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Food Security and Climate Change: Differences in Impacts and Adaptation Strategies for Rural Communities in the Global South and North

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This research highlights the mismatch between food security and climate adaptation literature and practice in the Global North and South by focusing on nested case studies in rural India and the United States during the COVID-19 pandemic. The United States is one of the wealthiest countries in the world, but also has one of the largest wealth gaps. Comparatively, India has one of the largest populations of food insecure people. To demonstrate how adaptive food security approaches to climate change will differ, we first review the unique climate, agricultural, demographic, and socio-economic features; and then compare challenges and solutions to food security posed by the COVID-19 pandemic. While both countries rely on rural, low-income farmworkers to produce food, the COVID-19 pandemic has highlighted how agricultural and food security policies differ in their influence on both food insecurity and global hunger alike. Emphasis on agricultural production in developing regions where a majority of individuals living in rural areas are smallholder subsistence farmers will benefit the majority of the population in terms of both poverty alleviation and food production. In the Global North, an emphasis on food access and availability is necessary because rural food insecure populations are often disconnected from food production.

Keywords: climate impacts, COVID-19, food access, food availability, India

INTRODUCTION

Climate change will affect both food security and the livelihoods of those engaged in production systems and their value chains. Already, the number of people affected by hunger globally has been on the rise since 2014 despite food production doubling over the last 3 decades (FAO, 2020). Over the course of 2019 "two billion people, or 25.9% of the global population, experienced hunger or did not have regular access to nutritious and sufficient food" (FAO, 2020, viii). Multiple pathways increase the number of food insecure people by shaping poverty, disaster recovery and migration patterns (Hertel et al., 2010; Lobell and Burke, 2010; Vermeulen et al., 2012; Wheeler and Von Braun, 2013; Porter et al., 2014).

Climate change also impacts agricultural production, supply chains and pricing. Production is projected to decline in tropical regions, while temperate regions will see some gains (Hertel et al., 2010; Lobell and Burke, 2010; Hertel and Lobell, 2014); but warming beyond crop thresholds will induce yield declines even in temperate regions (Peet and Wolfe, 2009; Wolfe, 2013). Countries bearing the brunt of changes in arability and production losses are also home to some of the poorest and most food-insecure (Fischer et al., 2005; Mendelsohn et al., 2006, 2007; Hertel et al., 2010; Lobell and Burke, 2010; Akter and Basher, 2014; Hertel and Lobell, 2014). Some models predict 120 million more people will become undernourished and under a high population growth pathway we can expect to see 175 million more undernourished individuals by 2080 (Fischer et al., 2005).

In order to meet future food needs scholars must consider changes not only in global demographics and climate impacts on food security (Lobell and Burke, 2010) but also the degree to which food and production systems can adapt (Lobell and Burke, 2010; Porter et al., 2014). Downstream, food access is linked to a stable food supply chain. Climate impacts disrupt the food supply chain and cut-off physical access to markets in several ways. Extreme weather events such as heavy precipitation—floods and snow—and storms affect public infrastructure, damaging roads and bridges, inundating transportation networks, and creating hazardous conditions for people to physically access markets (Koetse and Rietveld, 2009; Nissen and Ulbrich, 2017). In the U.S, post Harvey, Sandy, and Katrina, supermarkets struggled with limited stock as flooded infrastructure kept distribution centers from resupplying (Zeuli and Nijhuis, 2017; National Academies of Sciences, Engineering, and Medicine, 2020), in turn spurring intermittent spikes in food prices (Vermeulen et al., 2012). Following Tropical Cyclone Pam in the South Pacific, researchers noted that food prices increased three times the normal price in both Fiji and Vanuatu, making staples unaffordable for most (Magee et al., 2016). Price increases in food and food related services will especially affect low-income agricultural dependent economies who are net food importers (Hertel et al., 2010; Brown, 2014). Subsistence food resources are also undermined (Brinkman et al., 2016). For example, erratic and extreme weather conditions in arctic communities lead to increased injuries and deaths while hunting and fishing (Laidler et al., 2009).

Rural communities make for interesting case studies as they are paradoxically sites of both food production and food insecurity for both the Global North and the Global South (Hertel and Rosch, 2010). While there is little consensus on what constitutes rural, the United Nations Department of Economics and Social Affairs (UNDESA, 2019) estimates that close to 3.4 billion people live in rural areas globally. Africa and Asia are home to 90% of the world's rural population and a majority (70%) of the rural population is considered poor (UNDESA, 2019). While in the Global North, only 22% of the population is rural and poverty is not as pervasive or entrenched relative to the Global South (UNDESA, 2019). Globally, those that live in rural areas rely predominantly on smallholder subsistence farming for sustenance and livelihood (Baez et al., 2013; Brown, 2014). Despite being involved in food production, food makes up the largest portion of the budget for these individuals (Hertel and Rosch, 2010).

In both the Global South and North, rural and impoverished people will be particularly vulnerable to climate change impacts on food security (FAO, 2020). While rural communities in the Global North have more adaptive capacity and social safety nets to buffer them from climate change effects, the majority of rural poor in the Global North are often not directly involved in farming for their livelihoods (Primdahl et al., 2013; Zasada et al., 2013; Verhoeve et al., 2015). We hypothesize that the rural poor in the North will not directly benefit from adaptation efforts focused exclusively on food production. In contrast, the vast majority of the rural population in most Global South countries are small landholder subsistence farmers who will directly benefit from research and outreach efforts focused on farm-level adaptation. The determinants of food security also differ globally and hence we hypothesize that unique, case-specific strategies for adaptation are required.

To understand potential adaptive responses to food insecurity during climate change, we draw on two case studies of emergency food provisioning in rural communities during the COVID-19 pandemic. In so doing, we review unique climate, agricultural, demographic, and socio-economic features of rural populations in the Global South and North through the case studies based in the United States and India, countries which are both important to the global food supply chain and have large acreages of land in agriculture. In the case of the US, we use an agriculturally dependent, rural community, Madera County, California as an illustrative example of the American food system, while in India we chose the agrarian state of Kerala. We describe food system attributes of the nested cases below in **Table 1**[1]. Due to a mismatch in geographical boundaries and lack of data for district level food system mapping in India, we use state level data. In the case of India, because State and local government policy is so closely mirrored, we believe State level data captures local conditions sufficiently for the purposes of this study.

Global North Case Study

The American Food System: Disconnected and Disparate

In the United States reliance on agriculture and food production in rural areas for livelihoods is much less pronounced relative to rural communities in the Global South. The United States comprises, 50 states, and 3,143 counties (Parker, 2015; USDA, 2015). Only 14% of these counties are dependent on agriculture (USDA, 2015). Of the agriculturally dependent counties, 67 have persistent poverty (USDA, 2015).

The current American food system is a reflection of a century of food system modernization. Early 1900's was a time of laboriously intensive agriculture that employed 41% of the workforce, on small diversified farms producing *on average 5 commodities* per farm (Dimitri et al., 2005). A third of the

[1]Data for this table is sourced from Menon et al. (2009), Government of Kerala (2016), Government of India (2019), U.S. Census Bureau (2019), USDA (2019), and FAO (2020).

TABLE 1 | Comparative nested case study area attributes.

Food system attribute	United States	Madera County	India	State of Kerala
Number of farms	2,042,220	1,386	146 million	7.5 million
Land in agriculture	364 million hectares	261,167 hectares	194 million hectares	1.4 million hectares
Value of agricultural products	$388 billion	$1.49 billion	$38.5 billion	$6.54 billion
Direct sales	Only 6% of US farms sold directly to consumers	Only 4% of Madera County's farms sold directly to consumers	98% of the population buys food and produce from traditional markets (farm stand and farmers markets) supplied by farmers	
% food insecure	10.7% (35.2 million people)	13% (20,500 people)	14% (189 million people)	28.6% (9.4 million people)
% rural population	14% (46.1 million people)	47% (73,157 people)	65% (people)	53% (17.5million people)

country lived on farms and farming sustained their livelihoods, whereas today only 2% of the population lives on a farm (Dimitri et al., 2005). The rise of farm mechanization—the green revolution of the 1960's—was especially powerful in changing the dynamics of family farming (Lobao and Meyer, 2001). The increased efficiency and productivity of mechanization reduced labor requirements from 11 hectares/worker in the beginning of the twentieth century to 299 hectares/worker in 1990 (Spittler et al., 2011). Farm numbers have dwindled—from 6.8 million farms in 1935 to 2.1 million farms in 2002 (Spittler et al., 2011) but farms are more productive today than before due to availability and increased use of agricultural inputs: chemicals, fertilizer, pesticides and herbicides to reach the current levels of productivity (Dimitri et al., 2005).

Despite the domination of family farms, there is much inequality among farmers and concentration of wealth (Lobao and Meyer, 2001). Family farms are responsible for 85% of agricultural production in the U.S., but two-thirds of family farms earned <$50,000 in sales and made up only 3% of U.S agricultural production sales (USDA, 2014, 2015). While 4.5% of farms had sales of $1 million or more and produced 97% of agricultural products sold in 2012 (USDA, 2015). More and more farmer households are pursuing off farm income to offset farm risks: ∼33% in 1930 to 93% of farms earning off farm income 2012 (USDA, 2014). These changes in structure, wealth, specialization and technology have transformed agriculture, farming, and the American food system.

The changes in the structure of the food system, also changed how people interact with the food system. Americans procure groceries from food retail outlets and direct purchasing of food from farmers and farms remains extremely low. Through initiatives such as "Know Your Farmer, Know Your Food," and the 2008 Farm Bill (The Food, Conservation, and Energy Act of 2008. HR 6124), the US government has made a concerted effort to reconnect food producers and consumers (Park et al., 2014). However, although such initiatives have allowed *some* food producers to engage in different sales tactics such as direct marketing to consumers, though the results have not been as fruitful as hoped (Park et al., 2018; O'Hara and Low, 2020; Plakias et al., 2020).

Overall, the United States is a net exporter of food; on average there is more than enough food produced in the country to meet the dietary needs of all people in the country (Maxwell, 2019). Despite the level of food production and abundance of food in the United States, in 2019 10.5% of households were considered food insecure (Coleman-Jensen et al., 2020). Given the degree of separation between food production and consumption in the American food system, climate impacts on food production alone will not immediately impact consumption patterns or levels of food security in U.S. communities.

Determinants of Food Insecurity in the United States

Multiple factors contribute to high levels of food insecurity in rural areas in the U.S.: policy oversight of rural food systems, socio-economic dynamics of rural areas, and structural inequities. We explain the structural and policy mediators that lead to food insecurity by modifying the construct of availability in the North American context—access and use remain the same. Availability in this case is described as the presence of healthy and nutritious food at the neighborhood level. Most individuals living in rural areas, even those that are involved in agriculture, are not subsistence farmers but purchase a large amount of their food from food retailers (Jones et al., 2014; Sibhatu et al., 2015; Sibhatu and Qaim, 2017). Hence understanding the spatial distribution of food retail in rural areas and how this spatial distribution can impede the availability of healthful and nutritious food is important (Raja et al., 2008).

Rural areas in the United States are synonymous with consolidation of grocers (Sharkey, 2009; Piontak and Schulman, 2014). Between 2007 and 2011 rural counties lost 5.7% of its grocery stores (Piontak and Schulman, 2014). In a study looking at rural counties with high rates of poverty, researchers found supermarkets were more prevalent in urban counties than in rural counties (Morris et al., 1992). Supermarkets were also distributed in close proximity to each other in urban counties in comparison to rural counties: one supermarket every 75 square kilometers in an urban county while supermarkets were on average 686 square kilometers away in rural counties (Morris et al., 1992). Small and medium stores that are more prevalent in rural settings also offer limited selection of healthy produce: 23% of retail in the study stocked no vegetables and one in three did not have fruits (Morris et al., 1992). Residents in rural counties are frustrated with the lack of choice available to them both in terms of retail options and food options available in-store (Sharkey, 2009; Smith and Morton, 2009; Ramadurai et al.,

2012). This pattern of food retail distribution gives rise to large swaths of development without supermarkets or grocery stores in a 16 kilometer radius at the neighborhood level, described as "food deserts" by the USDA (Sharkey, 2009). There are 448 counties in the United States designated as food deserts and 98% of these are in non-metropolitan counties (Morton and Blanchard, 2007). The uneven spatial distribution of food retail reduces the availability and easy access to healthy food for rural residents.

The consolidation of food retail in rural areas has left residents with longer travel times to access food (Piontak and Schulman, 2014). The sprawling nature of the rural landscape makes public transit unfeasible, adding the burden of car ownership to the rural poor in order to access adequate food (Sharkey, 2009). One study in rural Central Texas found that residents would have to drive up to 80 km to be able to purchase groceries (Ramadurai et al., 2012). Given the spatial distribution of food retail, residents in Central Texas purchased most of their food from outside the county (Ramadurai et al., 2012). The price of gas impedes these trips as does the distance (Smith and Morton, 2009; Ramadurai et al., 2012). Similarly results from a study looking at food access among low income rural residents in Minnesota found transportation to be critical in eating healthy (Hendrickson et al., 2006; Smith and Morton, 2009). Lack of transportation was a greater impediment to rural residents eating healthy than to urban residents (Hendrickson et al., 2006). Residents in these low income rural counties also pointed out that if they did not have the money to purchase the higher priced items in the county, it was unlikely they had the resources to make the trips outside the county to purchase groceries (Smith and Morton, 2009). Food access is inhibited by the long travel times and a lack of transportation options to get to these far flung markets in rural areas (Dean and Sharkey, 2011).

Financial capital is a prerequisite for food access. Poverty in rural counties is more prevalent than in urban ones, and decline in poverty rate was more significant in urban and metro counties than in rural and remote counties (Kusmin, 2013). Additionally, while real income has grown over the years in metro counties, real income has declined in completely rural and non-metro adjacent counties in the U.S. between 2015 and 2017 (Kusmin, 2013). Through the Agricultural Improvement Act of 2018 ("Farm Bill") the US government has tried to provide food safety nets in the form of Supplemental Nutritional Assistance Program (SNAP) and various other smaller nutritional programs, including Women, Infant, and Children (WIC) to households and individuals who live in poverty (Lusk, 2018; Mozaffarian et al., 2019). However, these food safety nets are inadequate as multiple studies have demonstrated (Hendrickson et al., 2006; Ramadurai et al., 2012). The amount allocated to families and individuals is based on the thrifty food plan's market price calculations, and not on recipients' real food and nutritional needs and has been critiqued as being inadequate, especially in rural areas (Hendrickson et al., 2006; Ramadurai et al., 2012). While individuals in urban areas can benefit from other food safety nets such as meals on wheels, soup kitchens, food pantries and banks, these social safety nets are limited in the rural setting (Piontak and Schulman, 2014). Even when rural residents are able to access safety nets such as SNAP and WIC, their choices in redeeming these services is limited (Smith and Morton, 2009). While fruits and vegetables may be available in rural areas, most roadside vegetable and fruit stands do not accept SNAP and WIC (Smith and Morton, 2009).

Additionally, food costs more in rural areas in the U.S. In persistently poor rural counties food cost significantly more than the allocation for food stamps under the thrifty food plan to recipients (Morris et al., 1992). Generally, it costs more to eat healthy in the United States: energy dense fats, sweets and grains (cheap calories) are cheaper to purchase than lean meats, fruits and vegetables (Liese et al., 2007; Monsivais and Drewnowski, 2007). The price of fruits, vegetables, and other less energy dense foods has increased over the years while the price of energy dense foods has been resistant to inflation (Monsivais and Drewnowski, 2007). Cost of food for most people is key determinant of food choices (Hendrickson et al., 2006; Ramadurai et al., 2012), and food tends to cost more in small and medium food retail stores in rural areas in comparison to prices available in supermarkets and grocery stores in urban areas (Morris et al., 1992; Liese et al., 2007). The lack of competition in rural areas drives up local food prices, persistent poverty and inadequate safety nets make it difficult to afford foods according to individual nutritional needs.

While there are many aspects of the use dimension of food security, we focus on the availability and access to culturally appropriate foods. The U.S. is home to 40 million foreign born residents accounting for 12.9% of the total population—this is a rise of 50% points between 1980 and 2010 (Grieco et al., 2012). The lack of culturally appropriate foods makes it difficult for people to utilize available food. This fact is compounded in rural counties where spatial inequities and lack of transportation makes food choices limited and inadequate to meet the cultural appropriateness of all its residents. A study of Latinx and Hispanics in North Carolina shows food insecurity is higher for those who live in rural areas and lower for Hispanics and Latinx in urban areas (Haldeman et al., 2008). The study highlights that the level of food security is associated with time in the United States in rural areas (Haldeman et al., 2008). The less time they had spent in the United States, the more food insecure they were. The study sample identified a lack of familiarity with foods and ability to read food labels as a constraint to eating healthy (Haldeman et al., 2008). Food available is also hard to use when it is of poor quality. Residents in rural areas point out that a lot of the food available locally is not just over priced but also of poor quality (Smith and Morton, 2009; Ramadurai et al., 2012). In Minnesota for example residents report stale, out of date and spoiled food on their local food store shelves (Smith and Morton, 2009). The sub-standard foods in rural areas further impedes roads to addressing food security.

Madera County Case Study

We offer a look at Madera County (**Figure 1**) in California as an exemplar of the disconnected American food system. Madera County spans 5,561 square kilometers and is located in the Californian Central San Joaquin Valley and the Central

FIGURE 1 | Map of Madera County, California.

Sierras (Madera County EDC, 2013). Madera is bordered on the north by Chowchilla River and on the south by the San Joaquin River, and has some of the richest agricultural lands in the nation. The county is home to 157,327 people: 33% white, 58% hispanic, 4% African American (U.S. Census Bureau QuickFacts, 2019a). A fifth of the population is also foreign born (U.S. Census Bureau QuickFacts, 2019a). The median household income for the county is US$57,585, with 17.6% of the population living in poverty (U.S. Census Bureau QuickFacts, 2019a). The county has two urban centers (Madera and Chowchilla) and 11 unincorporated communities (Madera County EDC, 2013). People are spread across the urban centers and unincorporated areas: half the population lives in the unincorporated areas and the other half in the urban centers (U.S. Census Bureau QuickFacts, 2019b).

Agriculture plays an important role in Madera's economy, earning over a billion dollars each year in gross farm income (USDA, 2017). Agriculture accounts for about 46% (261,167 hectares of farmland) of land in the county, with farms averaging 188 hectares (USDA, 2017). Madera is home to over 1,300 farms, with many 3rd and 4th generation farm families (Madera County Farm Bureau, 2015). The county's top three products by acreage are almonds, grapes, and pistachios. There is an abundance of fruits, vegetables, grains, and dairy products harvested and processed in Madera County (USDA, 2017). Madera also ranks 8 in the state for milk production and earned over $254 million from milk sales in 2017 (USDA, 2017). Despite the agricultural abundance and wealth in the county, almost 20% of households (8,797 households) in Madera county received Supplemental Nutrition Assistance Program (SNAP), 24,000 households are low-income, and about 20,500 people in the county are food insecure (Feeding America, 2019; U.S. Census Bureau, 2019).

When we look at Madera County's community food system,[2] actors in the community food system are loosely connected (Raj et al., 2021). According to the USDA's food environment atlas (USDA, 2017), only 4% (62) of farms in the county directly sell to consumers. The number of farmers involved in direct sales has also been decreasing; between 2007 and 2012, there was a 22% decline in the number of farms participating in direct sales in Madera County (USDA, 2012). The Community Food Guide for Madera County reports that the community food network for Madera County is supported through farmers' markets, with restaurants being the second most important connection for local farmers and grocery stores coming in third (Raj et al., 2021). Most of the farmers' markets and restaurants that support Madera County farmers are in the San Francisco bay-area, a wealthier jurisdiction nearly 322 kilometers (a 3-hour drive) away. Some Madera County farmers travel as far as Southern California, over 402 kilometers away (a 4-hour drive) to sell their produce (Raj et al., 2021). Even when farms are listed as selling directly to people, the clientele tends to be outside the county boundaries, to wealthier, more affluent communities. Madera County's community food network illustrates how disconnected local agricultural production is from local consumption, and despite the county producing an abundance of fruits, vegetables and dairy products, much of it is funneled out of the county.

As case in point, Covid-19 presented a flashpoint for food systems globally. In Madera County, while small businesses, including restaurants were shuttered due to the pandemic, agricultural production held steady and remained the county's most economically valuable industry (Promnitz, 2020). However, food insecurity skyrocketed, with food distribution increasing 150% in Madera County, according to the Central California Food Bank (Ugwu-Oju, 2020). The most impacted were farmworkers, migrants, communities without easy access to food retail, and people who lost their jobs (Ugwu-Oju, 2020). While food banks had to turn people away due to the increased demand, farmers in Madera and neighboring counties, disced lettuce and other perishable produce back into the soil (Tobias and Rodriguez, 2020). With restaurants and large institutions closed that would otherwise buy the produce and milk, farmers found it more cost-effective to leave crops in the field and dump the excess milk, than to harvest. The state has facilitated re-routing of excess crops and milk to food banks in California, but local governments have been (un)surprisingly absent.

To enhance the adaptive capacity of communities experiencing job losses and business closures, the Federal Government stepped up food security protections countrywide

[2]Community food system refers to a connected and integrated system of sustainable food production, processing, distribution, and consumption that works together to enhance the ecological, economic, social and nutritional health of a community (Garrett and Feenstra, 1999).

through the enactment of the Families First Coronavirus Response Act (2020). The Families First Act ensured that children were able to receive free school meals despite school closures (Families First Coronavirus Response Act, 2020). In Madera County, the Madera Unified and Chowchilla Elementary school districts participated during school closure to provide free school lunches to eligible children—preschool through to year 12 (Madera Community College, 2020). The Families First Act also gave low-income families food dollars in the form of pandemic electronic benefits transfer (P-EBT), to compensate for meals missed due to school closures (USDA Food and Nutrition Service, 2021a). SNAP benefits were increased by 15% monthly in January 2021 to offset losses in income (USDA Food and Nutrition Service, 2021b). In California, SNAP benefits were expanded to include online food purchases at select stores including Amazon (USDA Food and Nutrition Service, 2021c). Federal expansion of unemployment benefits and loan forbearance programs during the pandemic also added to the vast blanket of social protection programming (Cooney and Shaefer, 2021). There were programs for paycheck protection available to businesses, as well measures put in place at the State level to prevent rent hikes and eviction protections. These measures have been extended or strengthened in the 2021 "American Rescue Plan" (USDA Food and Nutrition Service, 2021b). Additionally, in October 2020, California State legislated a farmworker relief package, which among many things, provided temporary isolation spaces to sick or at-risk farmworkers (Cimini, 2020).

The Madera County case is illustrative of the fact that food insecurity is produced by factors beyond food production and has potentially more to do with how community food systems are co-opted through the neoliberal food system, to support affluent communities elsewhere rather than support communities in the county. The outbreak of Covid-19 laid bare that agriculture and food security are loosely connected, and income and underlying structural vulnerabilities play a larger role in the determination of food security status.

Global South Case Study

The Indian Food System: Interconnected and Tightly Woven

India, home to 1.37 billion people, is one of the most populous countries in the world (The World Bank, 2020a). Spread across 3.3 million square kilometers, India is divided into 28 states and eight Union Territories; the States and Union comprise of 718 districts that are further subdivided into urban municipalities and rural villages (Government of India, 2019). Despite strong urbanization trends, a majority of Indians—65%—live in rural areas (The World Bank, 2020b). Additionally, a large proportion of the urban workforce are out-migrants, and due to the pandemic, 30 million of these migrants have returned to their rural homes, adding uncertainty to livelihood opportunities available to them (The World Bank, 2020c). While urban slums are certainly a vista of persistent poverty, poverty is concentrated and more prevalent in rural India (Aubron et al., 2015).

Despite declining agricultural growth, India is still the world's largest producer of milk, pulses and spices (M.S. Swaminathan Research Foundation and World Food Program, 2008; The World Bank, 2012). Globally, India has the largest cultivated land area for wheat, rice and cotton (M.S. Swaminathan Research Foundation and World Food Program, 2008; The World Bank, 2012). India also contributes to the global production of rice, wheat, cotton, sugarcane, tea, fruits and vegetables, sheep and goat, and farmed fish (M.S. Swaminathan Research Foundation and World Food Program, 2008; The World Bank, 2012). Much of the land is cultivated—195 million hectares or 60% of total land mass—of which 63% is rain-fed and 37% is irrigated (M.S. Swaminathan Research Foundation and World Food Program, 2008; The World Bank, 2012). Even though agriculture's importance to the economy has diminished over the decades, it still employs 60% of the rural workforce and remains the main source of livelihood for rural India (Aubron et al., 2015; Pillay and Kumar, 2018). In rural India, livelihoods, agricultural production, and poverty are interconnected.

Following a green revolution in the mid 1960's, agriculture in India focused on creating high yielding rice and wheat varieties, and increasing chemical inputs—fertilizers and pesticides—which in turn increased output per hectare without increasing cultivated land (Chakravarti, 1973; Parayil, 1992). In part the green revolution was driven by famine conditions experienced under British rule. Prior to independence in 1945, Indian agricultural products were exported by the British to support its empire and war efforts elsewhere, while millions of Indians were subjected to famine conditions (Sen, 1981). The great Bengal Famine in 1943 that resulted in the deaths of more than 1.5 million Indians was not a result of production shortfalls; Indian farms produced sufficient food, but the grains were funneled out, and what was made available in the local market was too expensive for poor Bengali's to afford (Sen, 1981). Since independence India has been free of famines, and much of their agricultural reorganization has been to undo British agricultural policies. However, farm sizes have hence remained small; in fact farm sizes have decreased between 1971 and 2011 by ∼1 hectare in India (Fan et al., 2013). Most farmers are smallholder or subsistence farmers in India, owning <2 hectares of land (Government of India, 2019). Agricultural productivity has increased since the green revolution, with India becoming self-sufficient in grain production since the 1970's and producing enough food to meet the caloric needs of its population (Narayanamoorthy et al., 2017).

Not surprising, farmers remain central to the food supply chain in India. Traditional food retail outlets still represent close to 98% of the food retail share with the market penetration of supermarkets remaining low: 2% (Tefft et al., 2017). Essentially, most Indians still participate in traditional food systems, procuring fresh produce and food items from traditional markets that either buy directly from farmers or through rural aggregators. In fact, rural business hubs linking smallholder farmers to rapidly growing urban markets are on the rise in India (FAO, 2020). In addition to food procurement, the hubs also facilitate purchase of farm inputs, equipment, and lines of credit for the farmers (FAO, 2020). Given that traditional markets and direct purchasing from farmers remain central to the Indian food system, disruptions in food production, and

the supply chain would also negatively impact food security outcomes in the populous.

Although India grows and maintains sufficient caloric supply of foods, and is even a net exporter of foodgrains and agricultural commodities, food insecurity is prevalent (Government of India, 2017; Narayanamoorthy et al., 2017). According to the FAO, 14% (189 million) of people in India are undernourished (FAO, 2020). In India food insecurity is also more prevalent in rural areas than urban areas (M.S. Swaminathan Research Foundation and World Food Program, 2008; Ahmad et al., 2011; The World Bank, 2012; Bhuyan et al., 2020). A national analysis of rural food insecurity found 13.2% of the rural population to be food insecure—consuming <1,890 kilocalories per capita per day (see **Figure 2** below). Rural food insecurity in particular is inextricably linked to small and marginal smallholder food production, income and debt, and climate shocks will further exacerbate rural food insecurity (Kumar et al., 2020). Given the connectedness of the Indian food system, we explore the determinants of food security in India.

Determinants of Food Insecurity in India

One key challenge in shoring up food security in India is the availability of food grains to meet dietary needs (M.S. Swaminathan Research Foundation and World Food Program, 2008; The World Bank, 2012). Even though India leads the world in the production of a number of agriculturally important crops, as a nation the average per capita net food grain availability has been variable and uneven across states (M.S. Swaminathan Research Foundation and World Food Program, 2008). To create greater and more equal access across states, the Indian Government instituted a public distribution system (PDS; George and McKay, 2019). The PDS is the largest social protection program globally, providing access to subsidized cereals for 800 million people that can be purchased from over 500,000 fair price shops across India (Pillay and Kumar, 2018). The PDS has had mixed results. As Ali et al. (2012) show in their study of Uttar Pradesh, 20% of households in their sample were unable to obtain food from the PDS despite having proper documentation. Similarly, Dhanaraj and Gade (2016) find that for every 5.43 kg of PDS rice distributed, only 1 kg reached those in need; in the case of sugar, distribution was even less efficient, for every 8.21 kg of sugar distributed, only 1 kg was consumed by those in need in Tamil Nadu. Others also report misclassification of households as above poverty line, as reason for exclusion from the PDS, as well as poor grain quality at the fair price shops, and corruption being a barrier for households purchasing through the PDS (Upadhyay and Palanivel, 2011; Kasim, 2012; George and McKay, 2019). Even though the PDS is touted as a social protection program, it was created to prop up the Indian agriculture sector providing remunerative prices for grains and in doing so supplement household food needs (Pillay and Kumar, 2018). Through the years, the Government of India has modified the PDS system to be more targeted and has added more grains (millets) to diversity the nutritional basis, despite these changes the PDS remains less than efficacious (George and McKay, 2019).

Aside from structural market impediments to food grain availability, crop losses also affect food availability in rural India. Water stress particularly is linked to losses in crop yields (IPCC, 2014). For example, the prolonged drought of 2019 affected over 70% of districts in Maharashtra and Karnataka, including 8.2 million farmers and resulted in crop failure of all major crops, including corn, soy, cotton, citrus lemon, pulses, and groundnuts (Relph, 2019). At current levels of water use, water levels in India are expected to fall below 50% of demand by 2030, placing India's river basins in dire stress (2030 Water Resources Group, 2009). Groundwater is also declining, especially in the North West region of India, notably in the states of Punjab and Haryana that produce the bulk of India's rice and wheat (Shiao et al., 2015). Approximately 75% of India's households are dependent on agriculture and any future losses in food grains is likely to exacerbate food insecurity for the rural poor in India (Ahmad et al., 2011; The World Bank, 2012; Merriott, 2016).

Crop losses not only reduce food availability but also decrease farm income exacerbating food insecurity in rural areas (Sam et al., 2019). Reduced income from crop failures can be devastating on small and marginal farmers. Farmers take on a high degree of debt in order to cultivate; debt that they are unable to pay when crops fail (Bashir and Schilizzi, 2013). Small and medium farmers across India collectively owe about 102,024 crore INR (about 14.7 billion USD) (Raja et al., 2021). The degree of indebtedness has contributed to farmer suicides enmasse (Merriott, 2016; Sathyanarayana Rao et al., 2017). Kennedy and King (2014) find that farmer suicide rates are positively associated with farmers with landholdings of <1 hectare, cultivating capital-intensive cash crops like coffee and cotton that are subject to price fluctuations. In Odhisa, Arora and Birwal (2017) found upper caste farmers with bigger landholdings are able to adapt to the adverse climatic conditions and losses by investing in crop insurance, using short duration varieties, and availing credit but lower caste farmers with smaller landholdings are not able to access such resources and instead either change their occupation, sell agricultural land or migrate out of agriculture. With few safety nets and limited credit available, small and marginal farmers are extremely vulnerable—conditions likely to be exacerbated with climate change (Sam et al., 2019).

Lack of physical infrastructure also impedes agricultural output. Poor food infrastructure in the Global South makes it harder to get perishable agricultural products to market on time (Brown, 2014). Fruits and vegetables are prone to spoilage if not stored and processed adequately. Rural regions in the Global South usually lack sufficient cold storage and processing facilities, necessitating high value crops to reach markets as quickly as possible to reduce post-harvest losses (Mohammed and Tokala, 2018). Provisioning of food infrastructure in rural India is not an easy feat. Consider that much of rural India has unreliable electricity supply: 54% (74 million households or 579 million individuals) of rural households are un-electrified (Kamalapur and Udaykumar, 2011). Shortfalls and outages in supply pose a problem in areas that have been electrified (Kamalapur and Udaykumar, 2011). In a survey of 30 villages in India, researchers found that only 36% of the households received 20–24 h of supply while the remaining majority received between <12 to <4 h of electricity (Krishnaswamy and Chatpalliwar, 2011). Lack of basic service infrastructure impedes upstream food infrastructure

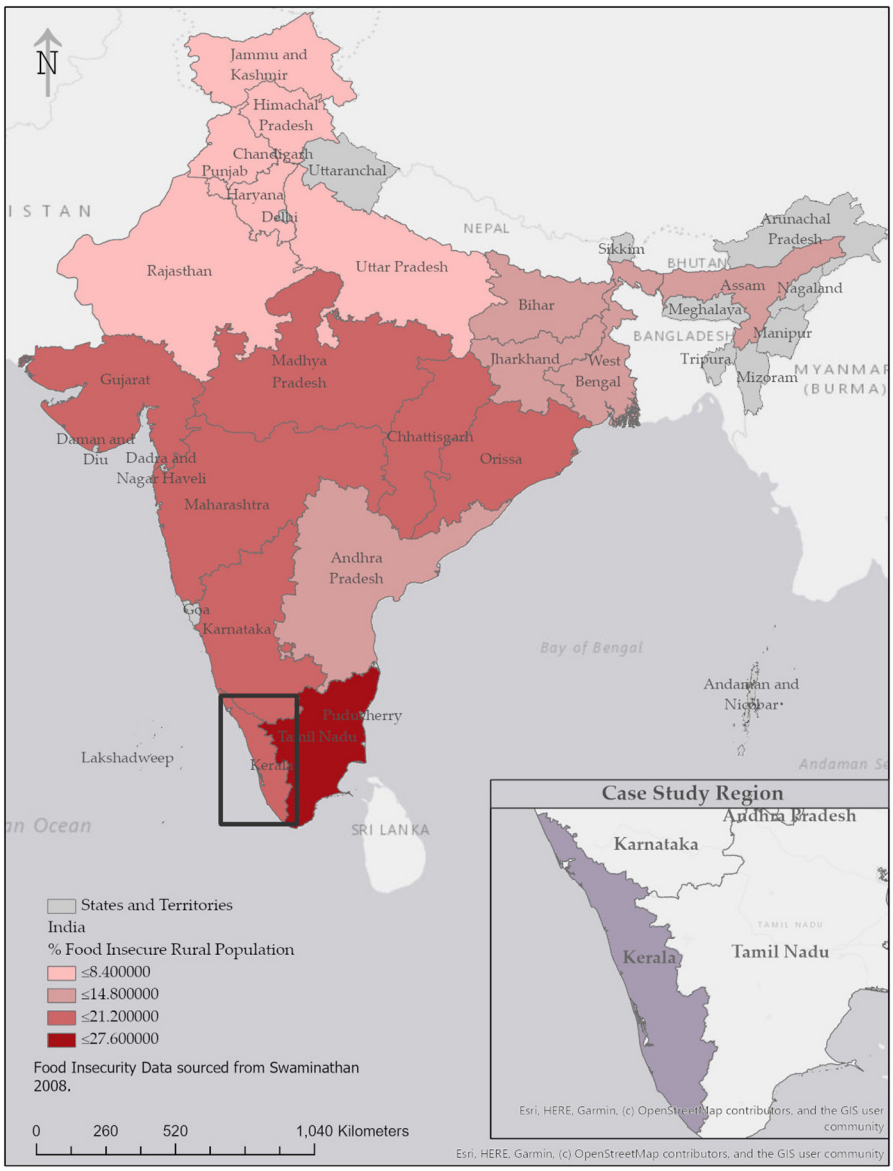

FIGURE 2 | Map of rural population in India consuming <1,890 kilocalories per capita per day.

development and farm modernization, contributing to lost rural purchasing power.

Food access in India is mediated by economic capital (Iram and Butt, 2004; Ali et al., 2012; Khan et al., 2012). Generally, small and marginal farmer households earn about US$843 (Rs 61,138) annually, and medium farmer households earn US$2, 125 (Rs 154, 099) annually (Government of India, 2017). Government estimates show that about 22.5% of farmers live below the poverty line in India (Government of India, 2017). Incomes are so low that it impedes access to adequate food and nutrition for these households (Ali et al., 2012). Iram and Butt (2004) find household income is significantly associated with calorie intake—caloric availability is higher in households with high incomes and lower in low income households. Households with low income are also vulnerable in times of food price increases. During the 2007–2008 global food price crises, household food security in rural Bangladesh suffered—the effect was much greater on rural poor and net food buyer households (Akter and Basher, 2014). In rural India, low income levels continue to impede financial access to available food.

Low income levels in rural India are also attributed to caste discrimination. Small and marginal farmers are from lower and landless castes and do not have access to the same social and financial networks and capital as upper castes landowners (Goli et al., 2021). Ali et al. (2012) find that food insecurity is worse in households of lower castes than upper castes. Goli et al. (2021) found similar results in Uttar Pradesh (UP), almost a decade later. In their study of over 5,000 households in the UP state,

food insecurity is four times worse in households with no or marginal landholdings, and three-four times worse in households of lower castes in comparison to households with medium to large agricultural lands and of higher castes (Goli et al., 2021). In their 2013 regional analysis of rural India, Mahadevan and Suardi (2013) also found belonging to a lower caste group relative to an upper caste group is associated with increased deficits in food security. Decades of cultural and institutionalized discrimination against persons of lower castes has excluded them from attaining economic mobility (Iram and Butt, 2004; Ali et al., 2012; Khan et al., 2012). In rural India the prevalence of caste discrimination continues restricting access to credit, resources and education (Mahadevan and Suardi, 2013; Goli et al., 2021).

The final food security construct—utilization—is quantified in terms of the body's ability to absorb nutrients measured in terms of access to health and sanitation factors. Studies have demonstrated access to water, sanitation, and health services are integral for the body's ability to appropriately utilize the food being consumed. However, many families throughout India lack access to clean, potable water. For example, only 14% of rural India has access to adequate sanitation and only 31% of rural households have access to drinking water (Khurana and Sen, 2008; The World Bank, 2014). Water quality is also a concern, most water sources in rural India are contaminated as a result of agricultural runoff and sewage (Khurana and Sen, 2008). Groundwater also has high levels of arsenic (Khurana and Sen, 2008; The World Bank, 2014). Lack of access to clean water impedes the health status of individuals living in rural areas. Research has shown increasing access to safe drinking water has a positive effect on food security outcomes (Iram and Butt, 2004; Khan et al., 2012). Similarly, lack of sanitation facilities has a negative effect on individual's food security status (Iram and Butt, 2004; Khan et al., 2012). Water and sanitation are proxies for good health and the ability to fully utilize the nutrients being consumed. Diarrhea, a water-borne ailment caused by contaminated water, is a good example of how nutrients are lost even when consumed. In rural India, food utilization is connected to water and energy security.

Kerala Case Study[3]

The state of Kerala, in the Indian South, is bordered by Tamil Nadu and Karnataka in the north and east and by the Arabian Sea on the west (see **Figure 2**). Kerala spans about 38,863 square kilometers, boasts a tropical climate, and enjoys access to abundant water resources (National Academies of Sciences, Engineering, and Medicine, 2020; Government of Kerala, 2021). Kerala is home to almost 33 million people, with the majority of people living in rural areas (17.5 million) (Raja et al., 2021). About 10.5% of Kerala's population are from scheduled caste and tribes, and a fifth of scheduled caste and about half of scheduled tribe work as agricultural laborers (Government of India, 2011). Agriculture employs 1,322,850 people as agricultural laborers and 670,253 people as cultivators (Government of Kerala, 2016). While Kerala has made strides in poverty alleviation, 11% of the population still lives in poverty (Raja et al., 2021). On the flipside, Kerala boasts a higher than national average unemployment rate of 12.5% (Raja et al., 2021).

Despite urbanization, Kerala remains an agrarian stronghold (Singh and Bhogal, 2008; Raja et al., 2021). Majority of land in the state is used for cultivation (51.86%), forests make up 27% of the land use, and non-agricultural uses account for about 11% of land in the State (Raja et al., 2021). There are 7.5 million farm holdings in Kerala, and about 98% of the farm holdings are considered small or marginal (Government of Kerala, 2016). A meager 0.2% of farms were medium to large (>10 hectares; Government of Kerala, 2016). Cash crops like coconut, rubber, tea, coffee, and spices dominate the agrarian economy (Singh and Bhogal, 2008). Coconuts are important both culturally and economically in Kerala, making up 39% of the cropped land area (Government of Kerala, 2016). Kerala also grows grain, with paddy accounting for 11% of land sown (Singh and Bhogal, 2008). However, grain production only reached 50% self-sufficiency in Kerala even at the peak of rice production in the 1980's (Kasim, 2012; Raja et al., 2021). Today the state produces about 10% of the rice it needs, and relies on the PDS to supplement the deficits in grain production (Kasim, 2012; Raja et al., 2021). Despite the state's agrarian aptitude, agriculture's contribution to the state GDP is paltry: 10% of the US$65.4 billion state GDP (Government of Kerala, 2016). With the cost of production increasing, the Government of Kerala estimates that 77% of all agricultural households are in debt (Government of Kerala, 2016). Despite the extensive network of farms, home gardening, and availability of subsidized food grains through the PDS, 17.5% of the rural population was considered food insecure (M.S. Swaminathan Research Foundation and World Food Program, 2008).

It was Kerala where the first case of COVID-19 was detected in India in January 2020 (Harris et al., 2020). By March a 3 months (March - June) nationwide lockdown curbed movement of people and coincided with peak harvesting season across the country, disrupting local food systems (Harris et al., 2020). Paddy harvest in Kerala was adversely affected (Pothan et al., 2020). The state government estimates that the rice sector lost nearly US$2 million due to shortage of farm laborers and truck drivers, and transportation restrictions that delayed harvest and processing of rice grains (Kerala State Planning Board, 2020). Similar losses were experienced throughout the agricultural production system in Kerala (Kerala State Planning Board, 2020). Casual workers and self-employed laborers lost an estimated US$47.9 million in income during the lockdown period - the loss of income had a devastating effect on small and marginal farmers especially who were unable to get their produce to market (Kerala State Planning Board, 2020). The loss in production had an immediate and cascading effect on the food system and food security (Harris et al., 2020; Pothan et al., 2020). As transportation of produce was delayed from the fields to the markets, notable increases in food price was recorded across the state and country (Harris et al., 2020; Pothan et al., 2020). In turn there was a surge for processed food items like instant noodles and biscuits, but even

[3]We chose to look at Kerala, as information for lower levels (districts) of analysis was unavailable. Kerala is still primarily an agrarian state and the example still offers insights into how closely knit agriculture, incomes, and food security are in rural and agrarian communities in India.

food manufacturing was running at low capacity without laborers who had returned to their villages (Pothan et al., 2020). The effect of the abrupt change (Covid-19) had an immediate impact on local food systems and on food security in Kerala.

To counter the food insecurity caused by the pandemic, the Kerala State Government put in place a number of social-protection measures. The State Government directed local governments to establish community kitchens, with the state coordinating supplies and logistics (Pothan et al., 2020; Sarkar, 2021). Distribution of free food kits consisting of 17 food items including food grains, to all households in the state, was instituted in early April (Pothan et al., 2020). Rural childcare centers were also instructed to deliver free mid-day meals to over 300,000 children registered under the Integrated Child Development Services (Pothan et al., 2020; Sadanandan, 2020). Local vegetable vendors partnered with auto rickshaw drivers to create a mobile market, transporting produce from farmers and markets to urban doorsteps (Pothan et al., 2020). Development of an app (Shopsapp) that informed people of open store locations where online ordering was possible was another lifeline for retailers and customers with disposable income (Sarkar, 2021). The State government also deployed existing social protection measures, advancing pensions, and made budgetary provisions to fulfill obligations under the Mahatma Gandhi Rural Employment Guarantee Scheme (Sadanandan, 2020). Unlike the US case, very little relief was received from the Indian Government to shore up social protections, and this lack of investment in social protection programming has been widely criticized (Ghosh, 2020).

The Kerala case study illustrates a tightly woven and highly interdependent food system in India, where adverse effects on food production has a negative cascading effect throughout the food system, including food security and health outcomes. Given the tight knit nature of agricultural production and food security in India, and implications for global food supply, it would be worth paying attention to the current farmer protests in India in response to macroeconomic policies tied to further liberalizing and undercutting Indian farmers.

Comparative Analysis of Determinants of Food Security and Adaptations in the Global South and Global North

Though the United States and India are geographically, socio-economically and culturally different, there are consistencies in the production of food (in)security in the two countries (see **Figure 3**). The similarity lies in the construct of food access. Access to food is impeded by the lack of economic resources and concentration of poverty in rural regions in both the US and India, though the severity of poverty is relatively worse in India. Rural areas in both countries face challenges in attracting development that would improve quality of life. Physical access to markets in both is a key challenge—though the nature of constraint is different between the two countries. In the United States grocery stores and supermarkets are far and few in between in rural areas making physical access to food challenging. In India physical access to markets is impeded by the sheer lack of infrastructure and utilities required by farmers to reach aggregators. Rural areas in both regions have struggled with government policy response to provide functional safety nets to alleviate food insecurity.

There are also key differences in the production of food (in)security between the two countries. In rural India, those that are food insecure are almost always engaged in farming, and their livelihoods are very much connected to gains and losses in agriculture. In the U.S. the rural landscape is different; agriculture is not the primary source of livelihoods and gains and losses in farming does not have as severe an effect on food security, as it does in rural India. Impediments to food security in the United States are structural, created in part by market forces and in part by planning and policy. Food availability in India and much of the Global South is tied to agricultural production as illustrated in this case study. In the United States and most of the Global North, availability of food is a function of neighborhood level factors—physical location of food retail and distance to food retail. Food utilization in India is dependent on the health access to clean water, sanitation and health services. In the United States food utilization is dependent on the quality of food available locally, cultural appropriateness of available food and agency.

While Covid-19 is not a climate related event, the pandemic provides a unique window to understanding how disruptions in the food system in the Global South and North, affect food security. At time of writing of this paper, India had recorded 12 million cases of COVID-19 and about 162,000 related deaths (WHO, 2021). The US had at the same time recorded about 30 million cases and 550,000 related deaths (WHO, 2021). We see two very different stories unfold in Kerala, India and Madera County, U.S. In Kerala, we see the pandemic related lockdown affecting all parts of the food system—production, supply chain, manufacturing and processing, retail, and immediately impacting food security. In part, because the lockdown coincided with peak harvesting times (Ghosh, 2020; Pothan et al., 2020). On the production end, yield losses were experienced as lack of labor prevented harvesting in time, as well as in-time transportation for processing. Farmers, and farm laborers lost income and we can infer accumulated more debt from the inputs required for the season. Transportation woes up and down the food supply chain appeared to be a weak link. Labor shortage also affected food manufacturing and processing plants and affected the availability shelf stable foods. With physical access to food retail cut off, the advent of the veggie rickshaw home delivery service and Shopsapp was a clever adaptation for the times. As was the State Government stepping in to open up community kitchens, and food rationing services that targeted both caloric and nutritional needs of diverse people in the state.

On the flip side, during the height of the pandemic in Madera County, there appeared to be minimum impact on the food system. Food retailers were stocked, and online delivery services were in high demand. A number of factors buffered the county's agricultural production sector from being adversely affected by the pandemic. While some farmers experienced on farm losses due to labor shortages, this was not widespread in Madera County, and on farm losses were underwritten by the USDA

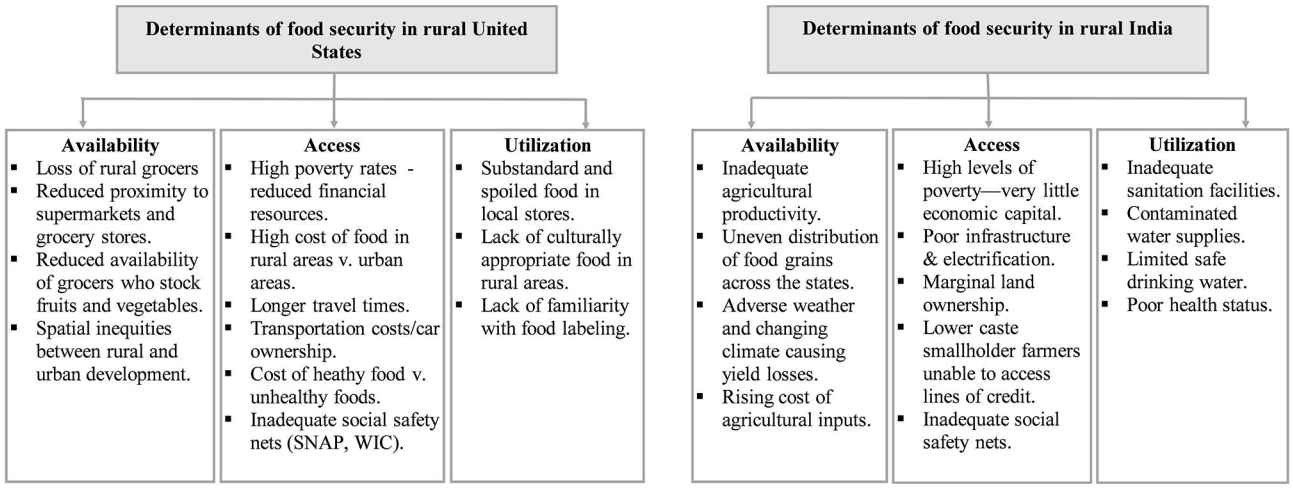

FIGURE 3 | Comparative analysis of food security determinants between the rural United States and India.

through their Coronavirus Food Assistance Program (CFAP 1) initially, and then through the CARES Act, with payments made directly to producers (Johansson, 2020). Additionally, many of the top agricultural crops (almonds, olives, pistachios, and corn) grown in Madera County are mechanically picked, and are less prone to spoilage than produce. Even if it was slower, the supply chain was still operational in Madera.

However, job losses were noted in Madera County. The most impacted were people who worked in a food related industry, majority of whom are Latinos (Ugwu-Oju, 2020). Latinos also experienced higher rates of COVID-19 infections and deaths in California relative to other races and ethnicities (California Department of Public Health, 2021). At a time when deportation was very much a reality, it is possible farmworkers, immigrants and restaurant workers from the Latino community avoided institutional support and were more at risk of contracting and dying from COVID. Recent work by Lusk and Chandra (2021) shows Madera County as having one of the highest rates of COVID-19 among migrant workers in the country. While unemployment benefits were expanded and stimulus checks mailed to tax filing citizens as a safety net, those in the above high risk groups in Madera may have been left out of the US Government response due to tax filing and immigration status. Food insecurity increased, especially among Latinos in Madera during the pandemic, and reliance on food banks grew (Ugwu-Oju, 2020).

Further analysis into the two case studies illustrates that communities adapted in different ways to the pandemic (see **Figures 4**, **5**). In Kerala, India there was a heightened focus on food security and ensuring people had sufficient food rations. We see State and local governments playing a critical role in coordinating food and ration distributions. There were also entrepreneurial adaptations with rickshaws being converted to mobile food vendors. In rural Kerala low and lost income were key determinants of food insecurity during the pandemic, followed by reduced access to traditional markets. While prepared meals and food rations were distributed, we could not find additional measures that protected livelihoods, on farm losses, the food supply chain, or safety nets that would give the rural poor disposable income for basic needs.

Despite the attention to food security in Kerala, the lockdown had a profound impact on rural livelihoods and food systems in Kerala and elsewhere in India. Other than the State led food distribution program, other coping mechanisms and adaptations mentioned in the literature appear to be sporadic and it is unclear how widespread their coverage has been. Without additional disposable income to make up for lost livelihoods during this period, families and individuals did not have improved means of coping with the vast impact of the pandemic on their health and security. Rural actors in the food system, especially small and marginal farmers of lower castes, with their limited ability to cope with the pandemic's impacts, were likely more vulnerable to the second wave of COVID-19 raging in India (Ghosh, 2020). As Ghosh (2020) points out in her paper, the timing and nature of the lockdown, the lack of Government stimulus funding to boost the rural sector, and other macroeconomic decisions contributed to increasing vulnerability of rural communities to the second wave of the virus, and did nothing for increasing their adaptive capacities.

In contrast, in Madera County, at the onset of the pandemic it was food banks and civic minded individuals who came to the assistance of the poor and vulnerable (Ugwu-Oju, 2020). Financial access to food, reduced transportation options to procure food, and lack of safe jobs in the food system were major hurdles faced by individuals in Madera County. Community adaptive capacity did receive a boost from the Federal Government with assistance targeting agricultural producers, underwriting production losses and food security measures through strengthening existing food security mechanisms. It is unclear what the participation rates were for the modified school lunch programs, or the P-EBT, or how information regarding the modified benefits were communicated to those in need. Federal

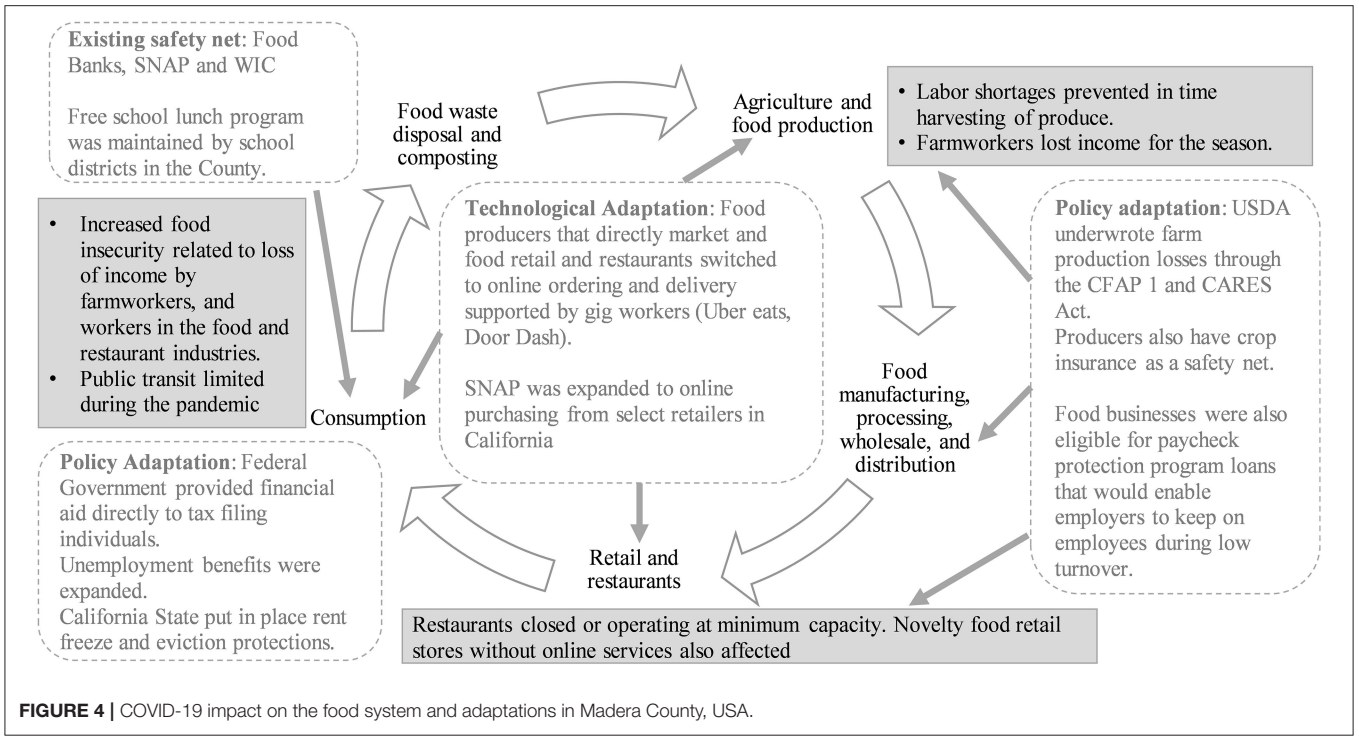

FIGURE 4 | COVID-19 impact on the food system and adaptations in Madera County, USA.

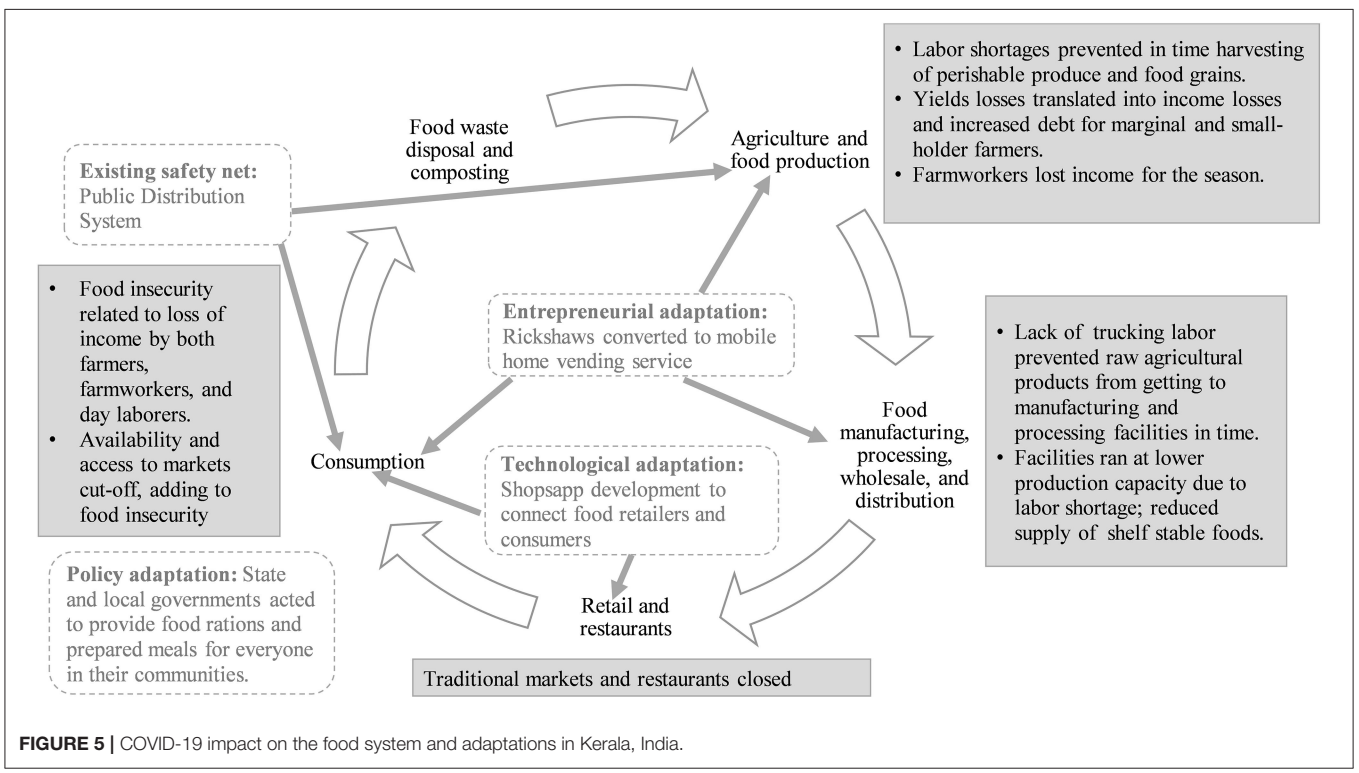

FIGURE 5 | COVID-19 impact on the food system and adaptations in Kerala, India.

legislation also supported food businesses through paycheck protection loans, as well as additional legislation that rebranded food workers as frontline workers, allowing food businesses to operate as essential services. Large scale direct payments to tax filing individuals and families also contributed to increasing community adaptive capacity. There were however people who fell through the safety nets—farmworkers, and migrant workers. Federal assistance for existing measures did not have expanded

eligibility to include farmworkers and migrant workers, despite them being the very people who grow and harvest food in the county and the country. While California finally provided some relief for farmworkers, the relief package did not put dollars' in individual's hands. Overall, the large swathe of Federal and State programming, alongside local actors in the emergency food system propped up communities and their ability to cope with and recover from pandemic related losses.

ADAPTATIONS FOR THE FOOD SYSTEMS TO IMPROVE FOOD SECURITY: A DIFFERENTIATED APPROACH

The two case studies presented in this research demonstrate the need for context-based adaptation strategies in the Global North and South to shore up food security against climate change and other large scale disasters. We note that most propositions for increasing food security tend to focus on food production and the availability component of food security (Schmidhuber and Tubiello, 2007). However, optimal adaptation will depend on the determinants of food security (Ziervogel and Ericksen, 2010; Myers et al., 2017): availability of food, accessibility (financial and physical), and the ability to utilize food and nutrients.

For example, in Kerala, India, supply chain considerations are critical to adaptation planning. Agricultural losses could have been alleviated with some on farm infrastructure adaptations, and modified policy responses. A degree of deference to rural producers at peak harvesting period, to match the community transmission of COVID at the time, may have prevented the extent of losses reported in the Kerala agricultural sector. It is also possible that the extent of post-harvest losses could have been reduced if small and marginal farmers had easy and localized access to cold storage or value adding facilities. Without supply chain considerations built in, post-harvest losses will continue to be a bottleneck (Pillay and Kumar, 2018). To this end, small and marginal farmers in the Global South are economically constrained and most do not have the resources required to invest in on-farm infrastructure and technology (Hertel and Lobell, 2014). If available, micro-credit financing and crop insurance for small and marginal farmers could have been key to coping with the losses incurred during the pandemic. Moreover, research shows investment in small-holder and subsistence agriculture has the greatest potential to reduce poverty than any other sector (de Janvry and Sadoulet, 2009). Underwriting yield losses due to disasters and extreme events, as a means to increasing adaptive capacity in the food system, has been an effect strategy as illustrated by the U.S. case study.

Conversely, in the U.S. the rebranding of food system labor as frontline workers, helped keep the system going. Allowing movement of labor and food products ensured that products continued to have a market domestically, and alleviated further production losses. Yet, while policy and planning kept the food system moving, COVID protections for food system workers were not institutionalized. After advocacy from farmworker justice organizations, in October 2020, California, passed legislation supporting prioritization of farmworker access to testing and personal protection equipment, as well as safe isolation safes. In the U.S. case it would be pertinent to develop more stringent farm and food worker protections that ensure worker safety and health, especially with extreme heat and air quality issues becoming prevalent with climate change.

While supply-side agricultural adaptations will help protect farmer yields, in the long-run addressing food insecurity requires a focus on rural infrastructure investment and poverty alleviation. Both case studies illustrated the benefits of cash transfers during disasters. The cash transfers in the U.S. helped families and individuals overcome material hardship, food insecurity, and reduced anxiety. As a counter point, the lack of cash transfers to the rural and agricultural communities in India, reduced rural purchasing power further, especially for those from lower castes. Since shocks like COVID can happen at any point, social protection programming, like SNAP and WIC need to be flexible. Benefits should be transferred as and when the event takes places, and should be topped up to reflect the magnanimity of the disaster. Benefits should also be increased to reflect current costs of nutritious food by locality. Expanded social protection programming is necessary both in the Global South and North, as the case studies illustrate. While India may not have similar financial reserves as the U.S. to take such an approach, any level of cash transfers to the poor in India would have helped. In the future, Global North countries, can redirect their overseas development aid and climate financing to Global South Countries as direct budgetary support to prop up social protection programming for poverty alleviation. The experience with COVID, and the results of cash transfers in the U.S. makes a great case for universal basic income as an adaptation measure.

Additionally, technology played a role in COVID adaptations. SNAP has strict guidelines about where and how it can be used. During the pandemic, California adapted its SNAP use guidelines to allow for online purchasing at select retailers. Online food purchasing would save families time, and transportation costs, and for those without transportation options, online purchasing and deliveries in Madera would have been a welcome recourse. Similarly, restaurants, retail, and even community supported agriculture models pivoted to online ordering and deliveries. Similar, roll-out of technological adaptations in India was hampered by the low levels of electricity and internet infrastructure and instability of the electricity grid in rural India.

These policy, technological, and on farm adaptations certainly helped communities in U.S avert a much larger socio-economic disaster, it did not however consider or address the inequities in the food system that continue to perpetuate disproportionate burden on the already vulnerable. Take for example, the lack of farm and food worker protection mandates during the pandemic or the lack of a Federal mandate for hazard pay for these workers. The lack of any concerted effort to provide farmworkers with cash benefits, or other social protection programming speaks volumes. The rate of COVID related infection and death in farmworker population is telling of who bore the brunt in the pandemic and where the gaps are. While tenuous, the U.S. food system relies on farmworkers, and regardless of their status in the country, in the midst of a global pandemic, farmworkers should have received

more deference. Similarly, in India, small and marginal farmers are the heart of Indian agriculture and should have received higher degree of consideration and protections.

CONCLUDING REMARKS AND FUTURE RESEARCH

The comparative analysis has laid out differences in the determinants of food security in the United States and India as proxies for Global North and South countries respectively. Despite the differences, food insecurity is likely to worsen in both places, especially with climate change (Birthal et al., 2014; Sun et al., 2019). In both India and the U.S., those that are vulnerable are also food insecure, experience persistent poverty, and will be unable to weather shocks from both market failures and extreme climate events (Wheeler and Von Braun, 2013; Brown et al., 2015). While food security scholars have recently started to integrate a food systems approach to their work, scholars have not paid as much attention to considering climate impacts on food security. As a result, there are knowledge gaps in shoring up resilience in food systems against climate impacts—both slow and abrupt changes.

Through this literature review and case analysis, we illustrate that the modernized community food systems in the Global North, dominated by grocery stores for food retail, are largely disconnected from local food production. As a result, food security is a determinant of financial and social capital to access food—food in itself is available abundantly if you can afford it and get to it. In the Global North, as pointed out in the case review, the most food insecure are the consumers, disconnected from land. Climate protective measures in the Global North should lean toward responsive social protection programming and universal basic income to overcome the economic shock brought on by climate disruptions, as was done with the COVID-19 response.

On the flip side, traditionally oriented food systems of the Global South with a heavy reliance on traditional markets that depend on deliveries from local farmers are tightly woven and interconnected to the fortunes of small and marginal farmers. Small and marginal farmers are also the most climate vulnerable and if they are adversely affected, so is food security for everyone downstream in the food system, as illustrated by the Kerala case study. The question of climate and food insecurity is more tightly connected in both problem and solution in the Global South.

Given the differences in vulnerability and the different ends of the spectrum of the food system that are affected by climate shocks, adaptations to protect food security outcomes need context and nuance. In short, although individuals in both the Global South and North are vulnerable to climactic stressors on their food ways, the impacts are unevenly distributed. As such, one-size-fits-all strategies and policies will invariably fail or work only for a subset of the population. While we have offered some ideas about what context driven food security adaptations could look like in the two regions, more research is needed to elucidate what works in what context. Future research should consider analyzing on the ground, situated, empirical relationship between social protection programing during natural disasters and food security outcomes as well as long-term social-ecological projects in the Global South that can highlight strategic options for food security and climate adaptation in the food systems.

AUTHOR CONTRIBUTIONS

SRa and DWW made substantial contributions to the conception and design of the study. SRa and SRo contributed to the data collection and SRa performed the analysis. SRa and CB revised the work critically and SRo contributed to the revisions. All authors read and approved the final manuscript.

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