changing nature of dietary preferences and values which may have long-term repercussions on health, moving beyond binary notions of "good" and "bad" when considering the food-system implications of taboos and other prohibitions. This information is key to the design of culturally sensitive dietary strategies and alternative livelihoods approaches that seek to minimize poverty. To conclude, the article discusses the importance of identifying changes in societal trends and structural conditions to elucidate the real factors behind dietary diversity and food security.

Background

The result of a mix between local hinterland and migrant groups from South Sulawesi, Endenese have inhabited the regency of Ende, in Central Flores, Eastern Indonesia, for at least 400 years (Figure 1). Known as avid seafarers, there are over 40 small-scale fishing villages dispersed along the northern coasts of the Savu sea. Communities are predominantly Muslim, with elaborate syncretic beliefs and cultural practices surrounding, circumcision, birth, and wedding ceremonies. Endenese are loosely organized in clans, with village leaders, shamans, and Imams constituting the main political forces at the village level. The coastal area was organized into a sultanate from 1630s until the mid 1950s. The sultanate exercised nominal and limited power in regulating military activities and trade (Van Suchtelen, 1921; Needham, 1980).

Fishing is of a highly artisanal nature, with no industry operating in the district. Endenese harvest over 100 species of fish, including pelagic and coral species. The fish species typically targeted are: flying fish (*Exocoetidae, Cypselurus* spp.), billfish (*Istiophorus, Xiphias gladius, Istiophorus platypterus*), tuna (*Thunnus tonggol*), skipjack (*Katsuwonu pelamis*), needle fish (*Belonidae, Tylosorus* spp.), scad (*Caesionidae*), snapper (*Lutjanidae, Lutjanus* spp.), and shark (*Alopias* spp., *Charcharinus* spp., *and Sphyrnidae* spp.).

A household head spends between 19 and 20 days per month fishing, and ∼9 h each day. Each household includes about five to six members, with an average of 1.5 individuals still in primary school and reliant on their elders for food provision. A large proportion,

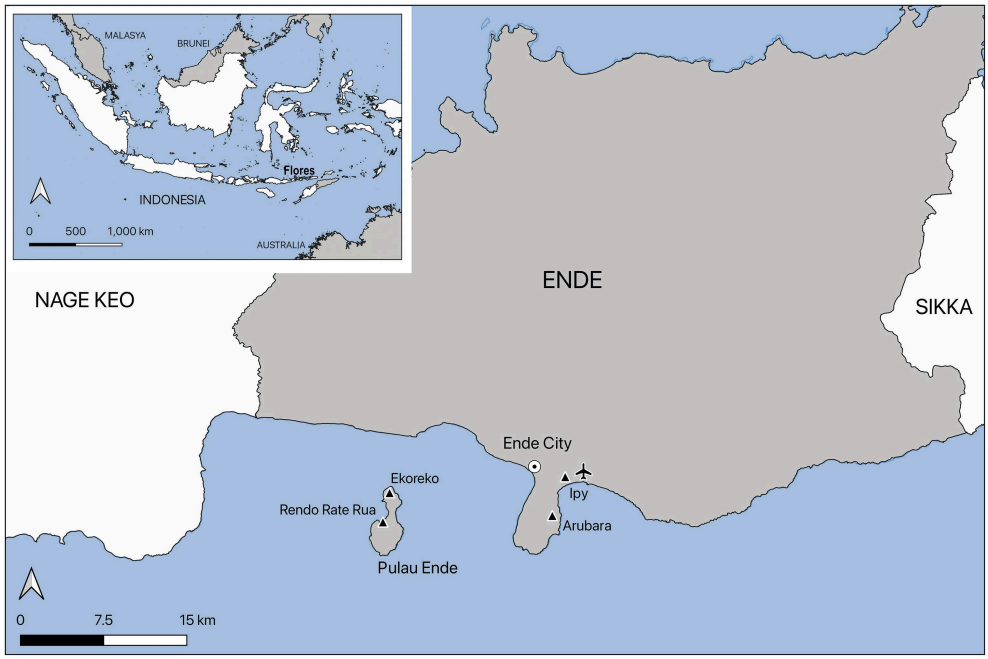

FIGURE 1
Map of Ende Regency, Flores, Eastern Indonesia.

if not all, of Endenese households own their home. However, only about half of these domestic units cultivate land in addition to fishing growing cassava and bananas, and seasonal crops such as beans and maize. There are virtually no other sources of income in the village but fishing and weaving, with the latter only marginally contributing to subsistence by the selling of sarongs. Occasionally, fishermen find employment in construction work, but these opportunities are not frequent. It is also common for younger sons to migrate to Malaysia and send remittances every few months. These irregular sources of income help families diversify their diets by including store bought items such as rice, noodles, snacks, and sugar. There is a large market in Ende city that is often visited by middlemen and household heads to buy coffee, green leafy vegetables, and other agricultural produce. Sharing represents a buffering strategy among households to reduce food insecurity and meet nutritional needs. Items commonly shared include fish and grown produce.

In terms of human well-being, recent studies in Ende regency have shown that <10% of families participating in the government program " Healthy Family", which includes about 4,700 family units, can be considered healthy (PPSDM, 2018). The index includes measures such as immunizations, sanitation, access to health services, monitoring, and medication. In what concerns disease incidence and prevalence rates for non-infectious pathologies, hypertension, diabetes, gastrointestinal issues such as ulcers, gastritis, acid reflux, and intestinal blockages, along with gout and kidney stones exhibit high values in the regency (Anonymous, 2016). Morbidities have a strong connection to diets and water quality. High levels of diarrhea (about 411/1,000 cases in Anonymous, 2016), malnourishment, and stunting constitute critical problems in Ende, and the larger Nusa Tenggara Timur Province (NTT; Anonymous, 2018). About 13.5% of children under 5 months of age were born with low weight in 2017 (Saleh et al., 2020), and 14% of all infants in 2020 were malnourished (BPSKE, 2022). Insufficiency in the intake of omega-3 fatty acids and chronic energy deficiency among pregnant mothers have been found in 61,5% of the population sampled (Saleh et al., 2019, 2020). Staggering rates of poverty also place the Nusa Tenggara province as one of the poorest in the whole country (Jotzo et al., 2009; Matondang, 2017). It has been estimated that one-fifth of the population of NTT, and close to 27 % of its children, are among the poorest of the poor (Anonymous, 2022). In Ende, poverty predominates in the rural segments reaching 25% of households (BPSKE, 2022). Thus, out of a population estimated around 280,000, close to 67,000 people live below the poverty line. The latter was placed at Indonesia Rupiah 14,277 per person per day in 2021 or at about one U.S. dollar (BPSKE, 2022). Due to poverty and precarious living conditions, NTT has become a place for slave work and human trafficking (Anonymous, 2021). These issues, in combination with infant mortality, and lack of economic development, suggest the urgency of developing nutritional interventions (Jotzo et al., 2009; Triratnawati et al., 2016; BPSKE, 2022). In the past decades, efforts have been made at the provincial level to increase the consumption of animal protein, and particularly, fish products. Unfortunately, the absence of industrial facilities that may allow for the processing and refrigeration of seafood limits capacity. While both the regional and local governments have encouraged an increase in marine landings, there is scarce support for long-term development of the fisheries and some issues of potential overfishing have been observed by the communities (Ramenzoni, 2017).

Methods

The main methods for this study include participant observation, focus groups, interviews, and surveys with fishing household heads

in four villages of Ende, Flores, Indonesia. Fieldwork data was complemented with additional conversations with key informants in village health centers, with official statistical reports from the regency, and with archival research. Statistical reports were collected over multiple field seasons from the Statistical Bureau of Ende, (Badan Pusat Statistik Ende or BPS), the Ende Regency Fishing Commission (Dinas Kelautan dan Perikanan or DKP), and the Health Services Office (Dinas Kesehatan, Diskes). Interviews and archival research were carried out from May until August 2009, from November 2010 until January 2011, and from June 2011 until January 2013. Additional trips were carried out in 2019 and 2020 to Jakarta, and 2022 to Ende to further validate findings. During the beginning of the main fieldwork phase in 2010–2011, three exploratory focus groups including three to six participants were conducted in the village of Arubara to elicit information about food security, consumption patterns, favorite foods, access and availability of key food items, prohibitions and avoidances, and health and illnesses associated with food. Focus groups were not recorded, and fieldnotes were collected by the main researcher. In 2011, 35 semi-structured interviews were carried out with household heads to further explore food consumption, dietary preferences, prescriptions or practices of food avoidance, taboo obligations, the individuals to whom such prohibitions applied, and their causes. A total of 12 of these exploratory conversations recorded with previous consent from participants. In late 2011 to 2012 a survey of food frequency, dietary diversity, and common illnesses. Exhaustive sampling was conducted in 3 smaller subdivisions of Ipy (RT 06, 02, and 01) and the village of Rendo Rate Rua, Pulau Ende. A total of 112 household heads which relied on fishing to meet subsistence needs, were interviewed to assess frequency of seafood consumption by seasons (wet and dry) and during the month of Ramadan. Further interviews with key informants (n: 15) were conducted to assess dietary prohibitions in childbirth and pregnancy. Consent was obtained from these interlocutors, interviewed household heads, and village leaders to discuss ceremonies and ceremonial principles while interviews took place. Information about ceremonies, as presented in this manuscript, combine findings from interviews as well as participant observation. Additional information about consumption was obtained by regularly weighing portions and special food items with a digital nutritional scale in two households during 3 months of fieldwork (March through May 2012). In 2019 and 2020 trips to Jakarta, the researcher obtained additional archival and statistical information which is generally accessible to the public and discussed findings with academic colleagues and non-governmental organizations. During 2022, a final trip allowed the researcher to visit previously interviewed households to validate findings in relation to avoidances and formal taboos, identify modifications or new inclusions of items in diets, and discuss aid programs. Finally, the researcher consulted academic and institutional partners, including local government officers, regarding the prevalence of issues related to stunting and nutritional deficiencies. In 2011 and 2012, two Indonesian field assistants helped the main author with data collection and translation while conducting their own master-level research on other topics related to fisheries and patronage. The main author supervised both students in their projects, developed protocols, and carried out measurements in the field. The field assistants participated in interviews and surveys along with the main author. Data collected for this article was transcribed and analyzed by the lead researcher.

Results

Diet characterization

Based on nutritional observations and surveys, an average Endenese household consumes two full meals a day, lunch and dinner (see Table 1). In some cases, like among lactating or pregnant women, leftovers from previous days are consumed for breakfast constituting a third meal. Morning and afternoon snacks consisting of tea or coffee with three spoons of sugar, and fried bread or biscuits are also frequently eaten. As measured during fieldwork, a meal usually consists of +/− 150 g of rice and/or cassava, cooked vegetables including papaya or manioc leaves, water spinach, or tomatoes, and a small portion of fish. Measured fish portions, excluding bones and large scales for larger fish, are about 150–300 g per individual per meal, with an average observed intake of 225 g a day (0–600 g total). Noodles or a fried egg are used as substitutes for protein when fish is not available. Fish are commonly fried in coconut oil with a paste of garlic and red onion, and black pepper, salt, and turmeric used for seasoning. They can also be grilled or chopped into small parts and cooked in a coconut sauce. Boiled or fried leafy vegetables, red beans, eggplant, or calabash may be added to the sauce. All preparations are often accompanied by small peppers, either ground and sprinkled on top or incorporated into the meal during the cooking process (see Table 2). In all, total intake of kcal per day is somewhere between 2,100 and 1,600, with observations matching district level figures

TABLE 1 Example of daily consumption.

Daily consumption	Energetic value
Rice 158 g (2 plates)	205 kcal
Fish grouper 120 g (2 portions)	142 kcal
Sambal (tomato, garlic, onion, etc.)	324 kcal
Fish sauce (100 g)	35 kcal
Santan (coconut shredded)	120 kcal
Coconut oil for cooking (2 spoons)	234 kcal
1 Cassava root (408 g)	653 kcal
Coffee (2 cups) and sugar (8 spoons)	145 kcal
Total	1,858 kcal

TABLE 2 Frequency of food consumption by item type.

Meats, vegetables, and fruits	Frequency of consumption
1. Cassava or manioc (*Manihot utilissima*); rice (*Oryza sativa*), chili peppers, red onions garlic, tomato (in small portions as condiment); tea, coffee.	Daily.
2. Coconuts and bananas. Fried bread and cakes of rice or maize flour.	2 times a week.
3. Manioc and papaya leaves, water spinach, breadfruit, spinach, eggplant, pumpkins, noodles.	1 or 2 times a week.
4. Mango, papaya, guava and pineapple; occasional maize and beans.	Seasonal (∼60 days)
5. Red and white meats (cow, chicken and goats). Milk (condensed) and butter.	In festivities. Yearly.

(BPSKE, 2022). Seafood is the main source of animal protein. Per capita intake of marine products among fishing households can be anywhere between 750 g and 1.8 kg a week, with consumption of seafood 5–6 times on average per week during the dry season. In the wet "Monsoon" season, per capita intake is 450 g to 1.2 kg a week, and seafood is on average consumed 3–4 times per week. The fish most frequently eaten are smaller tuna ("kembung", *genus Rastrelliger*) and scad ("kolo", *Decapterus macrosoma*), with other species availability varying according to the month of the year (see Table 3).

Although respondents indicated that fish is consumed daily whenever possible, they also indicated that depending on landing sizes bigger fish are sold to the market to higher profits. Direct-to-market species included red snapper, big tunas, marlin, rays, or sailfish. To substitute the larger captures, household heads would buy smaller size (and cheaper) fish such as sardines or pieces of bigger fish such as tuna. The consumption of marine products decreases dramatically in the full moon or during the Monsoon storms when fishing activity declines and prices rise. Restrictions in the consumption of fish by women by skipping meals or reducing portions to prioritize the nutritional sufficiency of children in the household are also observed then (Gibson et al., 2020, 2021). In all, ecological and economic conditions explain why a large proportion of the diet is characterized by carbohydrates (manioc, tubers, and rice), highly processed foods (noodles) or items of low nutritional value (snacks). Dry salted fish are also used as replacement for fresh seafood, becoming increasingly popular in hinterland villages throughout the island.

Among the most significant findings are issues related to food security, a topic to be further explored in future research activities. Discussing the Household Food Insecurity Access Scale and the Food Insecurity Experience Scale (Coates et al., 2007; FAO, 2022) during the exploratory focus groups and interviews, respondents indicated that their main difficulty was not related to hunger or scarcity but was related to "always eating the same" or "being bored with sardines". Preliminary results suggest issues with dietary variation and the access to healthy alternatives when fish was not available.

Findings were corroborated in 2022; follow up visits indicated no significant introduction of new items in the diet. Electricity reached villages in 2019 and has become accessible to all households for the duration of the day. However, given the costs of domestic appliances only a couple of homes possess a refrigerator. Changes in electricity have not resulted in the inclusion of items such as dairy nor in the increased consumption of perishable items. Even so, in order to capture a potential dietary transition and assess changes in nutritional health, more research is being planned with support from Indonesian sponsors to take place in the upcoming years.

Avoidances, taboos, and prescriptions

Endenese recognize two major types of dietary prohibitions: taboos and avoidances. Of the first one, the term "piré" is used in Endenese to designate a taboo. There are three sorts of taboos: Clan, family, and individually based, all of which will be briefly discussed below. Regarding the second type of dietary prohibitions, avoidances, there is no term within the Endenese language that refers to them. Avoidances, representing a generalized and widespread set of abstentions, are spoken of as behaviors or practices that are simply not done. Within Islamic beliefs, the terms "haram" or "halal" are used to denote prohibitions related to the consumption of red meat, blood, and particular animals such as pigs and dogs. These terms were not employed during conversations to account for other dietary avoidances and were not used to designate taboos. It should be said that, beyond general avoidances there is no encompassing set of taboos that applies homogeneously to every household among this population. Because coastal Endenese are a combination of Bajau and Bugis groups intermarrying with local Lio families, variation in taboos reflects the family of origin and the village from which ancestors emigrated.

General avoidances

These constitute, by far, the most common and adhered to prohibitions by the coastal Endenese. There are 7 different species groups which are not consumed: whales, dugongs, sea cucumbers, eels, snakes and snake-like fish, soles or flounder fish, and some coral fish such as pufferfish (Tetraodontidae family). Explanations for these avoidances are predominantly related to issues of flavor and taste, but also include beliefs about the abnormal morphology, physiology, and behavior of these species. Because of its high liquid and fatty content, whale meat is not considered tasty and is very

TABLE 3 Frequency of consumption of marine products.

Small tuna	Coral fish*	Sharks	Billfish	Dried fish	Octopus	Squid*	Frequency of consumption
72%	12%	5%	0%	11%	0%	43%	Daily
18%	16%	7%	4%	24%	0%	19%	2–3 times a week
4%	9%	20%	5%	29%	2%	9%	Weekly
4%	34%	34%	30%	25%	29%	10%	1–2 times per month
0%	0%	10%	20%	1%	8%	3%	>4 times a year
2%	26%	18%	30%	11%	55%	16%	No consumption
0%	3%	5%	9%	0%	4%	1%	Taboo

*Indicates seasonal consumption.

difficult to prepare and cook. Interviewees indicated aversion given the resemblance of whale's tissue to terrestrial mammals', including humans. Disgust was also associated to eels and snake-like fish such as needlefish (family Belonidae), hardtail (family Trichuiridae), and halfbeak (family Hemiramphidae), because of their oily texture, slithering movement, and oblong shape. An equal feeling of rejection was extended to flatfishes, which are considered "dirty fish" for they feed on debris and garbage. There are some cues that suggest that some of these avoidances, especially related to whales, snakes, and dugongs, may respond to foundational creation stories as reported by early colonial officers who visited the area (Roos, 1877; Van Suchtelen, 1921). However, they were not mentioned by interviewees at the time that nutritional surveys were conducted. Suggesting changes in traditional knowledge, more research needs to be carried out to clarify this aspect. Most significantly, all avoidances were of marine or coastal origin, as it will be discussed below.

Clan and family based taboos: Endenese cosmology

Unlike avoidances, clan and family-based taboos vary according to family origin and household, making their number lower. In fact, findings from surveys showed that taboos were present in close to 38% of the sample while avoidances are generalized to the whole population. In addition, the connection between taboos and family of origin refers to the migration of Buginese groups from South Sulawesi to Ende, a process that has reduced significantly nowadays. In the present, it does not suggest a different economic status, only a particular ethnic identity affiliation with a migrant clan. Taboo prohibitions are distinguished here based on the origin of the element that they apply to, with a special focus on discussing marine and coastal organisms as these are the ones subject to conservation concerns.

Representing a wide set of vegetal and animal groups, taboos of terrestrial species included water buffaloes, domestic fowl, ginger, beans, lemongrass, eggplant, and opo squash. They have a key significance for farming households among the coastal Endenese of Lio descent, with findings mimicking what has been established for nearby groups (Forth, 2020). On the other hand, marine species comprised billfish, sharks, octopus, squids, dolphins, and some coral fish like the surgeon fish (Balistidae family). The most frequently tabooed species group was that of billfish (Istiophoridae family) found in ten households. Sharks and octopus were the second largest taboo, with six and five households, respectively, reporting prohibitions. It should be said that the largest number of taboos was family-based, and prohibitions only applied to women. Taboos were acquired by marrying into a different clan, a less preferred type of marriage but the most prevalent nowadays. According to coastal Endenese descent principles, taboos became intergeneration impositions to be adopted by the new wife and not transmitted from mother to daughter, only from mother-in-law to daughter-in-law. Taboos were irrevocably acquired by the new bride upon relocation to a new patrilineal group, and if not followed they would ultimately result in death and misfortune. On the other hand, clan-based prohibitions were only found in two cases, indicating institutions that apply to the whole lineage. The result of breaking a taboo may produce skin infections and rashes, blisters or boils, breast pain, gastrointestinal diseases but also death. For instance, consumption of surgeon fish by pregnant women it is said to make the heads of the children itchy if eaten during pregnancy and immediately after labor (see below). Although varying according to each family, the way to lift an offense may require ceremonial offerings to the ancestors. Such ceremonies are supposed to appease the angry spirit and point to the rich symbolic beliefs tied to prohibitions. Along with numerous legends and stories, the existence of taboos in Ende is closely connected to the notion that ancestors were or became marine animals or that animals may have helped and guarded the ancestors at some primordial time. In both cases, the animal associated with the ancestor is regarded as sacred. It must not be eaten, it must be looked after, and it must be treated with respect. For instance, among the billfish group, the swordfish (*Xiphias Gladius)* was considered the king of the ocean. Upon capture, it was to be released immediately and not disturbed. Explanations about familiarity or kinship were offered in the case of sharks and dolphins, where eating their meat equated to eating human meat.

Created by Allah, Endenese believe that all marine creatures originate in earthly beings. For example, elongated species such as needlefish and eels, are said to come from snakes; blowfish and pufferfish from porcupines; and fish with whiskers from rats and rodents. Endenese see the similarity between terrestrial and maritime animals' physiognomy and behavior as a sign of their common source. For example, in the case of a coral fish known as "take", it moves in the same way as the gecko, it burrows and hides in the ground when being pursued, and it is of a similar reddish orange color. The common land origin for all creatures can be glimpsed in the resemblance between the behavior of humans and animals. The displacement of terrestrial animals to sea, like fishers do every day, is a regular event stirred by their search for food.

In addition to the transfiguration of terrestrial animals into maritime ones, Endenese legends and stories refer to the metamorphosis of humans into fish. In these mythical stories the encounter with a sacred being and the breaching of a prescription is signaled as the foundational element for the transformation of a human into a marine creature. For example, a woman is transformed to a manatee after consuming eggs that were taboo, or a woman is kidnapped by the swordfish and becomes a fish. The significance of fish and marine creatures is also perceived in a foundational narrative. After the sinking the island of origin of the Endenese (Ramenzoni, in press), it is said that those who did not manage to escape turned into fish. Marine creatures helped the ancestors of some clans to reach safety and to establish their current abode.

Dietary prohibitions during pregnancy and childbirth

During pregnancy or at the beginning of labor, Endenese families with connections to Bugis ancestors often follow a set of dietary prescriptions known as "mujó". According to this institution, new mothers are forbidden from eating rice and certain types of fish which may include sharks, surgeon fish, red snapper, or snakehead fish. The prohibition may occur during pregnancy, at the start of labor, and can extend several days after delivery. To prevent the mother-to-be from ingesting rice the whole household, usually other women, is forbidden from cooking it. If in the process of eating the mother drops a grain of rice it would be interpreted as a sign of misfortune and her child may die. When prohibitions are not respected, the child may suffer speech related pathologies or result in mental impairments.

While not all Endenese families follow mujó, there are a collection of prohibitions that are often respected during pregnancy. In general, restrictions about marine animals such as coral fish or red meat fish such as big tuna are related to beliefs about side effects of consuming certain organisms based on their qualities and morphology. For example, certain kinds of fish due to their presence of spines can endanger the pregnancy and the neonate. In terms of fruits and vegetables, women are discouraged from consuming durian, pineapple, and ginger for they may cause heat and lead to miscarriage (Triratnawati et al., 2016). Informal recommendations include abstention from cold beverages, sugarcane, and even certain weeds. Other prescriptions can extend to types of food based on their appearance, such as things that may look like a branch or may mirror the shape of a snake like a yam (Fernandez, 1990). These are said to make delivery more difficult.

To lift the taboos associated with mujó a formal ceremony is needed. Conducted among close kin and neighbors, special customary prayers would be uttered, and gifts given for the health of the baby. At the ceremony, the new mother is now allowed to eat yellow rice and fish. Once again, the fall of a single grain of rice may indicate danger, impairment, or death. A second larger ceremony would take place 40 days after the birth and when the baby is 6 or 7 months old. In these occasions, along with prayers the new parents would make offerings including rice and up to 44 different types of fruits.

Personal taboos and diseases

Along with avoidances, personal-based prohibition that pertain to the whole familiar group are the most frequently found within the sample with ∼45% of homes reporting at least one. These types of taboos are set idiosyncratically by household heads and usually respond to medical concerns such as hypertension, gout, or strokes. The highest item on the list of personal taboos was eggs. This was not surprising as most households reported having egg allergies (see Forth, 2020). Other personal taboos are associated with dry fish due to its high content of salt, noodles, and specific vegetables or fruits such as pineapple and papayas. As part of the survey, about one third of respondents also reported a list of different health complaints encompassing high blood pressure, strokes, diabetes, gout, kidney stones, parasites, gastritis, diarrhea, and skin infections. Prevalence for these diseases matched information reported from the local health office at the time.

Food, spirit intermediation, and Endenese epistemology of health

Among the Endenese, food constitutes the medium for establishing a relationship among different families and between humans and the spirits. In the first instance, the initiation of wedding ceremonies is marked by the drinking of hot water ("minu ae petu"), when, for the first time, the families of the bride and the groom and members from both clans come together. The formal marriage is followed by a large feast including halal goat and chicken, with everybody in the village invited to partake. During parties, financial help is requested from others through the expression "koru kesa anga" which translates to the exhortation "add to the pot". Commensality is also essential to ceremonies such as circumcisions and funerals, during collective work, and on the eve of fishing expeditions to complement prayers. Within this logic, the kitchen is perceived by Endenese as the place of providence or good fortune. Embodying the main source of sustenance, ashes from the hearth are used during rituals accompanying the first launching of a boat and sprinkled on fishing gear. It is believed that if the fire of a kitchen dies while the fisher is at sea, death is certain. Therefore, it is carefully tended to every night by women.

Combining the importance of the family kitchen with the sacred role of food, to placate the wrath, to obtain permission, or to extend gratitude, food offerings accompanied by hearth ashes are made to the ancestors and other supernatural beings. Spirits may respond back by granting favors or facilitating blessings from God. Fish are caught with the intermediation of marine spirits who teach humans the proper ways of fishing, effectively establishing an association among humans and the supernatural through the transmutation of fish into food.

However, the spirits may also use food to bewitch the incautious, a tactic that is employed by witches and sorcerers to poison their victims. An Endenese advice given to newcomers and children is captured in the sentence "jangan makan sembarangan" (do not eat random foods). It is believed that common food stuffs such as coconuts, tea, coffee, or bananas when offered in the house of a witch or when found randomly on the side of the road can become the vehicle for a magical attack. Spirits also use "fake" supernatural banquets and feasts, and gifts of food to trap their victims into stupefaction. Those that partake of the items offered would experience all the signs of a stroke, including slurred speech and paralysis. To a large extent, if not all, gastrointestinal diseases along with some chronic illnesses and their symptoms are considered by the Endenese to be caused by witchcraft hexes ("ru'u"). For example, intestinal blockage, a hard stomach, high fever, diarrhea ("nemba"), headache, heartburn, epigastrium pain, gastritis, and difficulty in intestinal movements are common signs of being cursed. Other signs like bruises ("penda pate" or red mark), neck or muscular pain, motor impairments, and afflictions that may turn the skin red or itchy can also be explained by the actions of a witch. Finally, issues with oral health such as teeth pain or mouth sores can also reflect maleficent spells. According to interviews, evil witches use their power to feed on the intestines of their victim from the inside out in a process that lasts 3 nights and 3 days. For instance, accompanying the tiredness and exhaustion that overcomes the sufferer is the feeling of pain in the stomach during sleep. Explained as the feeling of the insides being torn, this mortal disease is known as "nande" and there is no modern medical cure for it. Another mortal disease is associated with pain in the epigastrium ("dhuso mata" or "usu mata") and the transformation and resemblance of the internal tissue to palm fibers. It should be observed that witchcraft or spiritual diseases are considered to be "man-made" ("ata tau"). Jealousy and envy of what others possess are what inspires a witch's attack. Disrespect of the ancestors and transgressions of taboos make spirits angry. Thus, while there are illnesses that are the result of neglect or not looking after oneself, those brought about by magical or supernatural elements are ultimately caused by humans. Looking into this complex disease etymology, in its final section, the article will discuss the need to integrate Endenese epistemology of health into current efforts seeking to address malnutrition and dietary insufficiencies.

Discussion

As the previous results have shown, Endenese have a complex cosmology that connects avoidances, taboos, and dietary restrictions, to witchcraft and the world of the spirits, and to ill health and gastrointestinal diseases. This cosmology underlines the existence of human-animal-supernatural interactions and reflects Endenese beliefs about the origin of life. Even when some of the meanings behind institutions, rituals, and norms have morphed or disappeared over time, and while not all dietary prescriptions reflect origin stories but issues of preference, essential cosmological notions are still respected (Ramenzoni, 2017). This can be seen in the existence of generalized avoidances among the whole group, the presence of taboos among 38% of interviewed households, and the observance of special prohibitions set individually or determined by life stages such as those followed during pregnancy. In the case of taboos, dietary prescriptions are examples of an intricate pattern of social relations between tabooed species and particular families, lineages, or clans. Relations may be of a positive nature involving common kinship, fosterage, and reciprocity, and reflect transfiguration from animals to humans. Prohibitions help maintain cosmological order and secure prosperity for the family and the health of individuals. On the other hand, the breaching of norms associated with taboos may bring injury to the ancestors, creating an imbalance that spreads danger and disease. Because of what is at stake, they continue to be respected and upheld.

Most significantly, findings from surveys and interviews underscore the existence of broad-scale avoidances based on flavor, taste, and disgust. Generalized avoidances are applied to whales, dugongs, and certain kinds of coral fish, all animals that challenge cultural and "common-sense" expectations of what constitutes a normal process of cooking and eating marine foodstuffs. In addition to preference-based abstentions, results also indicate that families rarely use larger size species such as snapper, grouper, or large tunas in their preparations becoming de-facto avoidances. Discussed in interviews, households that depend on fishing for their living progressively consume lesser amounts of fish and increasingly rely in highly processed food stuffs. The reasons behind lack of consumption are to be found in market demand and the ability to replace economically valuable species by cheaper alternatives. Yet, with the exclusion of whales, the absence of consumption of certain items does not indicate that they are not being harvested for other ends.

The significance of avoidances and personal prescriptions suggest the need to assess how cultural and personal values interact with decisions about nutrition and resource exploitation within local households. Issues of taste, gentrification of marine products, and local perceptions about what is normal or what is healthy in shaping diets are key determinants of diets among this population, a fact that is probably similar among other coastal societies. But, excluding studies about marine megafauna (Barnes 1997; Mazzoldi et al., 2019), few scholars have explicitly covered these more nuanced dimensions pertaining to the value of seafood among coastal populations, actual fish products consumption, and the role played by economic markets (Cai and Leung, 2022). A growing body of work regarding processes of expansion in rural fisheries, however, can be found among developing countries (Salehe et al., 2017; Orire and Elijah, 2019). Trends in consumption indicate that preferences for fish products are significantly affected by socio-demographic factors including age, marital status, education levels, occupation, and place of residence (Wenaty, 2018). As fish is increasingly promoted as an essential source of micronutrients and proteins, the processes of commodification and market integration of artisanal producers has led to increasing prices and changes in dietary patterns (Loring et al., 2019; Arthur et al., 2022).

Finally, a third key finding from surveys is the importance of personal taboos which are based on medical concerns and individual preferences. This group of prescriptions includes an important source of animal protein such as eggs, and provides critical information about morbidities among Endenese families. Reported during interviews, personal taboos are seen as alternatives to biomedical treatments by poor households which cannot afford the long-term cost of medications.

In all, within Endenese cosmology, food constitutes an essential medium through which positive and negative dynamics play out. These dynamics, being of an economic, cultural, or moral nature, emphasize the importance of studying systems of representation surrounding dietary practices and food preparation in their own terms. Because food can also be a vessel of manipulation, where either human or supernatural spirits can utilize foodstuff to trap souls and bring about death. Illness and disease are closely related to diets and consumption behaviors. As seen in results, a large proportion of the pathologies that this community experiences are associated with gastrointestinal complaints. Despite widespread efforts by the UN in 2005 and 2006, given the precarity of many households in terms of resources, technology to store food, and access to clean water, diarrhea and poor nutrition continue to lead mortality among children (Anonymous, 2016). Endenese beliefs and practices surrounding food and disease mirror what has been discovered in other regions of Eastern Indonesia (Hasan and Suwarni, 2012; Fowler, 2016; Pauwelussen, 2021). Because most complaints are the result of witchcraft and black magic for which biomedical treatments are ineffective, local shamans and midwives are usually consulted first. When traditional medicine fails, patients reach health facilities in an acute state, reinforcing the belief that doctors often make the situation worse (Triratnawati et al., 2016). The perception that modern medicine is only good for certain things, such as dealing with headaches, colds, or backpain, continues to be prevalent.

Considering the efforts undertaken by Indonesia to improve food security and nutrition, information about food preferences and the etiology of gastrointestinal diseases is essential to government programs that seek to enact behavioral changes in resource consumption (Hasan and Suwarni, 2012; Triratnawati et al., 2016). With the goal of increasing success, intervention projects in Ende should consider the engagement of a wider set of local actors such as local middlemen, market vendors, shamans, and midwives not only to increase involvement and compliance, but also to address what are concrete needs of the population. Thus, in a port-town like Ende, the exploration of the motivations behind the consumption of seafood, the elicitation of nutritional trade-offs created by market opportunities, and the understanding the actual mechanisms that mediate a household's resource use are also key components to

support behavioral change. Among current needs, no less important is the understanding of the close relation between disease and food as well as the characteristics and steps associated with traditional treatments and local medicines. Moving beyond binary notions of "good" and "bad" when considering the biomedical implications of taboos and other avoidances within a certain food-system is a much-needed stage in this process.

The key seems to rely in the creation of culturally sensitive programs that can improve households' nutritional well-being and health not just by eliminating what are seen as outdated or irrational institutions, but by formulating a true participatory and genuine co-management partnership to construct new consensus. For example, several community-based participatory research applications in the food-systems policy world have provided important insights in the development and promotion of healthy community practices (Zerafati-Shoae et al., 2020). Inclusion of communities not only provides a powerful strategy toward securing consistency and permanency in the adoption of policies, but also works as a mechanism in eliciting and diminishing what are perceived as "dietary-related" health disparities associated with environmental and cultural factors. These disparities can avoid detection when complex socio-cultural frames of interpretation are required to understand the dynamics of exclusion and marginalization through which inequalities operate. Short-term intervention programs or initiatives that rely on rapid appraisal mechanisms to unpack societal and cultural determinants may not be adept at recording or identifying such interactions (Walker et al., 2010). With both practitioners and communities engaging in an equal capacity in the identification, selection, and planning of a research agenda, local needs and opportunities can become center in the formulation of an intervention framework (Breckwich Vásquez et al., 2007). The inclusion of a diversity of actors—not just community leaders but also minority groups and underserved sectors of the population—results in a richer characterization of what it means to be healthy, along with the singling out of the possibilities and the constraints that limit policies. As studies have shown, most community participatory approaches have only been able to involve actors in a limited capacity, mostly concentrating in the empowerment of the population and not in securing its full and maintained participation in the decision-making processes that are the basis of successful policy change (Zerafati-Shoae et al., 2020). Collaborative consensus building through dialogue, the support of organization as well as engagement efforts with appropriate budgets, the inclusion of incentives, trust-building, and the recognition that cultural and societal representations in their own term must be a part of any behavioral training program are but a few of the elements that can result in meaningful change.

Conclusion

Without a fine-grain understanding of local epistemologies of health and the role played by structural inequalities, nutritional policies and intervention mechanisms will fail (Anderson et al., 2003; Alvesson et al., 2013; Diaz-Cruz, 2019). Efforts that do not consider avoidances, taboos, and the diverse set of dietary prohibitions, beliefs, and possibilities that determine dietary choices in order to guide health programs targeting nutritional insufficiencies will struggle to achieve long-term relevance. This is so as choosing between incorporating a foreign practice or item into the diet, Endenese households may refer to economical or available solutions that have been proven effective in the past with partial rates of adoption of new treatments (Triratnawati et al., 2016). Furthermore, stigmatization and characterization by biomedical models of intervention of what are seen as the only alternatives under the rubric of "bad" practices will further alienate participants. Social scientists can help public health practitioners by working alongside community leaders in identifying local value systems, in eliciting the complex nature of socioeconomic structural factors behind health disparities and households' decisions, and by building new collaborations across all parties that are inclusive and respectful.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Institutional Review Board from the University of Georgia at the Office of Research Ethics, the University of Georgia. The patients/participants provided their written informed consent to participate in this study.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Alaszewski, A. (2018). "*Anthropology and risk: Insights into uncertainty, danger and blame from other cultures: a review essay*," in *Theories of Uncertainty and Risk across Different Modernities*, ed. P. Brown (England, UK: Routledge).

Alvard, M. S. (1998). Evolutionary ecology and resource conservation. *Evolut. Anthropol. Issues News Rev.* 7, 62–74. doi: 10.1002/(SICI)1520-6505(1998)7:2<62::AID-EVAN3>3.0.CO;2-I

Alvesson, H. M., Lindelow, M., Khanthaphat, B., and Laflamme, L. (2013). Changes in pregnancy and childbirth practices in remote areas in Lao PDR within two generations of women: Implications for maternity services. *Reproduct. Health Matters* 21, 203–211. doi: 10.1016/S0968-8080(13)42748-9

Anderson, L. M., Scrimshaw, S. C., Fullilove, M. T., Fielding, J. E., and Normand, J. (2003). Culturally competent healthcare systems: A systematic review. *Am. J. Prevent. Medi. 24,* 68–79. doi: 10.1016/S0749-3797(02)00657-8

Anonymous (2018). *1 dari 3 Balita Indonesia Derita Stunting [Government]. Direktorat Pencegahan dan Pengendalian Penyakit Tidak Menular*. Available online at: http://p2ptm.kemkes.go.id/artikel-sehat/1-dari-3-balita-indonesia-derita-stunting (accessed January 16, 2023).

Anonymous (2016). *Profil Kesehatan Kabupaten Ende 2016*. Dinas Kesehatan Kabupaten Ende. Available online at: https://docplayer.info/115411533-Profil-kesehatan-kabupaten-ende-tahun-2015.html (accessed January 16, 2023).

Anonymous (2021). *NTT Governor Admits Human Trafficking Due To Poverty. VOI - Waktunya Merevolusi Pemberitaan*. Available online at: https://voi.id/en/news/101053/ntt-governor-admits-human-trafficking-due-to-poverty (accessed January 16, 2023).

Anonymous (2022). *SDGs for Children in Indonesia: Provincial Snapshot East Nusa Tenggara*. Kementerian PPN/ Bappenas, Indonesia. Unicef. Available online at: https://www.unicef.org/indonesia/sites/unicef.org.indonesia/files/2019-05/NTT_ProvincialBrief.pdf (accessed January 16, 2023).

Arthur, R. I., Skerritt, D. J., Schuhbauer, A., Ebrahim, N., Friend, R. M., Sumaila, U. R., et al. (2022). Small-scale fisheries and local food systems: Transformations, threats and opportunities. *Fish Fisheries* 23, 109–124. doi: 10.1111/faf.12602 (accessed January 16, 2023).

Begossi, A., and Braga, F. (1992). Food taboos and folk medicine among fishermen from the Tocantins River. *Amazoniana* 12, 101–118.

Begossi, A., Hanazaki, N., and Ramos, R. M. (2004). Food chain and the reasons for fish food taboos among Amazonian and Atlantic Forest Fishers (Brazil). *Ecol. Appl.* 14, 1334–1343. doi: 10.1890/03-5072

Béné, C., Arthur, R., Norbury, H., Allison, E. H., Beveridge, M., Bush, S., et al. (2016). Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. *World Dev.* 79, 177–196. doi: 10.1016/j.worlddev.2015.11.007

BPSKE (2022). *Statistik Kesejahteraan Rakyat 2021*. Badan Pusat Statistik Kabupaten Ende. Available online at: https://endekab.bps.go.id/publication/2022/02/25/b2a37a51f294781fab3c4e10/kabupaten-ende-dalam-angka-2022.html (accessed January 16, 2023).

BPSN. (2022). *Badan Pusat Statistik Nusa Tenggara Timur 2022. NTT dalam Angka*. Available online at: https://ntt.bps.go.id/publication/2022/02/25/cc3b48ec498e16518636e415/provinsi-nusa-tenggara-timur-dalam-angka-2022.html (accessed January 16, 2023).

Breckwich Vásquez, V., Lanza, D., Hennessey-Lavery, S., Facente, S., Halpin, H. A., Minkler, M., et al. (2007). Addressing food security through public policy action in a community-based participatory research partnership. *Health Promot. Pract.* 8, 342–349. doi: 10.1177/1524839906298501

Cai, J., and Leung, P. (2022). Unlocking the potential of aquatic foods in global food security and nutrition: A missing piece under the lens of seafood liking index. *Global Food Secur.* 33, 100641. doi: 10.1016/j.gfs.2022.100641

Charles, A. (2012). People, oceans and scale: Governance, livelihoods and climate change adaptation in marine social-ecological systems. *Curr. Opin. Environ. Sustain.* 4, 351–357. doi: 10.1016/j.cosust.2012.05.011

Chuenpagdee, R., Jentoft, S., Bavinck, M., and Kooiman, J. (2013). "Governability—new directions in fisheries governance," in *Governability of Fisheries and Aquaculture,* eds. M. Bavinck, R. Chuenpagdee, S. Jentoft, and J. Kooiman (Netherlands: Springer), 3–8. Available online at: http://link.springer.com/10.1007/978-94-007-6107-0_1 doi: 10.1007/978-94-007-6107-0_1

Coates, J., Swindale, A., and Bilinsky, P. (2007). *Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide: Version 3: (576842013-001) [Data set]*. Washington, D.C.: American Psychological Association.

Colding, J., and Folke, C. (2001). Social taboos: "invisible" systems of local resource management and biological conservation. *Ecol. Appl.* 11, 584–600. doi: 10.1890/1051-0761(2001)011[0584:STISOL]2.0.CO;2

Diaz-Cruz, E. S. (2019). If cultural sensitivity is not enough to reduce health disparities, what will pharmacy education do next? *Curr. Pharm. Teach. Learn.* 11, 538–540. doi: 10.1016/j.cptl.2019.02.003

Douglas, M. (2002). *Purity and Danger: An Analysis of Concepts of Pollution and Taboo*. England, UK: Routledge.

Durkheim, E., and Mauss, M. (1967). *Primitive Classification* (R. Needham, Trans.). Chicago: University of Chicago Press. Available online at: https://press.uchicago.edu/ucp/books/book/chicago/P/bo25149490.html

Ekwochi, U., Osuorah, C. D. I., Ndu, I. K., Ifediora, C., Asinobi, I. N., Eke, C. B., et al. (2016). Food taboos and myths in South Eastern Nigeria: The belief and practice of mothers in the region. *J. Ethnobiol. Ethnomed.* 12, 7. doi: 10.1186/s13002-016-0079-x

FAO (2022). *Food Insecurity Experience Scale | Voices of the Hungry | Food and Agriculture Organization of the United Nations*. Available online at: https://www.fao.org/in-action/voices-of-the-hungry/fies/en/

Fernandez, S. O. (1990). *Kebijakan manusia Nusa Tenggara Timur dulu dan kini*. Sekolah Tinggi Filsafat Katolik.

Foale, S., Cohen, P., Januchowski-Hartley, S., Wenger, A., and Macintyre, M. (2011). Tenure and taboos: Origins and implications for fisheries in the Pacific. *Fish Fisheries* 12, 357–369. doi: 10.1111/j.1467-2979.2010.00395.x

Forth, G. (2020). *Taboo and Descent in the Articulation of Gender* Relations: An Eastern Indonesian Case. *Oceania. 90,2–17*. doi: 10.1002/ocea.5234

Fowler, C. T. (2016). *Biosocial Synchrony on Sumba: Multispecies Relationships and Environmental Variations in Indonesia*. Pennsylvania, USA: Lexington Books.

Gibson, E., Stacey, N., Sunderland, T. C. H., and Adhuri, D. S. (2020). Dietary diversity and fish consumption of mothers and their children in fisher households in Komodo District, eastern Indonesia. *PLoS ONE* 15, e0230777. doi: 10.1371/journal.pone.0230777

Gibson, E., Stacey, N., Sunderland, T. C. H., and Adhuri, D. S. (2021). Coping or adapting? Experiences of food and nutrition insecurity in specialised fishing households in Komodo District, eastern Indonesia. *BMC Public Health* 21, 355. doi: 10.1186/s12889-021-10248-3

Harris, M., Bose, N. K., Klass, M., Mencher, J. P., Oberg, K., Opler, M. K., et al. (1966). The cultural ecology of India's sacred cattle [and comments and replies]. *Curr. Anthropol.* 7, 51–66. doi: 10.1086/200662

Hasan, A. B. P., and Suwarni, E. (2012). Policies and Practices for Promoting Multicultural Awareness of Indigenous Early Childhood Education in Indonesia. *Int. J. Child Care Educ. Policy* 6, 63–94. doi: 10.1007/2288-6729-6-1-63

Hicks, C. C., Cohen, P. J., Graham, N. A. J., Nash, K. L., Allison, E. H., D'Lima, C., et al. (2019). Harnessing global fisheries to tackle micronutrient deficiencies. *Nature* 574, 95–98. doi: 10.1038/s41586-019-1592-6

Iradukunda, F. (2020). Food taboos during pregnancy. *Health Care Women Int.* 41, 159–168. doi: 10.1080/07399332.2019.1574799

Jotzo, F., Resosudarmo (Daju), I., Nurdianto, D., and Sari, A. P. (2009). Climate change and development in Eastern Indonesia. Institute of Southeast Asian Studies (ISEAS). Available online at: https://openresearch-repository.anu.edu.au/handle/1885/39707

Köhler, R., Lambert, C., and Biesalski, H. K. (2019). Animal-based food taboos during pregnancy and the postpartum period of Southeast Asian women—A review of literature. *Food Res. Int. (Ottawa, Ont.)* 115, 480–486. doi: 10.1016/j.foodres.2018.10.026

Köhler, R., Sae-tan, S., Lambert, C., and Biesalski, H. K. (2018). Plant-based food taboos in pregnancy and the postpartum period in Southeast Asia—a systematic review of literature. *Nutr. Food Sci.* 48, 949–961. doi: 10.1108/NFS-02-2018-0059

Levi-Strauss, C. (1971). *Totemism (R. Needham, Trans.; 1st. edition).* Boston: Beacon Press.

Loring, P. A., Fazzino, D. V., Agapito, M., Chuenpagdee, R., Gannon, G., Isaacs, M., et al. (2019). "Fish and food security in small-scale fisheries," in *Transdisciplinarity for Small-Scale Fisheries Governance: Analysis and Practice*, eds. R. Chuenpagdee and S. Jentoft (Berlin, Germany: Springer International Publishing), 55–73.

Malinowski, B. (1918). Fishing in the Trobriand Islands. *Man. 18,* 87–92. doi: 10.2307/2788612

Matondang, E. (2017). Finding Out the Potency of Nusa Tenggara Timur in Poverty Allevation: The Effect of Local Government's Policy. *Jurnal Bina Praja: J. Home Affairs Governance* 9, 2. doi: 10.21787/jbp.09.2017.231-242

Meyer-Rochow, V. B. (2009). Food taboos: Their origins and purposes. *J. Ethnobiol. Ethnomed.* 5, 18. doi: 10.1186/1746-4269-5-18

Needham, R. (1980). "*Principles and variations in the structure of the Sumbanese society*," in *The Flow of Life: Essays on Eastern Indonesia*, eds. J. J. Fox and M. Adams. Boston: Harvard Press.

Ogbeide, O. (1974). Nutritional hazards of food taboos and preferences in Mid-West Nigeria. *Am. J. Clin. Nutr.* 27, 213–216. doi: 10.1093/ajcn/27.2.213

Orire, A., and Elijah, Y. (2019). Survey of Tilapia Consumption in Benye State Nigeria: A case study of Makurdi Metropolis. *Int. J. Fisheries Aquacult. Res.* 5, 10–24.

Pauwelussen, A. (2021). "Rethinking human-sea relations through amphibious twinship in Indonesia," in *Environmental Alterities*, eds. C. Bonelli and A. Walford (Mattering Press), 69–94. Available online at: https://www.matteringpress.org/wp-content/uploads/2021/10/environmental-alterities-ePDF-1.pdf#page=71

PPSDM (2018). *Profil Keluarga Sehat Provinsi NTT Tahun 2018*. Pusat Perencanaan dan Pendayagunaan SDM Kesehatan, Badan PPSDM Kesehatan, Kementerian Kesehatan Republik Indonesia. Available online at: http://202.70.136.161:8107/114/2/Profil%20KS%20Provinsi%20NTT%20Tahun%202018.pdf

Ramenzoni, V. C. (2017). Reconstructing the history and the effects of mechanization in a small-scale fishery of flores, Eastern Indonesia (1917–2014). *Front. Marine Sci.* 4, 65. doi: 10.3389/fmars.2017.00065

Rappaport, R. A. (1968). *Pigs for the Ancestors: Ritual in the Ecology of a New Guinea People*. Yale University Press.

Roos, S. (1877). Iets over Endeh. *Tijdschrift Voor Indische Taal-, Land- En Volkenkunde.*, 24, 481–580.

Sahlins, M. (1985). *Islands of History*. Chicago: University of Chicago Press.

Saleh, A., Harsono, S., and Endang Sustina, S. (2019). Relationship of Gestational Age, Folic Acid Intake and Haemoglobin Level of Third-Trimester Pregnancy with Infant Birth Weight in Ende Regency, East Nusa Tenggara Province, Indonesia. *Indian J. Public Health Res. Dev.* 10, 953–957. doi: 10.5958/0976-5506.2019.02562.2

Saleh, A., Setia, A., and Adi, A. A. A. M. (2020). Relationship between Omega-3 Fatty Acid Intake, Nutritional Status of Third Trimester Pregnant Women and the Incidence of Low Birth Weight in Ende Regency, East Nusa Tenggara Province. *Kupang J. Food Nutr. Res.* 1, 8–12. Available online at: https://jurnal.poltekeskupang.ac.id/index.php/KJFNR/article/view/381 (accessed January 17, 2023).

Salehe, M., Luomba, J., and Mlaponi, E. (2017). Socio-economic factors affecting consumer behaviour and preference for farmed and wild fish around Lake Victoria, Tanzania. *Afr. J. Trop. Hydrobiol. Fisheries* 15, 15–24. Available online at: https://www.ajol.info/index.php/ajthf/article/view/172888 (accessed January 16, 2023).

Singhal, V., Ghosh, J., and Bhat, S. S. (2021). Role of religious beliefs of tribal communities from Jharkhand (India) in biodiversity conservation. *J. Environ. Plann. Manage.* 64, 2277–2299. doi: 10.1080/09640568.2020.1861587

Triratnawati, A., Kristianti, R. D., Putra, A. P., and Setyaji, P. B. (2016). The effort to decrease maternal and child mortality rates through cultural transformation. *Int. J. Public Health Sci. (IJPHS)* 5, 84–93. doi: 10.11591/ijphs.v5i1.4768

Valeri, V. (2000). *The Forest of Taboos*. Madison, Wisconsin: University of Wisconsin Press. Available online at: https://uwpress.wisc.edu/books/0814.htm

Van Suchtelen, B. C. C. M. M. (1921). *Endeh (Flores)*. Weltevreden,. Available online at: http://hdl.handle.net/2027/uc1.\protect\T1\textdollarc15924

Vasilevski, V., and Carolan-Olah, M. (2016). Food taboos and nutrition-related pregnancy concerns among Ethiopian women. *J. Clin. Nurs.* 25, 3069–3075. doi: 10.1111/jocn.13319

Walker, R. E., Keane, C. R., and Burke, J. G. (2010). Disparities and access to healthy food in the United States: A review of food deserts literature. *Health Place* 16, 876–884. doi: 10.1016/j.healthplace.2010.04.013

Wenaty, A. (2018). Fish consumers preferences, quantities of fish consumed and factors affecting fish eating habits: A case of Lake Victoria in Tanzania. *Int. J. Fisheries Aquatic Stud.* 6, 247–252.

Zerafati-Shoae, N., Jamshidi, E., Salehi, L., and Asgari Taee, F. (2020). How to increase community participation capacity in food environment policymaking: Results of a scoping review. *Med. J. Islamic Republic Iran* 34, 18. doi: 10.47176/mjiri.34.18

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On measuring "small potatoes": spatio-temporal patterning of agrobiodiversity-as-food presents challenges for dietary recall surveys

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A growing body of research seeks to measure the nutritional contributions of agrobiodiversity to the diets of small-scale farming households. While such articles frequently base analysis on nutritional surveys, particularly using 24-h dietary recall methods, there is as-yet little critical analysis of the benefits and drawbacks of 24-h recalls for assessing the nutritional contributions of agrobiodiversity, or for evaluating the biodiversity conservation implications of particular dietary patterns. The current article draws from mixed-methods research conducted in Cochabamba, Bolivia, between 2011 and 2015. Methods included both ethnographic research and a two-season, household-level survey of 414 households, distributed across a rural–urban gradient between urban Cochabamba and the rural municipality of Colomi. The survey included a 24-h "culinary recall," recording specific ingredients used to prepare foods, including variety-level information for key crops in the region. Results demonstrate that native crops play an important role in household diets, accounting for around a third of calories reported at the household level, and as much as 57% of caloric availability in the most remote agricultural communities. However, a fine-grained examination of the data shows that nearly a third of all calories reported are provided by potatoes and their derivatives; no other native, improved, or Andeanized crop accounted for more than 1.53% of reported calories. Using ethnographic data, the paper considers reasons for the lack of representation of other crops in dietary recall methods, including the difficulties of capturing the consumption of crops that are seasonal, or consumed as specialty foods under specific circumstances. Drawing from these observations, the paper argues that assessing the importance of local consumption as a driver of agrobiodiversity conservation requires methods that are better attuned to cultural and seasonally driven consumption practices.

KEYWORDS

agrobiodiversity, Bolivia, food security, nutrition, mixed methods, ethnography, dietary recall surveys

Introduction

In the past decade, the relationship between agrobiodiversity conservation and human food security and nutrition (FSN) has received a great deal of scholarly attention. The emerging body of research on this topic assesses the extent to which agricultural biodiversity—that is, the wide array of varieties of native and traditional crops, under-utilized species, or wild and gathered foods—contributes to food security and/or nutritional adequacy. Broadly speaking, researchers have found a positive association between agrobiodiversity cultivation, harvesting, or consumption and various measures of food security (Ekesa et al., 2009; Powell et al., 2011, 2015; Scurrah et al., 2011; Berti and Jones, 2013; Ickowitz et al., 2014; Jones, 2014, 2017; Jones et al., 2014, 2018; Remans et al., 2014; Keleman Saxena et al., 2016b; Keleman Saxena, 2017; M'Kaibi et al., 2017; Saaka et al., 2017; Lachat et al., 2018; Luna-González and Sørensen, 2018; Gitagia et al., 2019; Anderzén et al., 2020; Zimmerer et al., 2020; Lourme-Ruiz et al., 2021). These findings suggest that with greater agrobiodiversity there are better food and nutrition outcomes. However, these statistically significant, positive associations are often of relatively small magnitude (Jones, 2017), a pattern which is puzzling to long-term observers of the field given the importance of biodiverse crops for rural diets in many high-agrobiodiversity regions of the world (Jones, 2017; Keleman Saxena et al., in review).

In the context of these small-magnitude observed effects, this paper highlights some of the limitations of survey-based methods for understanding larger questions about food security, diet, and agrobiodiversity conservation. We report on data from household surveys of agrobiodiversity and nutrition in the department of Cochabamba, Bolivia, as well as data drawn from ethnographic research on the local uses of specific crops. Early analysis of these data demonstrated the challenge of distinguishing measurable effects of locally cultivated agrobiodiversity on household food security and nutrition outcomes. While initial assessments of the relationship between child anthropometric measures and agrobiodiversity consumption, showed a positive association between the consumption of native crops and child height-for-age scores (HAZ) (Keleman Saxena et al., 2016b), later analyses of a smaller sub-set of the most reliable anthropometric data in the sample did not replicate this association (Keleman Saxena, 2017).

The analysis reported here is a deeper exploration of the survey data to better understand why statistically significant relationships linking agrobiodiversity and food security and nutrition were difficult to pinpoint. In order to answer the question of why effect-sizes were small and/or ephemeral, we asked the question: where and to what extent is agrobiodiversity consumption reported in this dataset at all? To answer this question, we combined an analysis of the survey dataset with an analysis of typical circumstances of food consumption for specific native crops (e.g., specific elements of agrobiodiversity) in the department of Cochabamba, Bolivia. For many such crops, availability, access, and culturally valued consumption circumstances are spatially and temporally patterned. A one-day survey visit may fail to capture the moments or times of year in which these crops are consumed, and surveys that are not purposively sited to capture spatial variability may miss meaningful differences in diets across localities. These spatio-temporal limitations constrain the utility of dietary recall surveys to measure the contributions of agrobiodiversity to household consumption.

Our reflections on the spatio-temporal limitations of nutritional surveys for understanding how cultivated agrobiodiversity contributes to FSN mirror existing literature on the spatial nuances of agrobiodiversity management. This literature urges attention to territorial characteristics and spatial scales in order to understand how agrobiodiversity is managed as a food-system resource (Zimmerer, 1998, 2003; Gergel et al., 2020). While understanding these spatial and temporal dimensions may seem a minor, technical detail, this effort aligns with intersectionality-based approaches, in that it is an important aspect of understanding the "everyday lived experiences, diverse knowledges and intersecting social locations" (Hankivsky et al., 2014, p. 1). These findings also highlight some of the shortcomings of reductionist approaches to generating knowledge about food systems. While survey design often aims to collect data on highly specific constructs that can be measured precisely and analyzed with frequentist statistics, such measurements may not advance understanding of how systems (in this case, the social-ecological systems of agrobiodiversity-as-food) fit together and function (Meadows, 1999; Zhang et al., 2018). We expand on these observations in the discussion and conclusions, providing some suggestions on how field-based methods might be amended to make survey-based research more useful for the study of agrobiodiversity within larger food systems.

Background

Household survey methodologies in agrobiodiversity research

Agrobiodiversity and FSN are both multifaceted, complex concepts. Methods to measure them in real-world contexts generally rely on variables which reduce this complexity (Keleman Saxena et al., in review). For example, food security is usually defined as availability, access, utilization, and stability in time (Barrett, 2010), which can be operationalized in household- or individual-level survey questions assessing the extent to which individuals experience these conditions. Nutritional adequacy is operationalized by asking questions about household- or individual-level intake, comparing reported foods recommended intake of particular nutrients, especially micronutrients (Scurrah et al., 2011; Lachat et al., 2018). Dietary diversity, a measure of the number of food groups consumed, is also frequently used in this arena as a proxy for dietary quality (Ickowitz et al., 2014; Powell et al., 2017; Gergel et al., 2020).

Like food security, agrobiodiversity also encompasses a broad definition. The Food and Agriculture Organization (FAO) has characterized agrobiodiversity as:

> … the variety and variability of animals, plants, and micro-organisms on earth that are important to food and agriculture which result from the interaction between the environment, genetic resources and the management systems and practices used by people. It takes into account not only genetic, species and agro-ecosystem diversity and the different ways land and water resources are used for production, but also cultural diversity, which influences human interactions at all levels…. It comprises the diversity of genetic resources (varieties, breeds, etc.) and

> species used directly or indirectly for food and agriculture…. for the production of food, fodder, fibre, fuel and pharmaceuticals, the diversity of species that support production (soil biota, pollinators, predators, etc.) and those in the wider environment that support agro-ecosystems (agricultural, pastoral, forest and aquatic), as well as the diversity of the agro-ecosystems themselves (Food and Agriculture Organization of the United Nations, 1999).

Studies examining the relationships linking agrobiodiversity and food security usually choose discreet, easily measurable parts of this definition, and assess these in relationship to household FSN. Frequently, the measure used is species diversity, whether referring to diversity cultivated on-farm (Scurrah et al., 2011; Jones, 2014), diversity of crops consumed in the diet (Powell et al., 2015, 2017; Keleman Saxena, 2017), or diversity of crops in the larger food system (Remans et al., 2014).

Because data on these variables is frequently captured using surveys at the household or individual levels, understanding the limitations of survey-based data collection is important for advancing this field. In public health nutrition, dietary recall surveys are a common approach for recording a wide variety of foods consumed, usually relying on asking a respondent to freely list all of the foods they have eaten over a defined prior period (e.g., 24 h) (Gibson, 2022). Food frequency questionnaires, which ask individuals to report the frequency with which they consume foods on a pre-determined list, are also used to help generate measures of dietary diversity (Gibson, 2022). While these measurements are primarily designed to estimate the likelihood of an individual's diet achieving nutritional adequacy, they can also be analyzed in conjunction with measures of agrobiodiversity (e.g., on-farm species richness or variety richness) to assess the relationships linking agrobiodiversity and FSN.

The challenges to using survey-based measurement for understanding the overlap between agrobiodiversity and FSN have been addressed in the existing literature. For example, observers have argued that dietary diversity, as an assessment of dietary quality, is a better measurement than macro- or micro-nutrient intake for understanding the contributions of biodiversity to FSN (Berti and Jones, 2013; High Level Panel of Experts (HLPE), 2017). Similarly, Berti (2015) highlights an important difference in the way that agricultural analysts count types of food when referring to production diversity (e.g., by crop species), versus what nutrition scientists refer to when they discuss dietary diversity (e.g., number of food groups consumed).

The present article extends these discussions of survey methodology by demonstrating how survey design (e.g., via timing of data collection, and the degree of varietal and species-level data elicited by questions) may also influence results and their interpretation. The research reported below uses caloric contribution of individual foods as a core measure for comparing across food types. Because macronutrient reference values are available for a wide variety of crops, this measure allows for species-level (and, to a limited extent, intra-species level) differentiation of crop types. Inter- and intra-species diversity are important measures for agrobiodiversity conservation (especially in potatoes), and aid in understanding temporal patterning of food consumption. However, a calorie-based approach also has important limitations, including the extent to which it may over-weight the nutritional importance of starchy crops while under-weighting other nutrient-rich vegetable foods. We consider these limitations in the discussion section.

Study site: Cochabamba, Bolivia

The research described here was carried out in 2012–2014 in the department of Cochabamba, Bolivia. The department is located on the Eastern slope of the mid-altitude Andes (further details below). This region of Bolivia was chosen as a research site because of the extent to which it exemplifies a paradox in the relationships linking agrobiodiversity and FSN. Bolivia is, from one perspective, agriculturally rich, being a center of origin and diversity for many crop species (Vavilov, 1926; Sauer, 1969). However, from another perspective, the country has historically been among the world's most disadvantaged, especially in terms of poverty and child malnutrition. Bolivia's 2008 DHS survey reported that 30.5% of children under 5 in Cochabamba suffered from stunting (HAZ < -2SD), a figure three points higher than the national average of 27.1% (Coa and Ochoa, 2009).[1]

Due to its topography, Bolivia presents wide variability in agroecological contexts. On the acutely angled slopes of the Andes, a short linear distance may host a wide variety of climatic conditions, as well as variability in soil types. These conditions also vary seasonally (between wet and dry seasons), and daily (with temperatures fluctuating widely between night and day). This leads to spatial and temporal variability in what kinds of food crops will grow, and when they are harvested. The spatial distribution of agriculture in the Andes has been developed over long time-periods to allow farmers to take advantage of these patterns (Murra, 1985; Zimmerer, 1996; Skarbø, 2014).

There is also patterned variability in the social availability of food in this region. The Andes have long been known for a thriving culture of food exchange (Larson et al., 1995; Larson, 1998). In the larger valley of Cochabamba, during the time of research, most markets did not meet daily; rather vendors attended local markets on one or two set days each week. Products available in markets varied seasonally, with locally cultivated crops present in greater abundance, and at lower prices, close to the harvest season. While non-perishable or processed foods may also travel to these markets over longer distances, the regularity of food supply is often disrupted by, for example, mudslides, transport strikes, or political protest. Such disruptions amplify variation in prices and availability of products, both nationally produced and imported. Hence market availability of food responds to seasonal, spatial, and temporal patterning, as well as stochastic events.

The data and analysis we report here are part of a larger project which aimed to understand the relationships liking agrobiodiversity to food security and food culture using a mixture of qualitative,

1 Of note, there has been a marked improvement in these conditions since the time that this data was collected. In children under age 5, Bolivia's 2016 Demographic and Health Survey found a national average prevalence of 20.3% of chronic undernutrition, and a prevalence of 18.5% in Cochabamba (Instituto Nacional de Estadística Bolivia, 2017).

quantitative, and ethnographic methods. This paper reports specifically on data gathered via (a) surveys, and (b) ethnographic research (participant observation). Readers may refer to other publications (Keleman Saxena et al., 2016a,b; Keleman Saxena, 2017) for a description of the larger project.

Materials and methods

Study sites

Research took place in the rural municipality of Colomi and the departmental capital, the city of Cochabamba. Research sites spanned a distance of 86 km on the national highway and covered an altitudinal range of 2,200–4,200 masl, including the sub-tropical Yungas, the inter-Andean valleys, and high-altitude puna ecoregions. Within this area, nine research sites were purposively selected to represent a range of altitudinal, ecological, and market factors. Altitudinally, sites included an urban area of the city of Cochabamba, located in an inter-Andean valley ecoregion at around 2,700 masl; and multiple rural sites in Colomi, including three sites in the high-altitude puna, located between 3,600 and 4,200 m; three sites in Colomi's lowland puna, located at 3,200–3,300 m on a valley floor; and two sites in the Yungas, located around 2,200 m (Figure 1 and Table 1). To the extent possible, sites within ecoregions were picked to vary distance from markets and roads.

Prior informed consent

IRB Approval for both qualitative and quantitative research methods was obtained from Yale University's IRB (Protocol #1107008769). Additionally, approval for survey research was granted by the ethics committee of the Universidad Mayor de San Simón. Prior informed consent was secured verbally from all study participants before collecting data via either quantitative or qualitative methods, using approved consent scripts translated into Spanish and/or Quechua, corresponding to research participants' preferred language.

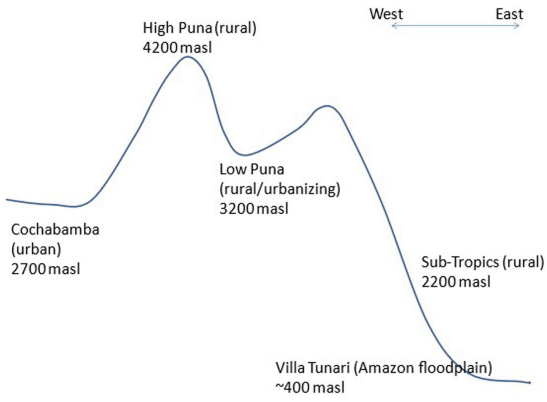

FIGURE 1
Altitudinal schematic of study sites. The diagram should be read as if the viewer were looking at the Andes in cross-section, standing to the south of the sites in the diagram and looking toward the north. Figure adapted from Keleman Saxena et al. (2016a).

Ethnographic research

Primary ethnographic fieldwork was carried out by the first author over a two-year period (June 2012–July 2014). This was preceded by short visits in 2010 and 2011, and followed by an additional visit in 2015. During this time, the first author undertook participant observation in the nine study communities, as well as in larger public spaces in the surrounding region and in the city of Cochabamba. Participant observation included taking part in food-related events (e.g., farming and food preparation activities, as well as attending fairs and festivals) and making careful observations in food-related spaces (e.g., restaurants, food stalls, open-air markets, supermarkets etc.) in both the urban and rural areas. Over the course of fieldwork, the first author spoke in depth with farmers, household food preparers, chefs, agronomists, NGO workers, and casual observers about the role that agrobiodiversity played in food security and food culture in the region.

The first author additionally observed how food products moved across transport networks linking rural and urban spaces, and under what conditions. Transport-related observations took place during the course of 1–2-h journeys from the city of Cochabamba to field sites in Colomi, which the first author made at a weekly and sometimes daily frequency during main periods of fieldwork. When using public transport, these trips often departed from Cochabamba's major market center, *la Cancha,* and arrived at the major market site in the town of Colomi. Because public transport was also often used by small-scale vendors to transport goods for sale, it was possible for the first author to observe and take notes during these journeys.

These observations were recorded in ethnographic field notes and, in some cases, in voice-recorded interviews, which were later transcribed. Field notes and transcriptions were managed in Atlas TI, and specific data relevant to the timing of agrobiodiversity consumption were extracted for the current article. Ethnographic data reported in the present article were cross-checked with the second author, a Cochabamba-based agrobiodiversity researcher who is a lifelong resident of the region.

Household survey

A panel survey was conducted in two periods: the months following the planting season in Colomi (November–December of 2013), and following the harvest (May–July 2014). As the larger project examined the role of agrobiodiversity in child nutritional health, recruitment targeted households with children under the age of 5. Households were recruited via community-meetings facilitated by local organizations, or by door-to-door knocking (see Table 1). Up-to-date list of households with young children were not readily available, and hence survey-takers used these methods to recruit households until all eligible households had been contacted or were determined to be unreachable.

Survey data was collected from female heads of household or primary food preparers. When neither the female household head nor the primary food preparer was present, data was collected from another individual (usually female) with detailed knowledge of the food that had been prepared in the household the day before the survey.

TABLE 1 Survey sites, site characteristics, and recruitment.

Site name	Ecoregion	Market/Road proximity	Characteristics	Household recruitment
OTB La Tamborada	Urban	Proximate	Low-income area, relatively recently urbanized, located in the southern zone of Cochabamba	Parents of children enrolled in local preschools (R1, R2); Preschools and period of annual checkups at local hospital (R2)
Linde	High puna	Distant	Small town comprised of a handful of families; practices livestock husbandry (sheep, llama); 1–2 h drive from either Colomi or Cochabamba on dirt/cobblestone roads	Community meeting called by partnering NGO (R1); Community meeting and door-to-door visits (R2)
Pisly	High puna	Distant	High altitude town on the border of the municipalities of Colomi and Sacaba; practices livestock husbandry (sheep, llama); 1–2 h drive from either Colomi or Cochabamba on dirt/cobblestone roads.	Community meeting called by partnering NGO (R2); Community meeting and door-to-door visits (R2)
Pico Central	High puna	Distant	Located in a moist, high-altitude valley; steeply sloped fields; 90 min drive from Cochabamba or 30 min drive from Colomi on dirt/cobblestone roads; road access often cut off in rainy season	Regular meeting of local farmers' organization (*sindicato*) and door-to-door visits (R1, R2)
Toncolí (1st and 2nd)	Low puna	Proximate/ Intermediate	Located on the border of the Corani reservoir and proximate to the municipal seat of Colomi; flat lands with relatively warmer climate, suitable for barley cultivation; many households keep dairy cows	Community meeting called by partnering NGO (R1); door-to-door visits (R2)
1a Candelaria	Low puna	Intermediate	Located on the northern end of the Corani reservoir; Site of regional high school, but has no weekly market; Known for high diversity of potato cultivation	Community meeting called by partnering NGO (R1); door-to-door visits (R2)
2a Candelaria	Low puna	Intermediate	Proximate to 1a Candelaria, shares similar characteristics but houses are farther removed from the main road	Community meeting called by partnering NGO (R1); door-to-door visits (R2)
Paracti	Subtropics	Intermediate	Subtropical town on the border of the municipalities of Colomi and Villa Tunari; spans both sides of the national highway; some households practice trout farming	Community meeting called by partnering NGO (R1); door-to-door visits (R2)
Corani Pampa	Subtropics	Distant	Subtropical town at approximately 1 h's distance from the national highway by cobblestone/dirt road; populated largely by *colonos* (colonists) arrived from highland regions since the early 2000s; some trout farming and tourism; *locoto* cultivation is the major economic activity; no weekly market	Community meeting called by partnering NGO and local health post (R1); door-to-door visits (R2)

Note that R1 refers to survey round 1 (post-planting 2013), and R2 refers to survey round 2 (post-harvest 2014).

Survey team composition and training

Surveys were carried out by a 10-person team led by the first author. The survey team consisted primarily of upper-level students in the Universidad Mayor de San Simón (UMSS) nutrition degree program, but also included individuals with training in agronomy and sociolinguistics. Survey-takers were chosen for their language capabilities, in particular the ability to speak Quechua. Prior to fieldwork, survey-takers completed multi-day trainings to familiarize themselves with the motivations, content, and format of the survey; to understand prior informed consent practices; and to practice asking and recording survey questions.

Survey instrument

The survey instrument was designed to collect data on multiple variables potentially contributing to food security/nutrition. Specifically, the survey covered: (a) survey respondent individual characteristics; (b) household demographic characteristics; (c) market access/proximity; (d) household wealth and expenditure; (e) government/NGO influence; (f) health and recent infections; (g) household food security; (d) culinary/dietary recall. The survey instrument was reviewed by a bilingual Quechua-Spanish speaker, and Quechua translations of all questions were added to the survey, generating a bilingual survey format. Surveys were administered in the language of primary fluency of the survey respondent, either Spanish or Quechua.

Full methods were published previously in Keleman Saxena (2017). The data reported here are primarily drawn from the culinary/dietary recall. A 24-h "culinary recall," capturing all dishes prepared in the household the day prior to the survey was administered. This recall was designed to record variety-level identity of locally produced ingredients, as well as the origin of those foods (market vs. home-produced vs. barter). Respondents were asked to report consumption amounts with reference to either a set of plates and cups (including small, medium, and large sizes), similar to those used locally, or a set of styrofoam balls (of a range of sizes), chosen to represent the shape

and volume of unprocessed/uncooked food ingredients. The purpose of using these props was to provide a visual reference of food/ingredient volumes that would be more meaningful to respondents than abstract quantities (e.g., "100 g"). The volumes of these plates/balls were measured prior to fieldwork, and were converted to metric volumes of prepared foods or ingredients after the survey was enumerated. The number of individuals consuming each meal (including any guests or missing household members) was also recorded. These data were supplemented with questions about food or drink consumed away from home. Instructions for replicating culinary recall methods are included as Supplementary material.

Data entry and cleaning

Survey data were entered into an excel spreadsheet by research assistants who were also members of the survey team. Survey data were checked for accuracy, and errors were corrected.

Data analysis: designating crop types and computing caloric contributions

In consultation with an agronomist trained in local genetic resource management, and outside sources where necessary, ingredients named in the survey were classified as processed, native, Andeanized, introduced, improved, unknown, or animal/meat. Table 2 describes these categories and gives examples of crops and foods belonging to each. Of note, these categories were built to correspond as closely as possible to ethnobotanical origin, also taking into account to the seed system characteristics of each crop/food. However, the resulting groupings do not correspond directly to meaningful nutritional categories (e.g., food groups), which demonstrates the challenges of overlapping the definitions used in ethnobotany, crop-breeding, and nutrition. A very small number of recalls (99, or less than one-tenth of 1% of the total number) were left uncategorized, either because the named ingredient could not be clearly associated to a crop species, or because the respondent had named a dish without identifying the ingredients.

Subsequently, researchers generated a table of nutritional values for each type of ingredient named drawing data primarily from the software Nutrisurvey (Erhardt, 2007), and specifically from the program's databases for Latin America. Values were also sourced from the searchable database of nutritional composition of the Fundación Universitaria Iberoamericana,[2] the USDA's Food Data Central,[3] and the Bolivian Government's Sistema Administrativo de Alimentación (SISADAL). Where necessary, these data were supplemented with information from other sources, including: the nutritional information on the labels of commonly named purchased ingredients; nutritional data associated with web-based recipes for common Bolivian foods (e.g., *buñuelos*; see Lynn, n.d.) and popular references for individual ingredients not available in other databases (e.g., an article on the seasoning ajino-moto from the website caloriecount.com, now verywellfit.com). Using this table as a database, the volumes of reported ingredients were used to calculate caloric values for each instance in which an ingredient was mentioned in household-level surveys.

Data analysis: household demographics and caloric availability

The survey collected data from 414 households. After cleaning, the data were divided into three datasets: a cross-sectional dataset of households and children surveyed only in 2013 ($N = 106$ households); a cross-sectional dataset of households and children surveyed only in 2014 ($N = 150$ households); and a longitudinal dataset of households and children surveyed in both periods ($N = 158$ households). The characteristics of these datasets are summarized in Figure 2.

Initial analyses, which focused on anthropometry (reported in Keleman Saxena et al., 2016b; Keleman Saxena, 2017) prioritized the longitudinal sample which was again narrowed to 117 households to eliminate households for which child anthropometric measurements required additional verification. This longitudinal sample was used to summarize basic demographic data about survey respondents and their households, and was also used for household-level dietary analysis. At the household level, we calculated the caloric contributions of key crop species and crop types (e.g., native vs. Andeanized) to household caloric availability. (Note that caloric availability is not the same as caloric intake, which would require an individual-level measure.) We also assessed each crop type's contribution to caloric availability varied across seasons, and by region of residence. Descriptive statistics were generated using Microsoft Excel and inferential statistics (paired-sample *t*-test and analysis of variance) were generated using SPSS (V23).

Data analysis: caloric contributions of agrobiodiversity

To understand the broader contributions of agrobiodiversity to regional diets, the average caloric contribution of specific named ingredients was calculated for each household in the longitudinal sample, and averaged within ecoregion. The top contributors by ecoregion were then ranked, and lists of the top 15 crops by caloric contribution for each region were generated. These lists were dominated by potatoes and processed foods (see data below), leading the researchers to ask: to what extent did other native crops appear in the dataset?

To answer this question, the sample was again widened to include all ingredients listed by all 414 households in dietary recall surveys. This resulted in a total of 10,926 individual ingredient recalls in the two survey years (see Figure 2). These are reported for the full sample, and are also broken down by year/season of survey (2013 post-planting and 2014 post-harvest), and by sub-set of the household sample (cross-sectional vs. longitudinal. The number of times an individual ingredient was mentioned by any household was summed, and estimates were made of each ingredient's contribution to total caloric availability across the 414-hh sample. Descriptive statistics of ingredient recalls were generated using Microsoft Excel.

2 www.composicionnutricional.com

3 fdc.nal.usda.gov

TABLE 2 Categories of ingredient-type with examples.

Category	Description	Examples
Native	Crops indigenous or authoctonous to Bolivia; generally propagated as farmer-saved (non-certified) seed or tubers.	Farmers' varieties of potato (*Solanum* sp.) not subject to formal breeding (e.g., papa qollyu, papa imilla); oca (*Oxalis tuberosa*); tarwi (*Lupinus mutabilis*); achojcha (*Cyclanthera pedata*); papalisa (*Ullucus tuberosa*); maize (*Zea mays*); locoto pepers (*Capsicum pubescens*); among others.
Andeanized	Andeanized (*andinizado*) is a term used locally for crops that were introduced to the Andes in the early period of European-American contact, and have adapted to grow well at high altitudes (Tejada Campos, 2008; Neito and Estrella, 2011). Generally propagated from farmer-saved seed or tubers.	Fava beans (*Vicia fava;* fresh or dried); wheat (*Triticum* sp.); barley (*Hordeum vulgare*); onion (*Allium cepa*); peas (*Pisum sativum*)
Introduced	Crops originating in other world regions and propagated as hybrid or certified seed	Carrot (*Daucus carota*); rice (*Oryza sativa*); cauliflower (*Brassica oleracea* var. *botrytis*); broccoli (*B. oleracea* var. *italica*); spinach (*Spinacia oleracea*); beets (*Beta vulgaris* subsp. *vulgaris*); bananas (*Musa* sp.); radishes (*Raphanus sativus*)
Improved	Crops or varieties obtained by formal breeding, with germplasm historically originating in Bolivia or to the Americas. Certified seed or tubers widely available in study site.	Formally improved potato varieties (e.g., Toralapa, Doble H, Holandesa; *Solanum tuberosum*); *pimetón* peppers (*Capsicum annum).*
Processed	Packaged commercial foods, or home-produced foods composed of a number of ingredients, and not primarily based in locally farmed raw materials.	Oil; noodles; bread; buñuelo (fritters); flour; soft drinks; cookies; salty snacks; spices, seasonings, and condiments
Animal/Meat	Any products of animal origin	Meat; fish; eggs; cheese; milk

Native, Improved, and Andeanized categories also include prepared or preserved foods using these crops as primary ingredients.

Results

Study population: demographic characteristics

Table 3 provides a description of the longitudinal sub-sample of the surveyed population. Average household size was 5.97 people in the pre-harvest (2013) season, and 5.64 in the post-harvest season. In the three rural ecoregions, the number of reported household members was larger in the pre-harvest (e.g., planting) season than in the post-harvest season. This trend was reversed in the urban sites, consistent with a pattern of seasonal rural–urban migration. 79.4% of the households responding to the survey classified themselves as "agricultural" whereas the remainder did not. However, this self-classification varied by site, with 84.8–100.0% of households identifying agriculture as a main activity in the rural sites, and only 22% identifying as such in the urban site.

Household food preparers interviewed were, almost without exception, female (data not shown). The average interview respondent age was 30.7 years (±8.67 years). Interviewees had completed an average of 5.42 years of school (±3.91 years), with a higher completion rate (8.0 ± 4.10 years) in the urban site. Eighty eight percent of the interviewees reported that Quechua was their first language, with a maximum of 100% of respondents giving this answer in rural sites, and a low-end value of 61.1% of respondents giving this answer in the urban site. The second most common primary language was Spanish, and a few respondents ($N = 3$) spoke Aymara as a first language (Table 3).

Survey research: how does agrobiodiversity contribute to caloric availability?

Mean contributions of each crop category to caloric availability by year are shown in Table 4. On average, within the longitudinal survey sample, approximately one third of reported calories originated from Native crops, accounting for 30.3% (±23.7) of caloric availability in the post-planting season and 32.3% (±24.2) in the post-harvest season. Processed foods were of similar caloric importance, accounting for 35.3% (±19.8) of post-planting season calories and 28.3% (±14.9) of post-harvest season calories. Introduced crops also made important contributions to caloric availability, accounting for 16.2% (±14.5) and 18.0% (±15.9) of calories reported in the post-planting and post-harvest seasons, respectively. Andeanized and improved crops accounted for a smaller percentage of caloric availability (>7%). Meat or other animal products accounted for 9.8% of calories available in each season. The standard deviations from these averages are large, reflecting a wide variation in diets among households.

The differences in averages suggest some patterns, e.g., that the consumption of Native and improved crops (most of which are locally cultivated) increased in the post-harvest season, while the consumption of processed foods was lower in the post-harvest season. To assess the significance of these trends, we did a paired-samples *t*-test. This test evaluates the differences between two measurements from the same household, and hence was appropriate for this longitudinal sample. The smaller contribution of processed foods to caloric availability in the post-harvest as opposed to the post-planting season was significant ($p < 0.01$). No other crop categories showed a significant difference, although the increases in caloric availability from improved and introduced crops in the post-harvest season were borderline significant ($p = 0.50$ and 0.648, respectively), and the decrease in caloric availability from Andeanized crops was also borderline significant ($p = 0.667$).

Patterns within these global results change when the data are broken down regionally. Table 5 shows percent contribution of each crop category by ecoregion. Notably, diets in the rural areas differ significantly from those in the urban field site. This is especially

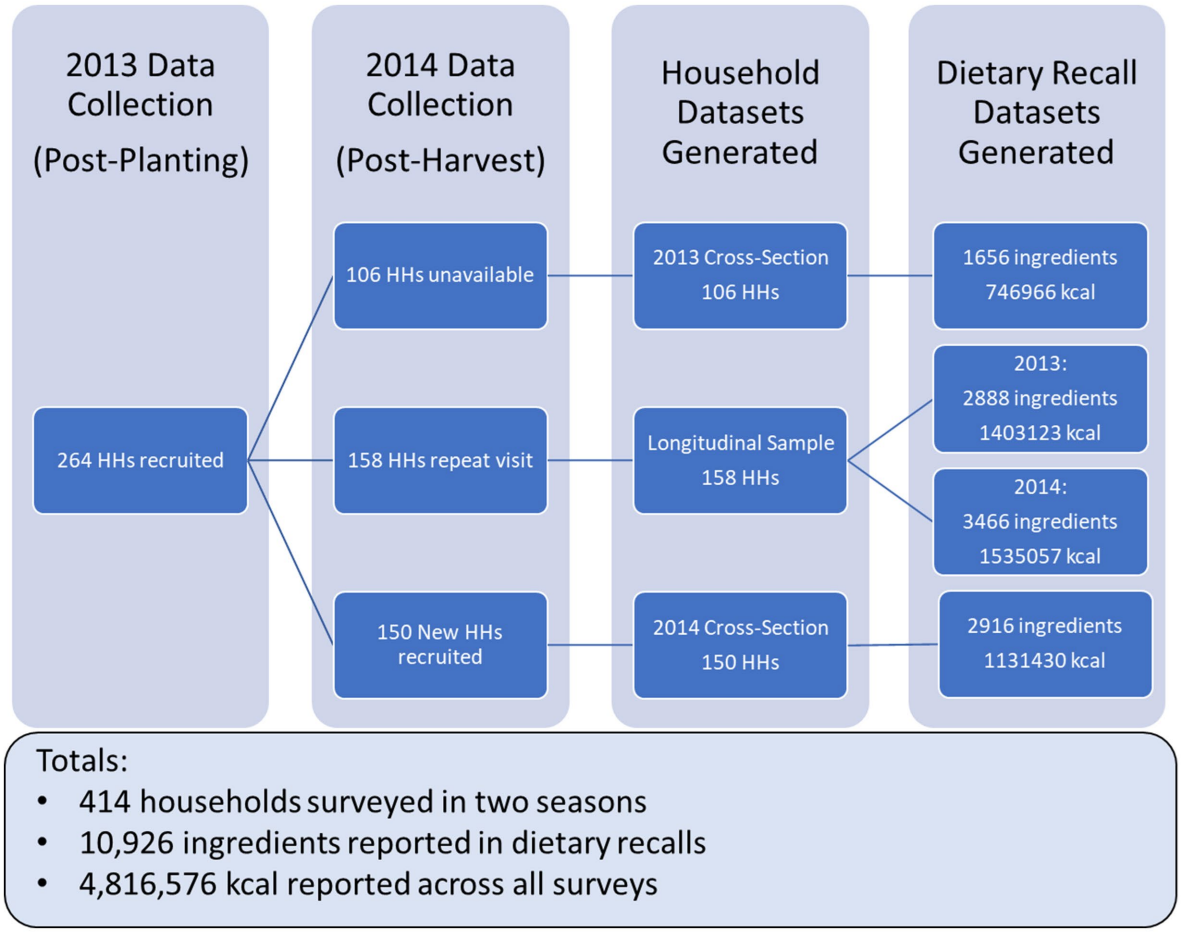

FIGURE 2
Survey sample by year of recruitment and sub-sets of data.

marked in the high puna, the most remote of the study regions. Here, foods derived from native crops made up more than half of caloric availability, accounting for 57.4% (±21.1) in the post-planting season and 57.3% (±18.4) in the post-harvest season. While processed foods were the second-most important category, their caloric contribution accounted for only 19.9% (±17.0) of calories in the post-planting period, and 21.7% (±12.7) in the post-harvest period, which was less than in other sites. Meat and animal products also accounted for a lesser proportion of caloric availability than in other sites, making up 5.2% (±6.4) of caloric availability in the post-planting season and 5.1% (±6.2) in the post-harvest season.

In the low puna, which is a primarily agricultural economy, but better connected to transportation and markets than the high puna, the contribution of native crops to caloric availability was also higher than the full-sample average. Caloric availability from native crops accounted for 34.5% (±21.3) and 39.5% (±20.0) in the post-planting and post-harvest seasons, respectively. Processed foods accounted for a similar proportion of caloric availability to native crops in the post-planting season (35.9% ±19.7), but in the post-harvest season they accounted for a lesser proportion (29.2% ±16.5). The proportion of caloric availability provided by improved crops was higher in the post-harvest season (8.2% ±14.8) than in the post-planting season (3.3% ±7.4). Caloric availability from meat products was lower in the post-planting season (7.9% ±8.7) than in the post-harvest season (5.9% ±7.1).

In the sub-tropics, where survey sites were remote but well connected to transport, and where agriculture largely centers on the production of *locoto* chile pepper as a cash crop, native crops accounted for a lower proportion of caloric availability than in the two other agricultural sites. Native crops accounted for 20.1% (±17.5) in the post-planting season and 21.6% (±21.7) in the post-harvest-season. Meanwhile, processed foods accounted for 39.0% (±18.4) of caloric availability in the post-planting period, a proportion which decreased to 29.5% (±13.9) in the post-harvest survey. The proportion of calories, provided by improved crops and introduced crops increased in the post-harvest season (from 5.8 to 10.1%, and from 21.1 to 25.4%, respectively). Caloric availability from meat or animal products stayed close to the same, accounting for 8.3% (±9.3) in the post-planting season and 7.9% (±9.3) in the post-harvest season.

Diets in the urban site differed markedly from the three other survey sites, with a higher reliance on processed and animal-based foods. In the urban site, native crops accounted for only 12.7% (±10.9) of caloric availability in the post-planting season and 16.1% (±16.0) in the post-harvest season. Meanwhile, processed foods accounted for 43.1% (±18.2) of caloric availability in the post-planting season, a figure which decreased to 30.7% (±15.1) in the post-harvest season.

TABLE 3 Survey population characteristics, 2013 and 2014.

	Total			Subtropics			Low puna			High puna			Urban		
	Mean	N	Std. Dev.	Mean	N	Std. Dev.	Mean	N	Std. Dev.	Mean	N	Std. Dev.	Mean	N	Std. Dev.
Household data															
Household size															
2013	5.97	115	2.23	5.31	35	1.64	6.82	39	2.36	7.10	20	2.29	4.43	21	1.50
2014	5.64	113	2.16	5.03	35	1.29	6.24	38	2.25	6.53	19	3.03	4.76	21	1.70
Agricultural household															
No		22	20.6%		5	15.2%		3.0	7.9%		0.0	0.0%		14	77.8%
Yes		85	79.4%		28	84.8%		35.0	92.1%		18.0	100.0%		4	22.2%
Interviewee characteristics (2013)															
Age	30.37	108	8.67	28.71	34	9.27	32.05	38	9.02	32.28	18	8.22	28.06	18	6.34
Years of school completed	5.42	108	3.91	6.06	34	4.42	4.42	38	3.41	3.72	18	1.71	8.00	18	4.10
Interviewee first language															
Spanish		10	9.3%		4	11.8%		0	0.0%		0	0.0%		6	33.3%
Quechua		95	88.0%		29	85.3%		37	97.4%		18	100.0%		11	61.1%
Other		3	2.8%		1	2.9%		1	2.6%		0	0.0%		1	5.6%

Note that total N differs from the full longitudinal sample of 117 households due to incomplete data in some surveys. For the individual-level characteristics, the total number reported ($N = 108$) reflects the elimination of 9 households in which survey respondents were secondary food preparers (rather than the primary food preparer).

TABLE 4 Mean % caloric contribution by crop category (2013 and 2014).

	2013	2014	Paired samples *t*-test
N (HHs)	114	100	97
	Mean (±SD)	Mean (±SD)	Sig.
Processed (% kcal)	35.3 (±19.8)	28.3 (±14.9)	**
Native (% kcal)	30.3 (±23.7)	32.3 (±24.2)	0.169
Andeanized (% kcal)	5.2 (±5.7)	4.8 (±4.9)	0.667
Introduced (% kcal)	16.2 (±14.5)	18.0 (±15.9)	0.648
Improved (% kcal)	3.2 (±7.7)	6.4 (±12.8)	0.050
Meat/Animal (% kcal)	9.8 (±10.7)	9.8 (±11.1)	0.994

**indicates significance at $p < 0.01$.

Meat and other animal projects accounted for a proportion of caloric availability 2.5–5 five times greater than in the other sites, representing 20.9% (±12.9) in the post-planting season and 24.2% (±11.4) in the post-harvest season.

Table 5 also reports results of analyses of the statistical significance in differences of means across the for ecoregional sites. (These were undertaken using a one-way ANOVA, Kruskal-Wallis, and Welch's ANOVA, as appropriate; see Table 5 for more detail.) Most crop categories show significant differences in percent contribution to caloric availability among regions within each time-period (2013 post-planting or 2014 post-harvest) at the $p < 0.05$ or $p < 0.01$ levels. The exceptions are percent caloric availability from processed food (which did not significantly differ among regions in the post-harvest season), percent caloric availability from introduced crop-based foods (where differences across regions were not significant in the post-planting period), and percent caloric availability from Andeanized foods, where differences among regions were not significant in either survey period.

Survey research: which native crops are most important in local diets?

As described above, caloric contribution of all ingredients named in dietary recalls was calculated for the longitudinal sample of households. The contribution of each food type was averaged within ecoregions, and food types were ranked in terms of their percentage contribution to caloric availability. The results of this analysis are reported in Table 6 (for the 2013 post-planting survey) and Table 7 (for the 2014 post-harvest survey).

These data describe the assemblage of foods that underpin household consumption in the two seasons. First, one variety of potato, *Huaycha* accounts for an important part of caloric intake in the rural sites. This variety accounted for 13.5% of caloric availability in the low-puna in 2013, and 19.7% in 2014. Meanwhile, in the high-puna, *papa Huaycha* accounted for 28.8% of caloric availability in 2013, and 21.5% in 2014. This variety also accounted for 9.1% of caloric availability in the Yungas in 2013. If potato is a key food security crop for this region, then *papa Huaycha* might be considered a "food security variety." As we elaborate in the ethnographic research results below, it is substantially more cultivated compared to other varieties, and also the most consumed.

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TABLE 5 Mean % caloric contribution by crop category and by ecoregion (2013 and 2014).

	Region	Subtropics (N 2013 = 35; N 2014 = 32)	Low puna (N 2013 = 39; N 2014 = 32)	High puna (N 2013 = 20; N 2014 = 17)	Urban (N 2013 = 20; N 2014 = 19)		
	Survey Year	Mean	Mean	Mean	Mean	Test used[a]	P-value
Processed (% kcal)	2013	39.0 (±18.4)	35.9 (±19.7)	19.9 (±17.0)	43.1 (±18.2)	Kruskal-Wallis	0.000**
	2014	29.5 (±13.9)	29.2 (±16.5)	21.7 (±12.7)	30.7 (±15.1)	ANOVA	0.247
Native (% kcal)	2013	20.1 (±17.5)	34.5 (±21.3)	57.4 (±21.1)	12.7 (±10.9)	Welch's ANOVA	0.000**
	2014	21.6 (±21.7)	39.5 (±20.0)	57.3 (±18.4)	16.1 (±16.0)	Kruskal-Wallis	0.000**
Andeanized (% kcal)	2013	5.7 (±5.6)	5.9 (±6.5)	3.3 (±4.2)	4.9 (±5.7)	Kruskal Wallis	0.095
	2014	5.5 (±5.6)	4.3 (±4.5)	4.7 (±4.5)	4.5 (±4.9)	Kruskal Wallis	0.788
Introduced (% kcal)	2013	21.1 (±16.3)	12.4 (±12.1)	14.3 (±12.2)	16.9 (±15.8)	Kruskal Wallis	0.106
	2014	25.4 (±15.3)	12.1 (±14.3)	11.2 (±10.0)	21.7 (±17.8)	Kruskal Wallis	0.000**
Improved (% kcal)	2013	5.8 (±10.5)	3.3 (±7.4)	0.0 (±0.1)	1.5 (±4.4)	Welch's ANOVA	0.001**
	2014	10.1 (±14.6)	8.2 (±14.8)	0.2 (±0.5)	2.9 (±9.2)	Welch's ANOVA	0.000**
Meat or animal (% kcal)	2013	8.3 (±9.3)	7.9 (±8.7)	5.2 (±6.4)	20.9 (±12.9)	Kruskal-Wallis	0.000*
	2014	7.9 (±9.3)	5.9 (±7.1)	5.1 (±6.2)	24.1 (±11.4)	Kruskal-Wallis	0.000*

[a]A requirement of a regular ANOVA is that data should be normally distributed and have equal variances. When data are not normally distributed but DO have equal variances, a Kruskall-Wallis test can be used. When data are neither normally distributed nor have equal variances, a Welch's ANOVA can be used. These criteria were used to choose which test to apply in each case.

*Significant at $p < 0.05$.

**Significant at $p < 0.01$.

Beyond this reliance on *papa Huaycha,* a large proportion of the diet, in all sites and in both seasons, is made up of a few key processed foods: oil, noodles (both *fideo* and *macarrón*), sugar, rice, and bread (generic and *tortilla*). These foods are carbohydrate-heavy, and limited in protein. They may also be relatively micronutrient-limited, although these limitations may be ameliorated when products are fortified, which is mandatory for wheat flour in Bolivia, but not for maize or rice (Food Fortification Initiative, n.d.).

Although these data do identify a few calorie-dense, starch heavy-crops which are central to households' diets, they also show that in the 2014 post-harvest survey, households were relying on a greater diversity of native and improved foods than in the 2013 post-planting survey. This includes a greater number of potato varieties (natives belonging to *Solanum tuberosum* Andigenum group, and also improved ones; e.g., different *qollyus*, *Yuca papa*, and *Qorisonqo*, in addition to *Huaycha*) as well as other minor tubers, like oca (*Oxalis tuberosa*) and papalisa (*Ullucus tuberosus*). The 2014 post-harvest list also includes crops like peanut (*Arachis hypogaea*) and cassava (*Manihot esculenta*), which are not directly cultivated in low puna, high puna, and urban sites, although they are grown within the subtropical Yungas. This suggests that both local production and regional markets are important in providing diversity to households in the post-harvest season.

In 2013, the percentage of total caloric availability accounted for by the top 15 crops is, across the board, greater than in 2014. This is especially notable for the high puna, where the top 15 foods account for 94.3% of calories in 2013, whereas the same number of foods accounts for only 86.6% of calories in 2014. This is consistent with a greater diversity of foods/ingredients in the diet in the post-harvest period.

Finally, the number of individual ingredients named in the 24-h culinary recall varies by site. In 2013, in the Yungas, low-puna, and valley (periphery city) sites, culinary recalls generated a list of over 90 ingredients. However, in the high puna, the culinary recall generated a list of only 47 ingredients. This number increased by nearly 50% in the 2014 post-harvest survey, with 66 ingredients named in the high puna. Meanwhile, in other sites, the number of ingredients named increased by fewer than 10 in the post-harvest period. This pattern is consistent with greater diversity in the post-harvest season across the board, but with the greatest effect of seasonality observed in the most remote (highland puna) site.

If the combination of a few potato varieties, processed foods, and some meats provides three quarters or more of the calories in the surveyed sites, to what extent are a wider diversity of native crops important to local diets? This question is explored in Table 8, which reports the caloric contributions of Native, Improved, and Andeanized crops reported in dietary recalls for the full sample of households surveyed. This table reports all categories of crop that are significant for agrobiodiversity conservation (but leaves out herbs, wild and gathered crops, or teas).

TABLE 6 Top reported ingredients by ecoregion, 2013.

	Subtropics			Low puna			High puna			Urban		
Rank	Food name	Type	% Kcal	Food name	Type	% Kcal	Food name	Type	% Kcal	Food name	Type	% Kcal
1	Rice	I	18.9%	Potato (var. Huaycha)	N	13.5%	Potato (var. Huaycha)	N	28.8%	Bread (generic)	P	14.3%
2	Bread (generic)	P	15.2%	Oil	P	9.8%	Chuño	N	16.6%	Rice	I	13.1%
3	Potato (generic)	N	13.3%	Rice	I	9.7%	Rice	I	16.2%	Oil	P	7.5%
4	Noodles (var. *fideo*)	P	8.0%	Chuño	N	8.4%	Potato (generic)	N	6.9%	Fish (var. Sábalo)	M	5.8%
5	Oil	P	7.7%	Bread (generic)	P	7.1%	Bread (generic)	P	5.0%	Sugar	P	5.7%
6	Sugar	P	4.2%	Potato (generic)	N	6.4%	Potato (var. imilla)	N	4.3%	Noodles (var. *marcarrón*)	P	4.7%
7	Noodles (var. *macarrón*)	P	3.2%	Noodles (var. *marcarrón*)	P	4.3%	Noodles (var. *marcarrón*)	P	3.3%	Potato (var. imilla)	N	4.3%
8	Potato (var. Rosita)	IMP	2.8%	Sugar	P	3.9%	Sugar	P	3.2%	Chicken	M	4.2%
9	Chuño	N	2.6%	Noodles (var. *fideo*)	P	3.7%	Oil	P	2.4%	Noodles (var. *fideo*)	P	3.7%
10	Chicken	M	2.3%	Cow's milk	M	3.2%	Noodles (var. *fideo*)	P	2.0%	Potato (generic)	N	2.9%
11	Wheat	A	1.8%	Fava (dried)	A	3.0%	Toasted maize (var. Jank'aquipa)	N	1.7%	Cow's milk	M	2.5%
12	Carrot	I	1.7%	Flour	P	1.9%	Cheese	M	1.5%	Boiled maize (mote)	N	2.3%
13	Potato (var. Holandesa)	IMP	1.5%	Chicken	M	1.7%	Dried meat (Charki)	M	1.3%	Sausage	M	1.9%
14	Onion (head)	A	1.4%	Potato (var. Holandesa)	IMP	1.6%	Beef (soft meat)	M	1.3%	Boneless cow's meat	M	1.9%
15	Egg	M	1.4%	Bread (var. Tortilla)	P	1.5%	Carrot	I	0.8%	Potato (var. qollyu)	N	1.8%
Cumulative % of Kcal			86.0%			79.7%			94.3%			76.6%
# of ingredients reported (2013)			91			91			47			92

I, introduced; P, Processed; N, Native; IMP, Improved; A, Andeanized, M, Meat or other animal product.

Following the patterns described above, potato (all varieties) and *chuño* (a form of freeze-dried potato, which can be made from multiple fresh potato varieties) account for more than 30% of caloric availability reported at the household level. This pattern holds across all sub-sets of the survey sample, and both survey seasons. However, only a handful of other native or Andeanized crops contribute any more than 1% of the caloric availability reported in either period. Maize (*Zea mays*) and maize-derived products accounted for 1.53% of caloric availability; green or dried fava beans (*Vicia faba*) accounted for 1.29%; and onion (*Allium cepa*) and carrots (*Daucus carota*) (both Andeanized crops) accounted for 1.19 and 1.13%, respectively.

These tables underscore the relatively limited household use of some native crops. Tarwi (*Lupinus mutabilis*) was reported in only one culinary recall in the full survey period. Quinoa (*Chenopodium quinoa*), an iconic crop of the Andes which is, nonetheless, not typically grown in the survey sites, accounted for only 0.10% of calories reported in the entire sample of households.

These data also indicate seasonality in the consumption of some crops. For example, in the post-planting survey (2013) oca (*Oxalis*

TABLE 7 Top reported ingredients by ecoregion, 2014.

	Subtropics			Low puna			High puna			Urban		
Rank	Food name	Type	% Kcal	Food name	Type	% Kcal	Food name	Type	% Kcal	Food name	Type	% Kcal
1	Rice	I	24.0%	Papa (var. Huaycha)	N	19.7%	Potato (var. Huaycha)	N	21.5%	Rice	I	16.8%
2	Potato (var. Huaycha)	N	9.1%	Rice	P	13.2%	Rice	I	11.9%	Potato (var. Imilla)	N	7.4%
3	Oil	P	8.8%	Bread (generic)	P	6.6%	Potato (generic)	N	7.8%	Bread (generic)	P	7.2%
4	Potato (var. Rosita)	IMP	8.3%	Sugar	P	6.1%	Chuño	N	7.7%	Bread (var. Tortilla)	P	6.4%
5	Bread (var. Tortilla)	P	5.5%	Chuño	N	4.6%	Potato (var. Imilla)	N	7.0%	Pork	M	5.7%
6	Sugar	P	4.8%	Oil	P	4.3%	Sugar	P	5.1%	Oil	P	5.0%
7	Flour	P	3.0%	Potato (var. Toralapa)	IMP	4.1%	Chuño (var. Tunta)	N	4.5%	Sugar	P	4.8%
8	Chuño	N	2.8%	Noodle (var. *Macarrón*)	P	3.1%	Oil	P	3.8%	Yuca (Cassava)	N	4.3%
9	Bread (generic)	P	2.5%	Noodle (var. *Fideo*)	P	3.0%	Potato (var. Qollyu)	N	3.6%	Oats	I	2.9%
10	Noodles (var. *fideo*)	P	2.5%	Fava (dried)	A	2.7%	Noodles (var. *Macarrón*)	P	3.5%	Mutton	M	2.7%
11	Maize (white)	N	2.2%	Potato (var. Yuca)	N	2.7%	Bread (generic)	P	3.4%	Potato (var. Holandesa)	IMP	2.3%
12	Peanut	N	2.0%	Papa (var. Qorisonqo)	IMP	2.5%	Beef (soft meat)	M	1.8%	Beef (with bone)	M	2.3%
13	Potato (var. Holandesa)	IMP	1.8%	Oca	N	2.2%	Wheat	A	1.7%	Noodle (var. *Fideo*)	P	2.2%
14	Potato (generic)	N	1.7%	Chuño (var. Waych'a)	N	1.7%	Mutton	M	1.7%	Chicken	M	2.1%
15	Noodles (var. *macarrón*)	P	1.4%	Papalisa	N	1.5%	Maize powder (*pito*)	N	1.6%	Peanut	N	1.8%
Cumulative % of Kcal			80.5%			78.1%			86.6%			73.8%
# of ingredients reported (2014)			96			99			66			84

I, introduced; P, Processed; N, Native; IMP, Improved; A, Andeanized; M, Meat or other animal product.

tuberosa; a native tuber) accounted for only 0.10% of caloric availability in households in the longitudinal sample, and 0.23% in the cross-sectional sample. Meanwhile, in the 2014 post-harvest survey, it accounted for a greater percentage of caloric availability in both the longitudinal (1.07%) and cross-sectional (0.75%) household samples. Likewise, the native tuber papalisa (*Ullucus tuberosus*) was absent from the 2013 dietary recalls, but accounted for 0.67 and 0.49% of calories reported in the longitudinal and cross-sectional sub-samples of the post-harvest survey.

A similarly pronounced seasonality is evidenced in the consumption of avocado (*Persea americana*) and cassava (*Manihot esculenta*). Both of these crops would likely only be grown in the lower-altitude sub-tropical site—but upon examination, the households reporting having consumed these crops were distributed across the ecoregions of the study, underscoring the importance of inter-regional trade for crops not grown locally during seasons of high availability.

Ethnographic research: when are crops used?

The results described above could be taken to suggest that, apart from potatoes, this region's agrobiodiversity is of relatively limited importance for household diets. However, it is important to contrast these data with ethnographically-derived understanding of how and when "minor" NTCs are available. This section describes patterns of consumption of a selected set of native and Andeanized crops as they are influenced by seasonal and spatial considerations, drawing from ethnographic data. It focuses on native and Andeanized crops that are cultivated locally in the study region

TABLE 8 Native, improved, and Andeanized crop contributions to reported caloric availability, and ranked by contribution to full sample of dietary recalls.

Crop name				Longitudinal Sample		Cross-Sections		Pooled sample
Spanish	English	Scientific name	Type	2013	2014	2013	2014	
Papa	Potato	*Solanum tuberosum*	Native and improved	23.28%	28.72%	26.28%	24.04%	25.66%
Chuño	Chuño (freeze-dried potato)		Native	7.40%	5.31%	6.30%	4.71%	5.93%
Maíz	Maize	*Zea mays*	Native	2.21%	1.14%	1.49%	1.26%	1.53%
Haba	Fava bean	*Vicia faba*	Andeanized	1.58%	0.87%	2.43%	0.73%	1.29%
Cebolla	Onion	*Allium cepa*	Andeanized	1.26%	1.11%	1.24%	1.17%	1.19%
Zanahoria	Carrot	*Daucus carota*	Andeanized	1.22%	1.02%	1.04%	1.21%	1.13%
Trigo	Wheat	*Triticum* sp.	Andeanized	0.70%	0.96%	1.26%	1.06%	0.95%
Maní	Peanut	*Arachis hypogaea*	Native	0.45%	1.02%	0.49%	0.83%	0.73%
Oca	Oca	*Oxalis tuberosa*	Native	0.10%	1.07%	0.23%	0.75%	0.58%
Avena	Oats	*Avena sativa*	Andeanized	0.25%	0.58%	0.23%	0.26%	0.36%
Papalisa	Papalisa	*Ullucus tuberosus*	Native	*	0.67%	*	0.49%	0.33%
Yuca	Cassava	*Manihot esculenta*	Native	*	0.61%	*	0.39%	0.28%
Tomate	Tomato	*Solanum lycopersicum*	Native	0.22%	0.17%	0.21%	0.20%	0.20%
Vainita	Green beans	*Phaseolus vulgaris*	Native	0.19%	0.18%	0.24%	0.18%	0.19%
Palta	Avocado	*Persea americana*	Native	0.38%	*	0.32%	*	0.16%
Pimentón	Bell pepper (fresh)	*Capsicum annum*	Improved	0.12%	0.16%	0.05%	0.14%	0.13%
Quinua	Quinoa	*Chenopodium quinoa*	Native	0.14%	0.06%	0.02%	0.18%	0.10%
Pepino	Cucumber	*Cucumis sativus*	Improved	0.11%	0.04%	0.11%	0.11%	0.09%
Arveja	Peas	*Pisum sativum*	Andeanized	0.12%	0.03%	0.15%	0.10%	0.09%
Achojcha	Achojcha	*Cyclanthera pedata*	Native	0.05%	0.07%	0.07%	0.08%	0.07%
Walusa	Walusa (taro)	*Xanthosoma sagittifolium*	Native	*	0.16%	*	*	0.05%
Manzana	Apple	*Malus domestica*	Andeanized	0.15%	0.01%	0.02%	*	0.05%
Cebada	Barley	*Hordeum vulgare*	Andeanized	*	0.01%	0.03%	0.15%	0.04%
Frijol	Beans	*Phaseolus vulgaris*	Native	0.13%	*	*	*	0.04%
Zapallo	Squash (yellow-fleshed)	*Cucurbita maxima*	Native	0.06%	0.05%	*	0.02%	0.04%
Locoto	Locoto (chile)	*Capsicum pubescens*	Native	0.04%	0.03%	0.03%	0.02%	0.03%
Papaya	Papaya	*Carica papaya*	Native	0.04%	*	*	*	0.01%
Sandía	Watermelon	*Citrullus lanatus*	Native	0.03%	*	*	*	0.01%
Camote	Sweet potato	*Ipomoea batatas*	Native	*	*	*	0.03%	0.01%
Ají	Chile (various)	*Capsicum* spp.	Native	*	*	*	0.03%	0.01%
Tarwi	Andean lupin	*Lupinus mutabilis*	Native	0.01%	*	*	*	*
Carote	Squash (similar to Zucchini)	*Cucurbita pepo*	Native	0.01%	*	*	*	*
Tomate de Arbol	Tree tomato	*Cyphomandra betacea*	Native	*	*	*	*	*
Tumbo	Tumbo (Passion fruit)	*Passiflora mollisima*	Native	*	*	*	*	*
Pacay	Pacay (leguminous fruit)	*Inga feuillei*	Native	*	*	*	*	*
Lacayote	Lacayote (squash)	*Cucurbita ficifolia*	Native	*	*	*	*	*
Maracuya	Maracuya (Passion fruit)	*Passiflora edulis*	Native	*	*	*	*	*
			Totals	40.25%	44.04%	42.24%	38.14%	41.27%

Table does not include caloric contribution of herbs or teas (cilantro, quilquiña, cedrón, jat'aqo, muña, perejil, arrayán; also excludes wild/gathered foods). *Indicates values reported accounted for less than 0.00% of total calories reported for sample/period.

TABLE 9 Summary of ethnographic findings and implications for survey research.

Crop name	Temporal patterning	Implications for nutritional recalls
Potato	Year-long availability (harvest, post-harvest storage, and market), but different varieties are available at different times and have different household and market uses	Question formats should differentiate between potato species and varieties
Oca	Seasonally available, with greater availability during harvest season; post-harvest storage limited; not available year-round in markets	If measuring consumption of oca, data collection should be timed to capture post-harvest consumption and/or storage
Papalisa	Available for brief period following harvest (March/April); post-harvest storage minimal; minimal market availability outside of harvest period	Timing of survey must be precise to capture household consumption
Tarwi	Long post-harvest storage durability but laborious to prepare; often eaten away-from-home as a snack	Surveys focusing recalls on food prepared within-household may miss away-from-home consumption
Fava beans	Can be eaten fresh or dry; has long post-harvest storage and wide inter-regional market circulation; available year-long but fresh most available following harvest season	Systematic differentiation between fresh and dry beans, or household production vs. market-sourced beans, may help shed light on household food security strategies

(vs. those which are consumed locally, but sourced primarily through markets, like high-altitude wheat or quinoa). This section reports general patterns which are relevant across all ecoregions surveyed. Key results are summarized in Table 9.

Potato

Potatoes (*Solanum* spp.) are the main locally produced staple of Andean diets. When local farmers were asked to describe what "food security" meant to them, they referenced the length of time that own-produced potatoes lasted over the course of a given year. Potatoes and *chuño* (a derivative of potato) account for more than 30% of calories reported in the full survey sample. Further, a single native variety of potato, *papa Huaycha,* accounted for a major proportion of caloric availability in three of the surveyed sites. This variety can be classified as native (i.e., not formally improved), and is widely planted because it is suitable for both commercial and household purposes; because it has reliable productivity across a wide altitudinal range; because it has at least moderate resistance to diseases; and because seed is widely available.

But despite the predominance of *papa Huaycha*, "potato" is far from a monolithic category; there are two species and many different varieties of potatoes (at least 60) cultivated in the study region, and these are cultivated for differing culinary, cultural and market purposes. For consumption, potato-producing households generally divide potato into two categories: *harinosa* (floury varieties) and *aguachenta* (watery varieties). *Harinosa* varieties are usually preferred for home consumption, and are used in soups, or boiled to be eaten as an accompaniment to other meals. *Aguachenta* varieties are considered best for frying (e.g., making French fries), and are usually produced primarily for the market. *Papa Huaycha* and *Papa Imilla* (see Tables 6, 7) are *harinosa* varieties, whereas *Papa Holandesa* is an *aguachenta* variety.

Harinosa varieties can include potatoes from the species *Solanum tuberosum* Andigenum group, tetraploid cultivars (4x; usually round tubers) and diploid cultivars (2x; long or oblong tubers; often somewhat wavy). While round-shaped potato varieties, especially larger-sized tubers (e.g., *papa Huaycha*), are often peeled and cut to eat in soups, or cooked to prepare in other dishes, non-commercial native varieties (e.g., *papa qoyllu*) are often prepared by boiling with the skin on, and can be served alongside other dishes, or carried as a self-contained meal for fieldwork (sometimes eaten with cheese or a chile-based sauce, *llajua*). Many of the non-commercial native varieties have brightly colored (blue, red, or yellow) flesh. Some varieties (e.g., *papa Pintaboca, papa Candelero*) have recently experienced increased market demand, both for home and restaurant consumption, and for industry (e.g., the production of purple potato chips).

Households also produce (and eat) varieties of other potato species, including *S. juzepczukii* (in the puna ecoregions) and, less commonly diploid cultivars of *S. tuberosum* Andigenum group (formerly *S. phureja*; usually in the Yungas ecoregion). These are produced in lesser quantities and are typically for home consumption (not market). *S. juzepczukii* varieties often produce small, bitter potatoes, which have historically been used to make *chuño*, a freeze-dried potato of long storage duration. The varieties formerly known as *S. phureja* (*papa pureja*) are distinctive in that they do not have a period of dormancy, and tubers must be replanted soon after they are harvested, enabling multiple cycles of planting and harvest per year (but also increasing labor requirements).

Potatoes may be available in markets throughout the year, due to differing timings of planting and harvest in different parts of the country. With the exception of *pureja* variety, the factors most affecting how long households can live from their potato crops are post-harvest storage conditions and how much they choose to produce. Potatoes do not last long in storage. In high areas where low temperatures predominate, they can be stored for about 4 months, but usually due to the diffuse light of traditional warehouses, after 3 months the potatoes already have sprouts and are slightly dehydrated.

Because some crops are considered "minor" crops for food security (like *S. juzepczukii* varieties in the puna ecoregion), and may be more susceptible to pests and diseases due to climate change (Gregory et al., 2009; Castillo and Plata, 2016; Keleman Saxena et al., 2016a), farmers may choose to produce less of them, dedicating more of their agricultural land and labor to producing varieties that have reliable market and food security uses.

Oca

Oca (*Oxalis tuberosa*) is a tuber crop native to the Andes, which has a sweet flavor, similar to sweet potato, and is rich in Vitamin A (Cadima Fuentes, 2006). In Colomi, it is planted at the beginning of

the rainy season in September–October, and is generally harvested in the main harvest season (March–June), alongside varieties of potato. There are no formally improved varieties of oca in Bolivia; all are farmer-saved and vegetatively propagated.

Freshly harvested oca can be cooked similarly to potato or vegetables, and it is often used as a component of dishes that include many ingredients (like soup or *samay*). Oca can also be boiled or roasted and be served as an accompaniment or side-dish to a meat-based meal. However, in these forms it is usually added for texture and flavor, but not as the meal's basic starch.

Oca has a shelf-life of several weeks to several months, when stored in cool dry conditions. If these conditions are not available, oca tubers can rot, or exit dormancy and begin to sprout. To combat short shelf-lives, oca can also be freeze-dried as *chuño* (like potatoes). However, while the first author (Keleman Saxena) did observe households preparing oca *chuño* during fieldwork for this project, she never observed people consuming it. This conforms to the experiences of the second author (Cadima Fuentes), who observes that local farmers seldom mention crops which are consumed only occasionally, at home, or species that are grown, for example, on the edges of the plots or between the rows of major crops.

Households usually consume farm-produced oca within a few months of harvest, and they may sell excess production as a cash-crop. The seasonal concentration of oca consumption is evidenced in Table 8. In the 2013 (post-planting) survey, only 0.15% of all calories reported across all households came from oca, whereas 0.93% of calories reported in the post-harvest survey of 2014 came from this crop. This more-than-five-fold increase likely reflects the greater seasonal availability of oca in the period of the year immediately following the harvest, vs. declining availability in later parts of the year.

Papalisa

Like oca, papalisa (*Ullucus tuberosus*) is a tuber native to the Andes, planted at the beginning of the rainy season (September–October). The main harvest period is around March/April, near the time of the Easter holidays (*semana santa* in Bolivia). Papalisa does not store well for long periods, and is not typically made into chuño. Papalisa has not been formally improved by plant-breeders in Bolivia, and propagative material (seed tubers) are entirely farmer-circulated.

Papalisa is commonly made for dishes served around *semana santa,* which is a major public holiday in Bolivia, as in much of Latin America. It has a flavor similar to beets and is often used in soup- and stew-type preparations, e.g., *sajta de papalisa*. Many urban migrants return home for *semana santa*, and urban residents also take days off to celebrate.

Because of this, the harvest of papalisa usually produces a large amount at a concentrated time-period. Farmers use some of it for home-consumption, and sell some to meet high market demand during this holiday period. Papalisa is less readily available in markets during the rest of the year. This is reflected in Table 8; papalisa was absent from household culinary recalls conducted in 2013, and accounted for only 0.59% of calories reported in 2014. Notably, neither of these surveys fell within the major period of papalisa harvest, having been conducted in Oct-Dec 2013 and May–July 2014.

Tarwi

Tarwi (*Lupinus mutabilis*) is a protein-rich leguminous crop in the lupin family, native to the Andes. Tarwi is a long-duration crop, both in terms of its growing season and its storage potential. It is planted in the main rainy season, like potatoes, and is not harvested until May–June of the following year. The grain, like a bean, is dry and can be stored for long periods, when protected from pests. Because of its durability, farmers reported waiting to harvest this crop until all other crops were out of their fields. At the time of this research, tarwi had not been formally improved in this region, and the seed system was entirely farmer-circulated.

Preparing tarwi for consumption requires a significant time and water. The grains must first be boiled, like beans. After boiling, they must be rinsed with water for a long period of time in order to remove alkaloids that are toxic. Typically, in rural areas, this rinsing is done by placing a container of boiled tarwi in a clean, cold stream with running water for a period of 3–4 days, to reduce the alkaloid content.

After tarwi has been boiled and rinsed, it can be used for many preparations, but it is most commonly served as a snack (*mote*). People eat the beans one by one, popping them out of their husks with their fingers. Though it may be consumed at home, tarwi is most often sold in small individual portion-sized plastic bags by vendors at roadside toll booths on the highway, and eaten as a snack while traveling. In 2012–2014 it was much less frequently observed in restaurants or home settings, though chefs were experimenting with including tarwi dishes on their menus (e.g., tarwi pure). However, it was near ubiquitous in public transport, particularly on the hour-long route linking Cochabamba and Colomi.

The low reported level of tarwi consumption in the surveys may reflect these consumption patterns. Survey respondents were asked to complete the culinary recall considering the last day that they cooked at home. While this day sometimes coincided with a day when they also went to the market (and hence some food-away-from-home was recorded), in most cases it did not, and hence consumption of tarwi is likely to have been under-reported using this method.

Fava bean

Fava beans (*Vicia faba*, or *haba* in Spanish and Quechua) is a crop originally from the Mediterranean, but considered to be "Andeanized." In addition to being well adapted to high-altitude cultivation, it is thoroughly integrated in Andean cuisine, and is consumed in soups, stewed preparations, as a side-dish, or as a snack (*mote* or toasted grain).

Fava bean is planted at the end of winter—beginning of spring in Colomi (July–September) and comes into production in the following year (January–April). Fava bean can be prepared to eat when it is green, or can be dried and saved to eat later in the year. Fava is a high-producing crop and households often plant it both for home consumption and for sale in the market. Like potato, it has a broad market circulation in Bolivia, due to its long storage capacity (when beans are dried), and to differing timings of production and harvest across different regions of the country.

Fava bean is important as a food-security crop, and may be particularly important in the post-planting season when few other agricultural crops are available. This is evidenced by its relatively

greater importance in the 2013 (post-planting) round of surveys (accounting for 1.58 and 2.43% of all calories in the longitudinal and cross-sectional samples, respectively; see Table 8), vs. the post-harvest round (when it accounted for 0.87 and 0.73% of calories reported for these two groups). The potential for long-term post-harvest storage as dried beans (*haba seca*) may underpin this long-duration importance, though culinary recalls did not systematically differentiate between dried and fresh fava as an ingredient.

Discussion: nutritional survey methodologies for agrobiodiversity and FSN

Describing agrobiodiverse diets

The survey data reported here paints a picture of household diets which rely heavily—although not exclusively—on Native, improved, and Andeanized crops. This is important because this basic characterization is not emphasized in much of the recent literature on agrobiodiversity and FSN. Many recent studies focus on the question of whether, all else being equal, agrobiodiversity does a better job of producing food security outcomes than other available dietary options. However, studies documenting the extent to which local diets rely on agrobiodiversity to cover basic needs are less frequent. The descriptive data presented here demonstrate that agrobiodiversity makes an important contribution to caloric availability at the household level for houses along a wide rural–urban gradient in Bolivia, which is complemented by other shelf-stable processed food options. As such, agrobiodiversity (and particularly potatoes) can be understood as a bedrock of food availability, and hence of food security and nutrition.

The results reported here are consistent with greater consumption of locally cultivated foods (including native crops, improved, and introduced) during the seasons of greatest abundance. Andeanized crops represent an exception to this pattern, which might be explained by the fact that many of the foods in this category, such as wheat, barley, or dried fava beans, can be stored for long periods post-harvest. Hence it may be that the availability of these foods is greater in the post-planting season, relative to other crops.

The consumption patterns reported here may also reflect a more subtle dynamic between the availability of food and the availability of cash. For farming communities (low and high puna and sub-tropics), the time of greatest availability of locally produced food is also an important time of cash influx from the sale of their harvest. People may then use this cash to buy foods they do not cultivate. This dynamic may account for the increased consumption of improved crops in the post-harvest season in these three regions, given that this category includes a group of crops that are usually produced from formally improved (and often purchased) seed, and which may not be grown by all small-scale farmers. A similar dynamic might be reflected in the small increase in processed food in the high puna in the post-harvest season.

Interestingly, meat and animal-based percentage of caloric availability decreased across the three rural sites in the post-harvest, as compared to the post-planting seasons. Though this may seem counter-intuitive, it is consistent with the findings of researchers in the Peruvian Andes. Scurrah et al. (2013), found that in the lean season a greater proportion of the diet came from animal source foods because the availability of other food sources was limited.

The contrast between rural and urban diets observed in this dataset largely tracks what one might expect from the larger literature. Writing on the "nutrition transition" suggests that with greater concentration in urban areas, diets based on animal-source foods and processed foods with higher fat content become more common (Caballero and Popkin, 2002). Accordingly, in the urban survey sample, between 50 and 68% of total caloric availability came from animal-source and processed foods. However, the large decrease in the percentage of calories from processed foods between the post-planting and post-harvest surveys suggests that price and availability may influence urban residents' food sourcing choices. This decrease is not countered by a proportionate increase in any other single category of food. Rather, it appears that urban residents shifted their consumption toward all other crop-type categories during the post-harvest period, when there is a greater abundance of produce at lower prices.

These choices may not be a function of price alone, but also of preference. Many of the residents of urban Cochabamba are recent migrants from rural areas, or descendants of relatively recent rural migrants, and continue to place cultural value on dishes made from locally cultivated foods. For some urban consumers, these consumption patterns may reflect what is known locally as a "nostalgia market," that is a continuation of consumption habits that were developed during childhoods in rural areas, and which they continue as a reinforcement of identity and cultural memory even while living in urban sites.

Capturing temporal patterning in survey methods

The survey data reported demonstrate potatoes to be the most important (and most agrobiodiversity-rich) crop in local diets in the study sites, including both the rural sites and the urban survey site. Most other native and traditional crops made only minor dietary contributions, measured in caloric terms, to local diets. However, ethnographic data describing how locally produced foods are used outside of the narrow frame of a 24-h recall demonstrate some important limitations of the dietary recall dataset. Dietary recall methods—even when carried out in repeat visits to the same household—may miss foods that are consumed seasonally or away-from-home. This is evidenced in the current dataset by seasonal differences in reported consumption (e.g., for fava bean and oca); and by limited reporting of consumption of widely available crops whose key period of consumption does not coincide with the period of the survey (e.g., oca, papalisa).

Hence, while dietary recall surveys may be useful to identify which foods are consumed in high quantities in the regions, days, and seasons of the survey, they may not be suitable for capturing locally produced crops that are most essential for food security in different seasons (e.g., plentiful vs. scarce) or under unexpected conditions (e.g., bad harvest years). A follow-on implication is that in regions prone to scarcity, 24-h recalls under "normal" conditions may underreport "emergency" foods, which are available for consumption when more preferred foods are scarce. In this way, dietary recalls may be prone to underestimating the importance of agrobiodiversity as insurance against hard times.

Adjustments to research methods may correct for some (but not all) of these issues. Panel (repeat-visit) surveys increase the range of circumstances that survey respondents report, but they are expensive and time-consuming, and single-visit household surveys are common. Furthermore, while a single survey timed in the post-harvest season may capture agrobiodiversity in the diet to a greater extent than a pre-harvest survey, even this approach may miss the complex patterning of food availability and consumption over many seasons. That is, foods that can be easily stored for a longer period, like dried fava beans, tarwi or *chuño*, may appear less important in a post-harvest survey precisely because they are being saved for "lean" seasons of the year.

Mixed methods research can compensate for some shortcomings of surveys, especially when qualitative research is undertaken prior to survey design, in order to better understand what will (and will not) be captured if surveys are conducted at specific times of year. For projects and research questions requiring a highly detailed quantitative dataset, more frequent surveys (e.g., quarterly or monthly) with a smaller population size might capture some of the temporal patterning of agrobiodiversity consumption. However, such surveys are time intensive, both for survey-takers and respondents. When undertaking more frequent surveys, it would be necessary to budget adequate time and funds for data management, and it might be appropriate to pay interviewees for their time.

For research questions that do not require highly detailed quantitative data, a lighter-footprint approach might combine ethnographic work with food frequency recalls, querying the timing of consumption of specific locally produced crops which have demonstrated importance for food security, nutrition, or agrobiodiversity conservation. For example, this type of approach might help to capture data about agrobiodiversity consumption that takes place near the times of particular festivities or festivals. Rather than repeating large-scale surveys near all festival periods (which might be difficult due to lack of availability of both interviewers and survey respondents), a sub-sample of a larger survey might be chosen to undertake short food frequency recall immediately following key festive periods (like the Easter holidays), in order to record fluctuations in the consumption of key crops of interest (like papalisa).

Consumption of such crops at occasional festivals (like weddings) might be slightly more difficult to capture, but in many places these types of festivals also cluster seasonally, and may effectively be community-wide events. Hence qualitative work might also identify key moments and points-of-entry (for example, interviewing the preparers of food served at community gathering) to capture the importance of agrobiodiversity during these moments of festival consumption.

Another mixed-methods approach might build on the principles of lot quality assessment sampling (or spot-checking), using a sample of quantitative information as a base for building qualitative information. For example, in another research project on forest-based livelihoods (Fischer et al., 2023), the first author has used surveys to select households for "stratified" semi-structured interviews. This selection takes households that represent the "tails" of a given variable of interest (high and low values), and then approaches these households for follow-up interviews to provide qualitative, contextual data about the conditions that lead to the quantitatively measured outcomes.

Finally, it is also important to consider when and whether surveys (and the quantitative data they provide) are the best approach for understanding the dynamic interactions between agrobiodiversity and food security. Qualitative research can also be designed to approach questions about, for example, the implications of agrobiodiversity loss for households' nutritional choices. Qualitative inquiry can provide information on, for example, what households do to substitute key native crops with other foods when they are not available. Researching these choices can help to identify likely food security strategies in the event of agrobiodiversity disappearance (e.g., replacing one crop with another, vs. replacing agrobiodiversity with processed food), and who is most likely to implement them. This in turn may help to project the larger implications of food-system change, and can help to inform food and agricultural policy in this arena.

Capturing variety-level data via culinary recalls

While the temporal patterning of agrobiodiversity availability and consumption presents challenges to survey methods, household-level surveys can nonetheless be valuable for assessing the role of locally cultivated agrobiodiversity in overall dietary patterns. This is especially so when methods differentiate among varieties that might be counted as a single food in a standard nutritional recall (e.g., among the different species and varieties of potato).

The survey data reported here did this by designing survey questions to prompt respondents to report ingredients used to make dishes, rather than prepared foods. This differs from a standard nutritional recall at an individual level, which might ask someone about how many plates of a given dish (e.g., *sajta de papalisa*) they ate, and would then calculate nutrient content of that dish based on reference values (typical values for that dish). However, the preparation of "typical" dishes can vary widely, as can the presence/absence of specific ingredients in those dishes, depending on cost, availability, and the preparer's preference. Hence a "culinary recall" (asking about food prepared at an ingredient-by-ingredient level, and adjusting caloric availability for the number of people eating at each meal) may be a better approach for detailed assessments of variety-level agrobiodiversity in the diet.

A culinary recall requires some prior knowledge on the part of the survey designer. The culinary recall format used in the current project is shared in Supplementary material. Notably, we did not ask for variety-level data for all types of food reported—this would not have made sense for foods reported outside of the region. Rather, we asked for variety-level data for crops for which there was significant agrobiodiversity (potato, oca, etc.).

This approach is not immune to error, and relies heavily on the knowledge and training of survey enumerators. For example, in the data reported here, mentions of generic "potato" (vs. specific varieties of potato) were higher in the first-round surveys ($N = 180$ mentions; data not shown) than in the second ($N = 138$ mentions; data not shown). Since there is no such thing as a generic potato, this difference likely reflects learning on the part of the survey takers, who became better able to prompt respondents to describe and identify specific potato varieties in the second (2014) round of the survey, as compared to the first.

Training for enumerators introducing them to some of the most commonly named varieties of locally prominent species might help to reduce this error, as might reference materials showing images of

varietal types that enumerators and survey respondents could use for clarification. However, given the fact that agrobiodiversity is managed dynamically *in-situ* (giving the possibility that new varieties might emerge), and that varietal names may have variable relationships with meaningful genetic diversity (Sadiki et al., 2007), surveys of this kind may simply always need to assume some margin of error in measuring varietal diversity.

Units of measurement for agrobiodiversity-as-food

Survey research in this field has emphasized the use of dietary diversity (developed from food-group scores) as a way to better understand the contribution of agrobiodiversity to nutrition (High Level Panel of Experts (HLPE), 2017). There are major advantages to this approach, including ease of survey design and implementation, and the extent to which dietary diversity helps connect nutrition to biodiversity at the scale of larger managed and non-managed ecological landscapes (Powell et al., 2015; High Level Panel of Experts (HLPE), 2017; Gergel et al., 2020). However, like standard 24-h dietary recalls, the methods used to calculate dietary diversity scores are not likely to provide the degree of fine-grained detail that would allow for differentiation among closely related species of crops, or at the sub-species (e.g., variety or landrace) level. This may be a particularly important lacunae for research in centers of origin and diversity of major staple crops, like potatoes, rice, maize, or wheat.

For this reason, the research reported here used caloric contribution of specific varieties to measure the relative contributions of field crop diversity to household diets. Macronutrient reference values for the majority of crop species are relatively widely available, although a focus on calories may under-value the importance of the micronutrient contributions of agrobiodiversity, especially in low-carbohydrate (e.g., lower calorie) foods. Even so, this approach allows for a rough comparison of the importance of, for example, locally cultivated tubers in households' overall diets.

Another approach to measuring the dietary contributions of agrobiodiversity would be to compare micronutrient values of reported crops and varieties. However, this approach poses challenges in a comparative framework, because different crop species and varieties are rich in different micronutrients. Finding a positive association between dietary species richness and micronutrient adequacy, Lachat et al. (2018) proposed dietary species richness as a measure of food biodiversity and nutritional quality. However, this measure may still be too broad to capture the importance of within-species diversity, especially for Andean diets, which rely heavily on potatoes.

Compounding this challenge, research demonstrates that within a species or variety there may be important intra-species variability in the availability of specific micronutrients (King and Gershoff, 1987; George et al., 2002; Campos et al., 2006; de Haan et al., 2010, 2012; Gabriel et al., 2014; Suárez et al., 2014). For example, a study comparing Iron (Fe) and Zinc (Zn) content in native Andean potato species found significant differences in Zn content between species and varieties, and found that while inter-species differences in Fe were not statistically significant, the overall range of Fe content of samples varied by a factor of 6 (ranging from 2.3 to 14.5 mg/kg). Critically, the authors point out, the varieties they analyzed all had higher levels of these two important micronutrients than levels reported in the more widely consumed *papa Huaycha*, suggesting that there is scope for improving micronutrient adequacy in the Andes by promoting the consumption of local potato varieties (Gabriel et al., 2014). Better understanding the extent to which the consumption of micronutrient rich species and varieties of potatoes is already influencing nutritional adequacy in households that consume, for example, purple or yellow-fleshed potatoes vs. white-fleshed potatoes, is an important arena for future research linking agrobiodiversity conservation in staple crops to household diets.

Importance for agrobiodiversity conservation

Data gathered via nutritional surveys does have the potential to shed light on the relationships linking agrobiodiversity and FSN, but such data does not automatically identify how or whether the surrounding food system supports agrobiodiversity conservation. To answer such questions, it is important to have additional information about, for example, the history of plant breeding in the region; major subsistence and market uses of key food crops; and how these crops move from farm to market to table. For such analysis, differentiation at the sub-species (varietal level) may be critical, especially in systems where different varieties have different nutritional and economic values, differing market outlets, and differing culinary uses.

The data on potato varieties presented here offer an example. To understand diet as a driver of agrobiodiversity conservation in this region of Bolivia, it is significant that formal improvement of potato varieties has not led to a differentiation between "commodified" and "non-commodified" seed in the same way as in other crops. Potato is a vegetatively propagated crop, and farmers typically save their seed tubers from year to year, although they may periodically refresh propagative material (especially if viruses have been introduced). The most widely cultivated variety in Colomi, *Papa Huaycha*, has not undergone formal improvement, and while many other widely cultivated varieties in the region have had some formal improvement, and the line between "native" and "improved" varieties is not stark.

This contrasts with a crop like maize, where the choice to use hybrid seed typically implies a commitment to re-purchasing seed every year. For potatoes, the line between farmer-improved varieties and varieties formally improved by crop breeders is much more fluid, as is the line between own-produced seed tubers and "refreshed" seed tubers. (Notably, a similar trend holds for maize in this high-altitude region, where seed is primarily farmer-saved; in Bolivia, hybrid maize is available only for lowland tropical cultivation conditions.)

Hence, for the more commonly consumed species of potato (*S. tuberosum* Andigenum group, diploid and tetraploid cultivars, in this site), small-scale agriculture for a combination of home and market purposes integrates agrobiodiversity conservation with nutrition, relying on annual seed selection by farmers and periodic refreshment of seed. In contrast, for a crop like hybrid maize, high reliance on formally improved varieties for food security may indicate that farmer-derived varieties are being pushed out of the system due to larger political-economic pressures. However, in the food system described here, the reliance on a mixture of "native" and "native improved" varieties can be interpreted to indicate a food system that robustly supports agrobiodiversity conservation for the major potato species (*S. tuberosum* Andigenum group, diploid and tetraploid cultivars).

However, for less widely planted potato varieties and species (e.g., *S. juzepczukii* in puna ecoregions, *papa pureja* in the Yungas,

and some other less pest-resistant varieties of *S. tuberosum* Andigenum group, diploid and tetraploid cultivars), biodiversity conservation is more precarious. These varieties are, to some extent, being out-competed for space in farmers' fields by other potato varieties, or other crops. This competition is attributable in some part to changing climatic and market factors which make yields of these varieties less reliable for farmers (*cf.* Keleman Saxena et al., 2016a,b), thereby curtailing their utility as food security crops for households. Even so, biodiversity conservation is dynamic, and it may not be necessary for species or varietal diversity to be distributed evenly across households for diversity to remain in the system. A few farmers who are "custodians" of rare varieties may effectively maintain and re-introduce seed to other farmers (even other "custodians"), supporting the conservation of varieties which are "minor" for day-to-day food security, but remain valued for their cultural meanings or uses.

For these less widely planted crops, research and development interventions may also be possible to help maintain agrobiodiversity in the food system. For example, in the time since the research reported here was conducted, Fundación PROINPA (the local project partner) has undertaken significant efforts to bolster the presence of tarwi in the food system. Formal crop improvement work by PROINPA has resulted in 4 new varieties of tarwi, now registered in Bolivia's National Registry of Varieties (though their diffusion is still limited due to the lack of a formal seed production system). In parallel, PROINPA has also promoted the development of a small company, PANASERI[4] which processes tarwi under high-standard sanitary conditions. This results in a commercial tarwi product (mote de tarwi) which can be consumed with the husk on. This is recommended because of the calcium and fiber content of the husk. In the long-run, such developments have the potential to increase both the supply of tarwi seed and market demand for the product within an urbanizing context, bolstering agrobiodiversity-driven food security in the Cochabamba food system.

Conclusion

This article considers the importance of understanding the spatial and temporal patterning of local food availability and consumption in order to better assess the role that agrobiodiversity plays in FSN in high-agrobiodiversity regions. It also shows evidence that this temporal patterning may relate to spatial patterns in consumption, especially in food consumed away from home (e.g., tarwi). Both spatial and temporal patterning of agrobiodiversity consumption, if not accounted for in nutritional surveys, may limit the extent to which important elements of agrobiodiversity are captured by standard dietary recall methods.

These observations coincide with both past and current conversations in the larger literature on agrobiodiversity conservation and smallholder agriculture. In the early 2000s, Karl Zimmerer, a prominent scholar of agrobiodiversity in the Andes, published an article with the title "Just small potatoes (and ulluco)?" which examined the relationship between seed size micro-variation in cultivated lands in the high-altitude Andes. His mixed-methods data called into question the predominant narrative that larger tubers were "better" seed than small tubers, demonstrating that farmers saw advantages and disadvantages to each, and that they preferred to plant large tubers in areas that were more likely to be drought-stressed, reserving smaller tubers for higher-altitude, less stressed agricultural sites (Zimmerer, 2003). These data demonstrated that farmers' seed-saving practices were difficult to assess by a singular size-based metric (e.g., small vs. large tubers), and rather responded contextually to spatial variations in the agroecological environment.

More recent literature examining the role of non-cultivated biodiversity in FSN (Gergel et al., 2020) makes a similar argument at a larger scale. The authors note that different forest types—that is, not only primary forest, but also disturbed secondary forest, edge habitats, agroforestry, and others—can make important contributions to diets. They argue that understanding land cover complexity, or the distribution of these types in relationship to forest users' needs, uses, and access, is critical to assessing the role of wild biodiversity in FSN. Such observations suggest that understanding the interlinkages between agrobiodiversity and FSN requires these relationships to be spatially contextualized.

The present article contributes to scholarly conversations about the methodologies needed to measure the nutritional contribution of "small potatoes," or other native, traditional, and/or locally produced crops, emphasizing the importance of not only spatial context, but also temporal patterning. This is important because farmers conserve, and consume, locally produced, agrobiodiverse foods for reasons which go beyond nutritional input; they are also important esthetically (Weaver et al., 2019), and for reasons of cultural memory and food sovereignty (Nazarea, 2006). Hence, policy recommendations derived from studies whose methods do not to account for temporal and spatial patterning of agrobiodiversity consumption risk downplaying the importance of locally produced crop species and varieties. Researchers can better align their work with intersectionality-based approaches (Hankivsky et al., 2014) by adopting mixed-methods approaches which will allow them to better target the timing of survey-based research, and to assess what can—and cannot—be measured in the time-frames adopted for nutritional recalls.

Data availability statement

The datasets presented in this article are not readily available because generalized data re-use statements for human subjects research were only required for data collection starting in 2017. As the IRB approval for this project was solicited and granted in 2012, the data was collected with the assumption that it would be held in confidence by the research team and not used for future purposes not in keeping with the initial research questions. Inquiries about the data should be directed to alder.keleman-saxena@nau.edu.

Ethics statement

The studies involving human participants were reviewed and approved by the Yale University Human Subjects Committee. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

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Author contributions

AKS had primary responsibility for research conceptualization, data collection, data analysis, and writing. XCF advised research design, facilitated data collection, and contributed to interpretation of results. DH advised and oversaw research design, data collection, and data analysis, and contributed to the conceptualization and writing of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1000735/full#supplementary-material

References

Anderzén, J., Guzmán Luna, A., Luna-González, D. V., Merrill, S. C., Caswell, M., Méndez, V. E., et al. (2020). Effects of on-farm diversification strategies on smallholder coffee farmer food security and income sufficiency in Chiapas, Mexico. *J. Rural Stud.* 77, 33–46. doi: 10.1016/j.jrurstud.2020.04.001

Barrett, C. B. (2010). Measuring food insecurity. *Science* 327, 825–828. doi: 10.1126/science.1182768

Berti, P. R. (2015). Relationship between production diversity and dietary diversity depends on how number of foods is counted. *Proc. Natl. Acad. Sci. U. S. A.* 112:E5656. doi: 10.1073/pnas.1517006112

Berti, P. R., and Jones, A. D. (2013). "Biodiversity's contribution to dietary diversity: magnitude, meaning, and measurement" in *Diversifying food and diets: using agricultural biodiversity to improve nutrition and health*. eds. J. Fanzo, D. Hunter, T. Borelli and F. Mattei (London: Routledge), 186–206.

Caballero, B., and Popkin, B. M. (2002). "Introduction" in *The nutrition transition*. eds. B. Caballero and B. M. Popkin (New York, NY: Elsevier), 1–6.

Cadima Fuentes, X. (2006). "Tubérculos" in *Botánica económica de los Andes Centrales*. eds. M. Moraes Ramírez, B. Ollgaard, L. P. Kvist, F. Borchsenius and H. Balslev (La Paz: Universidad Mayor de San Andrés), 347–369.

Campos, D., Noratto, G., Chirinos, R., Arbizu, C., Roca, W., and Cisneros-Zevallos, L. (2006). Antioxidant capacity and secondary metabolites in four species of Andean tuber crops: native potato (*Solanum* sp.), mashua (*Tropaeolum tuberosum* Ruiz & Pavón), Oca (*Oxalis tuberosa* Molina) and ulluco (*Ullucus tuberosus* Caldas). *J. Sci. Food Agric.* 86, 1481–1488. doi: 10.1002/jsfa.2529

Castillo, J. A., and Plata, G. (2016). The expansion of brown rot disease throughout Bolivia: possible role of climate change. *Can. J. Microbiol.* 62, 442–448. doi: 10.1139/cjm-2015-0665

Coa, R., and Ochoa, L. (2009). Bolivia: *Encuesta Nacional de Demografía y Salud*. Ministerio de Salud y Deportes y Instituto Nacional de Estadística. La Paz, Bolivia.

de Haan, S., Burgos, G., Arcos, J., Ccanto, R., Scurrah, M., Salas, E., et al. (2010). Traditional processing of black and white Chuño in the Peruvian Andes: regional variants and effect on the mineral content of native potato cultivars. *Econ. Bot.* 64, 217–234. doi: 10.1007/s12231-010-9128-x

de Haan, S., Burgos, G., Ccanto, R., Arcos, J., Scurrah, M., Salas, E., et al. (2012). Effect of production environment, genotype and process on the mineral content of native bitter potato cultivars converted into white chuño: effect of production environment, genotype and process on mineral content in white chuño. *J. Sci. Food Agric.* 92, 2098–2105. doi: 10.1002/jsfa.5589

Ekesa, B., Walingo, M., and Abukutsa-Onyango, M. (2009). Influence of agricultural biodiversity on dietary diversity of preschool children in Matungu division, western Kenya. *Afr. J. Food Agric. Nutr. Dev.* 8, 390–404. doi: 10.4314/ajfand.v8i4.19200

Erhardt, J. A. (2007). *Nutrisurvey*. Stuttgart, Germany: University of Hohenheim.

Fischer, H., Saxena, A., Saxena, A. K., Dutta, A., and Jantz, P. (2023). *Creating evidence for forest based resilience during Covid-19*. SLU.SE. Available at: https://www.slu.se/en/departments/urban-rural-development/research/rural-development/finished-projects/forest-based-resilience/ (Accessed May 20, 2023).

Food and Agriculture Organization of the United Nations. (1999). Sustaining the multiple functions of agricultural biodiversity (background paper no. 1, cultivating our futures). FAO/Netherlands Conference on "The multifunctional character of agriculture and land," Maastricht.

Food Fortification Initiative. (n.d.). *Americas: region profile [WWW Document]. Food fortification initiative enhancing grains healthier lives*. Available at: https://www.ffinetwork.org/americas (Accessed July 21, 2022).

Gabriel, J., Botello, R., Casazola, J. L., Vera, R., Rodríguez, F., and Angulo, A. (2014). Revalorización de las papas nativas de Bolivia (*Solanum tuberosum* L.) como fuente de hierro y zinc. *J. Selva Andina Res. Soc.* 5, 3–12. doi: 10.36610/j.jsars.2014.050100003

George, M. S., Lu, G., and Zhou, W. (2002). Genotypic variation for potassium uptake and utilization efficiency in sweet potato (*Ipomoea batatas* L.). *Field Crops Res.* 77, 7–15. doi: 10.1016/S0378-4290(02)00043-6

Gergel, S. E., Powell, B., Baudron, F., Wood, S. L. R., Rhemtulla, J. M., Kennedy, G., et al. (2020). Conceptual links between landscape diversity and diet diversity: a roadmap for transdisciplinary research. *Bioscience* 70, 563–575. doi: 10.1093/biosci/biaa048

Gibson, R. S. (2022). *Principles of nutritional assessment. 3rd Edn*. Oxford, UK: Oxford University Press.

Gitagia, M. W., Ramkat, R. C., Mituki, D. M., Termote, C., Covic, N., and Cheserek, M. J. (2019). Determinants of dietary diversity among women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru, Kenya. *Food Nutr. Res.* 63. doi: 10.29219/fnr.v63.1553

Gregory, P. J., Johnson, S. N., Newton, A. C., and Ingram, J. S. I. (2009). Integrating pests and pathogens into the climate change/food security debate. *J. Exp. Bot.* 60, 2827–2838. doi: 10.1093/jxb/erp080

Hankivsky, O., Grace, D., Hunting, G., Giesbrecht, M., Fridkin, A., Rudrum, S., et al. (2014). An intersectionality-based policy analysis framework: critical reflections on a methodology for advancing equity. *Int. J. Equity Health* 13:119. doi: 10.1186/s12939-014-0119-x

High Level Panel of Experts (HLPE) (2017). *Sustainable Forestry for Food Security and Nutrition*. HLPE Report #11. Rome, Italy: FAO Committee on World Food Security (CFS).

Ickowitz, A., Powell, B., Salim, M. A., and Sunderland, T. C. H. (2014). Dietary quality and tree cover in Africa. *Glob. Environ. Change* 24, 287–294. doi: 10.1016/j.gloenvcha.2013.12.001

Instituto Nacional de Estadística Bolivia (2017). *Encuesta de Demografia y Salud EDSA-2016*. Instituto Nacional de Estadística Bolivia, La Paz, Bolivia.

Jones, A. D. (2017). Critical review of the emerging research evidence on agricultural biodiversity, diet diversity, and nutritional status in low- and middle-income countries. *Nutr. Rev.* 75, 769–782. doi: 10.1093/nutrit/nux040

Jones, A. D. (2014). The production diversity of subsistence farms in the Bolivian Andes is associated with the quality of child feeding practices as measured by a validated summary feeding index. *Public Health Nutr.* 18, 329–342. doi: 10.1017/S1368980014000123

Jones, A. D., Creed-Kanashiro, H., Zimmerer, K. S., de Haan, S., Carrasco, M., Meza, K., et al. (2018). Farm-level agricultural biodiversity in the Peruvian Andes is associated with greater odds of women achieving a minimally diverse and micronutrient adequate diet. *J. Nutr.* 148, 1625–1637. doi: 10.1093/jn/nxy166

Jones, A. D., Shrinivas, A., and Bezner-Kerr, R. (2014). Farm production diversity is associated with greater household dietary diversity in Malawi: findings from nationally representative data. *Food Policy* 46, 1–12. doi: 10.1016/j.foodpol.2014.02.001

Keleman Saxena, A. (2017). *Out of the field and into the kitchen: agrobiodiversity, food security, and food culture in Cochabamba, Bolivia (doctoral dissertation)*. Yale University, New Haven, CT.

Keleman Saxena, A., Cadima Fuentes, X., Gonzales Herbas, R., and Humphries, D. L. (2016a). Indigenous food systems and climate change: impacts of climatic shifts on the production and processing of native and traditional crops in the Bolivian Andes. *Front. Public Health* 4:20. doi: 10.3389/fpubh.2016.00020

Keleman Saxena, A., Cadima Fuentes, X., Illanes Velarde, D., and Humphries, D. (2016b). Consumption of native and traditional crops in Bolivia varies along an ecoregional gradient. *FASEB J.* 30:891.12. doi: 10.1096/fasebj.30.1_supplement.891.12

Keleman Saxena, A., Sampso, D., Cely Santos, M., Limeberry, V., Luna González, D. V., Montenegro de Wit, M., et al. How Agrobiodiversity Nourishes: Mapping causal webs that generate agrobiodiversity, food security, food sovereignty, and nutrition. Manuscript submitted for publication.

King, S. R., and Gershoff, S. N. (1987). Nutritional evaluation of three underexploited andean tubers:*Oxalis tuberosa* (Oxalidaceae),*Ullucus tuberosus* (Basellaceae), And*tropaeolum tuberosum* (Tropaeolaceae). *Econ. Bot.* 41, 503–511. doi: 10.1007/BF02908144

Lachat, C., Raneri, J. E., Smith, K. W., Kolsteren, P., Van Damme, P., Verzelen, K., et al. (2018). Dietary species richness as a measure of food biodiversity and nutritional quality of diets. *Proc. Natl. Acad. Sci. U. S. A.* 115, 127–132. doi: 10.1073/pnas.1709194115

Larson, B., Harris, O., and Tandeter, E. (Eds.) (1995). *Ethnicity, markets, and migration in the Andes: at the crossroads of history and anthropology*. Duke University Press, Durham.

Larson, B. (1998). *Cochabamba, 1550-1900: Colonialism and agrarian transformation in Bolivia*. Durham, NC: Duke University Press.

Lourme-Ruiz, A., Dury, S., and Martin-Prével, Y. (2021). Linkages between dietary diversity and indicators of agricultural biodiversity in Burkina Faso. *Food Secur.* 13, 329–349. doi: 10.1007/s12571-020-01137-5

Luna-González, D. V., and Sørensen, M. (2018). Higher agrobiodiversity is associated with improved dietary diversity, but not child anthropometric status, of Mayan Achí people of Guatemala. *Public Health Nutr.* 21, 2128–2141. doi: 10.1017/S1368980018000617

Lynn, L. (n.d.) *Fried Bread (Bunuelo) Recipe [WWW Document]*. https://www.food.com/recipe/fried-bread-bunuelo-307915 (Accessed May 3, 2023).

Meadows, D. H. (1999). *Leverage points: places to intervene in a system*. The Sustainability Institute, Hartland, VT.

M'Kaibi, F. K., Steyn, N. P., Ochola, S. A., and Du Plessis, L. (2017). The relationship between agricultural biodiversity, dietary diversity, household food security, and stunting of children in rural Kenya. *Food Sci. Nutr.* 5, 243–254. doi: 10.1002/fsn3.387

Murra, J. V. (1985). "'El archipelago vertical' revisited" in *Andean ecology and civilization*. eds. S. Masuda, I. Shimada and C. Morris (Tokyo, Japan: University of Tokyo Press), 3–13.

Nazarea, V. D. (2006). Local knowledge and memory in biodiversity conservation. *Annu. Rev. Anthropol.* 35, 317–335. doi: 10.1146/annurev.anthro.35.081705.123252

Neito, C., C., Estrella, E. J. (2011). La Agrobiodiversidad en los Ecosistemas de Páramo: Una primera aproximación a su situación actual. in P. Mena Vásconez, A. Castillo, S. Flores, R. Hofstede, C. Josse and B. Lasso, S., G. Medina, N. Ochoa and D. Ortiz (Eds.), *Páramo: paisaje estudiado, habitado, manejado e institucionalizado*. ECOBONA, Quito, 41–62.

Powell, B., Bezner Kerr, R., Young, S. L., and Johns, T. (2017). The determinants of dietary diversity and nutrition: ethnonutrition knowledge of local people in the east Usambara Mountains, Tanzania. *J. Ethnobiol. Ethnomedicine* 13:23. doi: 10.1186/s13002-017-0150-2

Powell, B., Hall, J., and Johns, T. (2011). Forest cover, use and dietary intake in the east Usambara Mountains, Tanzania. *Int. For. Rev.* 13, 305–317. doi: 10.1505/146554811798293944

Powell, B., Thilsted, S. H., Ickowitz, A., Termote, C., Sunderland, T., and Herforth, A. (2015). Improving diets with wild and cultivated biodiversity from across the landscape. *Food Secur.* 7, 535–554. doi: 10.1007/s12571-015-0466-5

Remans, R., Wood, S. A., Saha, N., Anderman, T. L., and DeFries, R. S. (2014). Measuring nutritional diversity of national food supplies. *Glob. Food Secur.* 3, 174–182. doi: 10.1016/j.gfs.2014.07.001

Saaka, M., Osman, S. M., and Hoeschle-Zeledon, I. (2017). Relationship between agricultural biodiversity and dietary diversity of children aged 6-36 months in rural areas of northern Ghana. *Food Nutr. Res.* 61:1391668. doi: 10.1080/16546628.2017.1391668

Sadiki, M., Jarvis, D. I., Rijal, D., Bajracharya, J., Hue, N. N., Camacho Villa, T. C., et al. (2007). "Variety names: an entry point to crop genetic diversity and distribution in agroecosystems?" in *Managing biodiversity in agricultural ecosystems*. eds. D. I. Jarvis, C. Padoch and H. D. Cooper (New York, NY: Columbia University Press), 34–76.

Sauer, K. O. (1969). *Seeds, spades, hearths, and herds: the domestication of animals and foodstuffs*. MIT Press, Cambridge, MA.

Scurrah, M., Creed-Kanashiro, H., de Haan, S., Olivera, E., Ccanto, R., Carrasco, M., et al. (2013). Rich in agrobiodiversity but poor in nutrition: food security in communities of Chopcca, Huancavelica, Perú. Annals of nutrition and metabolism: paralleled Symposia. Presented at the 20th International Congress of Nutrition, Granada.

Scurrah, M., de Haan, S., Olivera, E., Ccanto, R. C., Creed-Kanashiro, H., Carrasco, M., et al. (2011). Ricos en agrobiodiversidad, pero pobres en nutricion: desafios de la mejora de la seguridad alimentaria en comunidades de Chopcca, Huancavelica [Peru]. Peru: El Problema Agrario En Debate SEPIA XIV: Dinamicas Territoriales, Seguridad Alimentaria, Desafios Ambientales, Mesa Regional: Piura. Seminario Permanente de Investigacion Agraria (SEPIA). Lima, 362–407.

Skarbø, K. (2014). The cooked is the kept: factors shaping the maintenance of agro-biodiversity in the Andes. *Hum. Ecol.* 42, 711–726. doi: 10.1007/s10745-014-9685-1

Suárez, S., Ale, N., Trabucco, J., and Sanabria, O. (2014). Polifenoles, micronutrientes minerales y potencial antioxidante de papas nativas. *Rev. Soc. Quím. Perú* 80, 108–114. doi: 10.37761/rsqp.v80i2.155

Tejada Campos, T. N. (2008). *El cultivo de trigo en la sierra norte del Perú: Triticum aestivum L. y Triticum durum L., Estación Experimental Agraria Baños del Inca*, Instituto Nacional de Innovación Agraria. Cajamarca.

Vavilov, N. (1926). *Studies on the origin of cultivated plants*. Institute of Applied Botany and Plant Improvement, Leningrad.

Weaver, L. J., Tadess, Y., Stevenson, E. G. J., and Hadley, C. (2019). "I want variety!": dietary variety as aesthetic pursuit, social signal, and nutritional vehicle in Brazil and Ethiopia. *Hum. Organ.* 78, 122–132. doi: 10.17730/0018-7259.78.2.122

Zhang, W., Gowdy, J., Bassi, A. M., Santamaria, M., deClerck, F., Adegboyega, A., et al. (2018). "Systems thinking: an approach for understanding `eco-agri-food systems,'" in *TEEB for Agriculture & Food: Scientific and Economic Foundations*. ed. The Economics of Ecosystems and Biodiversity (TEEB) (Geneva, Switzerland: UN Environment), 17–55.

Zimmerer, K. S. (2003). Just small potatoes (and ulluco)? The use of seed-size variation in "native commercialized" agriculture and agrobiodiversity conservation among Peruvian farmers. *Agric. Hum. Values* 20, 107–123. doi: 10.1023/A:1024097008693

Zimmerer, K. S. (1998). The ecogeography of Andean potatoes. *Bioscience* 48, 445–454. doi: 10.2307/1313242

Zimmerer, K. S. (1996). *Changing fortunes: biodiversity and peasant livelihood in the Peruvian Andes, California studies in critical human geography*. University of California Press, Berkeley, CA.

Zimmerer, K. S., de Haan, S., Jones, A. D., Creed-Kanashiro, H., Tello, M., Amaya, F. P., et al. (2020). Indigenous smallholder struggles in Peru: nutrition security, Agrobiodiversity, and food sovereignty amid transforming global systems and climate change. *J. Lat. Am. Geogr.* 19, 74–111. doi: 10.1353/lag.2020.0072

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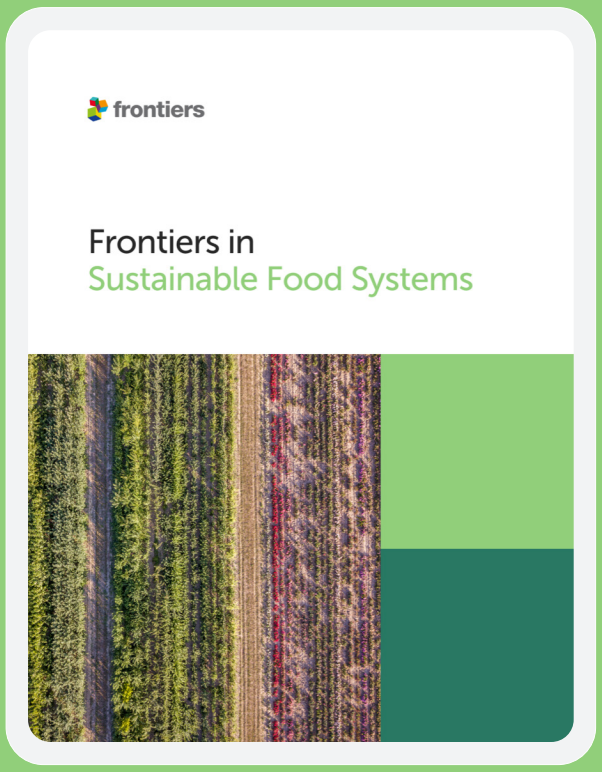

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