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Climate change loss and damage from droughts: key insights from Fiji's sugar industry

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ABSTRACT

Climate change loss and damage (L&D) due to both sudden and slow-onset events are a growing concern for vulnerable countries. Over the last decade, agricultural communities in Fiji have suffered a range of serious L&D from severe drought events. Through a grounded theoretical lens, qualitative research was used to gain in-depth insights into L&D from droughts in the Fijian sugar industry. In-depth semi-structured interviews ($n = 68$) were conducted in two Indo-Fijian sugarcane communities, Barotu and Toko settlements in Western Viti Levu, Fiji, and with key stakeholders from government ministries, academia, and climate change experts at the national level. Purposive sampling was initially used to identify smallholder sugarcane farmers and key stakeholders. Theoretical sampling further identified key stakeholders for the interview. Despite implementing various adaptation measures, the Fijian sugar industry has suffered severe L&D, including non-economic L&D (NELD) and associated cascading effects. L&D included reduced yields, loss of crops, and reduced income. NELD included deterioration of mental, physical, and emotional health, loss of hope, and uncertainty. Cascading effects included increased food insecurity risks and impacts on children's education. Key policy interventions are recommended, such as removing adaptation constraints, developing drought risk profiles and early warning systems, investing in livelihood diversification, and engaging in new markets to facilitate social and ecological transformations that will promote livelihood resilience.

Key Policy Highlights:

- Climatic and non-climatic stressors are inherently interconnected and interact in a complex and complicated manner to enhance social-ecological systems (SES) vulnerability.
- Inadequate drought adaptation measures further marginalise farmers and ultimately increase their vulnerability to drought risks and loss and damage (L&D).
- L&D presents itself in various ways, including non-economic L&D and cascading effects that are impacting upon future generations.
- With projected climate change and the likelihood of impacts worsening, there is an urgency to address L&D more coherently through crucial policy interventions.

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1. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) working definition of anthropogenic climate change loss and damage (L&D) is "the actual and/or potential manifestation of impacts associated with climate change in developing countries that negatively affect human and natural systems" (UNFCCC 2012, 3). Economic L&D includes resources, goods, and services commonly traded in the market. Non-economic L&D (NELD) consists of a broad range of losses that are not traded in the market (UNFCCC 2021).

Our research utilised a social-ecological systems (SES) approach to understand SES vulnerability, climate adaptation, and L&D in Fiji's sugar industry. According to Pearce et al. (2018), vulnerability is conceptualised as a function of exposure to bio-physical events, sensitivity to these exposures, and the adaptive capacity to deal with these exposure-sensitivities. Our study uses the same framework to document the vulnerability of Fiji's sugar industry to droughts. The ability of individuals and communities to experience and respond to exposure to hazards is determined by a wide range of social, economic, political, and economic factors that are distinctive to a particular place. Therefore, vulnerability is context-specific and a result of an interplay between biophysical, social, economic, political, and economic factors (Smit and Wandel 2006).

Climate adaptation is "the adjustment process to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" (IPCC 2014, 118). Adaptation action can range from incremental, systems, and transformational adaptation measures (Iese et al. 2020; Jakku et al. 2016; Moser and Ekstrom 2010; Rickards and Howden 2012).

Incremental adaptation refers to adjustments in SES where the system remains on a pre-existing trajectory and maintains its key elements and processes while adjusting to changes within the environment (Deubelli and Mechler 2021; Dharmasiri and Jayarathne 2021; Hadarits et al. 2017; Vermeulen et al. 2018). Incremental adaptation, such as adjusting planting times, introduction of irrigation technologies, and nutrient management has short-term benefits and often fails to address the underlying or root causes of SES vulnerability (Matyas and Pelling 2015; Termeer, Dewulf, and Biesbroek 2017; Webb et al. 2017).

Systems adaptation ensures some degree of fundamental change to an existing system in response to climate change (Dowd et al. 2014; Rickards and Howden 2012). Systems adaptation, such as the introduction of climate-resilient crops, livelihood diversification, and maintaining or regenerating diversity could offer a transitional path to transformational adaptation, ultimately transforming the SES (Iese et al. 2020; Morrison 2021). Transformational adaptation involves a radical change in the SES that entails a series of phases from incremental adaptation to transformational adaptation (Deubelli and Mechler 2021; Jakku et al. 2016). Transformational adaptation includes new processes and products such as changes in land use and the recognition of ecosystem services (Rickards and Howden 2012). Regardless, successful transformative adaptation must be context-specific, such that numerous incremental measures that involve ongoing systems co-evolution with the changing climate can end up becoming a transformative response. Yet, in vulnerable communities, the absence of new adaptation measures and the unavailability of resources limits effective transformations and generates inevitable climatic risks. As a result, despite implementing a range of drought adaptation measures, many communities globally are still experiencing severe L&D from droughts (Iese et al. 2020; Warner et al. 2012; Yaffa 2013).

Current framing of L&D focus on limits to adaptation (Dow et al. 2013), various categories of L&D (avoided, unavoided, and unavoidable) (Verheyen and Roderick 2008), and a values-based approach to L&D, emphasising the subjective nature of losses (Tschakert et al. 2019). In the Pacific Island Countries (PICs), L&D studies revealed major themes such as loss of biodiversity and ecosystem services, cultural heritage, sense of place and identity, and health and well-being (McNamara, Westoby, and Chandra 2021, 2021; Nand, Bardsley, and Suh 2023a). Regardless, current analysis does not fully capture the relationship between SES vulnerability, inadequate adaptation, and L&D and how communities dependent on natural resources for livelihood experience L&D, including NELD.

Drought is described as a "creeping disaster", and extensive L&D has been documented across the PICs due to droughts (Iese et al. 2021; 2020). The impact of drought varies depending on the type (meteorological or agricultural), the geographical location, and other factors such as socio-cultural and socio-economic condition (Iese et al. 2020). Agricultural drought is caused by below-average precipitation and high temperatures which evaporate moisture from the soil and plants and influence crop yield (Orimoloye 2022).

Drought is a growing concern for Fiji's agricultural sector because it has caused drastic reduction in rainfall, leading to devastating socio-economic loss, and physical and structural damage (Rhee and Yang 2018). Reductions in rainfall present particular challenges to Fijian agriculture as the country largely lacks modern irrigation systems (Nawai et al. 2015).

Most of the meteorological drought in Fiji is associated with strong El Niño events, which result in severe rainfall reductions (Koroiwaqa 2016; Kumar, Deo, and Ramachandran 2006; Mataki, Koshy, and Lal 2006). The 1997/98 El Niño drought in Fiji was described as a 1-in-100 year event, with rainfall failure occurring across two consecutive dry seasons (Rhee and Yang 2018). The resulting severe water crisis reduced agricultural production, increased mortality of livestock, causing numerous health problems, wildfires, loss of soil fertility, and saline water intrusions (Kelman 2019; Pearce et al. 2018; Rhee and Yang 2018; Terry 2005; The World Bank 2018).

During the severe drought of 1997/98, sugarcane harvest was reduced by 50 percent (Wairiu 2017), and in some areas, sugarcane crops were completely destroyed (Feresi et al. 2000; Lightfoot 1999). Consequently, sugar exports declined by nearly 30 percent (Zhongwei 2015). More than one-third of Fiji's population needed emergency food and water supplies (Terry and Raj 2002). Shortage of food and water also caused nutritional deficiencies and other health problems (Lightfoot 1999). This widespread drought and famine cost the agricultural sector an estimated US$65 million (Barnett 2001; Feresi et al. 2000), and in total, Fiji's economic loss was estimated to be FJ$275-300 million (Richards 2018). Yet, the estimated loss did not include NELD such as health-related costs for dengue fever, heat stroke, cardiovascular disease, and respiratory disease (Richards 2018). Government assistance and external aid were heavily relied on for recovery purposes, but they did not meet the needs of vulnerable communities (Feresi et al. 2000).

There are a limited body of empirical studies (e.g. Iese et al. 2021; Rhee and Yang 2018) on climate change impacts and L&D from droughts in Pacific Island Countries. To fill the research gap, the primary aim of our study is to apply a multi-case study approach to examine the relationship between SES vulnerability, adaptation measures, and resulting L&D from recent agricultural droughts in Fiji, focusing on the sugar industry. The paper is structured as follows: Section 1 provides an overview of SES vulnerability, adaptation, various framings and interpretations of L&D, and the aim of the study. Section 2 describes the study sites in detail and elaborates data collection and analysis methods. Section 3 presents key research findings in the sequence of SES vulnerability, current adaptation measures, and L&D. Section 4 discusses the findings with a link to the current literature and Section 5 details policy recommendations.

2. Research methods

Fiji's sugar industry has a rich history dating back to the late 1800s (Singh 2020). Sugarcane farms in Fiji are concentrated on the two larger islands – the Western side of Viti Levu and the North of Vanua Levu (Chandra et al. 2018). Sugarcane is an economically important crop, with 22 percent of Fiji's population directly or indirectly dependent on the sugar industry (Chandra et al. 2018). Sugarcane farming is primarily undertaken by Indo-Fijians with some 22,500 farms. The number of active sugarcane growers in 2019 was 11,638 (FSC 2020). At the farm level, demographically, Indo-Fijians make up 75 percent of the total sugar industry (Mahadevan 2007). Small farms are a characteristic feature of the sugarcane industry. Each cane grower, on average, has 7 hectares of land, of which around 4 hectares is used for sugarcane production (Prasad and Kumar 2016) and the rest is generally used for horticulture (referred to as cash crops in Fiji) and for subsistence purposes (Lal, Lim-Applegate, and Reddy 2001).

Field research was conducted in two Indo-Fijian sugarcane communities in Western Viti Levu, Fiji: Barotu settlement in Rakiraki, Ra Province and Toko settlement in Tavua, Ba Province (Figure 1). Nailawa creek and Nasivi river runs through the farming areas of Barotu and Toko respectively. In both settlements, the creek and the river have never dried up and serve as sources of water for manual irrigation that involves hand-watering of individual plants in cash crop fields. Both settlements are solely dependent on rainfall for sugarcane production and prolonged dry periods have devastating impacts on their agriculture and livelihood.

Barotu and Toko settlements were selected for research purposes because sugarcane farming is not only the primary source of local livelihoods but also frames the way of life, as the practice of sugarcane farming has been passed down through the generations (Gawith, Daigneault, and Brown 2016). Apart from sugarcane farming and following the norm for Fiji, farmers are also engaged in "cash crop farming" or small-scale horticulture and have a few livestock such as cows, chickens, and goats.

Using grounded theory, semi-structured interviews were used to gain an in-depth insight into local and national stakeholder perceptions of climate change L&D in Fiji's sugar industry. In-depth semi-structured interviews with Indo-Fijian sugarcane farmers and other key stakeholders were conducted from November 2019 to January 2021. Purposive sampling was initially used to identify smallholder sugarcane farmers and other key stakeholders. Theoretical sampling further identified stakeholders for the interview. A total of 20 sugarcane farmers from each of the two study sites were identified, and 28 other key stakeholders were identified. The 28 key stakeholders were interviewed from relevant government ministries, such as the Ministry of Sugar Industry, the Ministry of

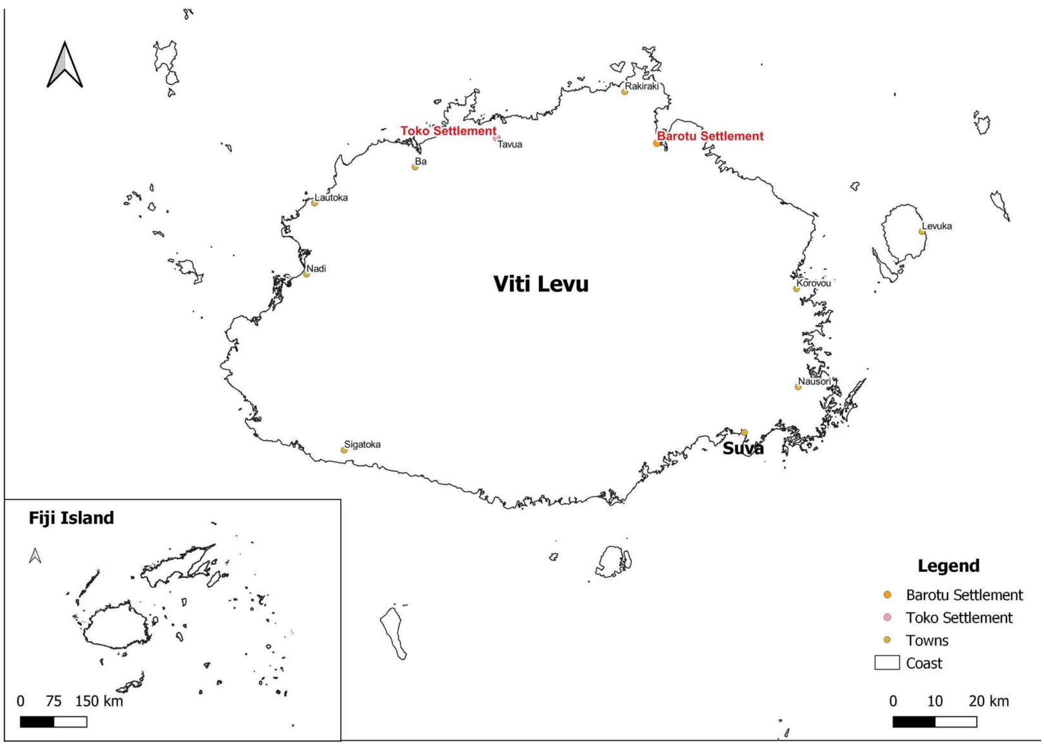

Figure 1. Location of study sites in Viti Levu, Fiji Islands.

Agriculture, the National Disaster Management Office (NDMO), academics, and climate change experts.

Each interview took around 60 minutes and was guided by a list of key questions. A blend of close- and open-ended questions were asked regarding the impact of droughts on sugarcane farms, the adaptation measures implemented by farmers, and the resulting L&D in Fiji's sugar industry. The interviews were audio-taped and a journal was used for memo writing to further help the data analysis process. The interviewer took notes when any of the interviewees preferred not to be audio-recorded.

Once the transcriptions were completed, it was read through thoroughly, coded, and analysed in accordance with guidelines for qualitative research (e.g. Charmaz 2006; Creswell 2014; Kvale 2006). Coding was conducted with NVivo 12 Plus to categorise the data using the most significant and frequently appearing codes. These categories or common threads in the data were developed into the themes outlined below in Section 3.

3. Results

3.1. Social-ecological systems vulnerability

This research used Pearce et al. (2018) vulnerability framework as a starting point to examine SES vulnerability in Barotu and Toko settlements. This section examines both climatic and non-climatic factors of vulnerability in social-ecological systems. These include exposure and sensitivity to drought, adaptive capacity, and drought impacts.

3.1.1. Exposure and sensitivity

Across the two field sites, farmers perceived increased incidences of drought and changes in seasonality. Farmers mentioned experiencing longer and severe droughts as compared to the past (Barotu Farmers 20 and 19 and Toko Farmers 1 and 17). Additionally, Toko farmers mentioned experiencing longer and severe droughts as compared to Barotu settlement. Many Toko farmers described the slow-onset nature of drought emphasising that the creeping nature of drought makes it harder to predict and "before you know it, we are in the middle of the drought" (Toko Farmer 15).

Farmers from both settlements raised concerns that the "seasonal calendar has become unpredictable" and "it has become hard to forecast the seasons" (Barotu Farmer 2 and Toko Farmer 8). Changes within the dry and wet seasons were also experienced in both field sites. Fiji experiences a wet season from December to April and a dry season from May to October. However, both settlements experienced unseasonal severe drought in the wet season of 2015/2016 (Barotu Farmer 12). Since both settlements lack formal irrigation systems, there was a growing concern among farmers regarding changes in rainfall patterns and the impact on agriculture (Toko Farmer 19).

The majority of the farmers considered changes in drought duration and severity as "not normal" and "not witnessed in the past" and attributed these changes to climate change (Toko Farmer 7). Barotu Farmer 18 reflected:

> Climate change is bringing about changes that we are experiencing. Now, we are experiencing hotter days and colder nights. It is very hot and there is a lot of heat. There is less rain but intense rainfall periods. Dry months are also longer.

Apart from climatic factors, stakeholders raised concerns regarding the high cost of living, high production costs, high cost of labour, cost of harvesting and transport, poorly maintained mills, expiry of a preferential trading agreement with the European Union, fluctuating market prices, declining sugar production, and declining numbers of sugarcane farmers. Exposure to such external and domestic shocks affects sugarcane production and export earnings in association with the changing climate.

3.1.2. Adaptive capacity

All households in Barotu and Toko settlements have access to piped water. In both settlements, farmers do not have formal irrigation systems as the infrastructure would be too expensive. Access to essential physical assets such as water pumps was also very limited in both settlements. During drought, farmers resorted to using the river to manually water plants over long periods. Water storage facilities were also limited and farmers made use of drums. Some households in Barotu did have access to larger water tanks, but only for household use among extended family members (Barotu Farmer 11).

Farmers also raised concerns about insecure land tenure. In Barotu settlement, the majority of land lease is issued by the Catholic church, while Toko settlement has Native land (where the land is owned by iTaukei Fijian landowning clans). Insecure land tenure has led to controlled development and high land rental prices, constraining long-term investment in farming, and precipitating feelings of helplessness within households (Barotu Farmers 1 and 14).

Lack of access to financial capital was also perceived as a barrier for implementing adaptation measures. Access to financial capital would enable farmers to invest in water storage facilities and irrigation. However, farmers mentioned that the constant devastating impacts of droughts further place households into financial hardship. Farmers also disclosed dissatisfaction with the limited government assistance, which results in farmers relying on extended family support (Barotu Farmers 1 and 19).

Farmers from Barotu and Toko have a long history of adapting to droughts. Observing changes in weather patterns, such as lack of rain and dryness and cracks in the soil, indicated that the drought was approaching. However, with the recent increase in the severity of droughts and seasonal changes and the slow-onset creeping nature of droughts, farmers mentioned facing difficulty in predicting droughts and implementing adaptation responses.

3.1.3. Drought impacts

During recent severe droughts, farmers from both settlements observed dry and cracked soils. Barotu farmers noted a decline in sugarcane and cash crop yields in association with extended dry periods (Barotu Farmers 19 and 3). Yet, due to the geographical location of Toko settlements, farmers experienced more severe drought and highlighted the burnt-like appearance of sugarcane and a major decline in cash crops (Toko Farmer 12). Farmers in Toko settlement also noted that prolonged drought stress affects biological processes in plants, such as germination and flowering (Toko Famer 19). Additionally, livestock such as cows and goats have inadequate feed in grazing areas.

Due to a reduction in sugarcane and cash crop yield, farmers from both settlements reported reduced household income. Additionally, vegetables are sold at high market value, resulting in food insecurity risks (Barotu Farmer 14 and Toko Farmer 13). Consequently, farmers had to modify food consumption and "resorted to buying less food" and also "relied on tin food" (Toko Farmers 19 and 16).

Farmers from both settlements also expressed concern that there are increased incidences of pest outbreaks during the drought. As a result, farmers from both settlements have intensified the use of agrochemicals as a response to pest outbreaks without necessarily accounting for the consequences to human health and soil and river resources (Barotu Farmer 20 and Toko Farmers 13 and 17).

3.2. Bearing the effects of drought

All local farmer respondents stated that no formal adaptation measures were implemented directly in the sugarcane fields in either settlement. Due to lack of formal irrigation systems, farmers mentioned that drought risks are inevitable and they simply choose to live with the risk and bear the effects of drought (Barotu Farmer 16 and Toko Farmers 1 and 16).

During drought, the Ministry of Sugar Industry, in collaboration with the Sugar Research Institute of Fiji (SRIF) and the Fiji Sugar Corporation (FSC), "has a farmer outreach component, updates on social media pages, and consultation on the radio" (Stakeholder 25). Regardless, farmers raised concerns that "the agricultural officers do not advise or help us during droughts" (Toko Farmer 2). Consequently, farmers have been "left to manage on our own" and have adopted a "do it yourself" attitude or "do what we think is right" (Barotu Farmer 8). Farmers raised further concerns that a period of severe drought is followed by a cyclone, which in turn is followed by another drought, and those compounding events places farmers in a constant recovery mode and are particularly difficult to overcome (Barotu Farmer 8 and Toko Farmer 20).

3.3. Adaptation measures

The section will present results on the various types of adaptation measures implemented by the sugar industry, including incremental, systems, and erosive adaptation measures.

3.3.1. Incremental adaptation measures

Reliable supply of water. The most widely adopted adaptation measure in both settlements included preparing for drought with a reliable water supply for farm and household consumption. At the farm level, adaptation measures in both settlements were usually geared towards maintaining the cash crop farms as this is a "regular source of food and income for the household" (Toko Farmer 16). Farmers who owned water pumps used them to irrigate cash crops. Farmers who did not have access to water pumps had "no option but go to the river and carry bucket loads of water to water the plants" (Toko Farmer 19). Many farmers reported that manually watering the cash crop "is more labour and time-intensive" and "is very tiring work, especially in the heat" (Barotu Farmers 10 and 20).

At the Ministry level, due to the lack of a formal irrigation system, the Ministry of Sugar Industry provides irrigation grants and irrigation tanks to drought-affected communities (Stakeholder 16). The water tanks are provided for free and used to irrigate cash crop fields (Stakeholder 11). Additionally, irrigation grants are provided to farmers with the aim to "assist growers to prevent farm losses during drought" (Stakeholders 16). The irrigation grants can be used to purchase equipment such as water pumps. However, while initiatives are being implemented by the Ministry of the Sugar Industry, such grant schemes are not reaching targeted communities, and farmers were unaware of these opportunities.

Furthermore, households in both settlements ensured a reliable supply of water for meeting household needs. Toko settlement has a regular supply of water for household consumption, while Barotu settlement faced challenges with water supply during drought. Barotu farmers have adapted to drought by investing in alternative water sources such as boreholes and water tanks. Yet, households with water tanks were still vulnerable during drought as their water tanks ran dry and were not filled on time by relevant authorities (Barotu Farmer 11).

Farm and soil management practices. The Ministry of Sugar Industry advocates for sustainable farm and soil management practices. These practices include using green manuring techniques, using mill-mud, leaving land fallow, and intercropping (Stakeholders 11 and 16). To demonstrate the importance of sustainable farm and soil management practices, SRIF invites farmers to field days, which are interactive platforms for technology and knowledge transfer and include observation of grower demonstration plots (Stakeholder 25). While sustainable farm and soil management practices could offer benefits under changing climatic conditions, their adoption remains very limited at the community level.

During the fieldwork in Barotu and Toko settlements, it was noted that farmers had not adopted these practices. For example, in both settlements, only mono-cropping was practised, making farms vulnerable to changing climatic conditions and pest outbreaks. Secondly, farmers practised "burning of sugarcane" for easier and faster harvesting. However, these actions are not only "seriously damaging the soil and causing soil erosion" but are also "deteriorating the quality of sugar produced" (Stakeholders 11 and 16). Additionally, during droughts, farmers from both settlements intensified the use of agrochemicals to respond to pest outbreaks without necessarily accounting for the consequences to human health or longer-term soil and river conditions. One reason farmers continue with unsustainable practices could be partly explained by farmers' conservative mindset and behaviours.

Relying on family support. Severe droughts in both settlements resulted in financial hardships. Farmers adapted to drought by relying on social capital through familial support. Farm households who had children engaged in off-farm employment relied on their children's remittances to provide financial support during drought (Barotu Farmer 13). Barotu Farmer 19 explained, "Sometimes, I rely on my son for household expenses as he is employed outside". Nonetheless, relying on family support as an adaptation measure was inadequate and farmers had to "fall back on their personal savings" (Barotu Farmer 16).

Weather and climate outlook. In Fiji, the Fiji Meteorological Services (FMS) provides the Ministry of Sugar Industry with a weather forecast called Fiji Sugarcane Climate Outlook to provide specific advice to sugarcane farmers to enable implementation of adaptation measures to prevent farm losses. Once the climate outlook is available, "extension officers are supposed to contextualise the information" and provide farmers with appropriate "seeds and planting materials" (Stakeholders 24 and 20). Yet, owing to drought's slow-onset and "creeping nature" (Barotu Farmer 5), the "droughts are not really captured" and "the government finds it very hard to know when to trigger the support" (Stakeholders 4 and 9). Stakeholder 9 explained:

> It is like killing you softly and it keeps going and going and going. Then, in the next six months, there is still drought. By that time, you have no crops, no water, no source of livelihood, and you don't know what else to do.

Additionally, there are a lack of drought response mechanisms such as early warning systems or drought-response plans (Stakeholder 16). In such circumstances, the Ministry of Sugar Industry is unable to trigger an emergency response and provide the necessary support to vulnerable communities further marginalising communities. Stakeholder 9 disclosed:

> There is no proper early warning system. It is not just the lack of an early warning system, but also a lack of responsive processes in place. We do not know when to trigger the emergency. That has been happening during the last drought in Fiji. We do not know when we are going to say that we are now going to declare a state of emergency because the drought is also localised.

3.3.2. Systems adaptation

Breeding climate-resilient varieties. The sugar industry is adapting to the changing climate by breeding new climate-resilient sugarcane varieties. The specific qualities that make some varieties more resilient to a range of different climatic events are recognised in the industry. Stakeholder 16 provided a succinct summary:

> Mana variety can withstand floods and is a good variety for drought tolerance. Mana, Qabia, and Naidiri – these three varieties can withstand drought. Viwa withstands strong winds. There is one salt-tolerant variety that is called Qalowa. Qalowa is suitable for low-lying areas, especially coastal areas.

Upon successful sugarcane breeding, FSC extension officers release new varieties to farmers with the expectation that communities will adopt the new varieties and maximise their yield and productivity. While adopting climate-resilient varieties may minimise farm losses, farmers are reticent to adopt new varieties and prefer cultivating the well-known Mana variety. The main reason why farmers do not adopt new varieties is because of the "current payment system which is based on weight payment system" (Stakeholder 16). Stakeholder 16 went on to explain, "The new variety may have good sugar content, but they are not as heavy as Mana variety. In Western Fiji, Mana variety is dominating – it is 95 percent". Therefore, the current payment system does not encourage the adoption of climate-resilient varieties and in effect, the marketing framework hinders systems adaptation.

Livelihood diversification. The Ministry of Sugar Industry considers livelihood diversification an effective strategy to adapt to the changing climatic conditions and encourages farmers to diversify their livelihood into "*cash crops or livestock*" (Stakeholder 16). For instance, "farmers have started to focus on cash crops" such as "okra, pumpkin, tomatoes, and bean to supplement household income" (Barotu Farmers 2 and 18). A few farmers in Toko settlement mentioned seeking off-farm employment such as working in towns and driving trucks to help meet household expenses. Both farm and off-employment provided increased benefits and were used to "cater for household expenses" such as "buying food, sending children to school, and for farm expenses" (Toko Farmers 2 and 4).

3.3.2. Erosive adaptation measures

Erosive measures are undesirable actions that constrain adaptive capacity, compromise livelihood security, and trap households in poverty (Warner and Afifi 2014). Several erosive adaptation measures were noted in both settlements. During drought, extension officers "discourage farmers from planting" crops to avoid severe impacts and L&D (Stakeholder 11). In response to drought, farmers from both settlements planted fewer cash crops and grew vegetables only for household consumption. Yet, such measures could be considered erosive because they have the potential to significantly "reduce household income" and undermine household food security (Barotu Farmer 20).

Farmers also modified their food consumption. Farmers from both settlements chose to "eat less because we do not have fresh vegetables in the farm during drought" (Toko Farmer 16). To overcome food insecurity issues, many farmers relied on personal savings to "purchase groceries" and to "send children to school" (Toko Farmers 2 and Barotu Farmer 18). However, since vegetables were sold at higher market prices, farmers resorted to buying less food which reinforced food insecurity risks (Toko Farmers 19). The reliance on personal savings has potentially severe long-term implications because it drains farmers' savings for their children's education (Barotu Farmer 14). Toko Farmer 1 explained, "So, it is like a vicious cycle. We earn and then we depend on the savings to get us through the financial hardship".

Another erosive coping measure practised in both settlements is the selling of livestock, particularly bullocks. Many poor households resorted to selling cows due to the "failed harvest and lack of income during severe droughts" (Toko Farmer 11). Although selling livestock such as cows provides an immediate source of income for farmers, this adaptation strategy is seen to be counter-productive for poor households in the longer term, as households are left "unable to plough their fields" when the next planting season arrives (Toko Farmer 17).

3.4. Loss and damage

Since no adaptation measures were being implemented in sugarcane fields, farmers from both settlements indicated facing "severe loss of sugarcane yield" (Barotu Farmer 18). Despite manually watering cash crops where possible, farmers observed a significant "reduction in cash crop yield during severe drought" (Barotu Farmer 15). Farm losses were more profound in Toko settlement due to "more severe and prolonged drought" (Toko Farmer 1). Toko Farmer 1 highlighted, "Within seven months, the matured and newly planted crops all start to dry up. I lost almost 100 tonnes of sugarcane".

Farmers from both settlements experienced "reduced household income" due to loss of crop yield (Toko Farmer 13), with some households experiencing "more than 50 percent income reduction" (Toko farmer 20). Due to reduced income, farmers found it hard to meet the minimum "household expenses" such as "buying food, paying bills, and meeting medical expenses", "sending children to school", and meeting "farm expenditure as there was no financial assistance for drought" (Barotu Farmer 11, Toko Farmer 2, Stakeholder 25, and Toko Farmer 6).

During drought, farmers from both settlements also experienced a range of NELD. NELD affected farmers' physical and mental health. Stakeholders mentioned serious health issues that were noted during the severe drought of 2011. As noted by Stakeholder 15, "Fiji's susceptibility to viral disease outbreaks had worsened and Fiji recorded a drought-induced outbreak of diarrheal disease". Farmers in both settlements faced other heat-related health issues such as "severe headaches", "high blood pressure", and "severe asthma" (Toko Farmers 19, 20, and 16). Additionally, food insecurity and access to poorly nutritious food also affect farmers' health and well-being (Toko Farmer 16, Stakeholders 9, and 18).

Alongside physical health and well-being, farmers' responses also highlighted how their emotional health deteriorated during drought. NELD was experienced in the form of uncertainty and emotional trauma. During drought, farmers were increasingly "uncertain if the crops will grow" (Toko Farmer 8 and Barotu Farmer 16). Barotu Farmer 1 explained:

> We lost a lot of sugarcane during the drought and now that we have replanted. I am not sure how this will turn out. So, as farmers, we are faced with such uncertainty and trauma.

Additionally, farmers emphasised loss of hope during drought. For example, during the dry period in 2018, Barotu farmers "only received rain in the last two days" and "almost gave up hope" (Barotu Farmer 19 and 1). During severe drought in Toko settlement, farmers noted similar experiences such as "losing hope" and "just waiting for the drought to pass" (Toko Farmers 8 and 4). To cope with severe drought, Farmer 8 mentioned praying to God for rain. "We start praying for the rain and leave everything up to the Almighty. We also conduct prayer rituals for rain and hope that it will rain soon" (Toko Farmer 8).

Other dimensions of NELD were associated with the cascading effects of drought on households. For example, farmers expressed concern that the loss of income could affect their children's education and translate into long-term impacts. Even though Fiji's government has introduced a tuition-free education policy for primary and secondary school, farmers highlighted concerns that because of loss of income, farmers faced difficulty in "sending their children to school" due to other expenses such as purchasing school books, bags, and shoes (Barotu Farmer 4). Such cascading impacts could generate "spiralling and intergenerational impacts" which undermine future livelihoods (Stakeholder 9).

4. Discussion

4.1. Social-ecological systems vulnerability

The findings reveal that climatic and non-climatic stressors are inherently interconnected and interact in a complex and complicated manner to enhance SES vulnerability. High SES vulnerability was noted in both settlements. Compared to the past, farmers perceived an increased exposure to severe and longer droughts. Although farmers utilised their local observations and seasonal calendars to predict droughts, regardless, the changes in drought, seasonality, and the slow-onset nature of droughts made it difficult to successfully identify the onset of droughts.

Overall, poor adaptive capacity was noted in both settlements due to various factors. Lack of access to water pumps and water storage facilities meant that households had lack of water for farm and household consumption. Water for household consumption and for farm usage was identified as one of the main concerns in Barotu settlements. For example, during a drought, households with water tanks were still vulnerable because their water tanks ran dry and were not filled on time by relevant authorities. Other factors that contributed to poor adaptive capacity included lack of financial capital, lack of engagement with extension officers, lack of government assistance, lack of warning systems, and insecure land tenure. Although each of these factors enhance SES vulnerability, they can also serve as an entry point for drought adaptation. For example, tenure for sugarcane farmers in Fiji is subject to the duration of lease under the Agricultural Landlord Tenants Act

(1976) (ALTA) legislation. This legislation provides a thirty-year lease period, but the option of renewal is entirely up to the landlord, which may limit investment into long-term adaptation measures and provide challenges for sugarcane farming households seeking lease renewal. The future of the sugar industry is heavily reliant on the resolution of the current land tenure system (Dean 2022).

Additionally, unsustainable farming practices, such as burning of sugarcane and maximising use of pesticides further degraded SES and enhanced vulnerability. Studies have demonstrated how degraded ecological systems can have severe consequences for human systems. For instance, a degraded ecosystem loses its capacity to safeguard local communities against hazards. In contrast, a well-managed ecosystem and its regulating services can buffer local communities against hazards and reduce risks (Begg, De Ramon N'Yeurt, and Iese 2021; Depietri 2020; Webb et al. 2017).

Due to high exposure and sensitivity and low adaptive capacity, both settlements suffered severe drought impacts. The impacts are not homogenous across the two study sites, with Toko settlement suffering disproportionately. These impacts included impacts on soil health, lack of germination and flowering, increased prevalence of pests, reduced sugarcane and cash crop yield, reduced household income, and food insecurity risks. To minimise the impacts of droughts, farmers tried to implement adaptation measures (Section 3.3). However, these adaptation measures were inadequate, which resulted in severe L&D (Section 3.4). Therefore, this research argues that to facilitate adequate adaptation and to explicitly understand and reduce L&D, attention must be paid to SES vulnerability, that is, broader social, economic, and political processes at national, sectoral, and community levels.

4.2. Adaptation measures

Similar drought adaptation practices were documented in Barotu and Toko settlements. Since the sugarcane farms are rainfed and lack formal irrigation systems, farmers were not really attempting to mitigate the impacts of droughts in their sugarcane fields. In the absence of adaptation measures, farmers had no option but to bear the effects of drought, accept and live with risks, and face severe L&D.

This research argues that bearing the effects of drought and incremental measures, such as manually watering cash crops offer significantly less benefit under increasing climate change and present marginal changes within the existing SES. Previous adaptation studies by Rickards and Howden (2012), Roberts and Pelling (2019), and Vermeulen et al. (2018) highlighted that incremental adaptation could act as a "lock-in trap" or a barrier for fundamental change in the existing system and lock system or societies into unsustainable pathways. Evidence from both settlements reveals that erosive incremental adaptation measures such as planting less can act as a lock-in trap by reducing household income and enhancing the risk for farmers to be trapped in cycles of poverty. Additionally, incremental measures maintain SES on the same trajectory (Fedele et al. 2020; 2019), thereby limiting any success in transitioning the SES to reduce vulnerability or improving social-ecological conditions (Boon et al. 2021; Fedele et al. 2020; Kates, Travis and Wilbanks 2012; Roberts and Pelling 2019).

Attempts at systems adaptation provided more benefits in comparison with bearing the effects of drought and incremental adaptation measures. For instance, livelihood diversification during drought was used to supplement household income, buy food, and send children to school. While systems adaptation provides some benefit under increasing climate change conditions, households still found it difficult to meet minimum household expenses and suffered severe L&D and NELD. Therefore, higher-level adaptation measures are still required under changing climatic conditions, to redirect the SES towards improved social and ecological conditions.

In the end, the adaptation constraints faced by farmers marginalise them further and ultimately increase their vulnerability to drought. For instance, adaptation initiatives implemented by the Ministry of Sugar Industry, such as grant schemes and irrigation tanks, are not reaching vulnerable rural communities. Additionally, the lack of assistance from agricultural officers is an adaptation constraint. Limited information flows, technical assistance, or advisory support services are available for implementing adequate drought adaptation measures, increasing the likelihood of severe L&D.

4.3. Loss and damage

The findings reveal that adaptation measures implemented were inadequate to avert and minimise L&D. Empirical evidence from this research indicates that farmers suffered severe L&D, NELD, and ongoing, cascading effects. L&D included loss of crop yield, livelihood, and household income. NELD in both field sites included severe health issues and disease outbreaks, deterioration of mental and emotional health, uncertainty, trauma, and loss of hope. In severe cases, farmers reported loss of hope and had no option but to wait for the drought to pass. Research on Fiji's severe drought of 1997/1998 by Gani (1999) noted similar impacts on quality of life such as households' restricted access to nutritious food. As a result, lack of access to nutritious food also impacted farmers' health and well-being.

This research argues that the quality of life depends not only on access to nutritious food but also on physical, mental, and emotional health and well-being. Barotu and Toko farmers expressed concern regarding severe deterioration of mental and emotional health associated with uncertainty related to receiving rainfall, which affected crop yields and income security. There is significant concern that the deterioration of farmers' physical, mental, and emotional health and well-being could erode household resilience and have severe implications for the sustainability of rural communities in the long term (McNamara, Westoby, and Chandra 2021; Nand, Bardsley, and Suh 2023a).

Evidently, cascading and compounding effects act as a risk multiplier, increasing the likelihood of future L&D. For example, farmers were deeply concerned that the loss of income could affect their children's education. Key stakeholders also highlighted concerns regarding "spiralling and intergenerational impacts' such as disruption to children's education which undermine future livelihoods. Previous studies have also highlighted that disruption to children's education could result in devastating consequences on sustaining future livelihoods and the welfare of smallholder communities (Chandra et al. 2017; van der Geest and Warner 2015).

The research findings emphasise the inherent interconnectedness of L&D, NELD, and cascading effects, which are deeply embedded in SES. For instance, farmers faced loss of crop yield and income, as well as food insecurity due to droughts, which in turn had a detrimental effect on farmers' health and well-being. In addition, loss of household income resulted in difficulties in meeting household and farm expenses, buying less food, and cascading impacts such as difficulties in sending children to school. Importantly, if the interdependencies between L&D and SES are ignored, this will significantly undermine the sustainability of SES and future well-being. Therefore, paying particular attention to people's perceptions and local experiences of L&D and the interaction between SES vulnerability and L&D allows us to comprehensively understand and respond to L&D across a range of social and ecological domains.

Finally, this research highlights the need to understand the complex interaction of impacts, L&D, and compounded uncertainties from slow-onset events such as drought, as well as specific extreme events such as cyclones or floods. For example, farmers highlighted drought-cyclone-drought succession, which led to a continuum of severe climatic impacts and L&D. Better understanding of drought-cyclone-drought succession is necessary under current and future climatic risks to prevent L&D in general in Fiji (Iese et al. 2021), but will be vital to formulate effective L&D policy and practices for Fiji's sugar industry in particular.

5. Policy recommendations

The research findings provide valuable lessons and necessitate crucial policy interventions as a way forward. In this case, unavoided L&D could be mitigated to some extent by removing adaptation constraints faced by the sugar industry of Fiji. The provision of irrigation grants and irrigation tanks would certainly be useful. However, these have yet to become accessible to rural and remote communities. One way to achieve such adaptation goals would be to improve the network links between extension officers and farmers (Antwi-Agyei and Stringer 2021).

Moreover, there is a need to develop a climate and drought risk profile and prioritise long-term adaptation for sugarcane-growing regions. To create a climate and disaster risk profile, the Ministry of Sugar Industry would need to collaborate across institutions such as the Ministires of Agriculture, Economy, Rural, Maritime Development and Disaster Management, and the Fiji Meteorological Services. One way to develop a climate and drought risk profile would be to integrate climate outlooks into decision-support systems such as crop modelling. The use of climate outlooks, decision-support systems, and geographic information systems could generate risk maps, identify vulnerable communities, understand current and future drought risks and L&D, evaluate crop management practices, and assist in resource mobilisation under different climate scenarios (Iese et al. 2020, 2021; Nand et al. 2016). In particular, the availability and dissemination of user-end-specific information in local dialects at various levels (national, sub-national, district, and community levels) would assist in understanding the practical action required to reduce SES vulnerability and L&D as well as monitor progress.

Furthermore, crucial policy reforms are required in the sugar industry. A recent study in Fiji's sugar industry by Nand, Bardsley, and Suh (2023b) highlighted institutional constraints such as lack of climate change and disaster risk reduction policies to avert, minimise, and address L&D. Developing climate change and disaster risk reduction policies and mainstreaming of climate change and disaster risk reduction strategies into existing policies, plans, budget would strengthen institutional preparedness to avert, minimise, and address L&D. Other policy interventions such as the resolution of the current land tenure system and the cane payment system are crucial. A transparent land rental system needs to be established involving all relevant stakeholders in good faith. The cane payment, which is based on weight payment, could be reformed in such a way as to promote the adoption of new climate-resilient sugarcane varieties, as well as planting a mix of sugarcane varieties. For example, a mix of early, mid, and late maturing varieties could improve efficiency to optimise sugarcane outputs in association with the new climatic risk (Renuka Mahadevan 2009).

To minimise loss of income, livelihood diversification combined with new market opportunities is recommended. The Ministry of Sugar Industry could collaborate with key stakeholders such as the Ministry of Agriculture to encourage livelihood diversification. For example, farmers can integrate sugarcane farming with livestock raising and horticulture (Singh 2020). Additionally, at the community level, facilitating access to new markets for the sale of cash crops provides rural households opportunities for trade and income generation. Engaging in new market opportunities is a crucial adaptation response for rural households (Mearns and Norton 2010) because income-generating activities could better prepare households for any adverse climate events and enable faster recovery process by ensuring that there are stable sources of income (Clissold, Westoby, and McNamara 2020; McNamara and Westoby 2020).

Social and ecological transformations such as changes in the behaviour of sugarcane farmers and reviving sustainable farm practices are critical to ensuring sustainability of the SES in the long-term. Farmers need to be educated on sustainable farm management practices such as intercropping, limited burning of sugarcane fields, sustainable soil management practices, limited use of fertilisers, and agro-forestry. Sustainable farm management and integration of ecological stewardship could limit ecological degradation and reduce SES vulnerability to current and future climate risks.

The findings from this research highlight a lack of an early warning system and recovery programmes for droughts in the sugar industry. As stipulated by Iese et al. (2021), lack of an early warning system for droughts in PICs results in the inability to forecast the start and end of droughts. Using empirical evidence from Fiji's drought studies, the Ministry of Sugar Industry and relevant key stakeholders could collaborate to develop an early warning system and early action system for droughts. Access to early warning signals provide an opportunity to better prepare and respond to droughts, reduce drought vulnerability, and prevent L&D (Magee et al. 2016; Naivalu et al.

2022). Drought recovery programmes should aim to increase drought resilience and consider that these activities are likely to coincide with cyclone impacts (Iese et al. 2021).

Equally important is paying attention on NELD and cascading effects. Health impacts, including mental health impacts, although experienced individually, could impact a society more broadly. L&D and NELD are also interrelated in SES. For example, loss of crops led to loss of income which resulted in uncertainty and loss of hope. Similar to Westoby et al. (2022) and McNamara et al. (2021), this research argues that NELD and cascading effects necessitate a holistic approach that considers social, ecological, physical and spiritual well-being.

6. Conclusion

This study contributes to the understanding of SES vulnerability, drought adaptation measures, and L&D in Fiji's sugar industry. The findings reveal that climatic and non-climatic stressors are inherently interconnected and interact in a complex and complicated manner to enhance SES vulnerability. This research highlighted that sugarcane farmers and Fiji's Ministry of Sugar Industry implemented various adaptation measures to prevent L&D. However, these adaptation measures were inadequate, and Fiji's sugar industry suffered L&D, including NELD and cascading effects. L&D included loss of crops, reduced yield, and reduced income. NELD included deterioration of mental and physical health, loss of hope, and uncertainty. Cascading effects included food insecurity risks and impact on children's education. Therefore, policy interventions are such as developing a drought risk profile, livelihood diversification and engaging in new markets, social and ecological transformation, and developing drought early warning systems are required to sustain the sugar industry under changing climatic conditions.

Vulnerable communities, like those examined in this research, are at the frontline of climate change impacts and L&D. The conceptualisation of L&D by systematically understanding the relationship between SES vulnerability, adaptation measures, and L&D could provide a framework to assist vulnerable countries in preventing current and future L&D. Decision and policy-makers should draw on this approach to facilitate the urgent mobilisation of support and action required to avert, minimise, and address L&D in vulnerable communities that lack the capacity to respond independently. Therefore, localised research, resource allocation, and policy actions should be prioritised for the most affected communities to reduce SES vulnerability, L&D, and enhance resilience.

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