Chapter 6
Farming Adaptations to the Impacts of Climate Change and Extreme Events in Pacific Island Countries:
Case Study of Bellona Atoll, Solomon Islands

Viliamu Iese
Pacific Centre for Environment and Sustainable Development, The University of the South Pacific, Fiji

Elisabeth Holland
Pacific Centre for Environment and Sustainable Development, The University of the South Pacific, Fiji

Joseph Maeke
Pacific Centre for Environment and Sustainable Development, The University of the South Pacific, Fiji

Morgan Wairiu
Pacific Centre for Environment and Sustainable Development, The University of the South Pacific, Fiji

Sumeet Naidu
Pacific Centre for Environment and Sustainable Development, The University of the South Pacific, Fiji

DOI: 10.4018/978-1-4666-6501-9.ch006

ABSTRACT

Farmers in Pacific Islands' communities are considered to be most vulnerable to the impacts of increased temperature, sea-level rise, droughts, cyclones, and heavy rainfall. Farmers living on a raised atoll in the Solomon Islands (Bellona) were interviewed to understand their perceptions and experiences on the impacts of climate change and extreme events on their crops. Some examples of damage and impacts according to the farmers included rotting of roots, damage to leaves and branches, and destruction of fruits and valuable yields. Interviews also revealed that the ability of farmers to recover after disasters was dependent on their pre-disaster conditions, number and varieties of crops they had planted, type of cropping system in use, and consistent use of simple, traditional, and innovative adaptive techniques. Such techniques included crop rotation, change of planting and harvesting dates, and the planting of new resilient varieties.

INTRODUCTION

The growth, development and production of food crops depend on both climatic (e.g. rainfall, temperature, humidity) and environmental (e.g. soil, water availability and topography) variables being sufficiently available and there is adequate protection from external factors (invasive species, pest and disease) (Wairiu et al. 2012). Any changes or shifts in the climate will therefore affect the physiology and output of food crops. While climate change will have global impacts, impacts on small islands are likely to be particularly significant. Mimura et al. 2007 asserted *"Small islands, whether located in the tropics or higher latitudes, have characteristics which make them especially vulnerable to the effects of climate change, sea-level rise and extreme events"*. These small island characteristics include their small area size, remoteness, isolation, exposure to extreme events or natural hazards, high or increasing population, low adaptive capacity and poor infrastructure and governance (Barnett and Adger, 2003). Both subsistence and commercial agriculture will be affected on small islands (Mimura et al. 2007). However, while coastal agriculture is likely to be most impacted by sea level rise causing inundation, intrusion and soil salinization, inland agriculture will be most vulnerable to extreme events such as flooding and drought (Mimura et al. 2007). As a consequence of climate change, the highest reductions in agriculture potential will be felt by the small Pacific Island countries (PICs) amongst other developing countries (ADB, 2009). Within PICs, it is the atoll islands and their inhabitants that are at greatest risk of climate change and extreme events (Barnett and Adger, 2003). Exacerbating this situation is the large dependence of PICs on their natural resources. Low-lying atoll countries such as Tuvalu, Kiribati and the Marshall islands are already experiencing the impacts of climate change and extreme events on their food crops, coastal fisheries and water (FAO, 2008). The Solomon Islands contains both atoll and low lying islands and also has problems in common with other atoll countries. Many Solomon Island communities on low-lying atolls are experiencing climate change impacts through sea level rise, salt water intrusion and extreme events (cyclones, droughts etc.) and have witnessed changes in the main staple food crops (Wairiu et al. 2012). One such atoll community is Bellona, located in southern Solomon Islands. The Bellona community has already experienced climate variations such as low rainfall and frequent cyclones which affected their food security and livelihoods (PACC, 2006; Rasmussen et al. 2009). In turn these impacts have been correlated with reduction of food production and food security. The Bellona community lacks adequate infrastructure. Difficulties in receiving service delivery from both the national and provincial governments are further highlighted by widespread tropical cyclone damage. For example, in the past five decades, four major cyclones have directly impacted the atoll, causing severe and extensive damage to crops, infrastructure (water tanks) and rural livelihoods (Reenberg et al. 2008). In many cases, periods of drought have followed cyclone events (Reenberg et al. 2008).

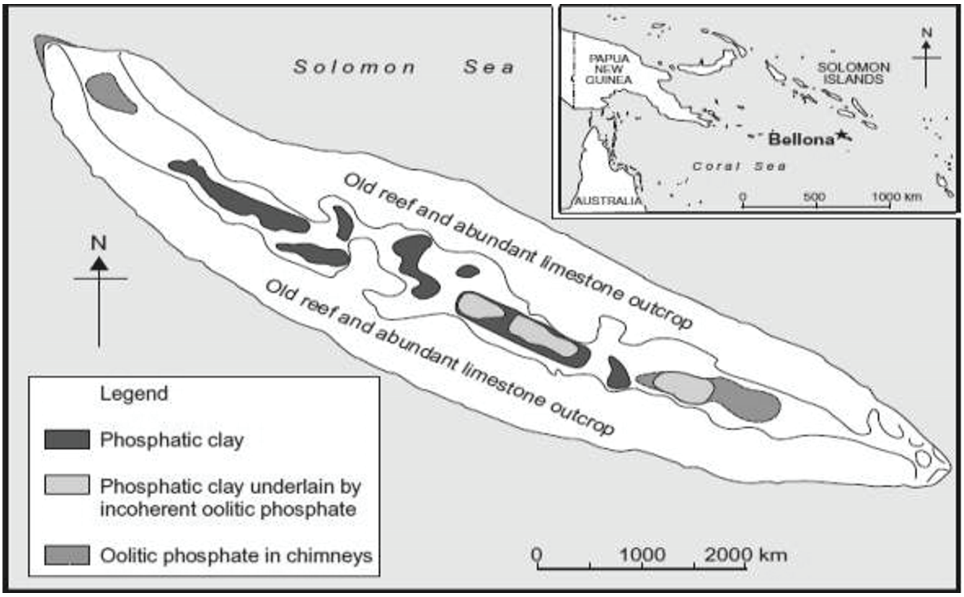
This chapter uses survey data from households and focus group discussions with farmers and elders to provide valuable insight into the impacts of climate change related extreme events on food crops in Bellona raised atoll in the Solomon Islands. Adaptation strategies that farmers have implemented to reduce crop yield loss and build their resilience against climate change uncertainties are also presented. Finally, conclusions and future research opportunities are considered.

BACKGROUND

Geographic Location

Bellona Island is located to the South of Solomon Islands, lying at approximately latitude 11° 11’ South and longitude 159° 15’ East (Christensen, 1975, Hansell & Wall, 1976). The island is situated at about 170km from the country’s capital, Honiara (Figure 1). Bellona Island is a small uplifted atoll which is elliptical in shape (Christensen, 1975, Breuning-Madsen et al. 2010, Borggaard et al. 2012) or resembles the shape of a canoe (SIG, 2001). Bellona is about 10km long and 2km wide and has a land area of approximately 20km^2.

Figure 1. Geographic location of Bellona Raised Atoll in Solomon Islands



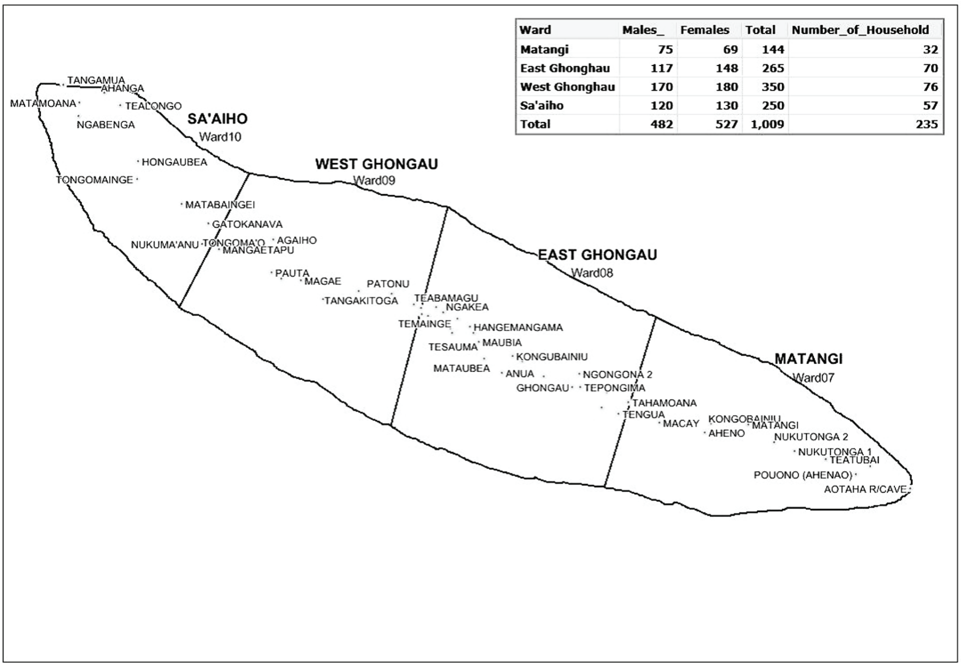
Social, Cultural, Political Structure, and Demography

Historically, Bellonese are believed to be Polynesian sea-farers travelling from Wallis and Futuna approximately 2500km east of Bellona (SIG, 2001, Birch-Thomsen et al. 2010). Bellonese claim a single ancestor known as Kaitu'u; partly god and partly human, who is thought to have travelled with seven clans in two canoes looking for land. The two islands of Bellona and Rennell are named after the canoe shape of these vessels (SIG, 2001).

Cultural practices of the Bellonese people have eroded as a result of influence from Christianity, interaction and contact with Melanesian culture and foreigners (SIG, 2001). The present day generation has vague remembrance of the way of life of their ancestors before Christianity. The Bellonese practised the patrilineal system where males have the dominant role in the Clan, Sub-clan or family. Thus, land ownership is mainly by way of inheritance. As a result, only the patrilineal kin is entitled to inherit land (Christensen, 1975).

In more recent history, Bellona Island combined with Rennell Island to form Rennell and Bellona Province, the smallest province in the Solomon Islands. Politically, there are 6 wards in Rennell and 4 in Bellona. The wards in Bellona are Matangi, East Ghonghau, West Ghonghau and Sa'aiho (Figure 2). Each ward has a provincial member who represents the people of each ward and brings their concerns or issues to the provincial executive members during their meetings. The province is repre-

Figure 2. Population map by wards in Bellona



Ward	Males_	Females	Total	Number_of_Household
Matangi	75	69	144	32
East Ghonghau	117	148	265	70
West Ghonghau	170	180	350	76
Sa'aiho	120	130	250	57
Total	482	527	1,009	235

sented in the provincial level by a premier while at the national parliament by an honourable member which is elected to serve for a 4 year term period (SIG, 2001).

The total population of Bellona in 2009 was 1009 (SINSO, 2009). There were more women compared to men by about 5%. Most of the populace is concentrated in central Bellona specifically in East and West Ghonghau while the lowest populace is on Matangi ward, East Bellona.

Climate

There are no established weather stations on Bellona Island. Thus, there are no continuous recordings of daily rainfall, temperature, sunshine hours, wind speed and solar radiation. The only available daily rainfall, minimum and maximum temperatures for Bellona were recorded from March 1965 to May 1967 (Christensen, 1975). Drawing from these recorded weather parameters and climate records of nearby islands, it can be concluded that Bellona has a temperature of around 25 ^{0}C -30^{0}C, with extreme temperature of about 33°C and yearly precipitation which exceeds 2.5m (Breuning-Madsen et al. 2010). Overall, Bellona experiences a tropical wet equatorial climate with high humidity. According to Reenberg et al. (2008) and Breuning-Madsen et al. (2010), though there is adequate precipitation on Bellona, it is insufficient for agriculture due to the limited capacity of the soils to withhold water. There is no surface water (streams, rivers, lakes) on Bellona which makes irrigation very difficult.

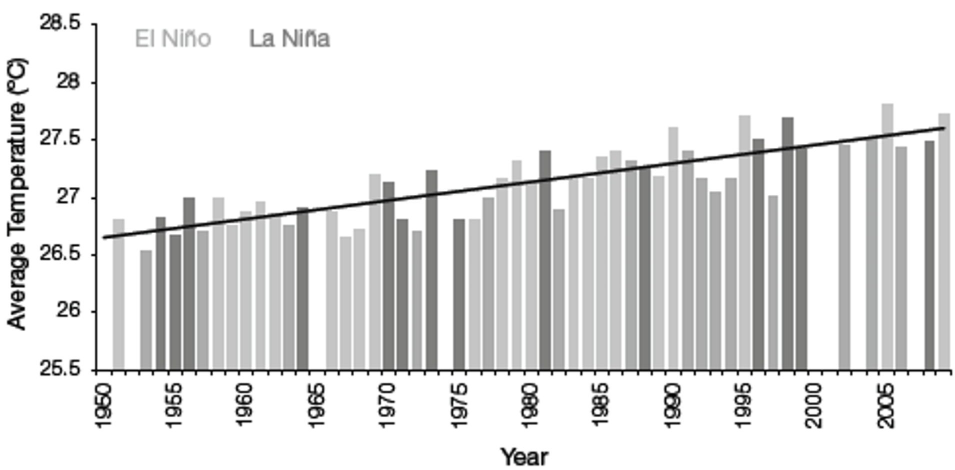
The Solomon Islands has two distinct tropical climates, marked by a wet season that falls between November and April and a dry season which is normally from May to October (PCCSP, 2011). These two seasons are mainly influenced by the Trade winds which are dominant and prevail across the Solomon Islands.

Temperature is normally constant all over the year with little seasonal variation. However, significant variation only occurs in July to August, when cooler air prevails from the south (PCCSP, 2011). Though the air temperatures indicated little seasonal variation they are correlated to sea surface temperatures. There are three main climate systems that affect rainfall distribution on the Solomon Islands namely, the West Pacific Monsoon, the South Pacific Convergence Zone and the Inter-tropical Convergence Zone. The eastern Solomon Islands experience constant rainfall throughout the year whilst in the west, rainfall normally occurs from November to April (PCCSP, 2011). However, with the influence of El Niño-Southern Oscillation (ENSO), there are significant variations of rainfall each year.

Temperature Change

Using the period from 1950-2009, there is evidence of an upward warming trend (annual and seasonal) in the mean air temperature at Honiara, the capital of Solomon Islands (Figure 3) (PCCSP, 2011).

Figure 3. Annual average temperature for Honiara, Solomon Islands (PCCSP 2011)



Rainfall Change

Rainfall trends according to the recent analysis by PCCSP (2011) for Honiara station indicate a non-statistically significant trend (Figure 4) for the period between 1950 and 2009. However, according to Talo (2008) despite the fact that there is upward warming trend of temperature, rainfall records show the opposite, a downward trend.

OBSERVATIONS ON THE TREND OF CYCLONES AND DROUGHT

The summary timeline drawn from the perceptions of farmers (Figure 5) revealed that in the years prior to 2001, major cyclones normally occur with an interval of 7 years. For instance there is a 7 years interval between Cyclones Keri, Namu and Nina. The trend of a 7 year interval was reported as allowing the Bellonese to predict when the next cyclone will happen and therefore prepare before it strikes. However, after cyclone Nina, the interval of time span of occurrence of cyclones not only became inconsistent but declined. Thus, generally, it is reported that while occurrence of cyclones have been observed to decline, the strength has been noticed as variable.

All the respondents from the focus groups agreed that they noticed changes in both the frequency and strength of drought. However, they reported a decline in the long term (months) drought but an increase in the short term (weeks) drought. Drought strength was assessed by summing up the effect of heat stress from drought on food crops. The Bellonese surveys suggested that although long term droughts

Figure 4. Annual rainfall trend for Honiara (PCCSP 2011)

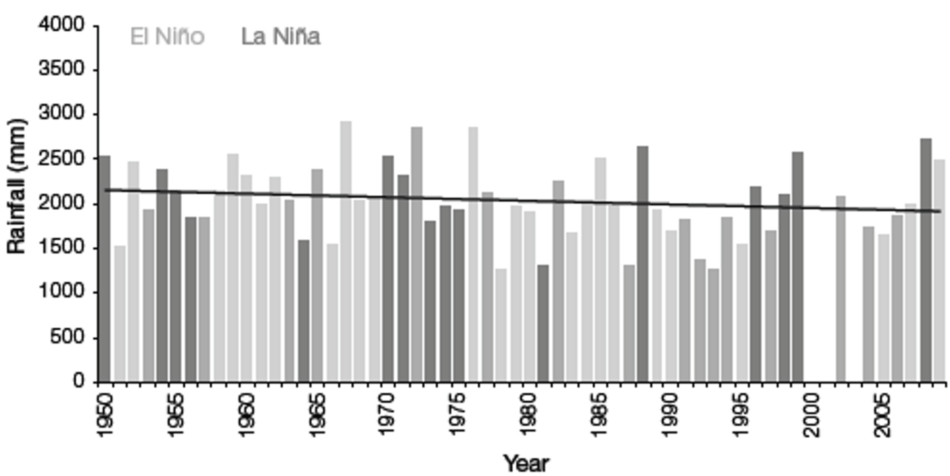
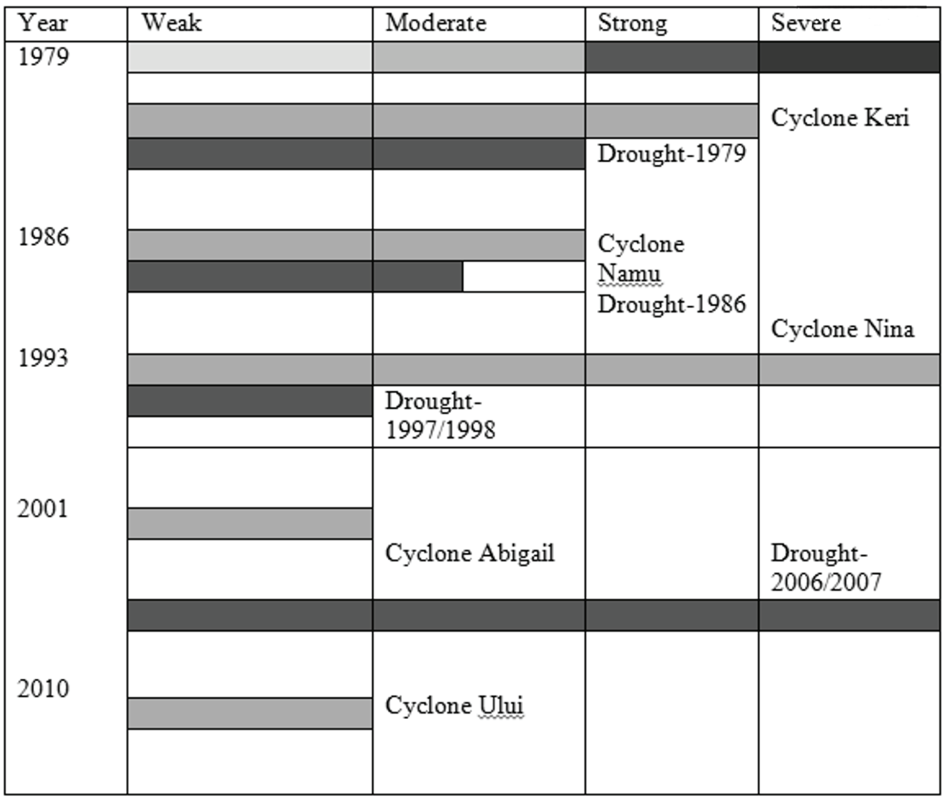


Figure 5. Farmers' perceptions on timeline and severity of cyclones and drought occurrences they experienced over 30 year period



were declining in strength, the short term droughts were increasing in strength. Short-term droughts were reported to adversely affect crops, mostly because of extreme heat stress on plants.

FOOD CROPS, CROPPING SYSTEM, AND FOOD SECURITY

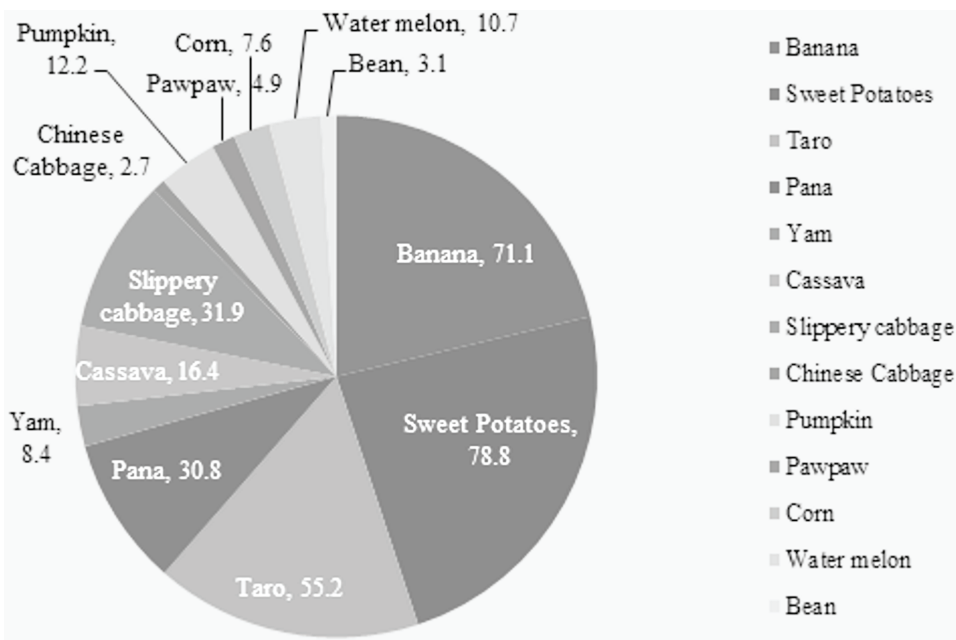
The main food crops cultivated on Bellona are greater yam (*Dioscorea alata)*, lesser yam or pana (*Dioscorea esculenta),* taro *(Colocasia esculenta),* giant *taro (Alocasia macrorriza)*, sweet potatoes *(Ipomea batatas),* potato yam *(Dioscorea bulbifera),* pacific yam *(Dioscorea nummularia*), cassava *(Manihot esculenta),* banana *(Musa spp.*), slippery cabbage *(Hibiscus manihot),* melon *(Citrullus lanatus)*, pumpkin *(Cucurbita pepo)* and corn *(Zea mays).* The main root crops are taro, yam, pana (lesser yam lesser), cassava and sweet potatoes and these account for the largest percentage of the cultivated crops (Figure 6). The majority of the households cultivate sweet potato (78.8%) which is a shift from the traditional root crops of yams and taro.

Banana is the second most cultivated crop by households (71.1%), and is usually intercropped with other crops like taro and slippery cabbage. Vegetables and fruits like Chinese cabbage, bean, pawpaw, water melon and pumpkin are least cultivated and are only planted during certain seasons.

In the past 50 years, yam and pana were the main staples planted because they gave good yields in both quantity and quality (Christensen, 1975). On the contrary, current results indicate that yam and pana are only cultivated by 8.4% and 30.8% of the households respectively due to a decline in yield and quality. Changing climate and unpredictable weather conditions affected the growth and yield of yams and pana; therefore farmers shifted towards cultivating a more resilient crop (sweet potatoes) which provided higher yields in a shorter time. However, this is not the case with cassava which is only cultivated by 16.5% of households.

Cassava is reported to be a more resilient and less vulnerable crop to climate extremes. Yet, the low percentage of cultivation is because the Bellonese only cultivates cassava in small quantities for puddings and for the times when their harvest of other crops like taro is not adequate. Cassava is often cultivated as a boundary crop

Figure 6. Percentage of food crops cultivated amongst the 59 households in Bellona



in some garden plots. Thus, it can be argued that while cassava is less vulnerable to climate change and extreme events, its adaptive capacity has not been exploited significantly by the Bellonese.

The average number of plots or garden fields per household was recorded. There was a decline in the number of plots per household compared with the records of 1962-1967 (Christensen, 1975) and 2006-2007 (Mertz et al. 2011). This may have been because householders rely more on food imports from Honiara to supplement their diet and as a result cultivated their crops in fewer locations (Birch-Thomsen et al. 2010, Mertz et al. 2011). The significance of this finding is that it indicates the exposure of the land/soil to various changes in climate and extreme events which in the long run resulted in lower soil fertility in some parts of the island. A study revealed that the centre of the island of Bellona is more fertile and has more inhabitants compared to the outer rim of the island (Mertz et al. 2011). The high fertility in the centre is believed to be due to the vast amount of bird droppings and decomposition of fish which formed a layer of guano on the centre of the island in the past (Breuning-Madsen et al. 2010). Therefore, in the low fertile areas, the farmers used less plots because even though much labour is invested, crop productivity is low. The results for 2006 compared to the results in 2012 clearly showed that Ghonghau ward which is in the centre of the island has more plots compared to the other wards which highlight the land exposure and fertility issues.

The farming practices on Bellona have generally remained the same over the years (Christensen 1975; Birch-Thomsen et al. 2010; Mertz et al. 2011). The farming practice is generally brushing, burning and fallow vegetation; without the use of fertilizers, animal manure, pesticides, insecticides and irrigation inputs. All of the households interviewed, including the focus groups substantiated that their farming practices do not include any chemicals, manure or irrigation input.

The system of using fallow periods to enable the land to replenish itself is commonly practised among the households in Bellona. Fallow periods ranged from 2 to 10 years depending on the type of food crops previously planted or which shall be planted. Table 2 outlines the average fallow period from the 1962-2006 records

Table 1. Average number of garden plots per households in major wards on Bellona Island

Ward	1962-1966	2006-2007	2012
Matangi	7.8	4.3	2.8
Ghoughau (East & West)	6.2	4.6	3.1
Sa'aiho	6.3	4.6	2.1
Total	6.8	4.5	2.7

Table 2. Average years of cropping fallow on Bellona Island

Crop Type	Average Fallow 1962-2006	Average Fallow 2006-2007	Average Fallow 2012
Sweet potatoes	4.2	7.8	1.7
Taro	5.5	16.6	5
Pana (lesser yam)	5.5	13.8	5.5
Yam (greater yam)	5.5	9.8	6

(Christensen, 1975), the 2006-2007 records (Mertz et al. 2011) and the results in 2012. It is obvious that the fallow periods increased in 2006-2007 compared to 1962, but declined in 2012.

The decline in the fallow periods may have been due to increased pressure placed on land availability by increased land intensification and extended cropping periods (Bourke et al. 2006, Jansen et al. 2006). However, a study showed that such decline in fallow periods may be due to the redistribution of land use intensity which is varied in Bellona (Mertz et al. 2011). Furthermore, it also showed that fallow periods increased in areas around the rim of the island where soils are less fertile, however in the centre of the island where most of the population lives and the soils are more fertile, fallow periods are shorter (Mertz et al. 2011).

In terms of vulnerability, the study showed that soils on Bellona Island have been impacted by short fallow periods; possibly implying that adaptive capacity of the soil to replenish itself has been limited mainly due to the conversion of remnant natural forest areas, small-scale brushing and burning and clearing of fallow vegetation. These could also be major reasons why the cultivation of sweet potatoes has become the dominant crop in Bellona. Moreover, the impacts of climate change and extreme events which are evident in the exposure of soil to climatic hazards like drought or extreme rainfall have the potential to further exacerbate soil infertility and reduce of crop yields.

Food security in Bellona atoll is sustained by the availability of food crops, fruits and vegetables provided by home gardens and several plots discussed above. Yams and taro are considered as important root crops for cultural activities. The ability of yams to maintain its eating qualities for a longer period of time makes it a long term crop preferred by farmers. The good eating quality of taro and availability of early matured varieties makes it an important crop for food supply both in the short term (6 months) and in the long term (yearly). Sweet potato's ability to be grown on poor soils and be edible within three months encouraged farmers to adopt and plant it to sustain food supply for the household level. It is also a favorable crop to be planted after natural disasters because most of the varieties matured in three months. This sustains food supply during the early recovery period. The cultivation of other crops such as banana, slippery cabbages and vegetables provide a much more nutritional diet for Bellonese. The farming system in Bellona where a farmer owns more than one home garden ensures both the availability and accessibility of foods when needed. This is crucial to maintain food supply before, during and after disasters.

The crop diversification and multi-plots approach is also very common in other islands of Solomon Islands (Quity, 2012). This is important not only because it supplies the various dietary needs of Solomon Islanders but also sustains food supplies during unfavourable conditions. For example, when pest and diseases affect one crop, others provide foods for the members of the household. The common crop that is cultivated all throughout Solomon Islands for food security is sweet potato. This is because it provides starch and nutrients that are important for the health of the general population. Furthermore, other non-edible parts of the plant are used as animal feed.

EXTREME EVENTS AND CLIMATE CHANGE IMPACTS

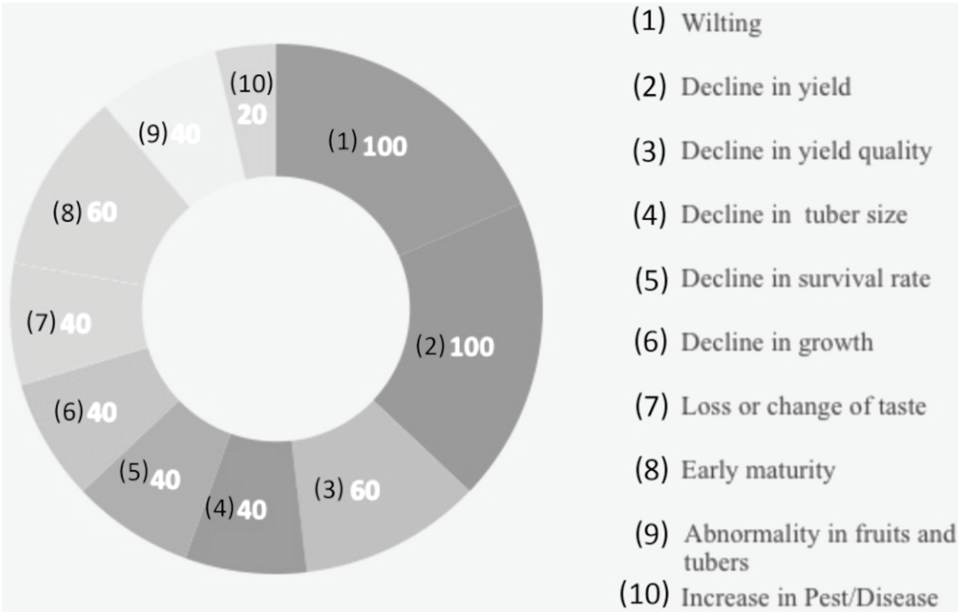
Almost all of the households confirmed that changes have been observed in the temperature (96.6%) and rainfall (98.3%) over the past 30 years. The other 3.4% and 1.7% of the households respectively, either stated that temperature and rainfall remained the same or that they were unsure.

Increase in Temperature

Survey respondents have suggested that the temperature change observed over the past 30 years has impacted food crops in several ways.

All of the groups (100%) identified wilting and decline in yields as the most significant impacts on the crops due to temperature increase. Sixty percent (60%) claimed a decline in yield quality and early maturity as adverse impacts whilst 40% mentioned decline in tuber size, survival rate, growth, loss or change in taste (flavour), and abnormalities in fruit shape. The wilting of crops refers to the loss of the firmness of the non-woody parts of the crops like leaves or young shoots due to loss of water in crop cells. This was suggested to be the effect of an increase in temperature which results in an increase in water loss from both soil and plant due to increased evaporation and transpiration. The results indicated that all the groups observed wilting as the major effect which suggested a significant impact of climate change on crop production. According to the observations of the Bellonese communities, the increase in heat stress which resulted in wilting of crops negatively

Figure 7. Responses of the five focus groups expressed as a percentage, on the impact of increased temperature on food crops in Bellona



affected the survival rate of newly planted crops. They stated that the effects of increased temperature include scorched young crops, leaves of the crops turning from green to brown resulting in stunted growth, as well as crops that die as a result of permanent wilting.

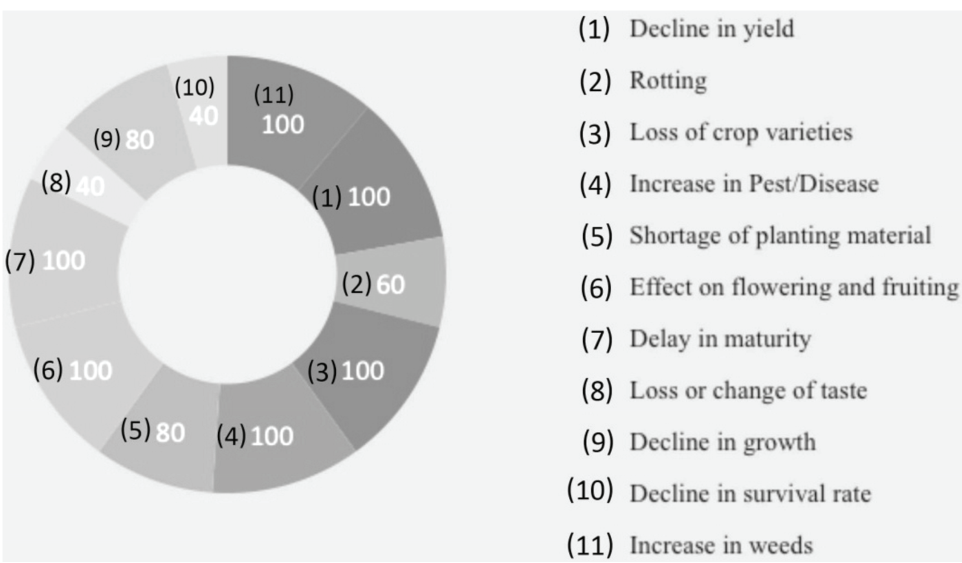
All the groups indicated that the decline in yield of crops was due to the increase in temperature. This may be because reductions in crop yields were observed to be related to the impacts of wilting, lower survival rate, decline in tuber size, early maturity and decline in crop growth and increase in pest/diseases. For example, wilting and the decline in survival rate of newly planted crops reduced yield because crop density or population decreased which resulted in lower production. Early maturity, decline in crop growth and increase in pest and disease also reduced yield because fewer tubers or fruits are produced, whilst the decline in tuber size affects the quantity of the yield. The Bellonese respondents observed that with early maturity, the tuber size of root crops and fruits were smaller with some deformity. For instance, the elderly and women's group mentioned that the size of yams 40-50 years ago were so large that they had to stand upright while peeling or grating them. They stated that while those yams were about 2-4 feet in length, the present size of yams rarely reached a foot and a half. In terms of the morphology and shape of the yams, irregularities in the shape were also observed whereby the shape of yams today are irregular with many crevices, whilst those in the past reflected more of a cylindrical shape.

Impacts of Heavy Rainfall

Similar to temperature, all focus groups reported that they observed an increase in rainfall over the past 30 years, resulting in serious impacts on the Bellonese food crops. Most of the respondents (80%) identified the effects on flowering/fruiting; and a decline in the survival rate as the second most severe impact on the crops. Some 60% claimed the loss of some crop varieties and 40% identified a decline in growth and an increase in weeds as some of the adverse impacts of increased rainfall.

Decline in yield is the most significant impact not only because it affects the production of the crops but the livelihoods of the people who depend on it. Rotting was reported to be severe because of excess water retained in the soil over long periods due to heavy rainfall. The Bellonese people reported that rotting affected the roots of crops like slippery cabbage, pumpkin, water melons and banana. It also affected the storage roots of sweet potatoes, yam, pana and corms of taro. Some of the members of the groups also mentioned that the stem of the bananas are also subjected to rotting during prolonged rainy conditions. It is unclear if the retention of water on the stem provides favourable conditions for plant pathogens to cause

Figure 8. Responses of the five focus groups expressed as a percentage on the impact of increased rainfall on food crops



rotting. For instance, a study conducted in Sri Lanka identified that a fungus *Marasmiellus* spp causes stem rot in banana particularly during rainy season (Thiruchchelvan et al. 2012). The study further claimed that this fungus affected banana during different stages of development. Wilting of leaves and death may occur in the early stages of development while reduced bunch size occurs during the mid to mature stage. All the groups interviewed highlighted that the increase in rainfall further exacerbated pest infestation. The most common pests identified are Bongu (Taro beetle, *Papuana* spp) that feeds on almost all root crops and the Takuku slug (*Leidyula floridana*) which feeds mainly on plant tissues and leaves of most vegetables and some root crops. Respondents also asserted that the increase in the population of these pests, as well as, their infestation is somewhat linked to the increase in rainfall. Increases in rainfall with excess water in the soil have been reported as providing an adequate condition for these pests to attack the plants. This occurs because;

1. The water causes the soil to be softer and looser around the tubers or corms providing easy access for a pest like Bongu to easily attack the tubers or corms.
2. Excess water induces rotting of tubers or corms allowing easy targets for the pests.
3. Excess water also enhances the rotting of not only tubers and corms but other dead vegetation like tree trunks and twig leaves which are favourable habitats and microhabitats for these pests, facilitating increased reproduction and distribution.

Delay in maturity and loss of taste (flavour) in food crops was also reported by all of the focus groups. They stated that the delay in maturity is a consequence of increased rainfall which damaged the flowers of some vegetables (pumpkin and water melons) and fruit trees (pawpaw, bread fruit and coconut). The increase in rainfall affected the pollination process which resulted in prolonged time to harvest and reduced the resulting yield because fewer flowers survive and are pollinated. Root crops too have been reported to have delayed maturity as excess water in the soil reduced the soil fertility, slowing the growth of the crops and extending the time to reach maturity. However, sweet potato is reported to have increased vegetative growth but less tuber formation and production as a result of increases or changes in rainfall. The Bellonese reported that increased rainfall resulted in increased vine growth but reduced tubers. Young shoots are therefore cut off and consumed as cabbage. Results from interviews suggested that sunlight induces tumour formation and production. Root crops such as sweet potatoes, taro, yam and pana were reported to be “less tasty” or lost their flavour, as a consequence of receiving too much rain. All the groups reported that root crops planted on soils that retained more water, lose their taste (flavour) compared to the ones planted on the more limestone, loosely packed soils. The amount of mineral or element content in a soil also plays an important role as some minerals or elements, for example, potassium, phosphorus and magnesium may determine to some extent the taste or flavour of tubers (Flis et al. 2012). This study also pointed to a significant relationship between the location of the sweet potato grown and their flavour or taste (Flis et al. 2012). Therefore, the results of this present study suggests that the increase in rainfall may have affected taste or flavour in root crops through the effects of nitrogen leaching; increased water infiltration or percolation promotes the washing away of nutrients, minerals or elements that influence the taste or flavour of the tubers.

The physical effect of increased rainfall as indicated by the Bellonese respondents reduces the survival rate of the newly planted and young crops. This reduction is believed to be caused by increased surface runoff and overland flow which washes away young and newly planted crops. Two thirds of the groups (60%) reported that some varieties of crops were lost as a result of an increase or a change in rainfall. The effect is significant on crops like water melon, pumpkin, sweet potato and slippery cabbage. The varieties of crops reported include Sinamu (*Dioscorea nummularia*) an old type of yam, Boiato (*Dioscorea pentaphylla*) also an ancient yam and Abubu *(Dioscorea bulbifera)* a bulbil-bearing yam with thorn-less vines. A report on these three yams during the period of 1962-1966, stated that while all of the yams are old types, only Sinamu is common, whereas Boiato and Abubu are rare (Christensen, 1975). A further study carried out on crop diversity and genetic erosion stated that among the 31 farms investigated, Sinamu was found on 21 farms, Abubu on 17 farms while Boiato was only found on 1 farm (Walkenhorst, 2005). This same author suggested that in comparison to Christensen's (1975) study in 1960s, there was a decline in varieties of Abubu from 10 to 3 and Boiato from 5 to 1. His study suggested that pests, introduction of new crops, change of farming practices and climate change are the reasons for the loss of crop varieties. In our study, 60% of the focus group stated that a change in or an increase in rainfall influenced the loss of the yam varieties; this though could not be substantiated with confidence. This is because other issues like change of farm management practices, lifestyle or choice of food could be responsible for the loss of the yam varieties (Walkenhorst, 2005). In fact, a detailed study on yam diversity and climate change would be useful in determining with confidence whether or not climate change is responsible for the loss of the yam varieties. About 40% of the focus groups identified increases in weeds as a consequence of change and increased rainfall. This may be because the prolonged days of rainfall prevented the farmers from attending to their gardens thus resulting in reduced labour input. For example, increased rainfall and more rainy days prevent farmers from burning their gardens for new cultivation, which further increases the need for more labour input as the weeds and shrubs recolonize the once cleared land. Some stated that increased rainfall encourages the growth of weeds thus increasing their competition with crops for space and nutrients.

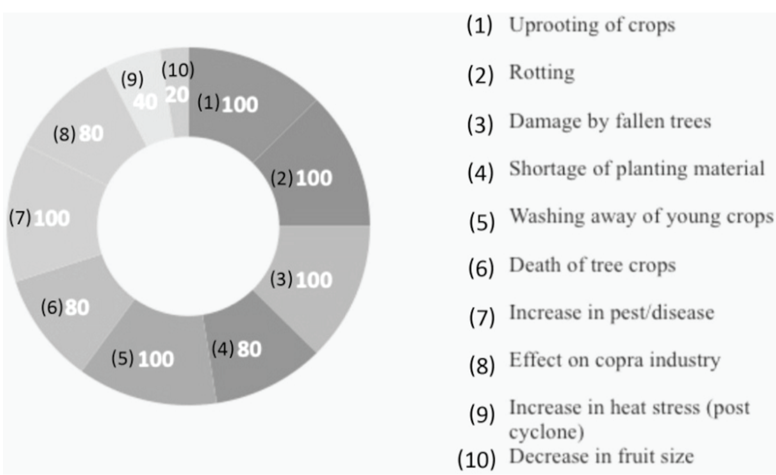
Impact of Cyclone on Crops

Respondents' listing of the impacts of cyclones on food crops is represented in Figure 9. All of the groups (100%) identified uprooting of crops, rotting, physical damage by fallen trees or debris, washing away of young crops and increase of pest and disease as significant impacts. Uprooting of crops is said to be caused by the extreme strength of the wind. Not only were the crops uprooted but also the supporting stakes for crops like pana and yam.

This has a significant impact on these two root crops as they heavily rely on the stakes for support; thus such uprooting adversely affects yield. The effects of winds associated with cyclones physically damaged crops, by causing nearby trees to fall, crushing crops planted below. The intense amount of rainfall associated with cyclones is said to induce rotting of tubers and corms of root crops, as well as, the physical washing away of newly planted or young crops such as sweet potato, cassava, water melon, slippery cabbage and corn. Excess water in soil also provides ideal conditions for the proliferation of pests, for example, Bongu on taro.

Most of the respondents interviewed (80%) highlighted a shortage of planting materials, death of tree crops and effects on their copra industry as significant. The shortage of planting material mainly applied to root crops like pana and yam. This

Figure 9. Percentage of respondents of the five focus groups to the impacts of cyclones on their food crops



is because excess water causes rotting of these two crops, inducing a shortage of planting material for the next planting season. Death of tree crops like pawpaw and coconut has been tied to the effect of the strong winds that normally tear off the leaves of these tree crops or uproot them. Cyclones are reported to be one of the main causes of crippling the copra industry on Bellona. It was reported that cyclone Namu and Nina in 1993 extensively destroyed most of the coconut plantations on Bellona.

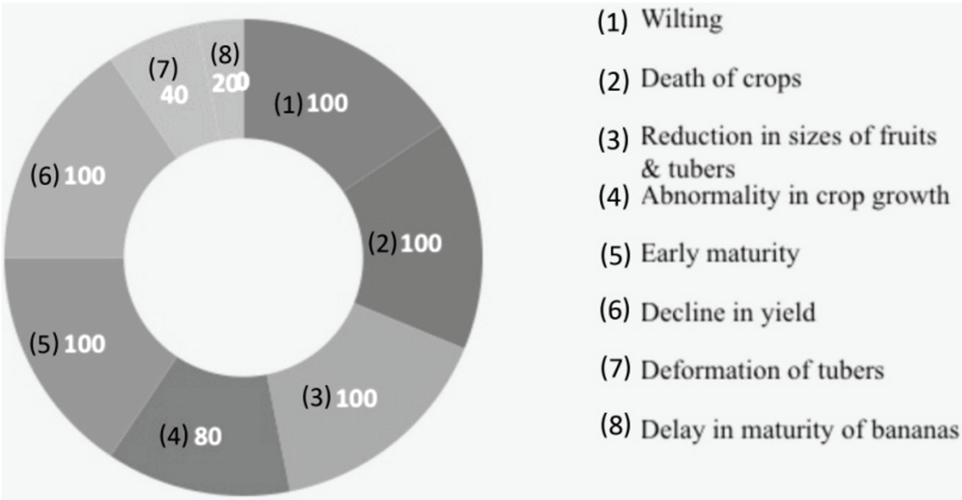
Due to extensive damage caused by cyclone Nina, copra farmers were discouraged to continue with the copra industry. While the decline in copra production is also linked to the inconsistency in shipping services and the high costs for freighting, the effects of cyclones are claimed to be the dominant causes for crippling the copra industry. For example, copra production ceased in the mid 1980s when cyclone Namu (1986) occurred in Bellona which devastated most of the coconut palms (Reenberg et al. 2008). Some of the key informants also mentioned that coconut palms are responsible for much of the damages on both their crops and houses. They argued that if coconut palms were not introduced as a cash crop, much of the damages on Bellona would have been avoided or minimal. Coconut palms were reported to be easily brought down by the strong winds of cyclones and pose a high risk to human lives, infrastructure and crops. There are still coconut plantations on Bellona at present, but these are only used for food, building materials and handicrafts.

The majority of participants of two focus groups noted the effect of heat stress on crops. This is because most shade trees or vegetation were destroyed by cyclones. This effect was reported by the men and farmers' groups who reported that after a cyclone, crops tend to wilt because of the effect of heat stress caused by direct sunlight on the crops. They added that when natural shade trees and canopies that filter direct radiation from the sun are lost, their crops are exposed to excessive heat. Only the women's group identified the reduction of fruit size as an impact of cyclones; the fruits of tree crops like coconut, bread fruit and pawpaw were mentioned. From the women's observation, after cyclones these crops bear fruits that are smaller than usual and some have abnormalities such as deformations and crevices.

Impact of Droughts on Crops

All participants interviewed (100%) acknowledged wilting, death of crops, early maturity, and reduction in size of fruits and tubers, as well as, decline in yield as significant impacts of drought on crops. Wilting, as a result of periods of no rain negatively affected most of the crops including vegetables like pumpkin, water melon slippery cabbage and other root crops. The Bellonese cropping system is totally rainfed since there are no rivers, lakes or any other water sources for irrigation during droughts. As a result, the extent of wilting due to heat stress is very severe, and

Figure 10. Percentage of respondents of the five groups to the impacts of droughts on their food crops



death of crops especially the young or newly planted is common, especially when additional input of water to sustain adequate crop growth during drought events is insufficient.

Early maturity in root crops (tubers) was noted by all respondents, yet they mentioned some crops produced smaller than normal tuber at maturity. This has reinforced the belief within the Bellonese communities that drought causes a decline in the yield of their food crops; both in sizes and the number of tubers or fruits. An example of a farmer's account is quoted below:-

Lo time wea hem no rain fo long time ya osem drought ya, me only save harvestem nomoa onefala or sometimes threefala small fruit kumara lo one fala hill. Fruit blo kumara ya smol osem nma fist blo me ya. But lo time we hem no drought ya me save tekem abaot 7 or 10 fala fruit osem lo one hill (Kiwa, pers. comm)

Translating this, Kiwa (pers. comm) is implying that during extreme drought, he can only harvest 1-3 small sized (smaller than his fist size) tubers per mound of sweet potato. However, during ambient conditions, he can harvest about 7 to 10 tubers per mound. The size of banana fruits and bunch was also reported to be smaller by some of the participants.

Abnormality in crop growth and physical structure was reported by most of the respondents (80%). They mentioned that some of their crops showed stunted growth and some lost their rigidity. A common example given by the participants is that of sweet potato. During droughts, the vines of the sweet potato grew to about less than 1 foot or just covered the area within the mound circumference, then stopped growing. Some respondents (40%) mentioned that droughts also affected the shape of their root crops. This effect is dominant in yams as have been described previously in the section which deals with the effects of increased temperature. Only the elderly people's group identified drought as having adverse effects on bananas by delaying their maturity. That is, depending on the varieties of bananas, normally, it takes about 9 to 12 months for maturity. However with the drought effect, it takes more than the normal length of time for their bananas to reach maturity.

Overall Impacts on Food Security

The reduction of yield due to the impacts of climate change and extreme events affect food security in Bellona atoll. The reduction in yields of taro, yam and other important crops leads to limited food supply for the islanders. This forced families to rely heavily on imported, expensive food sources such as rice and flour. This diet shift contributes to the increased incidence of non-communicable diseases in Bellona atoll. Furthermore, household members spend much of their incomes on purchasing food items rather than educating their children and building better homes. This contributes to poverty and overall, vulnerability of households members to deal with adverse impacts of climate change and extreme events. In addition, the frequent occurrence of extreme events forced the islanders to be in a constant status of recovery. This has caused many disruptions on continuous food availability and accessibility. This leads to poor health conditions of not only the older generation but also pregnant mothers and children.

The status of the impacts of climate change and extreme events on food security in Bellona atoll is not an isolated case. This is the general trend in all islands of Solomon Islands and other Pacific Island Countries. However, the vulnerability of each island varies depending on the levels of their preparations, awareness and overall resilience. Many Pacific Island Countries are now prioritizing food security as a challenge because of climate change.

ADAPTATION STRATEGIES

The Use of Shifting Cultivation and Fallow Practice

The history of shifting cultivation in the Pacific islands started about 4000 years ago (Kirch, 1996). Bellona has a long history of the practice of shifting cultivation according to past studies (Christensen, 1975, Reenberg et al. 2008, Breuning-Madsen et al. 2010) as well as more recent ones (Mertz et al. 2011). Responses from both the household survey and focus group interviews revealed that shifting cultivation and the use of bush fallowing and burning is still widely practised in Bellona. About 95% of the households reported that they use fallow periods ranging from 2 to 10 years (Table 2). The shifting cultivation and fallow periods have been identified as adaptation strategies because the process of shifting from one area to the next allows the soil in used areas to replenish and keep its fertility (Christensen, 1975). This is because during the fallow period, wild vegetation extracts nutrients or ions from the soil and concentrates them in their tissues. Thus, since the practice of Bellonese cropping system is fallow burning, nutrients and ions from the wild plants are being circulated back to the soil for use by the new crops. The use of fallow periods and shifting cultivation as adaptation measures are considered as highly significant strategies by all the households and focus groups, none of whom reported the use of fertilizers or any other form of manures as crop management inputs.

In other words, since these strategies (fallow and shifting cultivation) naturally allow the soil to regain fertility, their use is a more environmental friendly approach. Using agro chemicals, such as fertilizers, have the potential to improve crop productivity, but also contribute to greenhouse gas emissions that influence climate change. The practices of shifting cultivation and fallow periods enhanced crop productivity.

Crop Rotation, Intercropping, and Diversification of Crops Grown

Crop rotation is the practice of cultivating different sequence of crops on the same plot of land. It is a beneficial approach to balance, manage and improve the fertility of the soil, improve soil structure, avoid excessive depletion of soil nutrients, as well as control weeds, pest and diseases (Jackson et al. 2011, Berhanu & Gerald, 1998)

All of the households interviewed in Bellona reported having practised some form of crop rotation. A common practice among the Bellonese in terms of crop rotation is that they cultivate sweet potato, corn and melon subsequent to other major root crops like yam or pana. Figure 11A is a sequence of crop rotation reported by the Bellonese respondents during our study which is similar to the the findings of a study by Walkenhorst (2005) depicted in Figure 11B. The study by Walkenhorst (2005) supported our findings that sweet potato was commonly used in crop rotations normally subsequent to other main crops such as yam or pana.

About 74.6% of the households practised intercropping. Intercropping is a crop management practice where more than one crop type is planted on a given area. In Bellona, it is a common practice to plant a main crop with secondary crop groups. The choice of crops used for intercropping in Bellona is based on its level of competition with the main crop, harvestable part and the timeframe required for full

Figure 11. Sequence of crop rotation in Bellona (A) in our study in 2012 and (B) by Walkenhorst, (2005)

development (Reenberg et al. 2008, Christensen, 1975). For example, the long term root crops are usually intercropped with early matured fruit trees or crops with “above ground” harvestable parts. This avoids extensive damage to the roots of the main crops when the intercropped crops are harvested.

Intercropping as an adaptation strategy is a very significant approach as it maximizes and utilizes different soils, providing additional yield without additional work since different crops may create local environment that other crops may exploit better (Reenberg et al. 2008, Christensen, 1975). Thus, preservation of crop rotation and intercropping in Bellona as adaptation strategies is crucial to adapt to the changes in climate and extreme events which occur.

Maintaining Shade Trees After Clearing, Burning, and Mulching

In the Bellonese cropping system, the extent to which clearing and burning is undertaken to prepare an area for a garden plot is dependent on the crops to be planted. For example, for yam, pana and taro gardens, some trees will be retained for the purpose of providing shade and as support stakes for yam and pana. Taro farm in West Ghonghau are planted under Hau trees *(Hibiscus tiliaceus)* which were not cleared or removed during preparation of the garden area. The Hau trees are left on the garden as they are also considered important by the Bellonese for soil fertility recovery. The dead leaves, twigs and ash remains are left as mulch on the soil. These are maintained to prevent the soil from over-drying and ensuring that soil moisture is adequate. Mulch has been reported to not only protect the soil and crops from heat stress or extreme temperatures, but also aids in adding nutrients to the soil.

Planting Fast Yielding and Resilient Crops

The cultivation of early or fast yielding crops has become increasingly common in Bellona. Such crops include sweet potato, water melon, Chinese cabbage and corn. Cassava is also cultivated but not on a large scale. Varieties of sweet potato cultivated in Bellona have increased from 6 varieties reported in the 1960s to 12 varieties in recent years (Christensen, 1975; Walkenhorst, 2005). Thus, cultivating a fast or early maturity crop like sweet potato is an important strategy to adapt to the effects of climate change and extreme events because the period to harvest is less. Not only is the time span shorter but sweet potato and other crops like water melon, corn or cassava require less labour and shorter fallow periods compared to yam or pana. Cassava is considered a climate resilient crop in Bellonese communities, even though it is less common. Cassava is only planted as an emergency crop or as pig feed because the Bellonese prefers the taste of taro, yam, banana and sweet potato. Yam and taro are significant crops in Bellonese culture. This is the same trend with other Polynesian countries (Samoa, Tonga and Cook Islands).

Adjust Planting Dates

Traditionally, Bellonese people have a planting calendar for their crops. A detailed elaboration of this calendar is provided by Christensen (1975). Thus, a comparison is made on the planting dates as collected from farmers in the present study (2012) to what was recorded in the 1960s.

Only pana (lesser yam) and yam (greater yam) are seasonal crops as shown in Table 3. This implies that these two crops require a certain time of the year to be planted to coincide with favourable weather conditions. There is a slight shifting of the planting date for both pana and yam currently practiced as compared to the 1960s calendar (Table 3). According to the responses of the key informant interviews in the focus groups, pana is currently planted in September. This is two months earlier than what had been practised in the 1960s. The planting date of yam has also been shifted a month back compared to that of about 50 years ago. However, the planting dates given for 2012 are not the same for all the respondents. For instance, some mentioned that pana is being planted in January and harvested in June. Nevertheless, the shifting or adjusting of these planting dates according to the farmers, are mainly due to the changing and unpredictable weather pattern that they observed and the sensitivity of yam and pana to soil fertility and extreme climatic events. Farmers are observing that dry months are changing to wet months and there is an overlap between the hot and wet season and the cool and dry season. In addition, yams are vulnerable to pests and diseases during the hot and wet seasons; therefore

Table 3. Bellonese planting calendar

Crop	Christensen 1960s		2012	
	Planting Month	Harvesting Month	Planting Month	Harvesting Month
Pana (lesser yam)	November	April	September	February
Yam (greater yam)	August	May	July	April
Taro	Any month – no season	Any month – no season	Any month – no season	Any month – no season
Banana	Any month – no season	Any month – no season	Any month - no season	Any month – no season

they try to adjust the planting dates to avoid excess rainfall. This makes it harder for them to know exactly when to plant yams and apply the traditional knowledge their forefathers taught them.

Increase Number of Plots, Change Planting Site, and Increase the Mound Size

About 29% of the households indicated using the strategy of increasing the number of their plots or planting sites to ensure that when extreme events occur, an ample supply of food is available. That is because while some areas of their plots may be more exposed or susceptible to wind damage or increased surface runoff, they can depend on the other less vulnerable plots. Thirty-six percent (36%) of the households stated that instead of continuous planting on vulnerable areas, they shifted their garden plots to less vulnerable and more fertile areas. This is why most plots are located on the centre of the island in Ghonghau ward where it is believed to be more fertile and less susceptible to both climatic and non-climatic factors such as pest and diseases. A small percentage of households (9%) reported increasing the mound size in sweet potato, yam and pana to promote higher yields. They suggested that the bigger the mound size the greater the chances of protecting the tuber and roots from desiccation during drought and rotting during heavy rainfall. Furthermore, bigger sized mounds, they claim, provide ample space where more tubers can be accommodated and may provide more nutrients compared to smaller sized mounds.

Planting Distribution and Management

Some of the participants in the focus group interviews indicated that they also cultivated their crops in a pattern such that crops are planted according to soil fertility and depth. This is similar to studies carried out on Bellona in the past (Christensen, 1975, Reenberg et al. 2008). This form of planting pattern is referred to as dividing *(tohitohi)* the garden into sections *(potu)* according to soil fertility. This is considered as a significant adaptation strategy as it regulates the planting of crops according to their fertility requirements. For instance, it allows sensitive crops like yam or pana to be cultivated in highly fertile areas on the plot while establishing more resilient crops like sweet potato on less fertile areas. One of the farmers mentioned that the planting depth of crops is vital in terms of yield production and its exposure to climate extremes. He stated that the planting depth of the taro varieties depends on the bearing size of the corms. For example, the varieties *Tango Sua* and *Kamaamangu,* which have bigger corms have a planting depth of about 30cm, whilst for *Tango Ngeka* which bears smaller corms is planted to a depth of about 15cm. He further claimed that if the bigger taro varieties (*Tango Sua* and *Kamaamangu*) are not planted according to the required depth of 30cm, they are easily damaged by strong winds and their corms will be exposed to heat stress and pests.

Pruning of Crops

All focus group members mentioned that the pruning of sweet potato vines is normally done when the massive growth of vines is observed during prolonged rainy seasons. During prolonged periods of rainfall, sweet potato experiences limited tuber production but increased growth of vines. The Bellonese believed that pruning the vines starts tuber initiation resulting in high yield production. Despite the pruning of excess vines, tuber production is normally low during prolonged rainy season. The pruned vine cuttings are used as vegetables and are cooked as cabbage. In a way, they cope by maximizing the vegetative part of the sweet potatoes when tuber production is limited. Another coping strategy practised on Bellona is that during cyclones or extreme storms when banana plants are blown down to the ground, their stems are cut to initiate regrowth.

Gathering and Consumption of Wild Crops and Harvest Conservation

During extreme events such as cyclones or droughts when most cultivated crops are severely affected, many Bellonese people collect and gather wild crops as substitutes for consumption. One such important crop is the wild yam commonly known as “Black battery”, which is claimed to have high calories and can sustain a person for longer periods of time. Christensen (1975) found that there are other wild fruits that are collected for consumption including Morinda-Indian mulberry tree (nguna) (*Morinda citrifolia)* and Spondias fruits- Tahitian apple (bii) (*Spondias* *dulcis)*. Most of these edible fruit trees are not cultivated but are preserved when vegetation is cleared. Nguna and bii are also considered by Bellonese as important plants for the recovery of soil fertility in fallow gardens.

Another important coping strategy practised can be referred to as "conservation or sustainable harvesting". This has been reported as a result of our study and a study carried out about 50 years ago (Christensen, 1975). The Bellonese normally leaves small tubers of yam unharvested to be utilized later during periods of short food supply or when cyclones or drought destroy their food crops. Edible fruit trees such as *Isi* (Polynesian chest nut) *(Inocarpus fagifer), Banga* (Cut nut), Ghaapoli (*Ficus* spp.*),* and bii (Tahitian apple) are often not cleared during garden forest clearance. These fruit trees provide for the Bellonese during times of food supply shortage and disaster. Others persons in the focus group interviews stated that they also relied on their old garden plots which have been left to fallow as some of root crops developed new tubers.

CONCLUSION AND RESEARCH OPPORTUNITIES

This chapter highlighted the beliefs of Bellonese farmers on the impacts of climate extremes on crop growth, development and yield. The case in Bellona is an example of the vulnerability of Pacific crops and cropping systems to the adverse impacts of climate change. As also discussed, farmers shared stories of resilience and innovations both at the household farming level and at the community level to reduce the impacts of climate change and ensure food supply is maintained before, during and after disasters. Some of the noted adaptation measures were practised for many years and are still very useful in present times. The applicability and usefulness of these insights highlight the importance of considering and including traditional knowledge in national government assessments and policy formulations. As this chapter revealed, there are many stories of resilience and good practices of sustainable adaptations that should be documented, distributed and utilized to improve resilience of farmers in other countries of the Pacific and other Small Island Developing States. The most important research that is recommended is the need to apply crop models to quantify the impacts of climate change and assist farmers' decisions on the type of crop to plant, crop management options, and adaptation options based on various climate change scenarios. Farmers should be at the centre of this type of research. Furthermore, it is important that they be involved in all steps in the process to ensure that the outcomes of the model simulations be properly translated and disseminated to all stakeholders.

REFERENCES

Asian Development Bank (ADB). (2009). *Building climate resilience in the agriculture sector in Asia and the Pacific*. Philippines: Asian Development Bank.

Barnett, J., & Adger, W. N. (2003). Climate dangers and atoll countries. *Climatic Change*, *61*(3), 321–337. doi:10.1023/B:CLIM.0000004559.08755.88

Berhanu, G., & Gerald, S. (1998). *The Economic Importance Of Crop Rotation Systems: Evidence from the Literature," Staff Papers 11690, Economics*. Michigan State University, Department of Agricultural, Food, and Resource.

Birch-Thomsen, T., Reenberg, A., Mertz, O., & Fog, B. (2010). Continuity and change: Spatiotemporal land use dynamics on Bellona Island, Solomon Islands. *Singapore Journal of Tropical Geography*, *31*(1), 27–40. doi:10.1111/j.1467-9493.2010.00383.x

Borggaard, O. K., Koch, C. B., Elberling, B., Breuning-Madsen, H., & Stemmerik, L. (2012). Composition of characteristic soils on the raised atoll Bellona, Solomon Islands. *Geoderma*, *170*, 186–194. doi:10.1016/j.geoderma.2011.10.001

Bourke, R. M., McGregor, A., Allen, M. G., Evans, B. R., Mullen, B. F., & Pollard, A. A. et al. (2006). *Solomon Islands Smallholder Agriculture Study* (Vol. 1). Canberra, Australia: Australian Government AusAid.

Breuning-Madsen, H., Bech-Bruun, T., & Elberling, B. (2010). An indigenous soil classification system for Bellona Island – a raised atoll in Solomon Islands. *Singapore Journal of Tropical Geography*, *31*(1), 85–99. doi:10.1111/j.1467-9493.2010.00390.x

Christensen, S. (1975). *Subsistence on Bellona Island (Mungiki): A study of the Cultural Ecology of a Polynesian Outlier in the British Solomon Islands Protectorate*. National Museum of Denmark and the Royal Danish Geographical Society.

FAO. (2008). *Climate Change and Food Security in Pacific Island Countries*. Rome, Italy.

Flis, B., Zimnoch-Guzowska, E., & Mańkowski, D. (2012). Correlations among Yield, Taste, Tuber Characteristics and Mineral Contents of Potato Cultivars Grown at Different Growing Conditions. *The Journal of Agricultural Science*, *4*, 197–207.

Hansell, J. R. F., & Wall, J. R. D. (1976). *Land Resource Study- Land Resource Study-Volume 8: Outer Islands*. Tolworth Tower.

Jackson, G., Smith, C., Tahuniari, S., Wame, L., Tsatsia, H., Varuia, G., … Reid, C. (2011). *Crop Protection Curriculum and Teaching Methods for Solomon Islands: Improving Plant Protection in Solomon Islands*. The Australian Centre for International Agricultural Research (ACIAR).

Jansen, T., Mullen, B. F., Pollard, A. A., Maemouri, R. K., Watoto, C., & Iramu, E. (2006). Solomon Islands smallholder agriculture study: Vol. 2: *Subsistence production, livestock and social analysis*. Canberra, Australia: Australian Government AusAid.

Kirch, P. V. (1996). Late Holocene human-induced modifications to a central Polynesian island ecosystem. *Proceedings of the National Academy of Sciences of the United States of America*, 93. doi:10.1073/pnas.93.11.5296

Mertz, O., Birch-Thomsen, T., Elberling, B., Rothausen, S., Bech-Bruun, T., & Reenberg, A. et al. (2011). Changes in shifting cultivation systems on small Pacific islands. *The Geographical Journal*, 1–13.

Mimura, N., Nurse, L., McLean, R., Agard, J., Briguglio, L., & Lefale, P. et al. (2007). Small islands. *Climatic Change*.

PACC. (2006). *Pacific Adaptation to Climate Change: Solomon Islands Report of in-country Consultations*. PACC.

PCCSP. (2011). Solomon Islands: In Climate Change in the Pacific: Scientific Assessments and New Research Volume 2: Country Reports. Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Quity, G. (2012). *Assessing the ecological impacts of climate change on root crop production in high islands: A case study in Santa Isabel, Solomon Islands*. (MSc Thesis). The University of the South Pacific.

Rasmussen, K., May, W., Birk, T., Mataki, M., Mertz, O., & Yee, D. (2009). Climate change on three Polynesian outliers in the Solomon Islands: Impacts, vulnerability and adaptation. *Geografisk Tidsskrift-Danish Journal of Geography*, *109*(1), 1–13. doi:10.1080/00167223.2009.10649592

Reenberg, A., Birch-Thomsen, T., Mertz, O., Fog, B., & Christiansen, S. (2008). Adaptation of Human Coping Strategies in a Small Island Society in the SW Pacific—50 Years of Change in the Coupled Human–Environment System on Bellona, Solomon Islands. *Human Ecology*, *36*(6), 807–819. doi:10.1007/s10745-008-9199-9

SIG. (2001). *Rennell and Bellona Province Development Profile*. Honiara, Solomon Islands: SIG.

SIG. (2003). *Topograhical Map of Bellona*. Honiara, Solomon Islands: Ministry of Lands.

SINSO. (2009). *Population Map of Bellona by Wards*. Honiara, Solomon Islands: Solomon Island National Statistic Office.

Talo, F. (2008). *Solomon Islands National Adaptation Programmes of Action*. Honiara: Ministry of Environment,Meteorology, Climate Change and Disaster Management.

Thiruchchelvan, N., Thirukkumaran, G., & Mikunthan, G. (2012). In Vitro Biological Control of Marasmiellus sp. The casual of Stem Rot of Banana Grown in 198. Academic Press.

Wairiu, M., Lal, M., & Iese, V. (2012). *Climate Change Implications for Crop Production in Pacific Islands Region*. In-Tech Publishing. doi:10.5772/33885

Walkenhorst, T. (2005). *Crop diversity and genetic erosion on the South Pacific Island of Mungiki (Bellona)/ Solomon Islands*. (Masters thesis). University of Kassel.

KEY TERMS AND DEFINITIONS

Adaptation: Activities or actions (tangible or non tangible) to reduce the impacts of climate related hazards on communities.

Climate Change: A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Extreme Event: Climatic/weather events that induce damages to communities' livelihood and may cause disasters; eg: cyclone, drought, floods, and storm surges.

Food Security (Household): All members of households have at all times access to sufficient foods to sustain their dietary and nutritional needs to function normally in a society.

Resilience: The ability of a community, sector and a person to absorb, cope and recover efficiently and effectively during and after external and internal pressures.

Small Island Developing States (SIDS): Low-lying coastal countries characterized by similar sustainable development challenges such as limited resources, susceptibility to natural disasters, vulnerability to external shocks and an excessive dependence on international trade.

Vulnerability: The characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from, the impact of a natural hazards.