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"Central" and "peripheral" adaptation pathways of entangled agrifood systems transformations

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In the agrifood systems of developing countries, local adaptation actions and pathways often interact with other climate and development responses, creating new trade-offs, uncertainties, and potentially maladaptive outcomes. While knowledge on the interacting pathways of adaptation is expanding, previous studies have focused on complex systems dynamics, and studies that address the human, social, and political forces that drive the cascading of risks between different coupled social-ecological systems are few. This paper aims to examine climate adaptation trade-offs, uncertainties, and maladaptation through an interdisciplinary analysis of two interacting pathways of transformational adaptation in the Philippines: the post 2004 disaster rural transformations in the coconut-producing municipality of Infanta and a state-led urban water resilience strategy for the capital region of Metro Manila. Data were collected from January 2021 to March 2022 through ethnographic field visits, participant observation, focus group discussions, semi-structured interviews, geospatial analysis, multicriteria mapping sessions, and review of planning documents and secondary data sources. Key findings suggest that the pathways of transformation and their entanglement are rooted in historical processes of change and that maladaptation is contingent on the political relations between the "central" and "peripheral" pathways. Overall, the paper offers a significant contribution to adaptation research in the agrifood systems of developing countries as it calls for a deeper kind of collective reflexivity and action that can transform narrow notions and practices of resilience and sustainable development.

KEYWORDS

transformation, maladaptation, pathways, coconut, mega dam, climate resilience, rural-urban, Philippines

Introduction

"Sometimes, the changes we speak of are not just about the climate. We also need to adapt to government projects and to the changes they bring to our lives. What's the point of diversifying crops today if in the next year or so a major infrastructure project will displace our farms? What's the point of planting high value

crops in the hope of having a harvest 3-4 years from now if the threat of a huge flood is always here? What we need is real change that will truly improve our livelihoods"—A woman coconut farmer in Pinaglapatan, Infanta, Philippines.

The epigraph above reflects the complex link between climate adaptation and the broader pathways of change. With the surge in adaptation financing for developing countries in the coming years (UNEP, 2021; UNFCC, 2021), more adaptation initiatives focusing on the agrifood sector will emerge and will interact with climate and development responses in other sectors and scales (Rickards and Howden, 2012; Wise et al., 2014). The shifts in paradigmatic assumptions about adaptation as situated within complex adaptive systems (Chhetri et al., 2019) as well as the growing discontent with many institution-led adaptation programs in developing countries (Asante et al., 2017; Notenbaert et al., 2017) open up a wide arena for researchers to interrogate how adaptation itself creates new risks in the form of trade-offs (Eakin et al., 2009; Alcamo et al., 2020; Orchard et al., 2020), uncertainties due to incomplete knowledge (Scoones and Stirling, 2020) and maladaptive outcomes (Barnett and O'Neill, 2010; Juhola et al., 2016; Eriksen et al., 2019).

By way of definition, a trade-off refers to an undesirable outcome of an adaptation action in exchange for some positive results (Alcamo et al., 2020). Uncertainties pertain to the unpredictability of both the odds and the nature of adaptation outcomes (Mehta et al., 2019) while maladaptation is a state of worsening social-ecological vulnerabilities as a result of planned adaptation actions (Barnett and O'Neill, 2010; Juhola et al., 2016). Researchers often frame these undesirable effects in relation to a specific adaptation option even though much of these unintended consequences are co-products of multiple interacting adaptation actions and pathways (Shinn, 2016).

Finding a coherent body of knowledge on the interacting pathways of adaptation in agrifood systems is challenging, and defining its conceptual boundaries requires drawing perspectives from various fields. Systems and complexity science describes how adaptation creates new internal risks and vulnerabilities over time, producing feedback loops that constrain the flexibility in other adaptation pathways and systems (Anderies, 2006; Tellman et al., 2018). One type of adaptation (e.g., incremental) may also enable or restrict other types (e.g., transitional and transformational; Hadarits et al., 2017). Such insights have been applied in arguing that adaptation is inseparable from societal responses to change (Wise et al., 2014; Inderberg et al., 2015; Orchard et al., 2020), particularly from development investments on income and livelihood capitals (Lemos et al., 2016) and transitional strategies toward sustainable development (Butler et al., 2022). Analysis of the interactions between strategies that explicitly address climate risks and those that target non-climatic drivers of social vulnerabilities is vital in pursuing multiple, complementary goals such as climate resilience and sustainable development (Alcamo et al., 2020; Escarcha et al., 2020). Insights from socio-technical systems thinking suggest that "niches" of innovations depend on the transformations in the wider socio-technical "regimes" and the broader "landscape" of policy, culture, and society (Geels, 2005). This is relevant as adaptation actions and pathways at one spatial scale may support or constrain adaptation in a different scale (Rasmussen, 2018). Similarly, institution-led and climate-tagged interventions may be prioritized in public policy over community-driven, "hidden" forms of adaptations (Grüneis et al., 2018), and pathways for urban system resilience may influence the adaptive space in rural social-ecological systems (Spanier and Feola, 2022). What is often lacking is the deliberate coordination of actors and their decisions across spatial scales (Brooks and Loevinsohn, 2011; Chaudhury et al., 2017). Adaptation pathways also intersect across time. The time lags in feedback loops determine the kind of trade-offs that interacting pathways may produce and the policy responses available (Burnham and Ma, 2018). Lessons can also be found in coupled human and natural systems wherein past interdependencies can have "legacy effects on present conditions and future possibilities" (Liu et al., 2007, p. 1513).

This paper aims to study climate adaptation trade-offs, uncertainties, and maladaptation through an interdisciplinary analysis of interacting adaptation pathways, specifically transformational modes of adaptation. While complex systems science provides a raft of conceptual tools to analyze the unintended consequences of climate adaptation within a system, there is a need to adequately explain the human, social, and political forces that facilitate the cascading of risks among different coupled social-ecological systems as a result of interacting adaptation pathways (Liu et al., 2007; O'Brien, 2021a). The paper builds on the works of researchers who argued that pathways are inherently political as they embody different goals, values, and visions of the future (Wise et al., 2014; Butler et al., 2022) and that vulnerabilities shift toward the already vulnerable because of the political ecological and political economic relations in specific historical junctures that reconfigure the distribution of benefits and risks (Marino and Ribot, 2012; Taylor, 2015; Borras Jr et al., 2022).

The term *entangled pathways* as well as the heuristic device *central* and *peripheral pathways* are introduced to describe a certain configuration of interdependence among pathways that is not restricted to spatial networks of resources, commodities, effluents, people, and other quantifiable dimensions of resilience and vulnerabilities. Rather, pathways of transformational adaptation are entangled in temporal scales through historical and existing regimes of change such as colonialism, postcolonial and postwar development, globalization, and the sustainable development agenda as well as competing imaginaries of climate futures (Paprocki, 2021). These conceptual ideas emerged from a critical analysis of a case of "entangled pathways" in the Philippines involving nearly two decades of post-disaster rural transformation in a highly vulnerable, coconut-producing municipality of Infanta and a state-led urban water resilience

strategy *via* a foreign funded mega dam project for the capital region of Metro Manila.

Dubbed as the ultimate solution to Metro Manila's worsening water crisis, the $211 million-worth New Centennial Water Source-Kaliwa Dam Project will be constructed 100 kilometers south of the Philippines' capital in a mountainous area within the jurisdiction of the rural municipalities of Infanta and General Nakar, Province of Quezon. The national government considers it a "climate resilient" project to supply an additional 600 million liters of water per day to Metro Manila's population of 13 million along with several million others in surrounding provinces. Since 2018 when the project received an approval from the national government, local communities in Infanta and nearby towns expressed resistance against Kaliwa Dam because of concerns over the looming threat of flooding to downstream communities, the displacement of Indigenous peoples from their ancestral lands, the destruction of around 200 hectares of forest land that serves as habitat to endemic flora and fauna, the railroading of democratic processes in securing informed consent from affected communities as well as the uncertainties on the potential impact of the dam on the water security in downstream communities and coastal erosion in communities situated in the alluvial plains. What is often overlooked in this discourse of dissent is the ways in which the urban water resilience strategy supports or constrains rural agrifood systems' future adaptive capacity in the face of unprecedented impacts of climate change. This issue becomes apparent when juxtaposed against the ongoing, long social-ecological transformation in Infanta following an unprecedented flash flood disaster in 2004 that catapulted a new adaptation pathway toward new land use patterns, more diversified rural livelihoods, and improved system of governance.

The "pathways" lens is used in adaptation research and sustainability science either in a narrow or broad sense. The narrow view applies the metaphor of "pathways" for roadmaps or route maps commonly used in adaptation planning, implementation, and evaluation (Cradock-Henry et al., 2020). This paper takes a broadened view wherein the term "adaptation pathway" represents "alternative possible trajectories for knowledge, intervention, and change, which prioritize (different adaptation and development) goals, values, and functions" (Leach et al., 2010, p. 5). Conceptual frameworks on transformational adaptation vary in their understanding of what constitutes a "major, non-marginal change" (Stern, 2007, p. 1). In this paper, the categories of *efficiency-focused* and *situated* transformational adaptations are used to emphasize that the epistemological shift in approaching climate adaptation is what clearly distinguishes various modes of transformation as adaptation (cf. Singh et al., 2021). Efficiency-focused transformational modes of adaptation focus on reducing the exposure and sensitivity of the agrifood system to climatic hazards by altering the nature, composition or location of agricultural activities or the system itself (Kates et al., 2012; Fedele et al., 2020). Situated transformational adaptation, on the other hand, arises from interdisciplinary and transdisciplinary modes of inquiry that emphasize the interdependence of climate, human societies, biodiversity and ecosystems, and social progress (Pelling et al., 2015). As Pelling (2011) notes, "the vastness of climate change and the multitude of pathways through which it can affect life and wellbeing for any individual or organization make it almost impossible for 'climate change' in a holistic sense to be the target of adaptation" (p. 25). Hence, situated transformational adaptation widens the analytical lens of research and practice from a narrow focus on climate risks to a "wider transformation of development pathways that brings together adaptation, mitigation, and sustainable development" across sectors and scales (Few et al., 2017, p. 3). In this paper, the post-disaster rural transformations in Infanta and Metro Manila's Kaliwa Dam Project are selected as two different yet interacting pathways of transformational adaptation.

The paper attempts to address the following questions:

- How do transformational adaptation pathways become entangled in space and time?
- How and why do trade-offs, uncertainties, and maladaptive outcomes emerge from entangled pathways?
- How do institutions and society begin to "untangle' the interacting pathways in ways that may promote an equitable, just, and more sustainable climate adaptation outcomes?

From the ethnographic fieldwork in Infanta, aided by participant observations, focus group discussions, semi-structured interviews with farming households, community leaders, local and regional government officials and civil society, multicriteria mapping sessions as well as review of secondary documents on the contested mega dam project and on Metro Manila's urbanization and water security status, key findings emerged, revolving around the following themes: (i) pathways of transformation and their entanglement are rooted in historical processes of change; (ii) potential trade-offs, uncertainties, and maladaptation are contingent on the political relations between the central and peripheral pathways; and (iii) equity and social-ecological justice must be front and center in assessing the potential trade-offs and maladaptive outcomes of interacting pathways across spatial and temporal scales.

Materials and methods

Study area

The Philippines ranks among the top five countries suffering the most significant loss and damage from extreme climatic events between 2000 and 2019 (Germanwatch, 2021).

Since the mid-twentieth century, the country's average annual temperature has increased by about 0.6°C and is projected to increase by 2.9°C by 2090s (World Bank and Asian Development Bank, 2021). The frequency and intensity of extreme weather events is also rising (World Bank and Asian Development Bank, 2021). Such climatic trends are expected to further reduce the productivity of most agricultural production systems, and the indirect effects of these stressors on production and distribution in the supply chain (Comiso et al., 2014; Lansigan and Tibig, 2017) make the Philippines' agrifood systems one of the world's most vulnerable to climate change (OECD, 2017).

Although the share of agriculture in the country's gross domestic product is small at 10% compared to that of the manufacturing (30%) and service sectors [60%; (PSA, 2022)], prospects of achieving the Sustainable Development Agenda 2030 rest upon the successful adaptation of the agrifood sector since two-thirds of the country's poor eke out a living in agriculture (Ravago et al., 2018) and are at greatest risk of falling into extreme poverty when adverse weather conditions occur (OECD, 2017).

Coconut farmers are frequently regarded in public policy and academic literature as the "poorest of the poor" among Filipino farmers, a trope that simplifies the extent of the sector's social vulnerabilities to economic terms and conceals the contradictions critical in examining relevant cross-scalar processes of transformative change. At least two contradictions are palpable. The first pertains to the economic importance of the coconut sector as the country's top export earner, contributing an average of USD 1 billion annually from copra (dried coconut meat) and coconut oil (PCA, 2022), a position the country occupies since the post-war era (Boyce, 1992). Despite the sector's economic importance, most of the 2.5 million coconut farmers in 69 of the country's 82 provinces live below the poverty line (Batugal et al., 2008). The second contradiction concerns the dearth of climate adaptation studies on the country's coconut sector. From an agronomic perspective, coconuts are more resilient than other crops (e.g., rice and corn) as they can tolerate some increases in temperature and moderate salinity. Trees can recover in a year or two with little intervention when they lose their flowers and fruit from strong winds and rain (Javier, 2015). But from a social-ecological systems perspective, the country's coconut sector continues to bear the impact of a half a century of systemic neglect and structural injustice brought by neo-patrimonial economic policies in the 1970–80s (Camba, 2019; Ramos, 2019), worsened by the sector's constant exposure to uncertain and volatile global market forces, absence of genuine land reform, coconut farmers' weak political clout, and low public investment in research and extension. In addition, more frequent and intense tropical cyclones and tidal swells, flooding, and saltwater intrusions make future coconut farming in island provinces, riverine and coastal communities more challenging (cf. Ruales et al., 2020; Seriño et al., 2021).

Among the 69 coconut-producing provinces in the Philippines, the province of Quezon in southern Luzon stands out in terms of its historical, economic, and cultural ties with coconut. To identify a study site in Quezon in which to conduct the case study, extensive discussions with various government agencies and civil society organizations suggested Infanta, an agricultural and coastal municipality in the northern portion of the province. The municipality had a population of 76,186 in 2020 and a total land area of 19,934 hectares comprising six distinct ecological systems: urban, agricultural plain, riverine, coastal, estuarine, and mountainous. Coconuts are planted on 47% of the total agricultural land area, primarily in the coastal, riverine, and mountainous *barangays* and the crop ranks second to rice in terms of Infanta's agricultural production and economic value.

Consent for and collaboration in the research was sought from community assemblies of coconut farmers organizations in the two *barangays* of Pinaglapatan and Magsaysay and they readily gave their consent to take part. Pinaglapatan (98.56 hectares) is a riverine and coastal barangay with some portions lying along the coast of the Philippine Sea while Magsaysay (11,028.16 hectares) is a mountainous barangay situated along the southern tip of the Sierra Madre mountain range. Note that Kaliwa Dam will occupy an area in Magsaysay and the nearby town of General Nakar. In particular, the dam site will be located in the headwaters of *Agos*, a river system that connects Magsaysay to downstream barangays including Pinaglapatan as it flows out toward the Pacific Ocean (see Figure 1).

Located at the southern end of the Philippines' longest mountain range, Sierra Madre, barangay Magsaysay is situated within a complex ecosystem that plays essential ecological and social functions. Around 97% of its land area is protected by the state as a national park. The barangay itself is part of a bigger watershed that provides water to Infanta and neighboring towns and provinces for domestic, agricultural, and industrial use. Likewise, the mountains and river systems where Magsaysay is situated supply sediments and nutrients downstream *via* the Agos River, replenishing the alluvial deposits in the floodplains and preventing coastal erosion in areas such as Pinaglapatan.

In recent years, Infanta has gone through major social-ecological transformations. A series of typhoons in November 2004 led to a massive flash flood in the low-lying areas of the town. The amount of rainfall recorded on a single day in Infanta was equivalent to a 15-day rainfall for November that caused slope failures in the mountainous areas and triggered the Agos River to overflow (David and Felizardo, 2006). The disaster has affected around 12,000 families, left more than a hundred casualties and significant damages to property and agricultural infrastructures, and triggered radical changes in the natural environment, livelihoods, and local economy (David and Felizardo, 2006; Gaillard et al., 2006). Between 2006 and 2017, 39 tropical cyclones have affected Infanta. Twenty-one of these were typhoons and the remainder were weaker forms of

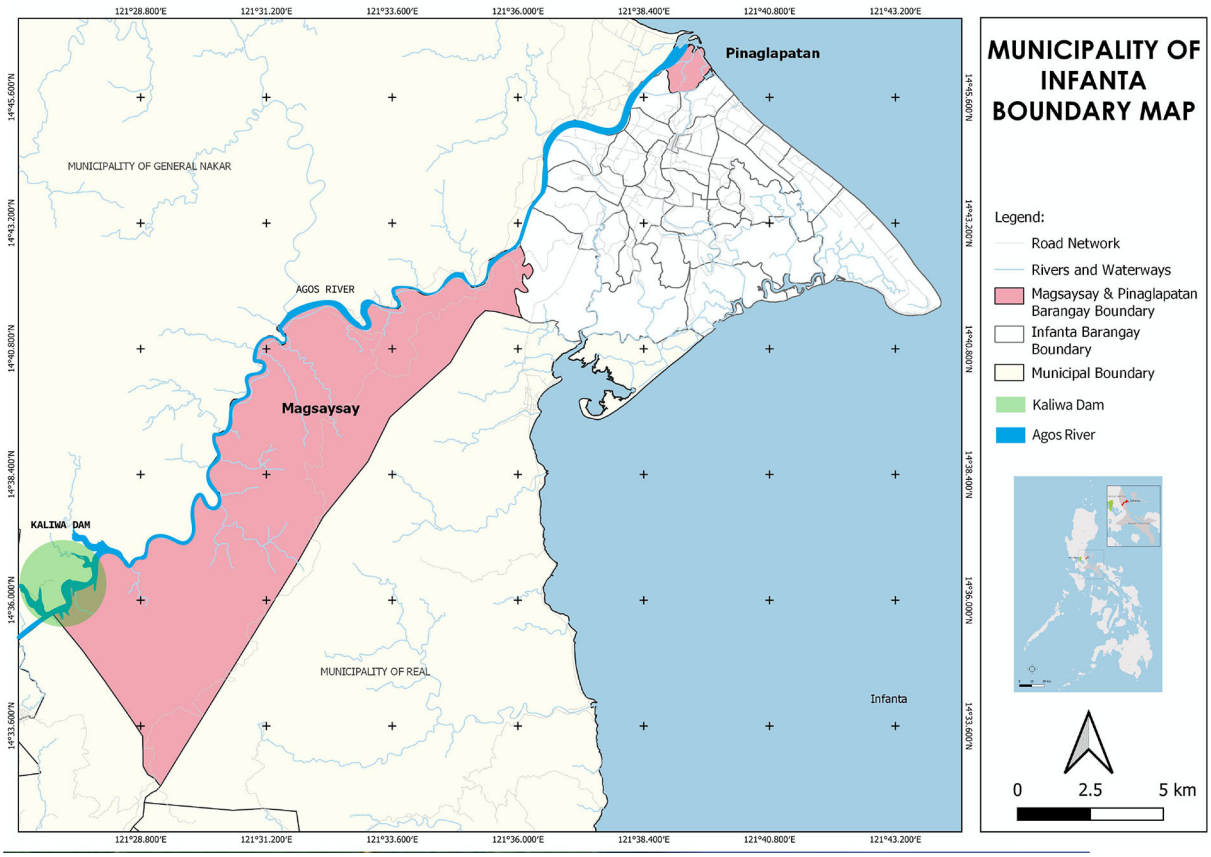

FIGURE 1
Location map showing *barangays* Pinaglapatan and Magsaysay and the site of the Kaliwa Dam reservoir in the municipality of Infanta, Province of Quezon in the Philippines. The location of Metro Manila relative to Infanta is also shown in the inset in the right bottom corner. Source: Data from National Mapping and Resource Information Authority (NAMRIA).

tropical cyclones. Climate models predict that extreme weather events will become more frequent in Quezon Province by 2050 (PAGASA, 2018).

Methods

This paper is drawn from a larger study of transformational adaptation pathways in the coconut farming sector in Infanta. Data were collected through ethnographic field visits, participant observation, focus group discussions (FGDs), semi-structured interviews, geospatial analysis, multicriteria mapping (MCM) sessions, and review of planning documents and secondary data sources. Fifteen field visits were conducted in Infanta from January 2021 to March 2022. During this period, the author stayed continuously in Pinaglapatan for 2 weeks and in Magsaysay for a week in addition to the intermittent field visits in other sites in Infanta, with each visit lasting for 1–3 days. The ethnographic approach to fieldwork enabled the researcher to understand the key drivers of social-ecological transformations after the 2004 catastrophe as well as the extra-local development programs and policies that influence local adaptation dynamics, particularly the Kaliwa Dam project, from the interpretive lens of coconut farmers in Pinaglapatan and Magsaysay, government officials, and representatives from the local civil society. Participant observation was done in six general assemblies of the coconut farmers organizations in Pinaglapatan and Magsaysay as well as in the farmers' field school and strategic planning workshop in Pinaglapatan in which the author served as facilitator.

Participants in the FGD sessions and in-depth interviews were mostly members of the two coconut farmers' organizations. They were selected through a participatory process during the farmers' organizations general assemblies and with the logistical support of the organizations' elected officers. Three FGDs were conducted in each of the study sites representing the different agroecological systems for coconut areas. An additional FGD session was also conducted with a group of community leaders representing coconut farmers who were not part of government-initiated farmers' organizations. One of the FGD sessions conducted in Pinaglapatan was designed as a hybrid of conventional group interview and a transect walk. The

researcher designed the guide questions in ways that avoided a reductionist approach to studying climate change adaptation in the agrifood systems (Nightingale et al., 2019) and enabled the author to situate climate change within the broader dynamics of rural livelihood change and multi-scalar development responses and trajectories (Wise et al., 2014; Ensor et al., 2019). Specifically, the conversations revolved around the major changes that have taken place in their ecological environment, settlements and other physical structures, livelihood systems, formal institutions, and people's way of life spanning four decades (1970–2010s). In addition, the author also facilitated a conversation about adaptation to major social-ecological changes, the relevance of coconut farming in dealing with major social-ecological changes, the changes they anticipate to take place in their communities in the next two-three decades, and the ways they intend to adapt to these anticipated changes. Around 60 men and women coconut farmers participated in the FGDs.

Ten semi-structured interviews were also conducted with the heads of the two farmers organization, selected elder members of the farmers organizations who have not joined the FGDs due to COVID-19 safety protocols, the municipal mayor and representatives of the relevant departments in the municipal government, and representatives of civil society organizations in Infanta. While questions differed for each stakeholder group, certain themes cut across all the groups such as the key drivers of vulnerabilities of coconut farming sector, notions and practices of adaptation, perceptions on Kaliwa Dam project, and future policy and institutional interventions needed to address the root causes of vulnerabilities of coconut farmers and their families to climate change.

Although the MCM sessions did not directly address the issue of interacting pathways concerning Kaliwa Dam, insights from the eight sessions conducted with the coconut farmers' groups, coconut traders, local and regional government officials, and CSO representatives have been useful in gaining a better understanding of how adaptation in the coconut sector interacts with multi-scalar, diverse institutional and community-driven responses to change such as the adaptation strategies in other agricultural subsectors (e.g., rice and high-value crops), ecotourism development, national-level economic development strategy for the coconut sector, and ecosystem-based adaptation. Twenty three individuals participated in the MCM sessions.

Geospatial analysis was also conducted to complement the empirical data collected from the ground. A review of land cover changes in Infanta was done using past land use plans and published scientific papers covering the period 2004–2009. This was juxtaposed with insights from the land cover maps generated for 2010 and 2015. Other secondary literature covering historical archives, academic publications, planning documents, video documentaries, and news reports on the 2004 flood disaster, Metro Manila's urbanization and water security status, and on the Kaliwa Dam project were also reviewed.

Results

Research results are presented in three parts. The first part describes the pathway of social-ecological transformations that rural Infanta has been going through since the 2004 flash flood disaster. This section begins with a brief description of the land use and livelihood patterns in the barangays of Magsaysay and Pinaglapatan in the 1950–1990s to highlight the extent in which the 2004 disaster has brought transformational changes to the system. This post-crisis social-ecological trajectory to new land use and livelihood patterns including the overall shifts in local economic development and governance is presented as an ongoing, long pathway of transformational adaptation with implication to existing and future social-ecological system resilience to climate change. The second part delves into the Kaliwa Dam Project as an urban water resilience strategy for Metro Manila. The Philippine government envisions the project to climate-proof the water systems of the country's capital region. It is presented here as an adaptation pathway that interacts with the ongoing transformations in Infanta as the dam structure is being constructed in the mountainous area of Magsaysay in Infanta. The last section briefly presents rural communities' perspectives on how Kaliwa Dam may bring cross-spatial and temporal changes that will, in turn, influence system resilience and adaptive capacities in Infanta.

Post-disaster rural transformations in Infanta

Before the second World War, the uplands of Infanta were sparsely populated with traditional shifting cultivators particularly the Indigenous communities of Dumagat and Dumagat-Remontado who were pushed to marginal forest lands because of state territorialization regimes. In the Philippines, the Spanish colonial government (1521–1898) imposed the Western concept of private property and declared all untitled lands as public domains under the Spanish Crown (Montefrio and Dressler, 2016). This policy called the Regalian Doctrine has made many upland communities illegal occupants in lands that were once their ancestral domains. This policy stance of separating forests from agricultural lands was carried on during the American Occupation (1848–1946). The institutionalization of such spatial categories also produced a new social classification of Christian lowland inhabitants and the non-Christian Indigenous peoples in the uplands (Pichler et al., 2021). The colonial construction of "idle" lands served as an opening for the postcolonial state to demarcate more areas for lowland agriculture and timber extraction in the uplands (Montefrio and Dressler, 2016).

Beginning in the 1960s, population in Magsaysay grew with the entry of logging concessionaires that attracted migrants

from lowland areas in other regions. This migration pattern in the postwar era and in places with logging concessions is well documented and is often attributed to poverty conditions and agrarian politics in lowland areas (Cruz et al., 1988; Kummer, 1992; Van Den Top, 2003). The Local Government of Infanta documented nine logging companies that operated in Magsaysay from 1960s until the banning of commercial logging in 1980s. Timber license agreements became instruments to advance the economic and political interests of a small group of loggers and cronies of former dictator Ferdinand Marcos Sr. (Kummer, 1992; Vitug, 2002).

At the peak of commercial logging from 1960 to 1970s, many residents, mostly men, were hired to work intermittently for the logging companies as tree cutters, sorters, and movers of timber. Upland farming was a key component of their livelihood portfolio but mainly for subsistence to augment the wages received from the logging companies (FGDs 1 and 2 in Magsaysay; informal interviews with participants in Magsaysay). Both men and women work in rain-fed rice fields and vegetable gardens, while tending the coconut farms was often left to men. These rice fields and coconut farms were passed on as inheritance from elders who were traditional shifting cultivators. But when the national government promoted community-led forest management in the late 1970s and with the easing of commercial logging in the 1980s, many residents in Magsaysay and in the broader Infanta municipality were emboldened to run their own logging business (FGDs 1–3 in Magsaysay; Local Government of Infanta Forest Land Use Plan, 2018). Most of these so-called *magkakahoy* or "carabao loggers" (in reference to the use of water buffalos that drag out timber down the forests) did not have legal permits to operate (FGD 1 in Magsaysay). For more than two decades (1980s-early 2000s), carabao logging became a lucrative source of income for many residents in Magsaysay, and upland farming became less of a priority (FGD 1and2 in Magsaysay). In 2004, close to half of the labor force in Magsaysay was engaged in illegal logging (Espaldon et al., 2009).

Meanwhile, in the riverine and coastal barangay of Pinaglapatan, the community has seen how the Agos River changed its course and transformed the landscape in just a few decades. For centuries, the deltaic plains of Infanta have been formed through alluvial deposits brought by the river (Abucay et al., 2012). Episodes of flooding have gradually swallowed areas that were once inhabited and created new patches of land where new settlements and agriculture thrive (cf. Cuevas, 2012). This feature of the landscape makes relocation of houses and livelihoods within the barangay a norm for many participants. Morever, heavy rains and tropical storms frequent this eastern side of Luzon from June to November and extreme rainfall events have become part of the seasonal cycle and of life itself. Hence, livelihoods change with the seasons. The participants recounted that back in the 1960–70s livelihoods were limited to fishing and planting of a few cash crops from February-August while the rest of the year is considered lean months or what the communities call *Amihanin* or the season dominated by northeasterly winds. As participants recalled,

> "Every year, when *Amihanin* comes, many people here become jobless. That is when the pots turn green as most people content themselves with crops that grow year-round such as ferns and taro" (FGD 2 in Pinaglapatan).

> "Back in the days, if you are a farmer, you do not go fishing. Now it is different. If the weather is bad, you can drive a tricycle and earn a living. You can offer your services to households here for a fee. Decades ago, this was unimaginable" (FGD 2 in Pinaglapatan).

In the 1980–90s, there were coconuts everywhere in Pinaglapatan. But as the population grew, more and more coconut trees were felled to give way to housing construction and the planting of rice and high value crops. Aside from land conversion, strong floods have eroded the riverbanks where most of the coconut trees were planted. Some men eked out a living from salvaging large volumes of cut timbers and residual woods that were carried by accident downstream because of the seasonal overflows of the Agos River (In-depth interview; FGD 2 in Pinaglapatan).

The pillage that took place from decades of widespread logging ended up in one of the deadliest flood events in the Philippines' modern history, which led local and state authorities to enforce a total ban of all forms of logging in the area. Almost two decades after the 2004 flash flood, rural livelihoods have taken a different turn. Studies conducted a few years after the disaster showed that the areas planted with perennial crops, particularly coconuts, and annual crops have increased significantly to as much as 97%, and more people have engaged in multiple jobs, including off-farm work, both in Pinaglapatan and Magsaysay (Abucay et al., 2012; cf. Asuero et al., 2012). In the highlands of Magsaysay, the disaster has set in motion the gradual conversion of grasslands and denuded parts of the forests into coconut groves and farms planted with more resilient and fast-growing crops such as sweet potato, cassava, and local vegetables. Many of the former carabao loggers have returned to upland farming and agroforestry alongside non-farm work done by other members of the household.

> "That flood was really bad. Everything I owned were wiped out. How could I raise my children? I am widowed. What I did was to plant *pechay* (Chinese white cabbage) and mustard greens on the flood plains by the river. I planted the sides with cassava. In a month, I could start harvesting the vegetables, and my children would sell them at school. They were able to finish their studies with the money I earn from making copra and coconut oil and through loans from a micro-finance cooperative" (FGD 1 in Magsaysay).

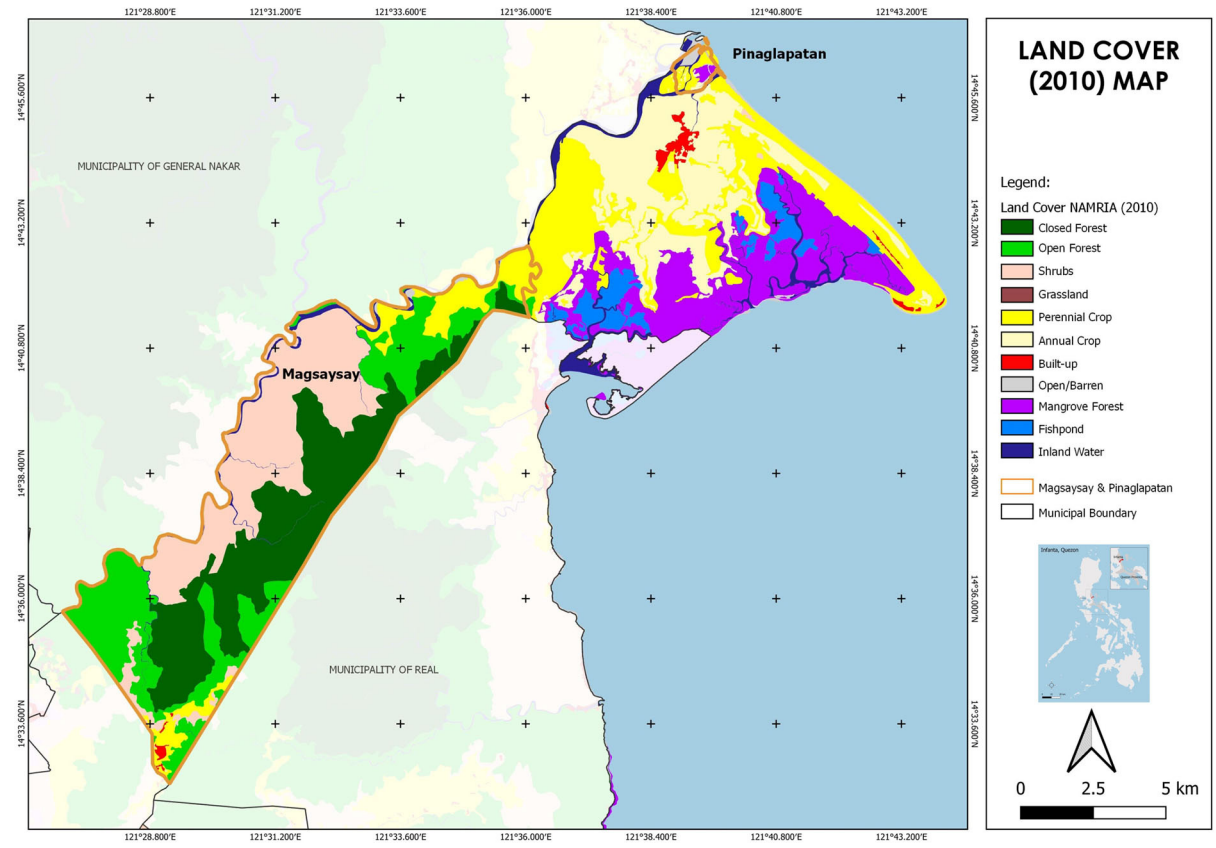

FIGURE 2
Land cover map of Infanta in 2010. Source: Data from National Mapping and Resource Information Authority (NAMRIA).

> "After the flood and when the relief from the NGOs has run out, we shifted our livelihoods to charcoal-making. When we ran out of driftwood, we resorted to quarrying small rocks by the river. When small rocks are gone, my husband went to construction work for many years. After construction work, he applied as a garbage truck driver in the municipal government and got hired" (FGD 1 in Magsaysay).

> If you plant coconut trees, you will survive (FGD 2 in Magsaysay).

These land use and livelihood changes also coincide with the further decline of the remaining primary forests, a trend that was seen in the first 4–6 years after the 2004 flooding (Espaldon et al., 2009; Abucay et al., 2012). This can be attributed to the undeterred carabao logging by the poorest members of the community as well as the ecological pressure from the gradual expansion of upland farms (Interview with a local official; FGD 2and3 in Magsaysay). Despite this trend, new growth woodlands have also been expanding in grasslands and deforested areas since 2010 as the fieldwork and the available geographic information suggest (see Figures 2, 3).

Aside from the government's total logging ban and the post-disaster efforts of local communities to rebuild their lives, there are other forces at play that drove such ecological and social transformations in the highlands of Magsaysay. First, the completion of the Marikina-Infanta road in 2010, a 117 km-long highway that traverses Magsaysay, connecting the northeastern part of Quezon Province to Metro Manila, has attracted legitimate landowners and holders of temporary land rights to tend their farmlands in order to protect their rights over the land. The road also drew new settlers who unlawfully established permanent settlements and ecotourism businesses inside the national park.

Second, government enforcers of national park regulations have become more visible in implementing forest protection rules following the establishment of the Marikina-Infanta road (FGD 2 in Magsaysay; informal conversations with participants). However, many upland farmers believe that the strict implementation of environmental laws is selective at

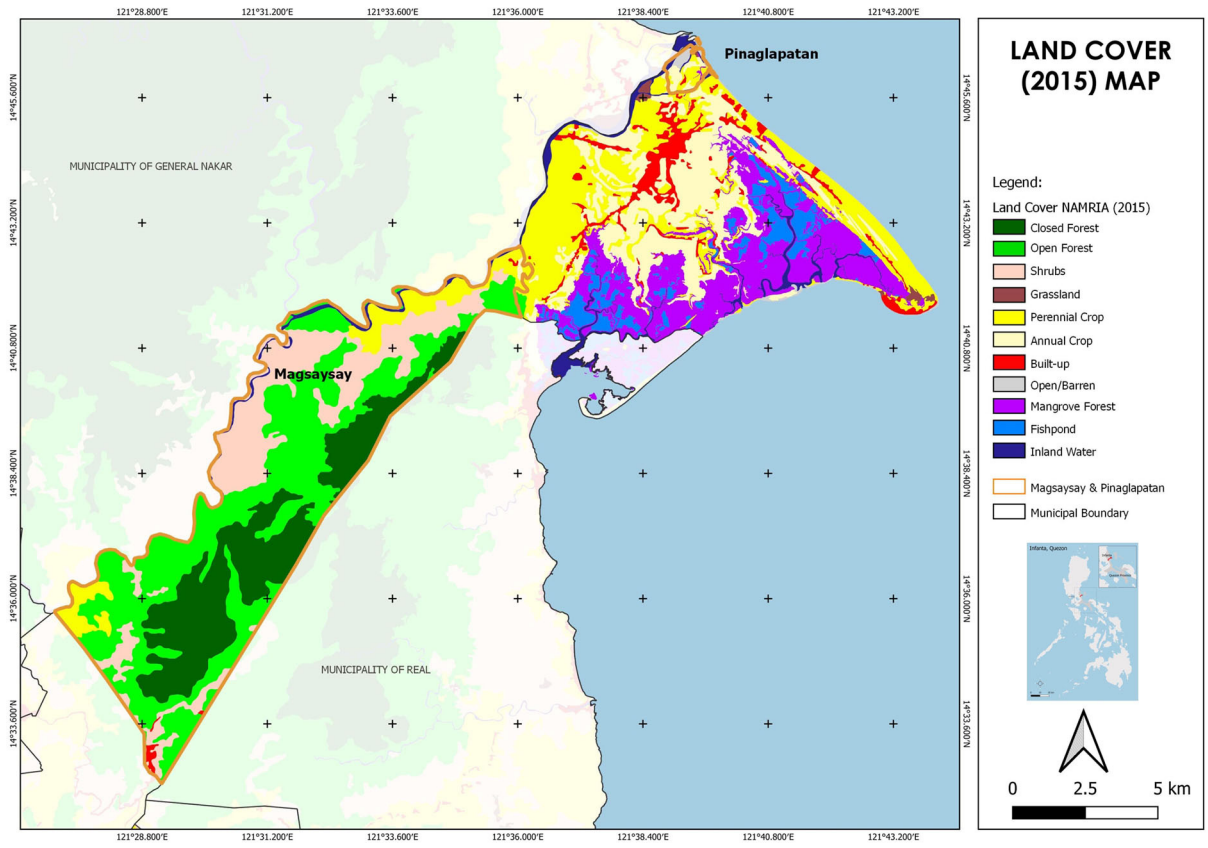

FIGURE 3
Land cover map of Infanta in 2015. Source: Data from National Mapping and Resource Information Authority (NAMRIA).

best as some wealthy outsiders have established residence and enterprises inside the national park, getting away easily from the national park regulations. As one participant expressed this sentiment, "Those people from DENR (Department of Environment and Natural Resources) are stepping on us, poor people, while favoring the *kapitalista* (capitalists)." Another participant made a comment on the seemingly contradictory policy stances of different government agencies that affect their livelihood:

> The Philippine Coconut Authority says we should plant more coconut trees, but DENR restricts us from clearing the surrounding areas of the trees. We are prohibited to use fire or cut even the shrubs that compete with the coconuts for nutrients. Their policies are contradictory (FGD 2 in Magsaysay).

Nevertheless, the stern enforcement of forest regulations in the last 10 years alongside the greening program of the national government and the local government's efforts of incentivizing members of the community who serve as forest guards have effectively contributed to the rehabilitation of denuded areas and to the gradual restoration of forest cover in Magsaysay (Interview with a local official; FGD 1–3 in Magsaysay). Many of the members of the coconut farmers association in Magsaysay are also part of a government-supported community-based organization whose work involves rewilding degraded portions of the watersheds and reporting activities that pose threats to the remaining forests.

Third, copra trading price is on the rise in recent years mainly due to the increasing demand for coconut oil in the global market. The high price of copra encourages farmers to replace unproductive old trees with improved varieties and invest on better farm management techniques including fertilization and soil conservation measures (Interview with Philippine Coconut Authority officials; interview with a coconut trader in Infanta).

And lastly, the collective experience of loss in 2004 resulted in a reorientation of values among the communities. As a woman farmer who used to have a family-run logging operation in Magsaysay explained, "Many of us here felt that we are being robbed (*inaagawan*) of resources by

the big logging concessionaires. If they can cut trees, we can do it too. But when the 2004 flood happened, nothing is left but regret." A number of civil society organizations have established their presence in Magsaysay and Pinaglapatan, providing not only humanitarian response but also organizational development support, technical trainings on sustainable livelihoods, scholarships for university education, and other interventions that raise the consciousness of local communities about environmental issues and their wellbeing.

> After the 2004 disaster, the religious organizations who came here made us realize the importance of investing on our children's education. Poverty is something that we should not pass on to our children (FGD 2 in Pinaglapatan).

Education is viewed both in Pinaglapatan and Magsaysay as a key driver of positive transformation, enabling them to land on better paying jobs outside the agricultural sector or to migrate overseas (cf. Rigg and Nattapoolwat, 2001). As one participant from Pinaglapatan attested whose daughter received a scholarship from a religious order and is now working overseas, "We lived in shanties before the 2004 flood. Logs carried by strong currents have destroyed our house. My daughter fears that a huge flood might happen again in the future, and so she built us a new house made of concrete" (FGD 2 in Pinaglapatan).

Aside from the changes in land use and livelihood patterns, the 2004 disaster is a turning point for Infanta's local economic development. From a second-class town in 2004, Infanta is now a first-class municipality with a more diversified and integrated local economy. It proudly brands itself as the "service hub" in this northern side of Quezon Province as banks, major fast-food chains, higher education institutions, hotels, and key commercial establishments prospered in its urban center, serving the people from the neighboring island towns. In 1996, around 70% of Infanta's population is poor (Thrupp, 1996; Lucas, 1998). In a matter of less than three decades, poverty incidence is down to 7.6% in 2018, which is significantly lower than the national average of 16.6% (PSA, 2018). Although agriculture still forms a significant share in Infanta's local economy, agriculture's contribution has dwindled over the years from 70% in 1996 (Thrupp, 1996) to 28% in 2014 (Acosta et al., 2016). This trend is consistent with macro-level trends in the Philippines of a shrinking agricultural sector with much of its labor force being absorbed by the service sector (Habito, 2016; World Bank, 2017a; ADB, 2020). Thus, rural poverty in Infanta and in many rural regions in the Philippines becomes increasingly detached from farm work and from agricultural land, a phenomenon that is also taking place in many developing countries across the world (Rigg, 2006; Hellin and Fisher, 2019; Voss, 2022).

The ecological and social transformations that ensued years after the 2004 flood disaster were often accompanied with fundamental institutional changes. Many observers were keen in pointing out that patronage politics, corruption, and weak social accountability mechanisms were the social and political processes that interacted with geological and ecological processes to co-produce the flash flood disaster in 2004 (Gaillard et al., 2006). In less than a year, the Municipal Mayor launched the Community-based Disaster Preparedness and Management Program (CBDP) that led to the creation of new institutions such as the Municipal Disaster Coordinating Council and the Special Committee on Agos River Rehabilitation and Flood Control as well as the mainstreaming of early warning system and disaster response down to the level of barangays and households. For these efforts, the Local Government of Infanta received a national award for good governance in 2007 (Galing, 2007). Moreover, Infanta's experience in institutionalizing capacities on disaster management has informed the drafting and enactment of the country's law on disaster risk reduction and management in 2010 (Interview with a local official). With meaningful participation of civil society organizations in the local planning process, the Local Government was able to incorporate key lessons from the 2004 flash flood were incorporated into the municipality's 15-year land use, legislative, and development plans. However, the integration of climate change adaptation and resiliency into the municipality's vision statement has yet to penetrate plans on the future of Infanta's agrifood sector (Interview with a local official).

Urban water resilience *via* a mega dam project

The World Bank (2012) projected that the annual medium-level demand for water in Metro Manila will cross supply threshold by 2020. This prediction happened earlier than expected (MWCI, 2020). With a population of 13 million, Metro Manila is one of the most densely populated cities in the world with 21,765 people per square kilometer (PSA, 2021a,b).

For more than half a century, the country's capital region has been drawing around 97% of its water needs from Angat Dam. The case for having in place an additional water source is not only justified by the growing demand for water and the need to "ensure the region's economic and social wellbeing and overall security" but also by the need to anticipate the impacts of climate change upon the city's water security (World Bank, 2012, p. 161). As the World Bank report states,

> In the face of climate change as well as unforeseen disasters affecting the current water supply capacity relying on Angat – Umiray System by 97%, new water sources shall be developed to provide water security to the Metro Manila

> and surrounding areas, and further provide redundancy to the System, even the existing water sources of Angat-Umiray System may well be maintained and developed to its optimum potential (World Bank, 2012, p. 161).

The project also signals the entry of the Philippines to China's Belt-and-Road Initiative (BRI), a global strategy of building economic corridors and cooperation between the Chinese economy and the economies across the world (Gu et al., 2019). For the Philippine government, Kaliwa Dam is the ultimate solution to cut the growing water deficit in Metro Manila. The plan of developing additional water sources in the watersheds of southern Sierra Madre was first drawn in the 1970s under the dictatorial rule of Ferdinand Marcos (Camba, 2021). It would take another authoritarian populist president, an alarmist discourse on climate change, China's financing, and a historic water crisis in 2019 to finally pursue the plan.

In the early weeks of March 2019, thousands of households from at least seven cities in Metro Manila as well as in the neighboring province of Rizal were left with no supply of water for several days (Rivas, 2019). Some analysts attributed the water outage to low water levels in the reservoir due to El Niño phenomenon (Lee et al., 2020) coupled with a surge in consumer demand and institutional lapses in regulation (Torio et al., 2021). The President and his economic managers seized the opportunity to make a compelling case for the construction of Kaliwa Dam amid fierce opposition from a network of protesters both in the Philippines and abroad. In press briefings, the President said he is ready to use the extraordinary powers of the Presidency if that is what it takes to break ground for the contentious project, adding that his main concern is the "greatest good for the greatest number," an obvious reference to the sheer size of Metro Manila's population (Corrales, 2016).

While politicians tend to frame Kaliwa Dam as a straightforward technological fix to a known supply and demand problem, official communications situate the mega dam project within the discourse of climate change adaptation and resiliency alongside the broader 2030 Agenda for Sustainable Development. Such framing puts Kaliwa Dam in a more contentious position, raising questions around uncertainties, social and ecological trade-offs, and their implications to either long-term positive transformations or maladaptation of the broader social-ecological system. An organized network of Indigenous people communities, farmers groups, environmental organizations, and church groups is quick to raise these uncertainties and trade-offs in a petition letter requesting the President to revoke the project (see Table 1).

Some of these uncertainties and potential trade-offs can generate multi-scalar and cross-temporal impacts on rural agrifood systems. For instance, while the displacement of the Dumagat-Remontados in their ancestral domain may fast-track their integration into market-based livelihoods (MWSS, 2019), it can also mean a permanent loss of traditional ecological knowledge about regenerative ways of growing food. And while there are engineering measures planned to allow upstream and downstream movement of aquatic animals, there is a wide range of variability in the biophysical requirements of aquatic species and in the levels of environmental stresses that they can withstand. A closer review of the environmental impact assessment report reveals that there seems to be little attention given to the long-term risk of coastal erosion in the deltaic plains of Infanta due to the expected reduction of sediments to flow downstream. It is yet unknown how much of such a change in the river flow and morphology is needed to intensify existing levels of saltwater intrusion in Infanta's water table and farmlands considering projected scenarios of sea level rise. The head of the Philippine Institute of Volcanology and Seismology once said that a shoreline protection measure might be necessary for Infanta should the construction of Kaliwa Dam pushes through (GMA Public Affairs, 2019).

With regards to offsetting the forest cover losses in the dam site and reservoir structure, the government ensures environmental groups that watersheds surrounding the dam will be protected and that degraded areas will be planted with tree species endemic in the area (MWSS, 2019). However, the extent of the potential impact of the forest cover loss upon the long-term ecological resilience of this southern tip of Sierra Madre ecosystems is largely unknown. Militarization in the area is expected to intensify, a process that began in 2019 when the government started constructing the bunk houses and the access roads leading to the dam site. While this heightened policing will protect the watersheds around the reservoir from illegal loggers and poachers, the presence of the military might inadvertently cut off local communities' rightful access to natural resources, particularly the Indigenous peoples whose rights to their ancestral lands are protected by the State (cf. Delina, 2020).

There are viable alternatives to Kaliwa Dam including the proposal of a Japanese firm for an intake weir that can meet the additional water supply requirements of Metro Manila without causing irreversible social-ecological disruptions in the watershed area. However, the Philippine Government prefers Kaliwa Dam for its storage capacity that can ensure a more predictable and reliable water supply during drought or when the water flow is weak. In a position paper submitted to the Committee on Cultural Communities of the Senate of the Philippines, civil society organizations have laid out integrated approaches in closing the water deficits in Metro Manila both from the demand- and supply-side including the rehabilitation of existing water sources and restoration of Philippine forests, increasing the volume of recycled water from Laguna Lake, more equitable water distribution across industries, high- and low-income households, and improving the efficiency of water distribution systems. Camba (2021) asserts that by privileging the China-funded Kaliwa Dam over other alternative pathways to urban water resiliency, the Duterte administration secures the President's political clout among a select group of local elites that

TABLE 1 Uncertainties and trade-offs raised by anti-Kaliwa Dam social movements and the corresponding government response and framing of the issues.

Uncertainties and potential trade-offs raised by groups against the Kaliwa Dam project	Government response/framing of the issue
Displacement of at least 5,000 Indigenous peoples from their ancestral domain	MWSS promises just compensation and proper relocation of displaced families. Alternative livelihoods will also be provided.
Loss of forest cover in the 300 hectares of Sierra Madre which serve as habitat for endemic species of plants and animals	MWSS has developed Environmental Management Plan that outlines the strategies to mitigate the loss of ecologically important species, including the collection and propagation of seeds of ecologically important species (MWSS, 2019).
Ecological and socio-economic impact of the changes in river flow and morphology.	Fish passes will be constructed to allow upstream and downstream movement of migratory aquatic species (MWSS, 2019). The government assures the public that water extraction for Kaliwa Dam will not affect the groundwater supply for Infanta.
Flood risk to 100,000 residents downstream especially when dam reaches its critical level during heavy rains and tropical cyclones	Kaliwa Dam will have mechanisms to control the rate of water flow when risk of overflow is present. Existing flood control measures will also be reinforced with the construction of the dam.
Risk of dam breakage due to earthquake	The government did not dismiss the possibility that the active fault 15 kilometers away from the dam can cause ground shaking, which might affect the engineering structures of the dam.
Railroading of the legal process involved in the issuance of the Environmental Compliance Certificate and in securing the free, prior, and informed consent (FPIC) of all six clusters of Indigenous people's communities.	In 2019, MWSS reported that the community assemblies required by the Indigenous Peoples' Rights Act in securing the FPIC have been completed. The government's Commission on Human Rights is investigating the alleged human rights and Indigenous peoples' rights violations, including the tagging of some Indigenous peoples as anti-government.
Increase in foreign debts and debt traps with China in case of loan default	Top-level government officials assured the public that the President will not allow onerous provisions in the China-funded Kaliwa Dam project (Parrocha, 2020) and that "the loan agreement does not state any collateral that the Philippines would give up if it fails to pay the loan" (Ranada, 2019).

will benefit from the project while leaving a legacy for building a monumental infrastructure project.

Perspectives of rural communities in Infanta on Kaliwa Dam

During fieldwork, posters of dissent can be seen in Infanta's *población* or town center. The tagline that seemed to capture the intertwined fates of Metro Manila and rural Infanta are these: *May buhay din kami* ("We have to live too"). This perspective that the government chooses the welfare of the people in Metro Manila at the expense of rural communities' future security and resilience is salient in the focus groups and interviews.

Many participants in the flood-prone areas of Magsaysay and Pinaglapatan fear a catastrophic flooding due to the imminent release of water in case the spilling level is breached, and these fears are often in reference to the 2004 flood disaster. First-hand accounts during the focus groups and records have indicated that the people of Infanta have also resisted earlier attempts (i.e., in the 1970s up to the 1990s) by the government to build Kaliwa Dam, but their collective memory of the 2004 flood disaster serves as a cognitive handle from which they process the uncertainties around Kaliwa Dam and what could possibly happen with extreme weather events and a damaged ecosystem.

In terms of key drivers, many participants believe that Kaliwa Dam's potential trade-offs, uncertainties, and maladaptive outcomes are the ones that can bring radical changes to their livelihoods and communities. In fact, the perceived impacts of Kaliwa Dam are already shaping the decisions of some households to buy or save for a property in a high-elevation area. Table 2 summarizes the key themes of local perspectives on Kaliwa Dam and supporting qualitative data.

Discussion

So far, I have described the social, ecological, and political changes that took place in Infanta after the 2004 typhoon disaster as an ongoing, long-term pathway of transformation. But such transformation is far from being clear-cut, and its outcomes are mixed and contested (cf. Blythe et al., 2018). For one, the poorest rural households had to carry the double burden of shifting their livelihoods and having the responsibility to protect the remaining forests, which was declared a national park. With limited institutional support from the national government for alternative and more sustainable livelihoods, this responsibility as stewards of the forests also means a restricted access to land and other livelihood assets while the state and major

TABLE 2 Local perspectives on Kaliwa Dam in Magsaysay and Pinaglapatan.

Themes	Representative statements from participants
The 2004 flood disaster shaping attitudes toward Kaliwa Dam	"We are terrified of Kaliwa Dam because of what happened in 2004" (FGD 1 in Magsaysay)
	"If Kaliwa Dam releases its water, Infanta will be first hit. Japanese scientists who came here right after the 2004 flood told us that our soil is not good in holding water" (FGD 2 in Pinaglapatan).
	"Kaliwa Dam will test the resilience (*katatagan*) of the people here" (FGD 1 in Magsaysay).
Urban-biased development	"They care for the people in Manila, but not for us here" (FGD 1 in Magsaysay).
	"The government only thinks of Manila and the majority who will benefit from the dam. What about the people here in Infanta who are not in favor of the dam? We are all equals. The government should strike a balance and do what is right" (FGD 2 in Magsaysay).
Lack of voice and power to shape the decisions over Kaliwa Dam	"In this day and age, the government gets what it wants even if the people opposes. Nobody knows exactly what the dam can do to our lives. It may put our lives in danger" (FGD 1 in Magsaysay).
Kaliwa Dam will bring radical changes to rural livelihoods and people's lives	"If there is one thing that will bring major changes in Pinaglapatan, it is going to be Kaliwa Dam. In our experience, water goes nowhere but here. Infanta will disappear from the map if Kaliwa Dam breaks" (FGD 2 in Pinaglapatan).
Perceived impacts of Kaliwa Dam are shaping individual and household decisions concerning livelihoods and wellbeing	"Time will come that we have to leave this place. It is written in the bible: the world will get worse; life will get tougher" (FGD 1 in Pinaglapatan).
	"We know people who are serious of relocating. Our relatives have been looking for a property in a high elevation area. There is no security (*kasiguraduhan*) here since it is really vulnerable to flooding" (FGD 1 in Pinaglapatan).

corporate players were, in many ways, allowed to use resource-rich forest lands with high-income urban areas often benefitting disproportionately in the process (cf. Li, 2002). This fortress-like conservation strategy ignores many forms of social injustice that forced landless farmers from the lowland to migrate to the upland areas and engage in extractive livelihoods (Bryant, 2000; Brockington et al., 2012). In the case of Magsaysay, local communities found themselves contending with the state who gave logging licenses to private concessionaires, some of which were owned by military officials and cronies of the then dictator Ferdinand Marcos during the Martial Law era (Kummer, 1992), while rural communities had to either work for the logging concessionaires or fend for themselves through illegal, small-scale logging and upland farming in marginal lands (Van Den Top, 2003). These "legacy effects" (Liu et al., 2007) of unsustainable regime of resource extraction have cascaded down in temporal and spatial scales as seen in Pinaglapatan and other downstream communities in Infanta and neighboring towns in the form of a flood disaster and its long-term consequences to community resilience.

It is against this backdrop of rural livelihood change and the collective experience with an environmental crisis that the widespread and stiff opposition against Kaliwa Dam can be interpreted as a tension between two pathways of transformation. The second pathway represents not only a particular socio-technical trajectory in maintaining urban resilience but also the dominant narratives of modernity and capitalist development (Rist, 1997), which in many ways have created the urban water crisis in Metro Manila in the first place. The preferred strategy of the Philippine government to make the water system of Metro Manila "climate adaptive" is a major techno-managerial fix by way of a mega dam project in an ecologically critical rural space. Its proponents contend that its long-term benefits far outweigh the costs. Conversations about the different forms of trade-offs and uncertainties have been either swept under the pretense of risk mitigation or dismissed as baseless claims in an effort to politicize and undermine a rather technical development intervention.

There are many reasons to believe that multi-scalar and cross-temporal pathways of transformations are *entangled* or caught up in interdependent relationships as when the amount of water that Kaliwa Dam can store depends on the ecological integrity of the Sierra Madre watersheds, a property of the ecosystem that has been gradually restored through the efforts of local communities and institutions. It would be easy to misconstrue this entanglement merely as spatial networks of resources, commodities, effluents, people, and other quantifiable dimensions of resilience and vulnerabilities between rural and urban spaces. A closer look at this interdependence reveals that these pathways of transformations are also entangled in temporal scales as certain decisions made today for urban water resilience will affect the adaptive capacities of rural agrifood systems in the future (Burnham and Ma, 2018). While it is essential to understand system flows, feedback loops, and time lags as a result of interacting adaptation pathways, it is also equally important to examine the underlying social forces and relations that have brought these pathways of transformations in ways that may potentially create new trade-offs, uncertainties, and maladaptive outcomes. Drawing on the case study and the broader literature on political ecology,

agrarian and development studies, and science and technology studies to complement complex systems thinking, three major analytical themes are developed below, which also serve as a summarized response to the research questions:

- Pathways of transformation and their entanglement are rooted in historical processes of change. In the context of the case study, the tension has its roots in the entangled histories of rural and urban Philippines.
- Potential trade-offs, uncertainties, and maladaptation are contingent on the political relations between the "central" and "peripheral" pathways. In the context of the case study, the control-oriented pathway of urban water resilience (central) tends to feed on the regained resilience and existing/future adaptive capacities of rural social-ecological systems (peripheral).
- Equity and social-ecological justice must be front and center in assessing the potential trade-offs and maladaptive outcomes of interacting adaptation pathways. This is possible only when questions of who decides which trade-offs and maladaptive outcomes are acceptable, what sorts of knowledge define acceptable trade-offs of interacting pathways, and who bears the cost of such trade-offs are taken into account.

It is hard to dissociate the tension between Kaliwa Dam as an urban water resilience pathway and the post 2004 social-ecological transformations in rural Infanta from the Philippines' skewed development trajectory toward urbanization. The major drivers of vulnerabilities in both urban and rural Philippines are rooted in key social processes that span across the colonial and post-colonial eras as well as post-war period. Among these key moments and social forces that illustrate the intertwined nature of the resilience and vulnerabilities of rural and urban systems are the state territorialization dating back to Spanish colonial rule (Montefrio and Dressler, 2016; Pichler et al., 2021), the postwar development regime (Hayami and Kikuchi, 2000; Balisacan, 2001; Ravago et al., 2018), and the neoliberal turn in public policy (Bello, 2009; Porio, 2009; Habito, 2016; World Bank, 2017a; ADB, 2020).

Aside from the structural issues that drove this skewed development, climate-related hazards are found to drive outmigration of people from highly agricultural regions (Bohra-Mishra et al., 2016). The internal migration from rural to urban areas and consequently, the shift from a low-productivity sector to another low-productivity sector (i.e., low-income jobs in the service sector, non-manufacturing industry) have created new forms of vulnerabilities such as precarity in employment, increasing urban poverty, and the expanding informal settlements in high-risk urban areas already exposed to recurrent flooding (World Bank, 2017a), a global trend linked to modern slavery (Natarajan et al., 2019; Bales and Sovacool, 2021). In a World Bank review on urbanization in the Philippines, urban population constitutes 44% of the entire population with cities accounting for more than 70% of the country's GDP (World Bank, 2017b). No wonder urban consumers and sectors receive far more political attention and support than their rural counterparts when the government is faced with policy dilemmas involving rural-urban trade-offs (Torio et al., 2019).

On one hand, this dialectical relationship echoes the classical Western critical thought on the origins of the rural-urban divide (Schneider and McMichael, 2010). As Moore (2000) explains, "Urban-based capital remade the social structure and ecology of the countryside, causing the latter to decisively condition the social structure and ecology of the cities and the emergent world-system as a whole" (p. 125). On the other hand, the historic and future outcomes of the entangled pathways of urban water resilience strategy in Metro Manila and the post 2004 social-ecological transformations in rural Infanta are context-specific co-products of complex ecological and socio-political forces, which should not be reduced only to the logic of capitalism and industrialization (cf. Spanier and Feola, 2022).

However, it can be argued that the potential adaptation trade-offs are contingent on the pathways' dialectical *and* political relations. In other words, the trade-offs inherent in a society's choice of adaptation pathway alongside the uncertainties and maladaptive outcomes that such a choice may produce are a function of power asymmetry between interacting pathways of transformation.

To illustrate this point, a heuristic device of "central" and "peripheral" pathways is hereby proposed. While similar typologies have been used in the past, some of these categories do not adequately express the interdependent relationship between pathways (such is the case of dominant vs. alternative pathways to sustainability, see Leach et al., 2010). Pathways of transformational adaptation are also rarely a product of a unidirectional vision of top-level planners and experts or grassroot actors (in the case of "above" and "below" approaches to address climate-related uncertainties, see Mehta et al., 2022). The heuristic device of central and peripheral pathways is being offered here not to discount the value of existing categories of socio-technical and policy trajectories but to highlight how a critical analysis of an inequitable relationship between different pathways of transformation is catalytic in producing new forms of risks and uncertainties in the context of unprecedented impacts of climate change.

Proponents of *central pathway* often adhere to the separation of nature and society as an implicit ontological stance shaping policies and programs, and thus, treat climate change as an external geophysical threat to social-ecological systems (Nightingale et al., 2019). Such view enables the incumbent power and knowledge of science and the logics of the markets to legitimize which framing of the climate adaptation challenge is acceptable, set how the future should look like, and decide which uncertainties are valid, notwithstanding the unpredictable

ecosystem dynamics, incomplete knowledge, and unwieldy political structures (Mehta et al., 2022). Thus, central pathway takes science and policy as instruments of politics in advancing a political vision by way of rendering a complex adaptation challenge into a technical, apolitical one (Li, 2007), and, in the process, avoiding to confront the uncertainties of complex realities (Arora, 2019). Consequently, these adaptation pathways are legitimized by a dominant group in society, enabling at times authoritarian populist policy stance and sustaining social inequities (Borras Jr et al., 2022). However, central pathways may also trigger counter reactions from a wide array of stakeholders particularly those whose resilience and adaptive capacities are on the line. Borrowing Tania Li's ideas and metaphor of *métis,* these pathways of transformation do not just simplify complex processes to satisfy state ideologies; "they also generate something new—new ways of seeing oneself and others, new problems to be addressed, new modes of calculation and evaluation, new knowledge and new powers" (Li, 2005, p. 389), making central pathways co-products of both top-down and bottom-up processes.

Peripheral pathway, on the other hand, often has an emergent, self-organizing property and takes the ontological stance of people's lifeworlds where environmental and social issues are entwined with everyday livelihoods, pragmatic responses to change, and with culturally situated and place-based experiences (Scoones, 2015; Clay, 2018). Thus, actions that may count as "climate adaptation" are often viewed by the actors themselves as inseparable from the assemblage of responses to interacting drivers of social-ecological change (Bennett et al., 2016; Ensor et al., 2019). It is characterized by the pluralities of ways of knowing in which science and top-down policies are seen through the optics of historical and everyday experiences of risks and uncertainties (Orlove, 2009). Such pathway of transformation is an outcome of incremental learning, improvisation, appropriation, resistance (Boyd and Richerson, 1985; Godin, 2008; Glover et al., 2016), and the collective effort to reclaim local knowledge and embrace new ones that fit evolving "civic epistemologies" (Jasanoff, 2005). Those who have been historically marginalized in society on the basis of their geographic and social locations (ethnicity, class, caste, and gender) are in the position to defend this personally valued trajectory of change as their identities, survival, and future resilience are at stake (Dutta, 2018).

In the context of climate change adaptation, the dialectical and unequal power relations between the central and peripheral pathways facilitate the spatial and temporal shifts of social-ecological resilience and vulnerabilities to the detriment of the peripheral pathway. This heuristic device can be applied in analyzing potential maladaptation in similar cases of interacting adaptation pathways such as the large-scale land acquisitions for economic development in Ghana that constrain farmers' local adaptation strategy called *zaï* (Nyantakyi-Frimpong, 2020) or the regional transition to export-oriented quinoa production in Bolivia and its non-linear interactions with traditional wetlands conservation and informal institutions, which are vital to long-term system resilience to climate change (Chelleri et al., 2016).

In the context of the case study, Kaliwa Dam will be built in a rural ecosystem that has been going through a social-ecological transition toward forest and watershed restoration and a more diversified rural livelihood. Even before the flood disaster of 2004, rural communities in Infanta have endured decades of postwar state territorialization and rural development schemes that contributed to the localized ecological and social vulnerabilities of the landscape and the agrarian communities, respectively. In many ways, the social-ecological transformations in Infanta over nearly two decades became an opportunity for local decision makers and communities to rectify the outcomes of social and ecological injustices committed in the past. The idea of Kaliwa Dam is plausible not because watersheds and water resources in the Sierra Madre region are readily available awaiting to get exploited but because the co-production efforts of rural communities, local and national public institutions, civil society, and research institutions made these natural capitals available. In the absence of a clear plan on how the benefits and risks can be equitably distributed, the control-oriented pathway of urban water resilience (central) seems to feed on the regained resilience and existing/future adaptive capacities of rural social-ecological systems (peripheral). This argument deserves more attention as there are indicators that the construction of the Dam will open the floodgates, so to speak, for other much bigger mega dam projects in the southern Sierra Madre region, a potential case of path dependency that can have serious effects to overall systemic resilience and adaptive capacities across rural-urban spaces and in different timeframes (cf. Barnett and O'Neill, 2010).

Is it possible to untangle a "mess of jumbled knots" (Hodder, 2020, p. 392) and spawn a new entanglement that promotes more equitable, just, and sustainable present and future for all? Related studies point to the importance of avoiding lock-ins and irreversible maladaptive outcomes by ensuring flexibility and robustness of adaptation options and designs (Nguyen et al., 2019; Butler et al., 2022) as well as the need to strategically engage decision makers and other stakeholders across levels in the adaptation planning process (Chaudhury et al., 2017). However, Schipper et al. (2021), while reflecting on "turbulent transformations" brought by COVID-19 and its implication to climate resilient development, have cautioned that strategic planning falters in the face of widespread disruption and the contested responses to it and called for transformative approaches in governance. But as this article suggests, by placing the analysis of the entangled pathways of transformational adaptation within relevant historical junctures of development and change, it is clear that equity and social-ecological justice must be front and center in assessing the potential trade-offs and maladaptive outcomes of interacting adaptation pathways (Marino and Ribot, 2012; Tschakert et al., 2013; Wise et al., 2014; Eriksen et al., 2015). Since adaptation inevitably creates

new uncertainties and vulnerabilities (Tellman et al., 2018), researchers and planners must seriously confront the questions who decides which trade-offs and maladaptive outcomes are acceptable (Chelleri et al., 2016), what sorts of knowledge define acceptable trade-offs of interacting pathways, and who bears the costs of such trade-offs. This approach should complement valuation and impact assessment methods, which currently dominate adaptation policy, planning and management. In particular, environmental impact assessment and valuation study should make use of a diverse range of appraisal methods to "open up" and "broaden out" knowledge of and perspectives on potential trade-offs, uncertainties, and maladaptive outcomes as well as entry points for positive tipping points (Stirling, 2008; Scoones and Stirling, 2020; Lenton et al., 2022).

Because transformational modes of adaptation tend to create bigger risks for trade-offs, uncertainties, and maladaptation (Barnett, 2013), the idea of entangled transformations behooves institutions and the wider society for a deeper kind of collective reflexivity and action that can transform narrow notions and practices of resilience and sustainable development (cf. O'Brien, 2021b). Adaptation research and policy in the agrifood systems can move toward this direction through multi-scalar and emancipatory engagement of various actors, transdisciplinary research that broadens the politics of adaptation, and methods that mobilize different ways of knowing. Adaptation researchers may also need to rethink the dominant assumption that little transformational adaptation is taking place (Fenton et al., 2017; Few et al., 2017) and start documenting instances of entangled adaptations in agrifood systems contexts particularly those embedded in emerging transnational patterns of global development (for example, see Nyantakyi-Frimpong, 2020). Transformational modes of adaptation could be far more inexorable and inescapable than is commonly thought. In this context, future evaluation and policy studies may focus on the interaction of multiple, entangled adaptation pathways and the development of research methods to better understand not only the dynamics of coupled social-ecological systems but also the evolving human, social, and political forces that drive systemic change.

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 study was reviewed and approved by the University of Guelph Research Ethics Board with approval number REB# 20-05-023. The 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.

Publisher's note

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