frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 18 March 2024
DOI 10.3389/fsufs.2024.1358647

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RECEIVED 20 December 2023
ACCEPTED 04 March 2024
PUBLISHED 18 March 2024

CITATION
Medina Hidalgo D, Mallette A, Nadir S and Kumar S (2024) The future of the sugarcane industry in Fiji: climatic, non-climatic stressors, and opportunities for transformation.
Front. Sustain. Food Syst. 8:1358647.
doi: 10.3389/fsufs.2024.1358647

The future of the sugarcane industry in Fiji: climatic, non-climatic stressors, and opportunities for transformation

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This study explores the complex dynamics of Fiji's sugarcane industry, shedding light on the challenges it faces and the implications for agricultural system resilience and sustainability. The primary aim of the study was to investigate the relationship between climatic and non-climatic stressors and farmers' decisions to abandon sugarcane farming. A total of 900 farmers were surveyed, which corresponds to approximately 7.5% of the sugarcane farming population in the country. Farmers were sampled using a stratified disproportional random sampling technique, by surveying 300 farmers from each of the three primary sugarcane mill regions in Fiji (Labasa, Lautoka, and Rarawai). Results depict an aging farming population with small land holdings, and limited income and agricultural diversification. While only 4% of farmers are currently considering abandoning sugarcane farming, a further 17.9% are uncertain about their future in the industry. The majority of farmers have been impacted by climate hazards, primarily tropical cyclones and floods, but the degree to which these hazards have affected livelihoods has had an effect on farmers' willingness to remain in the industry and on the extent to which they implement reactive or anticipatory responses to hazards. The study highlights the need for coordinated efforts to support sustainable intensification and planned adaptation, especially in the face of climate-induced vulnerabilities, this should be a priority as the sector continues to navigate sustainability issues. Additionally, it underscores the importance of transforming the industry to address both climatic and non-climatic stressors. Ultimately, this research offers valuable insights into the multifaceted issues confronting Fiji's sugarcane sector, and the broader agricultural systems it represents.

KEYWORDS
Pacific Islands, resilience, climate change, agricultural system, climate hazards

Introduction

The global sugarcane industry is a significant contributor to the world economy. Global sugar production is projected to expand by 15%, from 176 Mt. in 2019 to 203 Mt. by 2029, with 96% of the projected increase originating from developing countries (OECD & FAO, 2020). Sugarcane, originated in the Pacific region, where its domestication began approximately

10,000 years ago on the island of New Guinea. Over time, it spread to Southeast Asia and India, where crystallization methods were developed (Dinesh Babu et al., 2022). In the Pacific Region, Fiji and Papua New Guinea are the two countries that have the most developed sugarcane industry (Nandan et al., 2016). The historical origins of Fiji's sugarcane industry are deeply intertwined with the legacy of colonial rule, and the industry's influence has been profound in shaping the nation's culture, demographics, and political and economic landscape. Sugarcane was introduced to Fiji during the colonial period by the British, who also introduced indentured laborers from India to work in the newly established sugarcane plantations (Pandey, 2023).

Sugarcane production quickly became the main cash and export crop in Fiji and a key economic driver during the 1950s (Sami, 2020). The industry saw continued growth and expansion, becoming the country's main export income, until it began to stagnate during the 1980s and 1990s (Sami, 2020). Currently, approximately 2% of Fiji's land area is dedicated to sugarcane plantations. This land is primarily concentrated within the cane belt, which is situated on the western side of Viti Levu Island and the northern side of Vanua Levu Island, encompassing eight districts - Sigatoka, Nadi, Lautoka, Ba, Tavua, Rakiraki, Seaqaqa, and Labasa (Chandra et al., 2018).

In recent years, both sugarcane production and cultivated areas have experienced a constant decline. The production of sugarcane plummeted from 4.38 million tons in 1996 to a mere 1.60 million tons in 2022 (Ministry of Sugar Industry of Fiji, 2023). This decline in productivity has been closely paralleled by a reduction in the land under sugarcane cultivation. Most recently, the sugarcane cultivated area shrunk from 5,078 hectares to 1,562 hectares from 2018 to 2022 (Fiji Sugar Corporation, 2022). Considering the strong links between Fiji's sugar industry and its economy, the decline in sugarcane production has a ripple effect over multiple social and economic aspects. The industry decline has been linked to issues such as: the reduction in rural employment prospects, increases in rural-to-urban migration, reduction in foreign exchange earnings and overall economic growth, and ultimately, impacts to the well-being of over 200,000 individuals whose livelihoods are linked to the sugarcane value chain (Sami, 2020; Dean, 2022).

There are several issues reported in the literature that explain the contraction of the sugarcane industry in Fiji. One of the most frequently cited issues has to do with the unique way in which land tenure has been managed in Fiji. Most sugarcane cultivation is carried out on indigenous (iTaukei) land, which is collectively owned by indigenous Fijian clans or *mataqali* (Kurer, 2001). The Native Land Trust Board (NLTB) acts as a trustee for iTaukei land and administers leases for various agricultural activities, including sugarcane farming (Kurer, 2001). Commencing in 1967, farmers were granted 30-year leases under the Agriculture Landlord and Tenant Agreement (ALTA), which lacked a renewal option post-expiration (Singh, 2020). As the initial leases began to expire from 1998, with the majority lapsing between 2000 and 2006, a considerable number of farmers began exiting from the sugar industry (Mahadevan, 2009).

In addition to the reduction of active sugarcane farmers, the European Union (EU) offered preferential prices for sugar to certain countries, including Fiji, as part of its trade policies (Anderson, 2023). These preferential prices were primarily aimed at supporting the economies of former European colonies and African, Caribbean, and Pacific (ACP) countries (Kopp et al., 2016). The Sugar Protocol was an essential component of the Cotonou Agreement which granted ACP countries, including Fiji, access to the EU sugar market at fixed prices (Sami, 2020). In 2006, the EU reformed its sugar regime to comply with its international trade commitments, affecting the preferential prices from which Fiji had previously benefited (Haß, 2022). The reduction in prices and the end of production quotas significantly challenged the competitiveness of Fiji's sugar exports to the EU market (Sami, 2020).

Another significant pressure for the industry has been the impact of extreme weather events, in particular El Niño and La Niña (ENSO) events, and the increase in intensity of tropical cyclones (Gawander et al., 2018; Sami, 2020). In the past decade, Fiji has suffered severe impacts from tropical cyclones, which have impacted, not only sugarcane productivity, but other aspects of livelihoods and value chains including loss of critical infrastructure, properties and human lives (Nand et al., 2023).

While the literature has comprehensively addressed the various factors contributing to the decline of productivity and profitability of the sugar industry, a notable gap exists regarding the current motivations that drive farmers to remain engaged in the industry, especially in the context of prevalent climate-related challenges. Understanding this is an important indication for the sustainability of the industry and the livelihoods associated to the sugar value chain. Little attention has been given to understanding the interactions and relationships between how problematic farmers perceive both climatic and non-climatic stressors, the strategies employed by farmers to cope with such shocks, and their motivations to remain in the sugarcane industry.

The primary aim of this study is to understand whether farmers are contemplating abandoning sugarcane farming and, more critically, the extent to which climatic and non-climatic stressors influence their resolve to persist within the sugarcane sector. This study aimed to answer the following research questions:

1. What are farmers' intents to remain engaged in the sugarcane industry?
2. To what degree is the impact of past climate hazards on livelihoods affecting farmers' willingness to remain in the sugarcane industry?
3. What are other non-climatic factors affecting sugarcane production and farmers' willingness to remain in the sugarcane industry?
4. What types of adaptation and resilience building strategies are farmers currently implementing to deal with the impacts of climate hazards?

Conceptual framework

To examine the strategies farmers employ to proactively adapt or react to potential climate risks, this study applied principles of resilience thinking within social-ecological systems (SESs). When studying SESs, resilience-oriented approaches are often used to identify the drivers influencing a system's capacity to absorb shocks and stressors while maintaining structure and functionality and ability to shift between multiple stability domains (Folke, 2016). These drivers describe the attributes that allow a system to cope, self-organize, learn, and adapt in scenarios of change and uncertainty in order to attain desired outcomes, a framing that is often applied in the context of food systems research (Tendall et al., 2015). Strategies that increase a system's resilience can be implemented either *ex-ante* (anticipatory adaptation and transformational planning) or *ex-post* (response, reorganization and recovery) (Shah et al., 2017). Over the past 10 years, the use of resilience thinking concepts in the context of SESs has evolved. It no longer solely focuses on a system's ability to withstand shocks in order to maintain its equilibrium, but now encompasses its capacity to adapt and even undergo transformative changes. This expanded perspective recognizes the potential for a system to transition between multiple states of equilibrium (Folke et al., 2010; Bousquet et al., 2016). This study used the three most common attributes employed in SESs resilience to classify the different strategies implemented by farmers:

- Buffer or coping strategies: These strategies allow a system to recover from external shocks or stressors, while maintaining its current state and functionality. They support the system's ability to resist disruptions, without undergoing significant function or structural changes (Speranza, 2013; Folke et al., 2016).
- Adaptive strategies: These strategies go a step further than coping by allowing the system to adjust and make deliberate changes in response to disturbances. These strategies often involve the capacity of a system to learn, evolve, and reorganize in order to better deal with ongoing or anticipated challenges (Darnhofer et al., 2010; Petersen-Rockney et al., 2021).
- Transformative strategies: These strategies involve a higher level of action and change by recognizing the potential for a system to undergo fundamental and intentional transformations, often leading to a new state stability. These involve systemic changes to address long-term or existential threats (Fedele et al., 2019; Meuwissen et al., 2019).

In this research, these classifications were applied to organize the types of actions taken by sugarcane farmers in response to climate-related risks. Additionally, these classifications were instrumental in identifying the obstacles and prospects facing the sugarcane industry in Fiji as it seeks to transition toward more sustainable pathways.

Materials and methods

Results presented in this study correspond to select sections of a broader comprehensive farm household-level survey aimed at capturing development opportunities and constraints for sugarcane growers in Fiji. The survey was comprised of sections which included agronomical questions about sugarcane production and productivity, socio-economic conditions of farmers, and a section aimed at identifying climate-related links to livelihood and farm management choices. This paper presents only the findings from a subset of survey questions: those related to farmers' experiences with and responses to climate hazards and other non-climatic challenges they encounter.

Study site

Sugarcane cultivation areas in Fiji are primarily located in the drier parts of the western and northern divisions, due to unfavorable growing conditions elsewhere. The farm-household survey was conducted by sampling Fiji's three main sugarcane mill areas corresponding to the Lautoka mill and Rarawai mill in the Viti Levu Island, and the Labasa mill in the Vanua Levu Island. The map in Figure 1 shows the location of the three mills and the numbers of farmers sampled from each sugarcane growing sector.

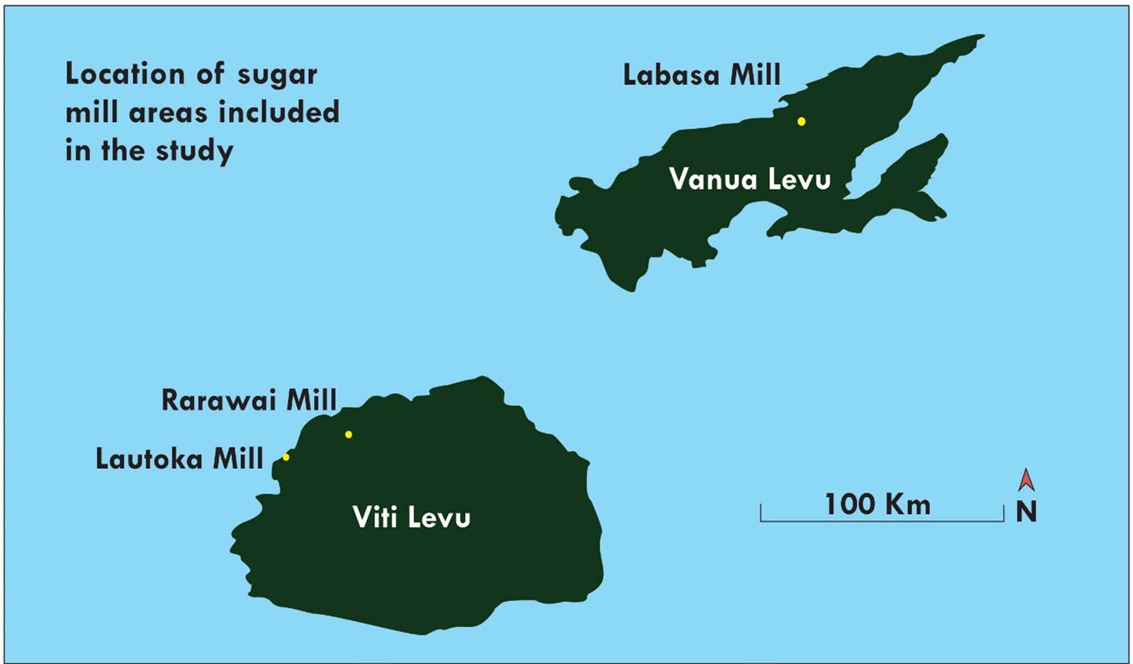
Farmers affiliated with the Lautoka mill were sampled from Sigatoka to Lautoka districts, while those associated with the Rarawai mill were sampled from Ba to Rakiraki districts. The sampling area in Vanua Levu Island included farmers from Labasa and Seaqaqa districts, which supply sugarcane to the Labasa mill.

Research participants and data collection

Census data from the Fiji Ministry of Sugar Industry indicates that in 2019, there were approximately 12,000 active sugarcane farmers in Fiji (Ministry of Sugar Industry of Fiji, 2023). This study surveyed 900 farmers in total, which corresponds to approximately 7.5% of the sugarcane farming population in the country. A stratified disproportional random sampling technique was utilized to divide the population of farmers into strata, based on each of the three mill regions. This sampling strategy was used to make sure the sampling effectively represented the socio-economic and agro-climatic characteristic of each of the three milling regions in the country. Each stratum included 300 farmers randomly selected from each of the three mill regions. This was the sample size that was viable for enumerators to manage, while also being above the 95% confidence level and 5% margin error for the population. A list of farmers from all sector offices was provided by FSC staff. The enumerators randomly selected farmers from the lists and contacted them to inform about participation in the survey, if a farmer was not available or willing to complete the survey it was replaced by another number from the list. The sampling was done randomly until the sample size of 300 farmers per stratum was achieved.

Prior to data collection, a draft survey was shared and validated with subject specialists for their feedback in areas of climate change, soil science, agronomy, entomology, pathology, agribusiness and extension. Also, stakeholders from the Fiji Sugar Corporation and the Sugar Research Institute of Fiji were invited to provide feedback and assess the relevance of the survey questions. Data was collected ahead of the cane crushing season in 2022 as a way to increase participation from farmers and extension officers who would otherwise be unavailable during the peak of the harvesting season.

Four enumerators were selected from a cohort of Bachelor of Science in Agriculture at Fiji National University and were trained in enumeration techniques as well as the use of Kobo Toolbox, which was the data collection toolkit employed in the study. Prior to the official data collection, the survey was piloted with 20 farmers across Meigunyah and Legalega sectors. Enumerators utilized the pilot to refine data collection methods and questions. The project was conducted in full compliance with ethics protocols established by the Fiji National University (FNU), Sugar Research Institute of Fiji (SRIF), and Fiji Sugar Corporation (FSC). Contact lists and details of farmers were provided by FSC. Each survey took approximately 20 min to complete. In circumstances where farmers were unable to participate in the survey, an adjacent farmer was substituted. The farmers' consent to be surveyed was collected, as well as the GPS location of the farm.



Lautoka Mill Sectors	Number of Farmers
Cuvu/Olosara	27
Lomawai	43
Nawaicoba/Yako	50
Malolo/Qeleloa	41
Meigunyah/Legalega	33
Saweni/Natova	35
Lovu/Lautoka/Drasa	71

Rarawai Mill Sectors	Number of Farmers
Varoko/Rarawai	46
Mota/Naloto	45
Koronubu/Veisaru	45
Varavu/Tagitagi	45
Drumasi/Yaladro	45
Malau/Nanuku	43
Eligton 1/Eligton 2	31

Labasa Mill Sectors	Number of Farmers
Wailevu/Waiqele	54
Labasa/Vunimoli	57
Natua/Solove/Bulivou	69
Daku/Wainikoro	65
Bucaisau	55

FIGURE 1
Map of Fiji and sampling locations (developed by the authors).

Data analysis

Survey items collected information on demographic characteristics, intent to stay in the sugarcane industry, experience with climate hazards, non-climatic issues faced by farmers, and types of responses implemented. Due to varying types of survey questions, which included structured and open-ended, the resulting various types of data required unique treatment and transformation. For example, the survey item designed to ascertain type of climate hazard experienced was open-ended. Therefore, the data was recoded based on a predetermined set of hazards.

Additionally, farmers were asked when a climate hazard had occurred, what had allowed them to recover. A time-recall period of 5 years was used to allow farmers to recall hazards that tend to occur every few years like cyclones, but not long-enough that memory of the events and actions taken could be compromised, which could happen as people experience stressful or traumatic events from disasters (Monteil et al., 2020). Answers were classified and recoded into three different types of strategies:

1. Coping strategies aimed at recovering from the direct impacts, such as receiving government assistance, or replanting lost crops.
2. Adaptation strategies aimed at implementing new practices, such as changing planting dates, implementing cover cropping or introducing drainage.
3. Transformation strategies, aimed at changing livelihood strategies, such as seeking other sources of income or diversifying production by introducing livestock or vegetable farming.

In addition to the above, farmers identified if they had not been able to recover from the hazard or if they did not implement any strategy after the hazard occurred.

Each of the areas examined in this study (e.g., demographic characteristics, intent to remain in the sugarcane industry, experiences with hazards, etc.) were first analyzed and described using frequencies. A series of chi-square tests of independence were then conducted to identify whether the three categories of future intentions for sugarcane farming, namely 'intend to remain,' 'intend to leave,' and 'unsure,' statistically differed across several demographic traits (e.g., gender, farm size). A chi-square test of independence was also performed to evaluate whether the farmers grouped on intent to remain in sugarcane farming differed according to their experienced level of impact from climate hazards. Due to the Likert-type items used to ascertain the non-climatic issues, the more conservative, non-parametric Kruskal–Wallis test was then conducted to determine whether the salience of each non-climatic issue differed across farmers intending to remain or leave the sugarcane industry. Finally, chi-square tests of independence were performed to evaluate if a farmers' level of impact from climate hazards statistically differed with whether they were implementing any reactive or anticipatory strategies and to evaluate if the farmers' willingness to stay in the industry had any relationship to the response they had taken after a hazard.

Results

Results are presented in six sections: (i) demographic characteristics of farmers, (ii) the likelihood of participation in the sugar cane industry in the future, (iii) the degree to which experienced climate hazards relate to remaining in the industry, (iv) the degree to which climate hazard impacts to livelihood relate to remaining in the industry, (v) the influence of other non-climatic factors affecting farmers' willingness to stay in the industry, and (vi) types of responses farmers are currently implementing.

Demographic characteristics of sugarcane farmers

The majority of farmers included in the study could be characterized as males (89%) of 52 years or above (64%). The majority can also be classified as smallholder farmers, cultivating less than five hectares (49%) or less than 10 hectares (34%) who have completed either primary (46%) or secondary (48%) education. Most farmers rely on sugarcane as their primary source of income (71%), which primarily supports households of four individuals or more (74%). Table 1 presents the frequencies of demographic characteristics of the 900 farmers included in the study. From the demographic traits examined, none were found to statistically relate to the likelihood of farmers to remain in the sugarcane industry (see Supplementary materials).

Proportion of farmers considering abandoning sugarcane farming

Participants were asked if they were considering abandoning sugarcane in the next 5 years. Only 4% of farmers are currently considering abandoning sugarcane farming. However, a further 17.9% are uncertain about their future in the industry. From those wanting to remain in the industry, almost half (49%) are planning to continue farming the same areas of land without making any substantial

TABLE 1 Demographic breakdown of surveyed farmers.

Variable	Value	*N*	%
Area of farmland (Ha)	<=5	445	49.44%
	<=10	308	34.22%
	<=20	114	12.67%
	>20	33	3.67%
Gender	Male	804	89.33%
	Female	95	10.56%
	Did not disclose	1	0.11%
Age	18–29	13	1.44%
	30–40	79	8.78%
	41–51	231	25.67%
	52 and above	577	64.11%
Education level	None	9	1.00%
	Primary school	410	45.56%
	Secondary school	433	48.11%
	Tertiary	48	5.33%
Main source of income	Only sugarcane	637	70.78%
	Sugarcane and other farming	215	23.89%
	Out of farm employment	31	3.44%
	Other business	17	1.89%
Household size	Live alone	16	1.78%
	2 people	85	9.44%
	3 people	132	14.67%
	4 people	244	27.11%
	5 people and above	423	47.00%

changes. In addition, 25.3% plan to expand the sugarcane farming areas and only 2% are planning for generational change to occur in the farm to allow other family members to manage it. Figure 2 presents a complete breakdown of farmers' intentions to modify their participation in the sugarcane industry in the near future.

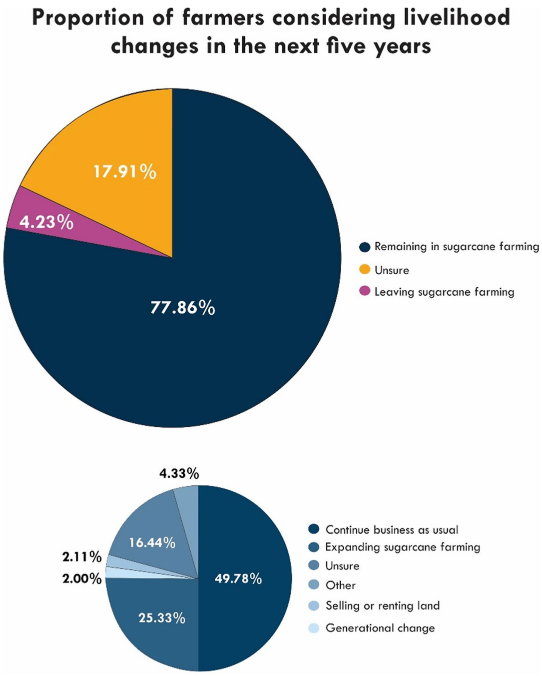


FIGURE 2
(Top) Percentage of sugarcane farmers considering remaining in sugarcane farming, leaving the industry, or unsure. **(Bottom)** From the subset of those that intend to remain in sugarcane farming, percentages show how they intend to continue with their farm.

Non-climatic factors influencing farmers' willingness to continue growing sugarcane

Farmers were asked to identify to what degree several non-climatic issues were affecting sugarcane farming. Figure 3 shows the percentage of farmers who identified different issues as being problematic. The issues that had the highest percentage of farmers identifying them as serious problems were the cost of labor, price of inputs, costs associated to harvesting and the mill payment system.

Table 2 presents the results of a series of Kruskal–Wallis tests conducted to identify the salience of issues across whether farmers intend to remain in the industry (for more detailed results disaggregated by farmers' intent to remain in the industry see Supplementary materials). The high costs of input are more problematic for those who are remaining in the industry, while land availability, access to loans, availability of planting material and pest and diseases are more problematic for those wanting to leave sugarcane farming.

Influence of climate hazards in farmers' willingness to continue growing sugarcane

Survey respondents were asked to identify climate hazards experienced in the past 5 years. Almost all farmers (97%) had experienced climate hazards impacting their production and

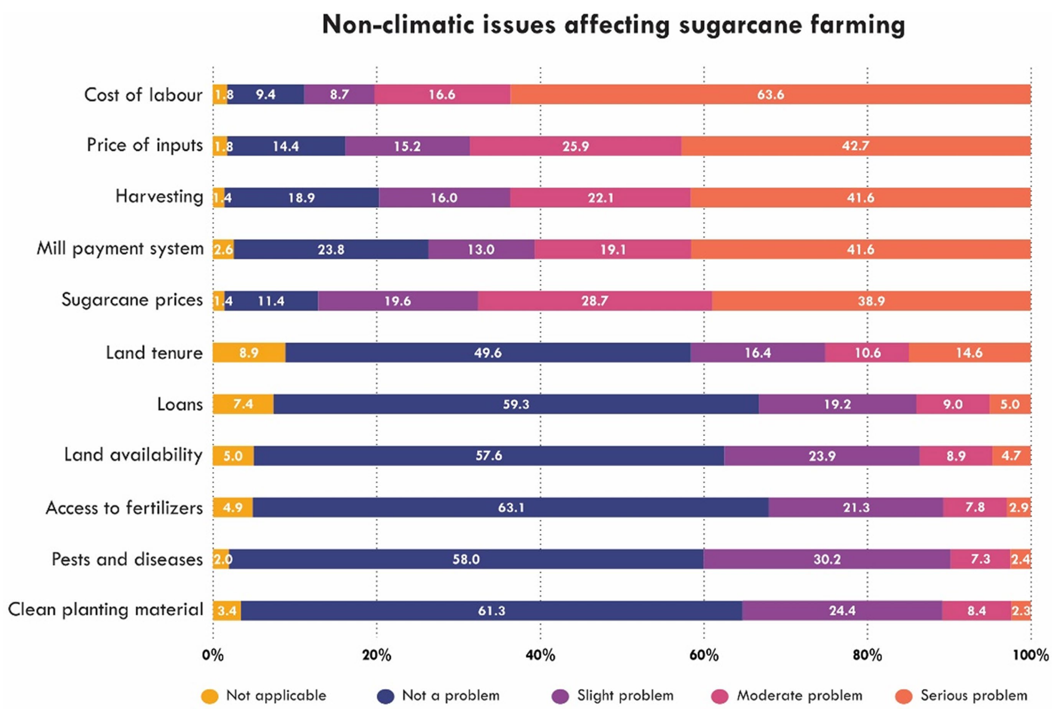


FIGURE 3
Priority of non-climatic issues affecting sugarcane farmers.

livelihoods. Given the large asymmetry in the dataset, as only a very small number of farmers were not able to identify climate hazards that had affected sugarcane production, statistical analyses were not conducted with this variable (i.e., whether experience with a hazard statistically influenced intention to stay in sugarcane farming). The figure below presents the breakdown of hazards most frequently experienced by farmers. In the period recalled by farmers, Fiji was impacted by three category five tropical cyclones (Winston in 2016, Yasa and Harold in 2020), as well as one category one (Ana in 2021) and one category two cyclone (Tino 2020). All of these events resulted in impacts across both the Northern and Western divisions in Fiji and were documented causing significant loss of agricultural production and livelihoods (Deo et al., 2022; Foley et al., 2022; Noy et al., 2023). These events are consistent with the fact that 724 farmers report having been impacted by cyclones and a further 383 by floods. Figure 4 presents the frequency of farmers who had experienced climate hazards.

It is important to clarify that farmers were asked to recall climate hazards which impacted their livelihoods and sugarcane production in the form of an open question, which would explain why other slow-onset climate hazards such as increases in temperature were not mentioned.

Impact of climate hazards on farmers' livelihoods

Approximately half of farmers classified the impact of climate hazards to their production and livelihoods as high. A high level of impact was described as a complete disruption to production and loss of all income, during which farmers had to rely on aid or other type of financial support to provide for their families. A medium level meant there was substantial disruption to production and loss of income of more than 10% of normal circumstances, and they had to

TABLE 2 Kruskal–Wallis test results for relevance of non-climatic issues and farmers' decisions to leave or stay in sugarcane farming.

Variable	Kruskal–Wallis *H*	df	Sig
High wages of labor	2.969	2	0.227
High price of inputs	15.750	2	<0.001*
Difficulty getting inputs (fertilizer)	22.922	2	<0.001*
Low selling price of sugarcane	0.970	2	0.616
Quality of planting materials	34.434	2	<0.001*
Insects, pests, and diseases	22.642	2	<0.001*
Harvesting	1.376	2	0.503
Difficulty in getting loans	14.996	2	<0.001*
Sugar mill payment system	0.888	2	0.641
Land availability	31.668	2	<0.001*
Land tenure	3.689	2	0.158

*Statistically significant at $p < 0.05$.

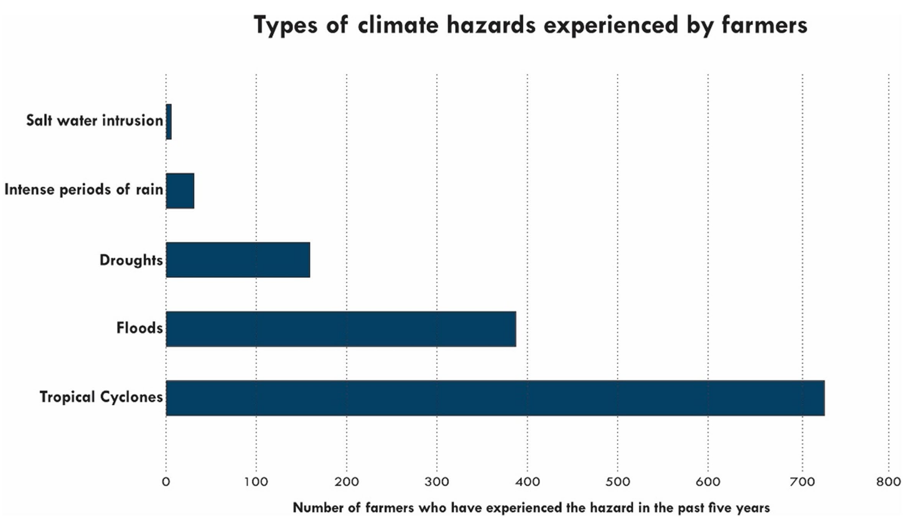


FIGURE 4
Breakdown of climate hazards experienced by sugarcane farmers in the past 5 years.

complement their earnings with alternative sources of income. A low impact level meant there was temporary disruption to production and loss of income of less than 10% of normal circumstances. The levels of impact were not associated to specific hazards and were judged by farmers based on the hazards that they had experienced; this was due to concerns of survey length and due to the complexities associated with ascertaining through a structured survey the impacts of climate hazards that were not determined *a priori*. Figure 5 presents the overall level of impact of climate hazards experienced by farmers.

A chi-square test revealed the level of impact experienced significantly differed across farmers grouped on their intention to remain in the industry; χ^2 (4, $N = 893$) = 19.494, $p < 0.001$. From the farmers who have considered abandoning sugarcane farming, 83% had experienced a high impact from climate hazards. In the case of farmers who are unsure about their future in the industry 54% had experienced a higher level of impact to their livelihoods as a result of climate hazards. Farmers remaining in the industry had the lowest proportion from the three groups reporting a high level of impact from climate hazards (47.6%).

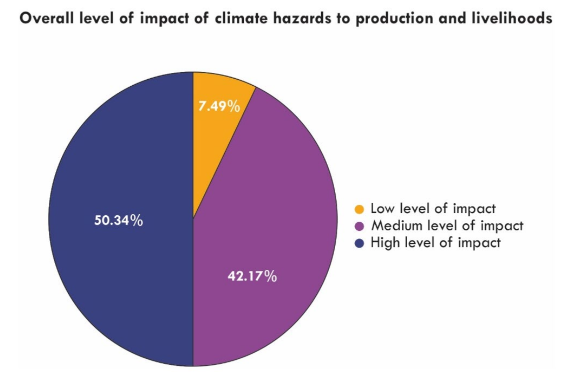


FIGURE 5
Self-reported impact of climate hazards to sugarcane production and livelihoods.

Types of strategies farmers are implementing in responses to climate hazards

Farmers were asked which strategies they had implemented to prepare for or anticipate the effects of specific climate hazards. Virtually the entire sample of farmers (96%) did not engage in any anticipatory responses. In terms of reactive responses, slightly over half of farmers (54%) did not implement any strategy to recover after a climate hazard. Those who did implement a reactive response implemented mostly coping strategies, the majority associated with receiving monetary support. The proportion of farmers who reported receiving financial assistance from the government or non-governmental organization was 83%. Figure 6 shows the different types of reactive strategies implemented by farmers after being affected by a climate hazard.

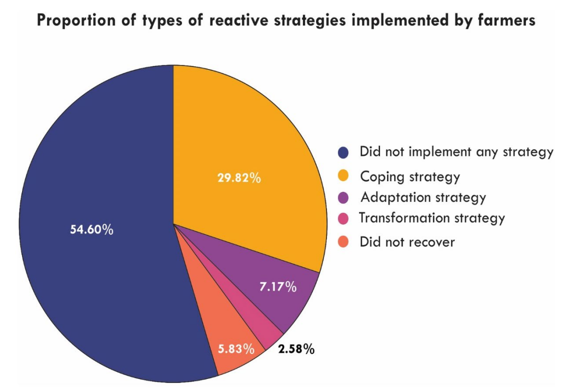


FIGURE 6
Breakdown of types of reactive adaptation strategies implemented by farmers.

A chi-square test of independence was performed to evaluate whether farmers that are taking action (i.e., implementing any reactive or anticipatory strategies) differed in their level of impact from a hazard to those not taking any action. The relationship between these variables was significant, χ^2 (8, $N = 888$) = 116.983, $p < 0.001$. Farmers who had experienced a higher level of impact to their livelihoods as a result of climate hazards were more likely to not have taken any action. Figure 7 shows the percentage of farmers who took action based on their level of impact from climate hazards to their livelihoods.

A chi-square test of independence was performed to evaluate whether farmers grouped on their intent to remain in the industry differ in the types of responses implemented. The relationship between these variables was not significant, χ^2 (2, $N = 891$) = 5.800, $p = 0.055$. However, the sample size of farmers who have considered abandoning sugarcane in the next 5 years is only 4.2%. Yet, the farmers who plan on leaving sugarcane farming had a high proportion (71%) of individuals who either did not implement any action to recover from an event or did not recover, compared to 67% of those who were 'unsure' and 58% of those who intend to remain. Evidently, the percent of farmers taking action (whether coping, adapting, or transforming) is highest for farmers who intend to remain.

Discussion

This research sought to investigate the intentions of sugarcane farmers in Fiji to exit from the industry. It aimed to assess the extent to which their decisions were influenced by a range of factors, including both climatic and non-climatic stressors. These stressors encompassed the consequences of climate-related hazards on livelihoods as well as obstacles related to enhancing productivity, such as increasing labor and input costs. Furthermore, the study employed the principles of climate change adaptation and resilience within social-ecological systems to gain a deeper insight into the strategies that farmers are adopting in response to climate hazards, and to identify opportunities for the systems to effectively respond to future shocks.

Overall, the sample of 900 farmers from the three main mill regions in Fiji shows that sugarcane farmers constitute an aging population, which is currently farming on relatively small areas of land, engaging in low levels of income and agricultural diversification. Low prospects of generational change in the industry have already been documented as being a factor affecting the sustainability of the industry, as the younger generation has little incentive to work on sugarcane farms and the industry has struggled with shortages of

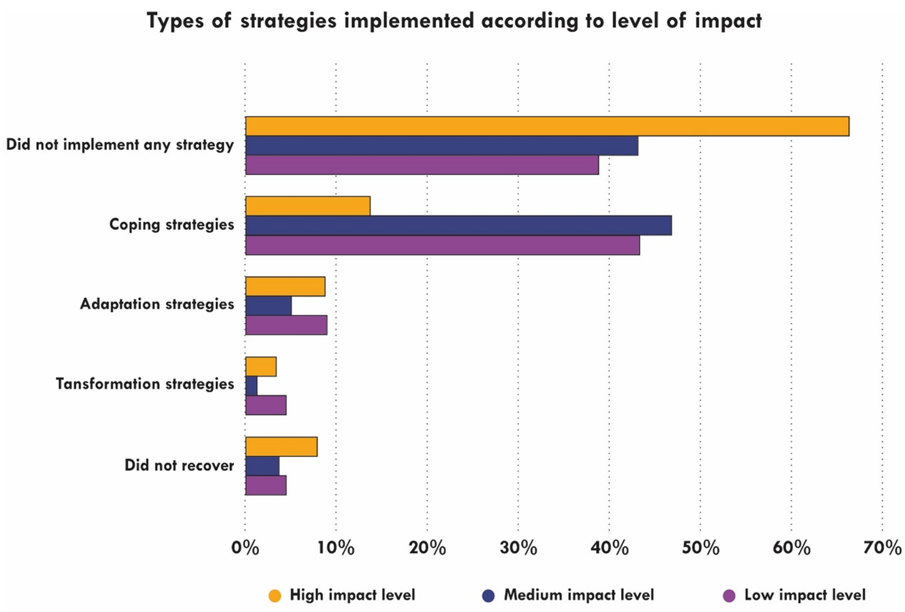


FIGURE 7
Strategies implemented by farmers based on level of impact of climate hazards. Note that the percentages within each type of adaptation category do not add up to 100 because results are presented based on the percentage within the 'level of impact' category.

labor, irrespective of production falling over 50% since 1999 (Singh, 2020). This is a trend that is also observed more generally in the agricultural sector worldwide, for which intergenerational knowledge exchange has been identified as a key element needed for agricultural systems to be able to better cope with current and future social and environmental challenges (Huambachano et al., 2022).

While the number of active sugarcane growers fell from over 21,000 to around 12, 000 in the period 1995 to 2020, it appears the number of farmers exiting the industry has somewhat stabilized, compared to the period where land leases commenced to expire (Ministry of Sugar Industry of Fiji, 2023). A minority of farmers sampled in this study (4%) are considering abandoning the industry in the next 5 years. However, an additional 17% of farmers are unsure about their future in the industry, which shows that the industry is still facing challenges to provide a reliable source of income that would motivate farmers to remain engaged. Global projections indicate that the number of farms could decrease from 616 million in 2020 to 272 million in 2100, with the average farm size doubling (Mehrabi, 2023). This declining trend in the number of smallholder farms have implications for the sustainability and resilience of food systems.

Other studies have also reported that leaving sugarcane farming in the short term may not be economically feasible due to contractual obligations associated with land leases (Kurer, 2001; Singh, 2020; Dean, 2022). The majority of farmers remaining in the industry are planning to continue managing their farms without any plans to either expand or contract their growing areas. This underscores the need to support farmers to sustainably intensify production in existing areas so that productivity and profitability can increase without further degrading soil resources, increasing greenhouse gas emissions and affecting ecosystems services (Chandra et al., 2018). Longitudinal studies conducted over 30 years in Vanua Levu indicate that after continuous and intensive sugarcane production, topsoils have suffered significant changes in their properties, which are detrimental to sugarcane growth and have contributed to declining yields, and which are likely to be exacerbated without effective soil and nutrient management practices (Morrison and Gawander, 2016).

The majority of farmers surveyed were able to identify climate hazards that have affected their livelihoods; the most notable ones related to tropical cyclones and floods. Farmers who are considering abandoning sugarcane farming had a higher proportion who had also experienced high levels of impact to their livelihoods after a hazard. This could be an indication that for these systems which are already being stressed by productivity issues, climate hazards which result in high levels of impact reduce the systems' capacity to bounce back and absorb the shocks. This is a problematic issue considering that even if the total number of tropical cyclones has decreased over the past 40 years in the Pacific region, an increase in their intensity has been observed. Under future climate projections, fewer tropical cyclones are expected, yet their intensity may increase by up to +10% for a high emissions scenario (Australian Bureau of Meteorology & CSIRO, 2014). Intensifying cyclones, potentially resulting in heightened impacts on farmers, could consequently affect the willingness of farmers to remain in the industry, an important consideration for the future of the industry.

Additionally, in the survey, farmers did not recall slow-onset events that are being exacerbated by climate change such as temperature increases (Wang et al., 2016). However, studies have shown a decline in sugar yield with an increase in mean and extreme temperature (McGree et al., 2020). Other elements of climate variability such as ENSO events have an impact on sugarcane yields. ENSO events in the Pacific are the main drivers of sea surface temperature and precipitation variability (Becker et al., 2011). In addition, likely projected changes to the frequency of extreme El Niño and La Niña events may increase the frequency of droughts and floods, with direct implications for water availability and food security (Gutiérrez et al., 2021). Very strong El Niño events have shown to have a negative effect on sugarcane yields particularly for the Lautoka mill area, and very strong La Niña events have almost the same negative effect in the Labasa mill area (Gawander et al., 2018). The differentiated effects of future climate projections, including temperature changes on different sugarcane growing areas emphasizes the need for a more planned and informed response to potential risks, that goes beyond dealing only with extreme events.

For farmers who expressed willingness to remain in the sugarcane growing business, labor and input costs, logistics associated with harvesting, the payment system and sugarcane prices seem to be overall most problematic. Issues surrounding the cost and availability of labor, as well as the logistical difficulties for the effective mechanization of harvesting have been previously highlighted as the main issues limiting the profitability of sugarcane farming in Fiji (Mahadevan, 2009). While mechanical harvesters have been introduced in Fiji, not all terrains, particularly those in small areas and with slopes and gradients are suitable for mechanization. The issues surrounding the sugarcane payment systems have also been documented. Farmers receive an average of 72% of the income distributed into several payments throughout the year, with the remaining 28% going to the mills (Dean, 2022). There are usually five payments spread over 18 months. Under the Sugarcane Master Award the first payment corresponds to 60% of the forecast price and is paid out 3 weeks after harvest, with harvesting, transport, fertilizers, and debts to FSC are deducted from the payment. The second payment equivalent to 20% of the forecast price is paid 5 weeks after closure of the mill and the payment is made with all relevant deductions. The third payment is processed at the end of March, which is based on sugar sales to the end of February. The final payment is to be made in May based on sugar proceeds in April. Such prolonged payment system sometimes affects farmers' cashflow throughout the year, potentially limiting their capacity to invest in anticipatory adaptation options. On the other hand, land availability, access to loans, availability of planting material and pest and diseases seem to be more problematic for those wanting to leave sugarcane farming. While the above issues have been documented in the literature, this paper makes a novel contribution by demonstrating from the perspective of farmers which issues are more problematic and how these correlate with the willingness of farmers to abandon or remain in the sugarcane industry. In other words, the literature tends to focus on describing the intricacies and underlying factors of the various non-climatic issues in the sugarcane industry without much engagement with the farmers. The findings presented here demonstrate a potential disparity between the literature and the actual influence on farmers. For example, while the payment system is discussed as an issue for the sugar mills, as it undoubtably is, perhaps farmers perceive it as a surmountable challenge, while the factors associated with intention to leave the industry may not be perceived as surmountable. We argue for a redirection of the research to understanding the influences of challenges on farmers' willingness to remain in the industry.

To support farmers, the government provides several subsidies for the use of fertilizers and other inputs focused on increasing the sugarcane production levels. However, a more systemic approach to understanding productivity is needed in the industry to tackle inefficiencies along the value chain (Dean, 2022). Short-term measures to increase sugar income will mostly be ineffective, and a more coordinated industry-level reform is likely needed to address both the climatic and non-climatic stressors that are impacting the sustainability of the industry (Sami, 2020). While the primary from of support to farmers has been through emergency payments and input subsidies, this approach has the risk of becoming maladaptive and unsustainable under scenarios of higher climate risk. Our research shows there are other important issues facing farmers and a more systemic approach is needed rather than delivering reactive quick fixes.

One of the most concerning results from this study has to do with the lack of planned or proactive adaptation and climate risk management undertaken by farmers. Even after farmers have been impacted by climate hazards, slightly more than half would still not implement any strategies to recover from such events. The majority of strategies undertaken have been coping strategies and approximately 83% have received payments from the Government or other organizations to recover. Some agronomical practices related to water management have been adopted, but farmers with high levels of impact were less likely to implement any recovery strategies. One possible explanation could be that the systems are already under so much financial pressure, which limits the availability of resources needed for farmers to invest in adaptation options. Into the future, this means that the industry and the Government will need to invest more substantial resources to help farmers cope with climate associated loss and damage, or finance the more structural transformation needed to allow systems to become more resilient (Nand et al., 2023). Yet, due to the fact that the survey was not followed by a more in-depth interview, it is not possible to conclude from the data obtained if farmers experienced more severe consequence because they did not take anticipatory actions, or because the continued and severe pressures to the system reduced farmers' capacity to adapt and invest in adaptation actions. This is an area of opportunity for future research, as it would help to quantify the value of early adaptation and the risks of inaction.

As has been document in other cases, climate hazards seem to be amplifying the vulnerability of sugarcane industry because the systems are already stressed by pressures such as productivity, labor and cashflow (Sachan and Krishna, 2021; Anderson, 2023). While it seems like the number of farmers leaving the industry is somewhat stabilizing and the majority of farmers are planning on remaining in the sector, at least in the short-term, there needs to be stronger investments aimed at developing sustainable intensification programs (increase productivity per area while reducing use of inputs), allowing for intergenerational knowledge sharing and change, promoting agricultural and income diversification, and engaging in planned adaptation. Considering that more intense cyclones are likely to affect the region in the future, additional efforts need to be targeted to establishing safety nets and recovery plans for specific hazards. Issues of profitability need to be addressed for farmers to be able to make investments and engage in sustainable practices, otherwise public investment to save the industry might eventually become unsustainable (Anderson, 2023). In addition, diversification plans for the industry are likely to be more successful if they are supported by networks of agricultural innovation which include public and private extension services, research organizations and industry stakeholders all working to support common goals (van Zonneveld et al., 2020).

Transformational adaptation in the context of food systems is likely to require long-term commitments to adaptation planning, alongside financial and technical assistance that can go beyond offering single technical solutions and move toward presenting a wide array of alternatives inclusive to changes in system's governance (Vermeulen et al., 2018). This is an issue that is particularly complex in the case of the sugarcane industry in Fiji and more widely in the Pacific, in which complex land management and tenure systems informed by traditional knowledge co-exist with more modern ways of governance (Mcleod et al., 2019). Given that climate change will likely exacerbate pressures on the system, and impacts are expected to intensify in the future, adaptation, and more likely transformation of systems, will be required. Our findings demonstrate that farmers are not currently considering anticipatory responses to change and there is a higher prevalence of coping mechanisms rather than efforts toward transformation. Hence, the resilience of the systems is largely dependent on the coping capacity dimension, which is being sustained through the provision of subsidies or relief payments. While this has allowed the systems to maintain one attribute of resilience, the current pathway of the industry could lead the systems to undesirable states of resilience which are not likely to be sustainable under higher levels of uncertainty or pressures (Oliver et al., 2018). Coping strategies, such as those employed by the majority of farmers, increase the reliance on these mechanisms and reduce the incentive to adapt as well as the capacity for learning and consequently, the ability to adapt or transform (Barnett and O'Neill, 2010; Thomsen et al., 2012). This suggests untenable trajectories alongside reduced adaptive capacity of the industry.

Transformational change is anticipated to be necessary to address the dual issues of farmers exiting the industry and those who choose to remain but are likely to face heightened impacts due to climate and environmental changes. The transformation of the industry needs to extend beyond merely enhancing on-farm productivity. It calls for more ambitious policies and robust governance systems that can bolster all facets of the system, thereby supporting food security, livelihoods, environmental objectives, and resilience in a comprehensive manner (Ruben et al., 2021). The sugarcane industry in Fiji has undergone substantial changes, leading to a decline in productivity, cultivated land, overall soil fertility, and the number of farmers involved in the industry. While some of these factors appear to be stabilizing, a significant number of individuals still depend on the industry's success for their livelihoods. As the sector undergoes further change and potentially transformation, it must consider deliberate actions to respond to climate impacts, explore innovative methods of resource distribution such as land and labor, and fundamentally alter system attributes that hinder generational change and poverty reduction (Tomich et al., 2019). For these changes to be genuinely transformational, they need to happen on a large scale and with increased ambition over extended periods. This necessitates a fresh vision for the sector as well as coordinated efforts that transcend individual farms or isolated technological innovations, requiring ongoing monitoring (Herrero et al., 2021).

To enhance the insights garnered from this study and to supplement the findings, more comprehensive interviews with farmers could provide a deeper understanding of the underlying reasons for the seemingly limited adoption of planned or reactive measures in response to climate-related challenges. Furthermore, this research could be broadened by incorporating the perspectives of various stakeholders within the sugarcane value chain. This would entail investigating to what extent key players such as the Fiji Sugar Corporation, the Ministry of Sugar, and the Sugar Research Institute of Fiji have already integrated coping, adaptive, and transformative strategies into their long-term plans for the industry's sustainability. Another essential aspect would be to assess the capacities required for these value chain actors to effectively consider climate change and the implications of climate-related hazards in their operational activities.

Conclusion

The sugarcane industry in Fiji exemplifies numerous development challenges that extend beyond land and resource management, illustrating the broader issues involved in increasing the resilience of agricultural systems. This study aimed to explore the intentions of sugarcane farmers in Fiji regarding their continued involvement in the industry and the factors influencing their decisions, including the impact of both climate-related and non-climate stressors. The farmers sampled revealed that Fiji's sugarcane farming population is aging, while farming primarily small land holdings, and engaging in limited income and agricultural diversification. These production challenges combined with little evidence of proactive climate adaptation strategies, suggest a scenario of increasing vulnerability for the sector, particularly into the future. Similarly, the industry faces challenges associated with failing to encourage generational change, and climate hazards are amplifying these existing vulnerabilities. Despite the majority of surveyed farmers expressing intent to remain in the industry, there is a need to put in place better support systems to ensure the sustainability of those farmers willing to stay, while also addressing the issues that are affecting those who are considering abandoning production. While the number of exiting farmers has somewhat stabilized, there is a substantial number of farmers facing uncertainty about their future. Those who are considering leaving have experienced high impacts from climate hazards which means that the combination of worsening climate impacts and the lack of adaptation observed amongst farmers could force more farmers out of the industry.

The study highlighted that an overwhelming majority of farmers have struggled to respond to the impact of climate hazards, including tropical cyclones and floods, with more significant impacts observed among those contemplating leaving the industry. Climate change's slow-onset effects, such as rising temperatures, were not well-recognized by farmers, which could imply the need to directly prompt for these types of slow-onset changes in the survey. This is important, as the literature shows they are likely contributing to reduced sugar yields. Labor and input costs, harvesting, payment systems, and sugarcane prices are major concerns for those farmers intending to stay in the industry, while land availability, access to loans, planting materials, and pest and disease management are more significant for those considering an exit. These results underscore the need to simultaneously support sustainable intensification and planned adaptation in the systems.

This study highlights the need for a more systemic approach and industry-level coordination to tackle climatic and non-climatic stressors. It also emphasized the importance of a systemic perspective and networked innovation in supporting the sugarcane industry's resilience. In addition, transformational adaptation and governance changes are crucial for long-term success. Future research could add value by providing more in-depth interviews with farmers and include various stakeholders in the sugarcane value chain for a more comprehensive understanding of the reasons behind people's decision to either remain in or exit the industry, and the low levels of implementation of anticipatory and reactive strategies to deal with climate hazards.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Fiji National University (FNU), Sugar Research Institute of Fiji (SRIF), and Fiji Sugar Corporation (FSC). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

DM: Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. AM: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. SN: Data curation, Investigation, Project administration, Validation, Writing – review & editing. SK: Funding acquisition, Resources, Supervision, Validation, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. Fieldwork and data collection were funded by a student research grant from Fiji National University (FNU) and a seed funding grant from the Office of Research at FNU. Publication of this work was funded by the Australian Centre for International Agricultural Research, through the Pacific Agriculture Scholarships, Support and Climate Resilience Program.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2024.1358647/full#supplementary-material

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