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Assessing the impacts of climate change on domestic crop production: Experience and perception of local farmers in North Malaita, Solomon Islands.

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Abstract

The aim of this research was to: 1) gather farmers' experiences and observations of climate change impacts on domestic crop yields during the last thirty years (1988-2018); 2) study climatic projections (2050) and their potential impacts on Sikwafata and Malu'u's crops; and 3) understand the knowledge engaged with, and adaptations taken, to avoid susceptibility to climate change. The data was collected using the snowball approach, in which the researcher contacts informants using information provided by previous informants. A thematic analysis was performed using NVIVO 10 software. For both sites, soil samples were taken to determine moisture content.

Farmers reported changes in rainfall patterns (73.5%) and temperature (44.9%), while 26.5% indicated no change in rainfall or temperature (55.1%). About 83.7% of farmers anticipate increasing temperatures and rainfall to occur by 2050, with extreme impacts on crop productivity. The majority of the gardens (87.5%) were on hillsides, while 8.5% were on the lowland, with an average of three garden per farmer. The gardens (57.0%) were on rotational sites that had been abandoned for two to five years, while 43.0% had never been rotated. In comparison to Malu'u moisture content (47.4%), Sikwafata moisture content is 66.4% higher. Furthermore, farmers are aware of adaptation measures to reduce the risk of crop failure. However, the absence of scientific information on climate change and agricultural resilience has increased the vulnerability to extreme climate-related events harming food security and nutrition. Climate change will undoubtedly intensify, resulting in a global and local drop in crop production, thus compromising livelihoods in the future.

Keywords: climate change, adaptation, farmers' perceptions, domestic crops, descaling crop yield, soil moisture

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Introduction

In many countries, including the Pacific Island Countries and Territories (PICTs), agriculture accounts for around 60.0% of the national gross domestic product (GDP), with a global average of around 4.0% in 2017 (World Bank, 2019). To meet rising demand, the agriculture sector will need to increase more than triple by 2050 in Sub-Saharan Africa and South Asia, while the rest of the world's increase will only be one-third higher than the current levels. To meet rising demand, agriculture will need to produce almost 50.0% more food by 2050 (FAO, 2017). In the PICTs, climate change is already putting strains on fisheries, health, agriculture, food security, and economic development (Barnett, 2020: McCubbin et al., 2015; IPCC, 2019; Klöck and Fink, 2019). Climate change has also directly or indirectly threatened the workforce. For example, extreme heat or rainfall affects agricultural productivities and economic activities through the agricultural labor force. This may lead to a drop in labor productivity, particularly when manual human labor is involved, and increasing the risks through hazards. For instance, increased temperatures reduce the amount of time spent on the field to avoid heat stroke or bad weather. Climate change also affects the quality and availability of natural resources, the geographical redistribution of pests and diseases (FAO, 2020; Wairiu et al., 2012; Walsh et al., 2020l), and the agricultural management practices. This can influence livelihoods and will likely worsen in the future. Climate hazards are becoming more intense and frequent, posing a serious threat to PICTs and having direct consequences for already vulnerable states (Barnett, 2020). Climate-related extreme events can jeopardize the stability of local food systems in PICTs, where rural communities rely on subsistence farming.

According to a meta-analysis of climate change impacts, 70.0% of studies predict a decline in crop yield by 2030. Half of the studies (10.0–50.0%) projected a long-term decline (Challinor et al., 2014). The 2021 International Panel on Climate Change (IPCC) Summary for Policymakers stated that, as global warming continues, many changes in the climate system will become more evident. For example, the frequency and intensity of extreme heat, marine heatwaves, heavy precipitation, agricultural and ecological droughts in some areas, and the proportion of intense tropical cyclones. It was also projected that there would be a decrease in Arctic sea ice, snow cover, permafrost with a high degree of certainty. This will cause the global surface temperature to warm faster, exceeding two times the rate of global warming. The land surface will also continue to warm faster than the ocean surface in the coming years (by 1.4 to 1.7 times) (IPCC, 2021: 41). Increased temperatures generally promote crop growth. However, modelled output under different representative concentration pathways (RCP) has shown that when daytime temperatures exceed a certain crop-specific threshold, yields will actually decrease (FAO, 2016), thereby increasing crop vulnerability (FAO, 2017; Thornton et al., 2014). A Representative Concentration Pathway is a greenhouse gas concentration trajectory adopted by the IPCC for its fifth Assessment Report (IPCC 2019).

"The Sustainable Development Goals are a universal call to action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere. The 17 Goals were adopted by all UN Member States in 2015, as part of the 2030 Agenda for Sustainable Development which set out a 15-year plan to achieve the Goals" (United Nation, 2015). It aims to address many areas, including agricultural food production in a variety of ways by 2050, to improve food security and eradicate hunger and poverty. Agriculture, when carried out correctly, can provide nutritious food for all, while also supporting people-centered rural development and conserving the environment (Ritchie et al., 2018). Additionally, the food system is related to all of the sustainable Development Goals (SDGs) in its own way. This is why there is an urgency to combat climate change, which SDG 13 (Urgent action is needed, by regulating emission and promoting renewable energy) is targeting. For example, minimizing the number of individuals who become food insecure as a result of a climate-related hazard, and mitigating the effects on national food production to avoid poverty. This involves integrating disaster risk reduction across sectors into agriculture policies, food security and nutrition management. Also, it is critical to monitor the extent to which climate change funding is given to Least Developed Countries and Small Developing Sate s to meet their targeted goals.

With a focus on climate change adaptation and anthropogenic greenhouse gas mitigation, subsistence farming, which predominates in the PICTs regions (Barnett, 2020) can be harnessed to nourish the growing population. For instance, climate action will need to identify the most economically feasible and socially acceptable solutions that also provide SDG co-benefits. Development policies and appropriate initiatives must be well coordinated and comply with the Paris Agreement in order to tackle climate change and achieve the SDGs. A total of 80.0% or more of Pacific Islanders, like those in Vanuatu and the Solomon Islands, rely on subsistence farming and fishing (Handmer and Nalau, 2019). However, some Pacific Island populations are already experiencing climate-related impacts such as rising sea levels, storm surges, cyclones, and extreme weather events. Also aridity and depleting freshwater resources. These effects result from rising temperatures that were not anticipated to occur until 2030-2040 (Handmer and Nalau, 2019). This indicates the accelerated impacts of medium-term climate change, occurring before the projected timeframe.

Climate change-induced warming, shifting precipitation patterns, and increased frequency of extreme events have already impacted food security (high confidence) (IPCC, 2019). Local food production relies on adequate rainfall distribution, temperature, and stable weather for effective food production, which makes production extremely sensitive to current conditions and future changes. In the context just outlined, this paper aims to look at: 1) farmers' perceptions of climate change impacts on domestic crop yields and observations since 1988; 2) climate projections (2050) and their impact on crop yields in Sikwafata and Malu'u; and 3) knowledge and adaptations to prevent vulnerability. Understanding farmers' perspectives and experiences can contribute towards achieving the SDGs and provide a way forward for rural farmers in northern Malaita to a better future.

Study background

This study focuses on farmers in Sikwafata and Malu'u communities in the To'abaita region, North Malaita constituency (Figure 1). According to the Australian Bureau of Meteorology and CSIRO (2014), the climate of the Solomon Islands has been warming since 1953, with annual minimum temperatures (Tmin) increasing. Warm nights have increased significantly, whereas cool nights have decreased, thus showing signs of global warming. Since 1950, annual rainfall patterns have remained relatively constant. Between 1969 and 2010, an average of twenty-nine cyclones formed within or crossed the Solomon Islands Exclusive Economic Zone (EEZ). El Niño years (thirty-nine cyclones per decade) had the most tropical cyclones, while La Niña had twenty-one cyclones per decade. In the Solomon Islands EEZ, 27.0% of cyclones between 1981 and 2010 were severe occurrences (Category 3 or stronger) (Australian Bureau of Meteorology and CSIRO. 2014).

The climate projections for the Solomon Islands by 2100 indicate a continued increase in annual mean temperature, and the frequency of extremely high daily temperatures (very high confidence). A slight increase in annual rainfall (low confidence) with more extreme heavy rain events (high confidence) will be expected, and drought incidence will decrease slightly (low confidence). Ocean acidification is anticipated to continue (very high confidence), and El Niño and La Niña occurrences are likely to persist (very high confidence). However, long-term trends cannot be assessed with the data currently available for El Niño and La Niña (Australian Bureau of Meteorology and CSIRO, 2014).

Fig. 1. Location of Sikwafata and Malu'u in Malaita. CartoGIS Services, College of Asia and the Pacific. The Australian National University

Materials and Methodology

A qualitative questionnaire was used to allow interviewees to elaborate (Flick, 2009) on the existing and future (negative) consequences of climate change on their crop production. The adaptation strategies questions were aligned with the Post Disaster Needs Assessment tool and the Solomon Islands Agriculture and Livestock Policy 2015-2019. A disaster assessment toolkit ranging from the most basic assessment of immediate needs to the most detailed assessment of long-term recovery and risk reduction requirements (Assessments, P. D. N, 2013: Solomon Island Government [SIG], 2015). Since there was no climate change awareness or farmers never attended any awareness, the perception of farmers is based on their local knowledge.

There are various languages and dialects spoken at the selected location. For example, To'abaita, Baelelea, Lau, Baegu, and Fataleka (Siegel, 1986) in Malaita's northernmost region. They are composed of individuals from various ethnic backgrounds. However, because of the principal researcher's familiarity with the location and people living in the area through tribal/family ties, this network system was used to approach respectable local leaders (community and church) and elders in the communities for permission to conduct the study in their communities. Before our meeting with the respectable leaders, our visit was made known to them a month earlier to visit the communities with brief outline of the purpose and awareness of our arrival. With their permission, a total of ninety-eight individual farmers (43 females and 55 males) took part in the survey. The assessment was carried out between April and May 2019, using the snowball method. A snowball is a method used in qualitative research in which the researcher contacts informants using the information provided by previous informants, who then refer the researcher to additional informants, and so on (Noy, 2008). Six focus groups were identified by the church leaders and grouped into age-categories (youths: eighteen to thirty-five; middle-age: thirty-six to fifty-five; and elderly: over fifty-six). Each group consisted of five to ten members per group organized according to gender.

Both individual farmers and the focus group were informed of the purpose of the survey, which was administrated and documented through recording and note taking in English. Pidgin was used as a verbal communication tool which was then translated back into English for transcription. An ethnographic observation approach was used, which involved participating in the discussion during interviews and making personal observations of the farmers' daily agricultural practices and adaptations. Farmers were informed of the study's ethical background, which had no intention of causing harm to their families or communities. Given the information, the consent of the farmers identified was obtained through a assigned form and their data was taken into account for analysis.

This research employed thematic analysis using NVIVO 10. The raw data was transcribed and organized after the field survey and entered into the NVIVO 10 software (project file) for analysis. Within the database, the data was coded as nodes (tree nodes) according to the responses under their specified themes (hierarchical structure). This entailed sorting similar comments into categories based on their assigned themes. Thematic analysis is used to search for and identify common threads, or patterns of reactions, throughout a dataset of interviews (Braun and Clarke, 2006). The results are then organized around these themes, presented in the results, and then discussed. To determine the moisture content of the soil, samples were taken from both research sites at two different locations on a clear day. A shovel and a tape measure were used to collect soil samples from a depth of 34cm. Samples were stored in an airtight bag for testing at the Solomon Island National University (SINU) Department of Agriculture laboratory. The samples were baked at a controlled temperature of 110±5°C for 24 hours to determine the soil moisture content.

Results and Discussions

Observation on slow and rapid-onset events on crop production

The majority of farmers believe the weather in their area has, and still is, changing over time. They have observed rising temperatures (44.9%) and patterns of increasing rainfall (73.5%)

over the years, with climate-related extreme occurrences (67.3%). However, a minority of farmers expressed no changes in occurrence.

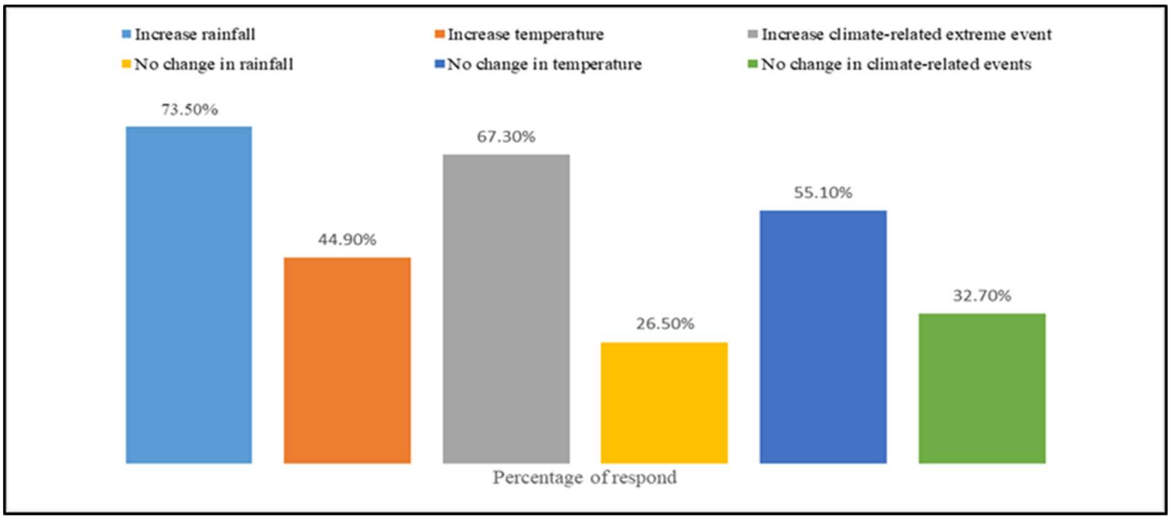

Fig. 2 illustrate the responses of farmers on rainfall, temperature and climate-related extreme events currently experienced

The findings by Trenberth *et al.* (2007) on regional climate change indicate that the region around the Solomon Islands has been subjected to long-term change for the last thirty to hundred years. According to the analysis (Fig. 2), these findings were similar to farmers' responses related to changes in seasonal rainfall by Harvey et al. (2018). Farmers tend to describe increased rainfall distribution as related to cyclone intensity and intensity of change, as stated by Harvey et al. (2018). The higher the intensity of the cyclone, the higher the rate of rainfall. As a result, the farmers in this study reported a shift in precipitation to be higher than in the past years. Previous studies found that the frequency of cyclones in the Solomon Islands decreased by -0.09 per year between 1986 and 2016 (Maru *et al*., 2018).

Similar results have been shown with the farmers' observations and experience (Fig.3a) from 1956 to early 2019, compared to the national hazard statistic record from 1986-2015 (Fig. 3b). During the interview, one of the farmers described the change in hot days:

> *Over the past thirty years, I have experienced an increase in hot days. It lasted for two to three months without any rainfall, causing the crops to wilt. However, today, the frequency of hot days is unstable. Some days it would be very hot, and then all of a sudden it would start to rain. I think our weather pattern has changed a lot since 1980 (Sikwafata, 37).*

Additionally, 55.1% of farmers shared consistency, or no change in temperature, while a minority (44.9%) reported an increase. A prior study by Keremama *et al*. (2019) mentioned an increase in mean temperature over thirty-five to sixty-one years by 0.14°C to 0.39°C in Malaita.

The possible reason for the minority responses in this study is that, not many people noticed the change in temperature increase because it happened gradually over many years.

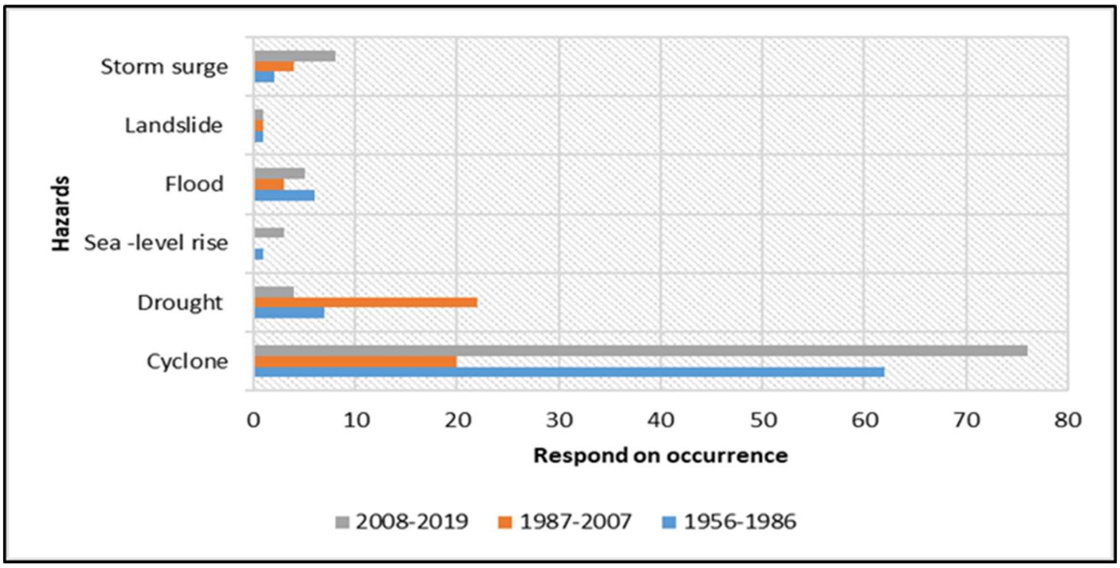

Fig.3a. Frequency of responds by farmers on based on observations and perception on occurrence of events between 1956 to early 2019

Cyclone was found to be the most recalled natural hazard. The majority of the farmers (77.6%) recalled at least one to two cyclone events that occurred between 1956 and 1986, and 63.3% recalled cyclones between 2008 and 2019. Other hazards experienced include flooding, landslides, sea-level rise, and storm surge (including coastal flooding) (Fig. 3a). These responses were also shared by the focus group, who expressed rapid onset from 2008 to early 2019. It was stated that there were few changes in the weather pattern in the past twenty (1999-2018) to thirty (1988-2018) years compared to the early ten years (2008-2018). This has resulted in a more severe negative impact on their crop production.

Drought events were also mentioned, particularly during the 1987-2007 period, as reported by 22.4% of farmers. Although the occurrence of drought is rare (El Niño-related drought), we concluded that there has been some confusion between droughts and prolonged dry seasons or rainfall deficits affecting their crops. This has resulted in the drought perception, instead of a prolonged dry season. These results were similar to those of a study by Tahu (2011) on drought. Thus, these events were vividly remembered by the farmers because of the damage they caused to their crops. As expressed by one farmer:

> *Sometimes rainfall and temperature are inconsistent, and it sometimes changes from the normal monthly condition, especially during the wet and dry seasons. Sometimes it increases and sometimes it decreases when least expected (Malu'u middle-age-female).*

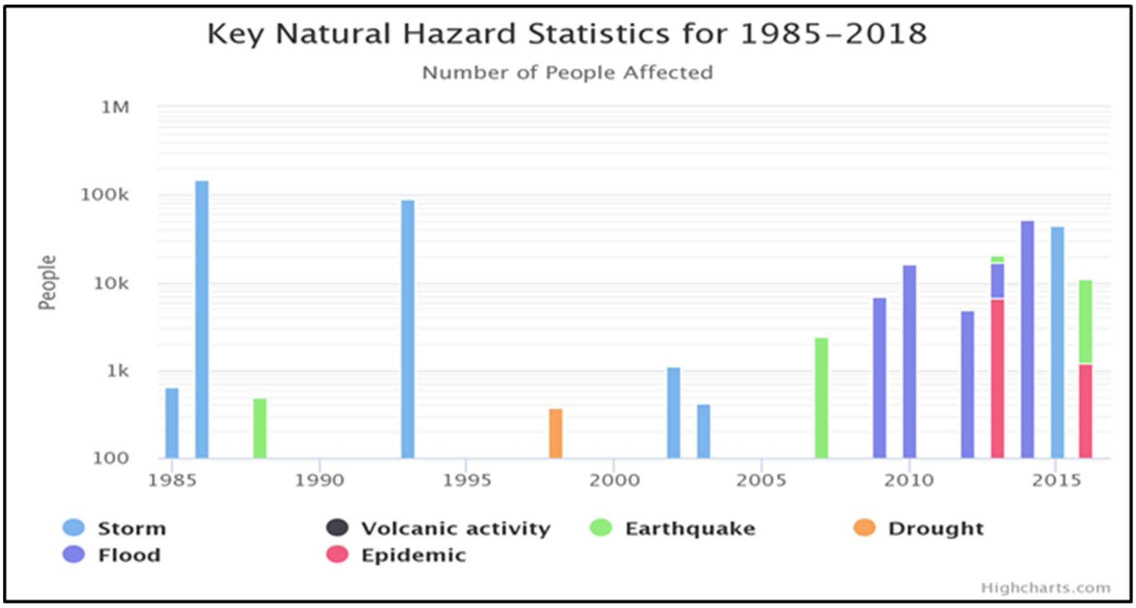

Fig.3b. National hazard statistic for the Solomon Islands. Source: https://climateknowledgeportal.worldbank.org/country/solomon-islands/vulnerability

Climatic attributes: impact on domestic crops

Farmers reported changes in climatic attributes that resulted in the loss of crops or poor harvests, altering the efficiencies in achieving food quality, safety, and nutritional requirements. Studies by Iese *et al.* (2015) and Gachene *et al*. (2015) also found a similar result on the impacts of climate change on yields, mainly attributed to the increasing frequency and intensity of extreme events reported in Bellona and Sub-Saharan Africa. It is generally observed by farmers that most of the losses in crop production were caused by cyclones and increasing temperature (over time). Several farmers shared:

After rain or a cyclone, and the sun comes out, it becomes hot and the soils starts to harden and dry up causing less harvest because of the tough soil. which can also cause shortage of planting material for replanting. So I must change the site to where it is much cooler and won't be affected by rain (Malu'u-50).

The taste of sweet potato was sweeter because there was not much rain, but when it rains a lot, it becomes tasteless (Malu'u middle-age_female),

Other farmers stated an increase in pests during the wet season.

Crops were damaged by pests and disease due to heat, especially with caterpillars damaging the leaves (Malu'u elderlies_male).

When it rains, sweet potatoes grew well, especially the vines, but not the yield. Because the fruits have not produce at all. Same with taro because of too much rain. However, it affects most of my crops. Also, when it rains, pests' number decrease compared to when there is no rain. So as for me, I will change the crop type to other varieties where the harvest will not be affected by too much rain. Also move to another site (Malu'u, 62).

Prolonged hot days were considered to negatively affect the early stages in the development of crops such as taro (*Colocasia esculenta*) (23.0%) and sweet potato (*Ipomoea batatas)* (22.0%). Mature crops like lesser yam (*Dioscorea esculenta*) (18.0%), particularly the vines, (8.0%) giant taro (*Alocasia macrorrhiza)* (which affects the leaf), cassava (*Monihot esculenta*) (8.0%), banana (*Musa*) (8.0%), yam (*Dioscorea alata*) (7.0%), Hong Kong taro (*Xanthosoma sagittifolium*) (3.0%), and giant swamp taro (*Cyrtosperma chamissonis*) (3.0%) were also affected. Previous studies by Bird *et a*l. (2021); Kumar and Sidana (2018) and Iese *et al.* (2015) found a similar pattern in their results due to prolonged hot days.

Heat stress over time also affects soil moisture content, contributing to the wilting process of crops, physical change or deformations, change in taste, and change in tuber, corm, or root size. This has influenced the crop outputs as reported by the farmers, resulting in a declining harvest, as Iese *et al*. (2015) also reported. Additionally, a long-term change in the rainfall pattern was also identified to affect crops. Particularly sweet potato (29.0%), lesser yam (17.0%), cassava (16.0%), taro (14.0%), banana (9.0%), yam (8.0%), Hong Kong taro (3.0%), giant swamp taro (2.0%), and giant taro (2.0%), according to farmers' experience. A similar trend was mentioned by Bird *et al*. (2021) in the area. Wang *et al*. (2021) also stated that Brazil, India, China, Egypt, and Ethiopia are also facing similar negative impacts on crop yield due to global warming.

Farmers have become more vulnerable to small fluctuations in harvests as a result of the increased number of domesticated crops harmed. This is because climate change is escalating climate-related catastrophic events that threaten their food security and financial situation. The assessment by SIG (2020) reveals a consistent loss in crop productivity between 2008 and 2016 (tons per hectare), posing threats to food security. In 2008, one hectare producing 2.6 tons of crops (average) decreased to 1.7 tons in 2016, and may continue to decline. Although this survey does not include the quantity and value of declining yields, farmers' responses to the decline were inevitably to have a tendency to affect their food security.

This indicates that farmers globally are experiencing similar problems because of climate change, which is expected to intensify in the future. The crops identified as affected were domestically grown across the local communities. Although most of the crops grown are tubers, corms, starchy roots, and are tolerant crops, they are affected by both rainfall and temperature change, as observed farmers. As Benkeblia *et al.* (2018) explain, increasing temperature also increases the evapotranspiration, thus shortening the crop cycle. Climate change can have two side effects on crops; winner crops that will benefit from climate change and loser crops that become disadvantageous due to climate change.

For instance, sweet potato vines increase in growth but produce fewer tuber/roots, indicating increased growth but low yield. Nevertheless, analysis showed that crops highly affected were based on farmers' observations corresponding to their traditional knowledge and daily practices. Although these crops may have tolerant features and are traditionally known as being resilient to high rainfall or temperature, little change to their biological and physical environments will be noticeable to farmers whose daily livelihoods depend on them. As a result, farmers have reported a declining yield; nevertheless, it would be much less compared to other non-resilient crops or vegetables.

Based on the responses, it shows slow-onset poses threats to farming practices over time, compared to rapid-onset, which causes more loss and damage to farmers' crops, as van der Geest (2020) also highlighted. This is unpreventable, which the current study has also found. Bouwer (2019) indicated that the risk from extreme weather events would continue to increase in the future due to anthropogenic climate change, thus leading to an increase in loss and damage. Nevertheless, some of the risks can be avoided or reduced through disaster risk reduction (DRR) and adaptation. This is what farmers in Sikwafata and Malu'u are in desperate need of in order to sustain their subsistence agriculture. For example, although the crops identified have tolerant features, Iese *et al*. (2018) suggest that they are likely at risk of global warming and pests and disease. It is also unclear how different varieties will be able to deal with the context of projected hazards becoming more intense, or how farmers will manage to reduce future risk, loss, or damage (Iese *et al*., 2018).

Adaptation strategies to minimize risk

Farmers reported that climate change is influencing local weather (23.4%), threatening food security (28.4%), affecting the environment (20.3%), and livelihoods (25.5%). Howes *et al*. (2018) reported a similar situation, with farmers who were becoming more vulnerable in losing their primary source of fresh produce within the PICT. Analysis revealed that 45.9% of gardens were single-cropping, and 52.1% were mixed-cropping. Farmers have used some forms of climate change adaptation in order to reduce damage and improve crop management systems in the short and long term.

Table 1 presents the percentage of adaptations to minimize damage to their crops. Replicating the same crops in different locations involving shifting cultivation was ranked highest, followed by other adaptive measures.

Table 1 percentage of adaptation frequently mentioned by farmers

Adaptation Practices	**Rainfall (%)**	**Temperature (%)**
Replicate same crop in different site (Shifting cultivation)	37.7	38.8
Change planting date	27.4	27.1
Change crop type	19.8	17.8
Increase garden plots	7.5	7
Implementing soil and water conservation	4.7	6.2
Use cover cropping/trees and crop residue	2.8	3.1

Shifting cultivations is an adaptive strategy used by farmers. However, it involves vegetation removal, thereby triggering land degradation. This was supported by Spann (2018) on farmers from Central Kwara and Fo'ondo in the To'abaita region who are members of the Bushman Farming Network. It was observed that this practice contributes to soil infertility, with erosion being amplified by climate change. This can increase nitrous oxide emissions in soil, as shared by Luizão *et al.* (1989). Because it is commonly practiced, farmers shared that replanting/preserving trees is one way to protect/retain the soil in order to improve its nutrients. Also, avoid leaching and erosion during heavy rain (especially on sloppy areas) and direct sunlight during long intense hot days, as Dollinger and Jose (2018) also established. As quoted by the farmers from Malu'u:

> *Newly grown taro (new shorts) wilts while maturing taro survives. Vine plants like yam and sweet potato dried because of the heat. I think implementing soil, irrigation, and using cover crops can help new crops till maturity (Malu'u, 30).*

Adjusting crop planting dates (i.e. planting several months before or after the typical planting seasons) before the next hazards occur, for example, cyclones or prolonged hot days, is carried out as a way to ensure that food is available. Furthermore, increasing the size and number of garden plots was a strategy to ensure that the crop would survive bad weather and produce a higher yield. Shifting to a new location where farmers assumed the crops would be less vulnerable to the change in weather patterns was also adopted.

Other adaptation methods

Implementing a drainage and water conservation/irrigation system is another adaptation mentioned by farmers. Although the soil type in north Malaita is mainly shallow to deep, dark brown, brown clay, and well-drained (Wall and Hansell, 1973), farmers experienced water damage in their garden during cyclone events. However, during hot days, farmers suggested that an irrigation system might be a solution to avoid wilting and losing their crops due to the long duration of hot days. Only 6.1% of farmers indicated the implementation of soil and water conservation practices for good irrigation. This also involves mulching selective crops to avoid losing moisture, and to protect the plant from direct sunlight. Farmers also emphasized the importance of facilitating proper irrigation systems during prolonged hot days. Also a proper drainage system during heavy rain or the wet season, to reduce the risk or damage to their food production.

> *During a cyclone or long days, it affects the gardens, which then affects the income from sales because of the bad harvest causing a declined. We think to protect our gardens, we have to move to another site and dig a proper drainage system during the wet session (Sikwafata YF-2).*

For taro, especially, we dig a hole and half-bury the corm. When it rains, the soil can fill in the hole. For sweet potatoes, big mounts can avoid soil loss from being removed during heavy rain (Malu'u-41).

About 15.3% of farmers indicated that soil erosion could be prevented by mini drainage systems and diversion canals to redirect or aid in minimizing erosion and run-offs from their gardens. This is in the hopes of lowering the physical and biological impact on their crops.

Constructing a drainage system on a small scale was part of the traditional practices that are still used. However, poor planning and design can lead to further environmental problems in the long-term (Easton *et al*., 2017). This was observed in some of the gardens. Although designing a proper irrigation system is still in question for the communities, it is an option farmers are considering. Nonetheless, better training on how to initiate the system to be less costly and affordable is needed.

Farmers reported shifting to early-maturing crop varieties for food and income purposes. This is in order to minimize vulnerability intensified by climate change impacts on their livelihoods. Farmers tend to venture into early-yield crops that can produce food in a shorter period before or after disasters. Maximum of three to four months. This can facilitate access to, and availability of food at all times. Especially sweet potatoes, cassava, and taro, because some varieties have a shorter harvest period. The finding on this was consistent with studies in Bellona (Iese *et al.,* 2015) and Malaita (Bird *et al*., 2021) on preferable early-maturing crops. Additionally, 34.7% of farmers mentioned that during wet and dry seasons, they will maintain Hong Kong taro, followed by yam (23.5%), cassava (22.4%), and giant taro (20.4%). However, 48.0% shared that they will still cultivate all crops, despite being faced with challenges. It was said that:

> *We must plant crops or vegetables that can be gathered quickly, such as within three months. For example, cabbage, corn, pumpkin, and sweet potatoes, so that we have food. Because, if we continue planting varieties that take longer to harvest, we may face food shortage when disaster strikes (Sikwafata-55).*

Although the adaptive strategies that farmers mentioned do not eliminate the risk they face, they will nonetheless continue utilizing traditional practices as a means of adaptation. If policies are effectively implemented, with resources devoted to basic training and awareness to all local communities, the ability for these farmers to cope with and adapt to climate change will benefit them to reduce vulnerability. Maketa (2019) also emphasized that this could help to minimize the challenges farmers face, improve adaptation, and conserve agriculture.

Many land management choices, such as better agriculture, enhanced sustainable forest management, and increased soil organic carbon content, do not necessitate land-use change and do not demand much land (high confidence) (IPCC, 2019) for agriculture. This would also be a good solution for the communities to improve their agricultural activities. Though farmers are facing losses and damage, when compared to the losses and damage caused by climate change in terms of human, environmental, economic, and infrastructure damage, food security receives far less attention (van der Geest et al., 2020). Based on the farmers' responses, we can say that they will eventually become more vulnerable to extreme hazards and global warming if climate change is not addressed.

Importance of land/soil for food production

From our analysis, the majority of gardens (87.5%) are located on hillsides, while 8.5% are located in lowland areas. Despite having multiple garden with an average of three per farmer, the majority (57.0%) were on rotational sites before re-cultivating, while 43.0% were on the same piece of land with no crop rotation. Changes in temperature and rainfall are concerning, as these affect soil quality by causing the soil to lose its nutritional content or making it unsuitable for planting. Thus, different locations will require specific adaptations to reduce crop damage. In addition to providing 98.8% of humanity's food, soil provides a variety of services such as carbon storage, greenhouse gas control, and flood mitigation (Kopitike et al., 2019). It is concerning because, soil content influences the ability to meet supply, quality, and food safety standards to achieve food security. If there is no proper management, crops will also become affected.

Table 2 Percentage of MC in Sikwafata (sample 1) and Malu’u (sample 2)

Soil Analysis	Sample 1 (34cm in depth)	Sample 2 (34cm in depth)
Moisture Factor (M.F)	1.7	1.5
Moisture content (M.C)	66.4%	47.4%

As presented in Table 2, Sikwafata’s soil has more moisture content than Malu'u, based on analysis. Sample 1 reveals moisture content is 66.4%, and moisture factor is 1.7 at a depth of 34cm for Sikwafata, whereas Malu’u (sample 2) moisture content and moisture factor are slightly lower at 47.4% and 1.5 respectively. This indicates that the soil holds less moisture. Based on observations, Sikwafata also received more rainfall, contributing to the differences in moisture level as shown in Table 2. It was observed that Malu’u is drier, which may be attributed to the fact that Malu’u is a small center, and therefore development is slightly higher than in Sikwafata, which has more thick vegetation from the lowland right uphill. Perhaps this has influenced the differences in crops affected by considering the moisture level of the areas and why tolerant crops were identified as affected. The study suggested that, based on the sample, Malu’u is likely to experience more extensive hydrological and agricultural drought or more vulnerability to rain deficiency.

Perception of climate change by 2050 and crop production

Farmers predicted that by 2050, temperatures (83.7%/16.3%), rainfall (79.6%/20.4%), sea-level rise (69.4%/30.6%), cyclones (66.3%/33.7%), flooding (66.3%/33.7%), and drought (59.2%/40.8%) would increase in intensity and frequency. Thus affecting agricultural food production systems. If global warming exceeds 1.5℃, then the IPCC projection of increases in mean temperature, severe precipitation and drought, and a rise in global mean sea levels will negatively affect food production (IPCC, 2021). The Australian Bureau of Meteorology and CSIRO (2014) projected that mean temperatures will continue to rise, and rainfall will increase slightly. With more extreme rainfall events that may indicate more flooding for the Solomon Islands. Although the farmers’ responses in this study are based on their perceptions, the results show a slight consistency with climate change projections. Thus, crop destabilization is a concern associated with climate change. Because it is unknown whether crops may naturally develop tolerance features to climate change without human intervention, production might continue to drop at a greater rate in the future. A farmer from Malu’u shared

I will not make any change in planting because if the weather is unstable like now, it will still affect the growth of crops. For example, the vines (sweet potato) will die, and while taro growth will increase, especially for mature taros, the harvest may still decline because of the increase in heat and because the soil will be too hot. (Malu'u, 63).

Improve farmer's wellbeing and knowledge gap

Cultivating multiple garden is a standard practice to reduce poverty and malnutrition and to improve farmers' health and food security. There are a few priorities under the SDGs and the Solomon Islands–Pacific Community Country Programme 2019-2021. This includes assisting agriculture, eliminating poverty, and avoiding the spread of non-communicable diseases (NCDs). Farmers need sufficient training and awareness if they are to effectively combat climate change and to achieve the SDGs 1 and 2: poverty, hunger, and better health.

Based on the farmers' responses in this study, food insecurity was noted as a key threat to livelihoods, especially during natural hazards. This limits households' ability to access food from their gardens in order to satisfy their basic needs, thereby potentially reducing their nutritional requirements. SDG 13.1, for example, encourages countries to take steps to combat climate change-related food insecurity and malnutrition. Assessments and policies can be integrated to improve agriculture strategies to encourage food security management and adaptation. Examples could include, for instance, the Post Disaster Needs Assessment tools, the Solomon Islands Agriculture and Livestock Policy 2015-2019, and the Sendai Framework for Disaster Risk Reduction. This is one area that needs further improvement in order to properly implement current frameworks in rural communities like Sikwafata and Malu'u.

The analysis of farmer's responses to climate change awareness and training revealed a knowledge gap, as Mitra *et al.* (2021) also discovered in India. Thus, active engagement in climate change awareness programs, training, and including it in the educational curriculum, is advocated as a means of improving communities' understandings of agriculture and climate change. This can help to reduce the effects of climate change. This may require gaining a better understanding of the levels of communication that will address farmers' needs, ranging from the upper levels (government and its ministries, organizations, and non-governmental organizations), to the community levels. As stated

Climate change should be included in the educational curriculum beginning in kindergarten and continuing through high school, if possible. To assist our children in learning and understanding what is happening, as well as to help us understand the changes. Perhaps not in its whole, but it may assist us in being more aware (Sikwafata-58).

Nguyen et al. (2021) emphasized the importance of raising awareness, education, and improving communication throughout the Pacific Islands in order to build resilience. Farmers in this study, however, expressed difficulty in accessing scientific or climate change information. This includes adaptation methods, through numerous government ministries to help strengthen or improve their farming system. Thus, this shows that a community's ability to deal with the effects of climate change is also associated with the level of public awareness and information available to improve their crop production system. As a farmer expressed,

> *We require assistance from the government or other non-governmental organizations. To advise us what would be a decent way of improving our agricultural system. Because our current strategy may not be viable in the future due to the changing weather. I believe we should present this to our members of parliament (MPs) for them to see how climate change is already affecting us and whether there is any effectiveness/adaptation they can provide. We need awareness. (Sikwafata, 79).*

Through the application of traditional knowledge, crops have been identified as being sensitive to heavy rainfall and temperature change as also observed by Dhanya and Ramachandram (2016) in India. Because of their levels of knowledge and experience and the only crops available to them, farmers (21.4%) stated they would continue to practice traditional farming and grow the same crops. This emphasizes how critical it is to address the negative effects of climate change to safeguard their livelihoods. In southern Brazil and the United States, Foguestto and Machado (2021) and Prokopy et al. (2015) came to the same conclusion, noting that the policy's implementation was lacking and that it needed to be addressed.

The Solomon Islands Agriculture and Livestock Policy 2015–2019, for example, emphasized its priority on disaster risk mitigation and climate change adaptation, agro-processing, value-added, agribusiness, and rural credit facilities. In addition, collaboration with the private sector, non-governmental organizations (NGOs), donor partners (national and international), and other service providers should improve the agricultural sector's productive capacity. The goals were to strengthen farmer institutions as well as research and development capabilities to increase productivity of food crops and livestock. As well as value-added technologies to enhance output for both local consumption and export (Solomon Island Government 2015). However, the ministry's policy is still far from achieving its given policy.

The reason is maybe policymakers throughout the world are challenged by climate change, and the stakes are especially high like in Asia and the Pacific. Asia and the Pacific's adaptability capability is roughly equivalent to the rest of the world. The region has an adaptive capacity index of 0.53, which is comparable to the global average (also 0.53) (Bellon et al., 2021). However, the region has to enhance its capacity even more since it is the world's most vulnerable area to climate change threats, with an average of 0.39, significantly higher than the global average (Bellon et al., 2021). Nonetheless, many of the PICT are especially vulnerable. Because the costs of adaptation are so high, financial resilience will be crucial. Growth and development will be jeopardized if adequate adaptation is not implemented as a result of ineffective or difficult climate change policies. This can only mean, food system for the region will be jeopardized.

Conclusion and Recommendation

This study has explored the impacts of climate change and extreme events that farmers have experienced, including on their future crop production. Farmers' perceptions of the changes they are experiencing must be included in the development of policies and interventions to assist farmers in dealing with the negative effects of climate change and environmental change. Farmers' greatest challenges are tied to climate-related extreme events, which inflict more harm on their crops than climate change, which occurs over time and hence has cumulative negative effects. Although all farmed crops are believed to be resilient/tolerant, they were all affected to some extent. Farmers are sensitive to slight changes in the crops because they are grown domestically throughout the year. Farmers were able to identify some adaptation measures to address their production loss, For instance, changing planting methods, shifting cultivation sites, changing crops/early yielding crops, expanding garden plots, replanting/protecting trees, and having a proper drainage/irrigation system. The vulnerability to climate change has been aggravated by a lack of information, awareness, and training from appropriate government ministries that can help farmers. Thus, causing a gap to see the implications of climate change on local food production, sustainable agriculture, food security, and the health of farmers. Therefore, there is an urgent need for actions to mitigate the impacts of climate change to reduce farmers' vulnerability or risk, and to minimize crop loss and damage now and in the future. If this is not addressed now, future production will be more challenging and people will tend to depend on processed foods.

Based on the findings from this study, we make the following key observations and recommendations:

- Food production is affected by both climatic change and extreme climate-related events, influencing farmers' food system and financial security.
- This calls for three approaches – increase awareness on relationship between climate variability and climate change impacts on crops. Approaching awareness and adaptation strategies through integration of traditional knowledge and modern science but consider the level of education of farmers in communication and awareness materials. Also, approach awareness of climate change through the churches, community meetings, and schools.
- Farmers are worried about climate change in the future which is a form of declaration of interest from farmers to learn more about climate change. Thus, the Solomon Islands Ministry of Agriculture and Livestock (MAL) needs to increase the number of extension officers to the local communities.
- We recommend more community awareness on climate change and its impacts and further research on food production and attribution to climate change to enable farmers to make informed decisions about improving their food production systems.
- It is recommended that further study is needed to confirm the finding and government ministries need to ensure that their policies set to improve agriculture, health, and the livelihoods of its populations are achieved and applied equally across the communities.

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