Vanuatu Agricultural Climate Risk Profile

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APEC Climate Center

Contents

Summary

Vanuatu agricultural climate risk profile has been prepared as a part of scoping efforts of Van-KIRAP project, which is to understand present and potential climate risks in the agricultural sector in Vanuatu and any relevant climate services to cope with the climate risks. Therefore, the main objective of this profile is to provide background information on climate-related risks due to climate change, risks from extreme weather and climate events, and to define a baseline capacity and the needs for climate services for agriculture in Vanuatu, to increase the awareness of present and future risks, as well as to provide potential solutions to the identified risks in the agriculture sector.

Regarding the impacts of climate change, Vanuatu is one of the most vulnerable countries in the Pacific region. These impacts are evident in the multiple climate hazards that result from climate change and variability and extreme magnitude of meteorological events. To address existing climate impacts and to prepare for predicted increases in such risks in Vanuatu, it is important to establish institutional frameworks to facilitate practical application, not only of long-term climate-smart policy development and planning, but also of short-term strategic and tactical climate-smart decisions firmly based on available climate information. These frameworks need to be constantly revamped by timely, cost-effective, and scientifically sound, evidence-based, climate products and services. Such products and services should consider multiple spatial (national to local community level) and temporal (short-term to long-term, i.e., weather to climate) scales to achieve sustainable, climate resilient adaptation and associated development outcomes for all stakeholders in Vanuatu.

For the identified climate risks to agriculture in Vanuatu, recommendations are made on appropriate local-specific climate-smart practices and realistically applicable technologies based on information from selected climate services against extreme weather and climate events, such as drought, flooding, tropical cyclones, tsunamis, and pest and disease epidemics. Effective communication of such recommendations will enhance the use of climate services by agricultural stakeholders by showing the affordable and realistic climate-smart options that can be easily taken, upon timely detection and warning (forecasts) of extreme events in Vanuatu. The underlying principle is the basic idea that information must be relayed to facilitate informed decision-making through the availability of subsequent actionable options (or plans) by the end-users of climate services.

The main activities and associated outputs of the GCF funded Van-KIRAP have been designed specifically to address the priority climate service needs to cope with the climate risks identified. The project will also feature direct engagement with and among all stakeholders, from providers to users of climate services; and thereby it shall be developed and implemented to demonstrate and evaluate best practice approaches to incorporate climate services in decision-making.

1 Understanding agricultural climate risks in Vanuatu

Strong scientific evidence links climate change with increasing extreme weather and climate events (IPCC, 2014). More intense extreme weather and climate events could lead to loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources (SPREP and GIZ, 2015).

Extreme weather and climate events are generally defined as the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) end of the range of observed values of the variable (WMO, 2016). In many cases, weather or climate events with a high impact are deemed as extreme events, such as droughts, floods, tropical cyclones, extreme sea level, storm surges, and landslides. For example, droughts and floods may be the result of an accumulation of weather or climate events that are not extreme by themselves, yet the resulting accumulation is extreme. Many weather and climate extremes reflect natural climate variability (including phenomena such as ENSO).

Climate change is likely to have substantial and widespread impacts on Pacific Island Countries (PIC), including Vanuatu. However, the greatest impact will occur on the poorest and most vulnerable segments of the region (ADB, 2013). Coastal areas will witness some of the most substantial damages resulting from sea level rise, leading to soil erosion and coastal inundation; more intense cyclones and storm surges will cause flooding and severe damage to crops and infrastructure; while, higher sea surface temperatures will lead to a decline in coral reefs and fishery production (WB, 2009).

The PICs experience the highest numbers of cyclones in a season during El Niño events. For example, during the 1992/93 El Niño, there were 16 cyclone events, and in the 1997/98 El Niño, there were 17 events. The average (mean) for the South Pacific is between 9 and 10 cyclones per season (Reti, 2007). During October 2007, rainfall was extremely high in areas under the active South Pacific Convergence Zone (SPCZ). Heavy rainfall and flooding occurred in parts of Vanuatu at the end of the month, with Aneityum registering a record monthly high of 443.8 mm. Mean air temperature in October was 1.5°C or more above normal in parts of Tonga and the Southern areas of Cook Islands. Temperatures were also above normal in Vanuatu at that time.

Agriculture will be mostly affected through the changes in rainfall and temperature, sea level rise, and intensified climate variability. In this chapter, we discuss the impacts of climate change and extreme weather and climate events on Vanuatu in general; long-term impacts of climate change are reviewed, as well as extreme weather and climate are discussed primarily based on their short-term impacts on the agriculture sector in Vanuatu.

Historical and projected impacts of climate change on Vanuatu, and specifically on the agriculture sector, are discussed in the first section of this chapter; while, extreme weather and climate events over the historical periods and the possible impacts of the extreme events on agriculture are discussed in the last section.

1.1 Agriculture in Vanuatu

The economy of Vanuatu is largely comprised of a smallholder subsistence agriculture sector. This small-scale agriculture provides livelihood for approximately 70% of the Ni-Vanuatu population. The agriculture sector is dominated by land cultivation. Crop production represented 79% of the contribution by the sector to the GDP in 2013, a significantly higher proportion than that contributed by livestock (14%), forestry (4%), and fisheries (3%) (Government of Vanuatu, 2016).

Dominant food crops in Vanuatu include taro, yam, banana, plantain, peanut, corn, and leafy vegetables. Copra (dried coconut kernels), kava, and cocoa are the major export crops and important sources of cash income for many rural households.

The agriculture sector in Vanuatu is divided into three distinct sub-sectors, with the subsistence sector accounting for more than 75%, located in tiny village communities throughout the islands. The rest of the agriculture sector consists of a growing semi-commercial sector and a commercial plantation sector. The semi-commercial sector is based on a limited range of traditional cash crops and has the potential for expanding into the emerging vegetable market. It contributes to around 10% of the total production in the agriculture sector.

The subsistence sector is engaged in farming on small agricultural plots called the food garden. It is predominantly centered around root crops (taro, yam, cassava, and sweet potato) for both consumption and cultural purposes, and is characterized by total dependence on rain-fed irrigation. The small plots provide for the subsistence needs of farmers who grow these root crops and sell the produce at local markets. However, productivity of these food gardens is low; thus, the challenge for this sector is to increase productivity and minimize climate risks by introducing sustainable and affordable management practices.

Increasing the number of small plots is a strategy favored by the Ministry of Agriculture, as opposed to increasing the size of existing farmlands. This is because most smallholder farmers are isolated and separated from each other by long distances, with poorly maintained access roads, thereby transportation of products and equipment is extremely difficult and expensive.

Nevertheless, the smallholder involvement in the agricultural cash economy has increased remarkably in recent years. Output from export commodities composed of smallholder farmers exceed the output of the purely commercial plantation sector; smallholders contribute to 80% copra, 70% cocoa, 20% beef, and the entire kava production. In the 1990s, beef was mainly supplied by the smallholder farmers, although this has changed in recent years with the commercialized operations now providing the bulk of the beef consumed locally.

Vulnerability factors identified

Although natural resources, including climatic conditions, are ideally favorable to the agriculture sector of Vanuatu, extreme weather events caused by climate change and variability undermine efficient management and rational use of natural resources. Under these circumstances, while planning strategies for future management and use of the national resources, the impacts of climate change and variability on the natural environment, human health, and other development sectors, should be taken into account. The major factors that are likely to contribute to the vulnerability of the agriculture sector in Vanuatu are discussed below (Reti, 2007).

- **Increasing climate variability and extremes** – The negative effects of climate change and variability exacerbate the inability to increase and sustain agricultural production in Vanuatu. With the increase in temperature and shift in seasonal rainfall patterns, the incidence of frequent and severe extreme events is drastically hampering the already risk-prone agricultural production. The wet season is from November to April, which coincides with the cyclone season. Out of the total number of tropical cyclones affecting Vanuatu over the last 49 years, 36% carried hurricane force winds, 23% storm force wind, and 20% gale force winds (Barnett, 2001). The probability of occurrence of hurricane force winds every year is very high in Vanuatu, which results in storm damage to crops and critical agricultural infrastructure. Although agricultural climate adaptation policies and plans are now widely established, there is still a severe deficit in climate knowledge, information, and implementation of technology in vulnerable agricultural communities.

- **Increasing seasonal variability** – Prolonged wet seasons lead to favorable conditions for pests and diseases that could considerably reduce crop production. Similarly, prolonged dry seasons cause plant stress, leading to reduced production. These seasonal abnormalities are causes of concern for national food and socio-economic security.

- **Lack of access to supporting infrastructure in remote farms**– Due to the great distance, irregular air and boat transportation, and poor road conditions, it is extremely difficult to provide services to the large number of small farms scattered over the islands, especially during times of natural disasters. In addition, extreme weather and climate events have implications for the transportation of agricultural produce from rural areas to markets in the main urban areas In this regard, declining productivity of these small farms will surely affect food security of the smallholder farmers who cannot afford access to distant markets.

- **Loss of traditional farming techniques** – Since ages, wild yam, taro, and sweet potato have been stable food crops, particularly during times of natural disasters. However, yields have been declining in recent years. Besides change in climatic conditions, the loss of traditional planting techniques is believed to be largely responsible for this situation.

- **Poor understanding of the country's forest resources and lack of a sustainable forest management plan** – Knowledge of Vanuatu's forest resources is based on outdated forest inventories. Detailed, up-to-date inventories of the national forests do not exist; therefore, it will be extremely difficult to plan effective management strategies for the valuable forest resources against climate change and variability.

- **Lack of understanding of the impact of climate change on coastal ecosystems and fisheries resources** – There has been no attempt to monitor changes in the health of coastal ecosystems or to establish the association between such changes and climatic events that affected the country over the years. It is likely that coastal ecosystem trends in Vanuatu are similar to those of other PIC, necessitating serious and urgent action. If degradation continues unchecked, the productivity of these coastal ecosystems may collapse, affecting food security of the coastal population.

- **Lack of understanding of the impact of climate change on livestock** – How climate change and climate variability impact livestock remain poorly understood, compared to other sectors. Any climate-change-induced health risks in the livestock animals in the country could pose severe risk to animal production and food security in the country.

- **Limited irrigation water supply** – Prolonged dry spells and drought periods can cause exhaustion of irrigation water, particularly on the small outer islands in the northern part of the country. Many ground water sources on the outer islands of Vanuatu have been rendered useless due to salt water intrusion or simple by overuse. Water levels in the few rivers that exist on the larger islands are reported to be declining, and this trend will continue considering projected decline in rainfall. Such situations will adversely affect agricultural production and food supply in Vanuatu.

1.2 Impact of climate change on agriculture

1.2.1 Climate change

The impacts of climate change are already being felt across Vanuatu, including sea level rise, increased intensity of extreme events, and changes in agricultural productivity and water availability (WB, 2011). Historical trends in Vanuatu suggest a gradual increase in temperature (1950–2010) that is more pronounced in the south (Fig. 1). Aneityum, located at the southern tip of Vanuatu, has witnessed an overall gradual decline in rainfall, although there are no clear trends in seasonal or annual rainfall over Vanuatu. There has been substantial variation in rainfall from year to year over this period. Similarly, there has been a significant increase in the frequency of tropical cyclones in the country over the recorded period (CSIRO et al., 2015); however, the introduction of the satellite tracking technology and the improvement of recording technology could influence this apparent trend.

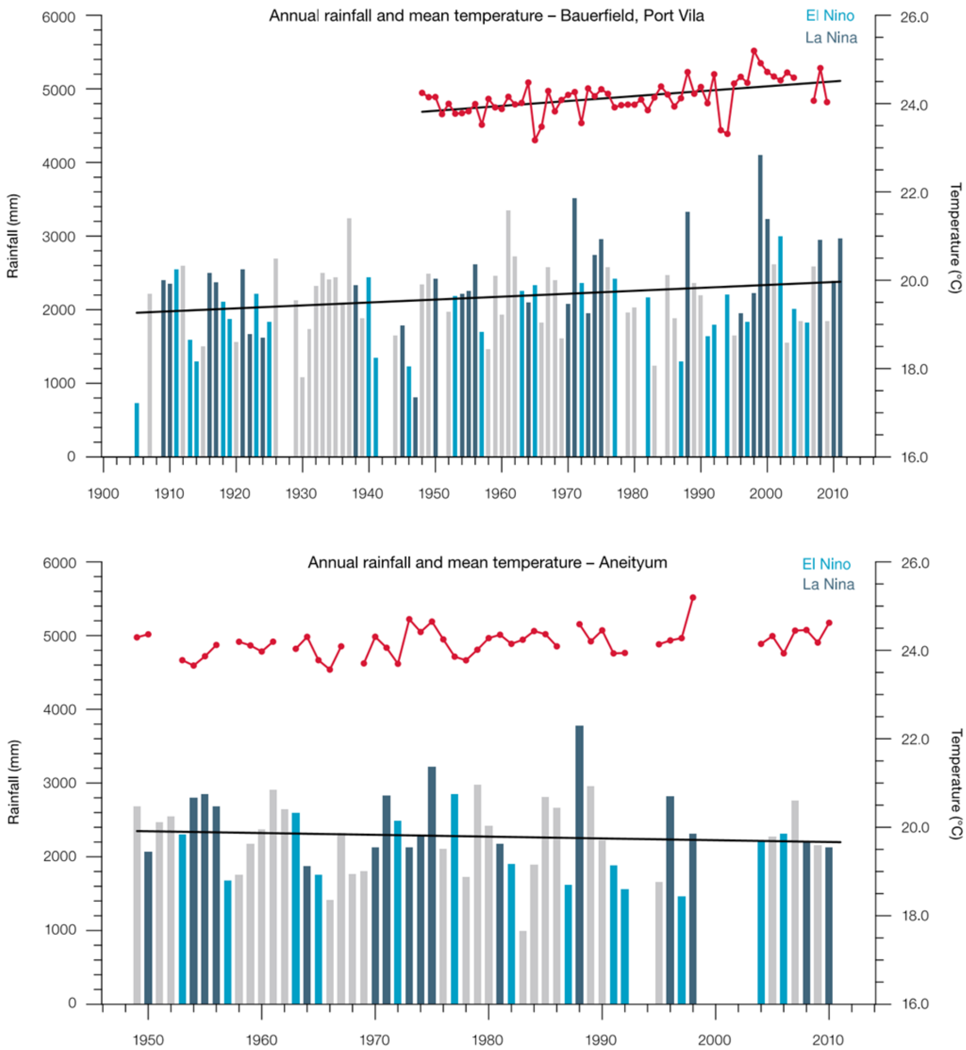

Figure 1. Annual average air temperature (red dots and line) and total rainfall (bars) at Bauerfield Airport, Port Vila (top), and Aneityum (bottom). Light blue, dark blue, and grey bars indicate El Niño, La Niña, and neutral years, respectively. No bars indicate no available data. Solid black lines show the trends (Source: CSIRO et al., 2015).

Based on climate scenarios from global climate models and historical records available, it has been predicted that climate change will lead to warmer and drier conditions in much of Vanuatu over the next century, with the magnitude of the change increasing, away from the equator (CSIRO et al., 2015). However, the possibility of increased rainfall should not be dismissed. These effects will be accentuated by more frequent and severe cyclone events. Heavy rainfall is a normal component of tropical cyclones; thus, a greater proportion of rain will be associated with the passage of cyclones. Indications are that there will be more frequent El Niño type conditions, which are usually associated with prolonged dry seasons, eventually leading to severe drought.

Some of the climate risks expected include the following (BoM and CSIRO, 2014):

- by 2040, daily temperatures will increase by 1.2°C relative to the 1995 levels;
- sea level rise will continue and accelerate; whereby, risks of coastal inundation will be high when combined with storm surges and high seas;
- ocean acidification will degrade 80% of coral reefs within 20 years;
- extreme temperatures will reach higher levels and become more frequent;
- extreme weather events, including cyclones and storms, will increase in intensity, although not necessarily in frequency;
- dry periods will last longer; and
- extreme rainfall will be more frequent and intense; thus, Vanuatu will be susceptible to erosion and flooding due to expected periods of intense rainfall.

Climate change is likely to impact all sectors that are pertinent to the sustainable development of Vanuatu (NACCC, 2007). Therefore, the Vanuatu Climate Change and Disaster Risk Reduction Policy 2016–2030 (SPC, 2015) sets the framework for mainstreaming climate change and disaster risk reduction into sustainable development processes for Vanuatu. The policy identifies key climate change impacts for Vanuatu as follows:

- reduced availability of freshwater (in quality and quantity)
- shifts in crop seasonality of planting, fruiting, and harvesting
- more pests and diseases of animals, crops, and trees
- saltwater intrusion into areas critical to sustainable food security and groundwater
- compromised food security due to less favorable growing conditions for certain important crops
- damage to coral reefs and fisheries leading to reduced fisheries productivity
- increased risk of human disease and health problems, including vector-borne diseases and heat stress
- damage to infrastructure and loss of coastal land
- reduced economic growth and revenue generation

1.2.2 Impacts of climate change on agriculture

The impacts of climate change on agriculture in Vanuatu are not well understood. However, general knowledge of possible impacts suggests that changes may be detrimental to overall aspects of agriculture and, thus, to national food security. In fact, the limited historical data, necessary for the reliable assessment of the likely impacts of climate change on the agriculture sector in Vanuatu, suggest that the impacts given below are likely to be realized for the various components of the agriculture sector in Vanuatu. The following excellent review on the long-term impacts of climate change on crop production, livestock, agricultural water management, and soil and land management in Vanuatu was adopted and modified from the study by Reti (2007).

Crops

Although the impacts of climate change on plant growth, productivity, and the nutrient value of crops commonly grown in Vanuatu are not well understood, climate-related incidences are already affecting crop production. Increased temperatures, more frequent and prolonged dry conditions, increased variability of rainfall, salt-water intrusion, drought, soil erosion, and frequent cyclones have been experienced in the past decades. Some crops are showing signs of stress under current climatic conditions. Phenological changes observed show earlier flowering than usual in some plants; while, others are late fruiting than normal during the past 3–4 years. Pest activities have also increased, with yams being the most affected crop in Vanuatu. Water scarce areas and small islands that depend entirely on rainwater are also experiencing severe water shortage resulting in reduced crop production. Therefore, food supply has become limited in dry areas such as the flat-plains immediate to the Yarsu (Tanna), and Benvor and Marum (Ambrym). A similar situation exits in the atoll island of Lau in the Toress Group of islands and the northern part of Marae (Emae) (FAO, 2013). Coastal erosion and inundation are reported from coastal communities in recent years. These problems will be aggravated by any further changes in current climatic conditions (Kumar and Taylor, 2015).

Although some progress has been made in recent years to understand and appropriately address climate change issues, there is currently limited data to enable Vanuatu to plan effective responses to climate change impacts. At the projected temperature increase, heat tolerance threshold of crops is likely to be reached and this will most likely induce heat stress, wilting, and crop failure. Subsistence crop production may fall as a result and, in turn, threaten food security on the islands.

Both commercial and subsistence agriculture in Vanuatu are based on rain-fed agricultural production systems. Changes in rainfall, high intensity storm events, increased evaporation, and more pronounced dry seasons could have severe impacts on crop production. Intense rainfall during planting seasons could have severe impacts due to soil waterlogging and, thus, cause decreasing agricultural production. In contrast, increased humidity and rainfall could provide ideal conditions for the proliferation of many plant pathogens. On the other hand, more pronounced dry seasons, warmer temperatures, and greater evaporation could induce plant stress, thereby, reducing productivity and subsequently affecting food security in the country.

Livestock

It is predicted that increased carbon dioxide concentrations in the atmosphere and warmer temperatures will be conducive to rapid growth of green matter rather than crops (NACCC, 2007). However, rapid growth of pastures could decrease their nutritional value, which in turn would result in fewer animals supported per unit area of pasture land; thereby, potentially reducing beef production, both for export and for local consumption. In fact, the Ministry of Agriculture has reported an increased incidence of intestinal problems in cattle, which is likely associated with the low nutrient pasture. Similar problems (parasites and infections) have been encountered by pig farmers.

The Ministry of Agriculture offers limited veterinary service to farmers on Efate and Espiritu Santo only, but is not equipped to offer proper assistance during major outbreaks of animal diseases due to climate change-related events or otherwise. Hot temperatures could result in the relocation of stocks to cooler climates as an adaptation measure, which could translate into significant costs to the farmers, especially given the poor state of most roads in Vanuatu.

Increased temperatures and drought will mostly affect small-scale livestock farmers, as they could cause soil compaction and drying of river streams on which the farmers depend for their primary source of water. Overstocking and overgrazing could result from dried conditions, which in turn would result in loss of animal weight and further degradation of pasture lands.

Water Management

Water is vital to agricultural production in Vanuatu. Population growth, particularly in urban areas, is already placing increased pressure on water resources and supply. Climate change is likely to escalate the demand for water and yet reduce the quality and quantity of water sources. This will have implications for water resource management and water use, especially for industry and agriculture, which are heavy water users.

Vanuatu has limited surface water resources; therefore, people on many rural areas and residents of both urban areas (Port Vila and Luganville) are dependent on ground water. Increased temperature is likely to increase the demand for drinking water; however, increased heat, greater run-off from high intensity rainfall events, decreased rainfall, and an associated increase in evaporation, could reduce the rate of ground water recharge and decrease surface water flows. Water shortages that already occur in dry seasons, would become more pronounced, and thus may require a more strategic water management scheme to maintain human populations and agriculture production in severely affected areas.

Any increase in sea level could cause salt water intrusion into the shallow groundwater lens in coastal areas, particularly if ground water recharge is reduced or ground water is over-extracted. Increased rainfall often associated with cyclones could also cause flash floods, soil erosion, and further pollution of freshwater and marine environments. Increasing population will place additional pressure on the already stressed water supply systems and any further pressure resulting from climate change and variability would compound the issue, posing serious problems for Vanuatu.

Soil and Land Management

Increased rainfall could result in waterlogged soils, unsuitable for agriculture and other uses. It could lead to soil erosion and loss of soil nutrients that are important for plant growth. Climate change could influence the traditional methods of land management in Vanuatu. Change in rainfall could lead to the introduction of crop species and varieties with lower water demand or the introduction of new land management regimes that are better tailored to cope with the changing rainfall patterns. Monoculture plantations may no longer be suited to the changing climate in certain parts of the country, and changes in rainfall and temperature could result in the proliferation of new or dormant pests and diseases that could cause considerable damage to crops and hence, endanger food security for the people of Vanuatu.

Agriculture crops, such as wild yams, traditionally used as a soil cover to minimize run-off, are reported to be sprouting during the wet season, later than the regular sprouting time at the end of dry season. This means that this crop might have lost its soil protective function because of shifts in weather patterns. The promotion of multi-cropping systems, which are likely to increase the resilience of agricultural crops to extreme weather and climate events and to prevent the spread of pests and diseases often associated with increased temperature and rainfall, may be an appropriate approach to managing soil and land in response to future changes and shifts in weather patterns.

1.3 Impacts of extreme weather and climate events on agriculture

Between 1950 and 2004, Vanuatu reported the highest number of natural disasters in the Pacific Islands region (Bettencourt et al., 2006), including droughts, floods, extreme temperatures, earthquakes (and tsunamis), and cyclones (WB, 2009).

Based on (a) the impact of external shocks over which an affected country has little or no control and (b) the resilience of a country to withstand and recover from such shocks, the Commonwealth Vulnerability Index ranks Vanuatu as one of the most vulnerable nations to natural disasters in the Pacific (Atkins et al., 2000).

According to Mahul (2013), the estimated financial losses inflicted by natural disasters are the highest among PICs (Fig. 2). Furthermore, the high population growth rate and the rapid urbanization in Vanuatu have compounded the magnitude of these losses. An ADB report indicated that exposure to cyclones is 40% higher for urban than for rural populations; while, the risk of floods is 17% worse in urban areas in the PICs (ADB, 2012).

A FAO report (2013) identified extreme weather and climate events commonly affecting Vanuatu and geographical distribution of the extreme events over six provincial areas in this country. Fig. 3 shows the geographical location of the six provinces of Vanuatu where impacts of extreme weather and climate events are prominent.

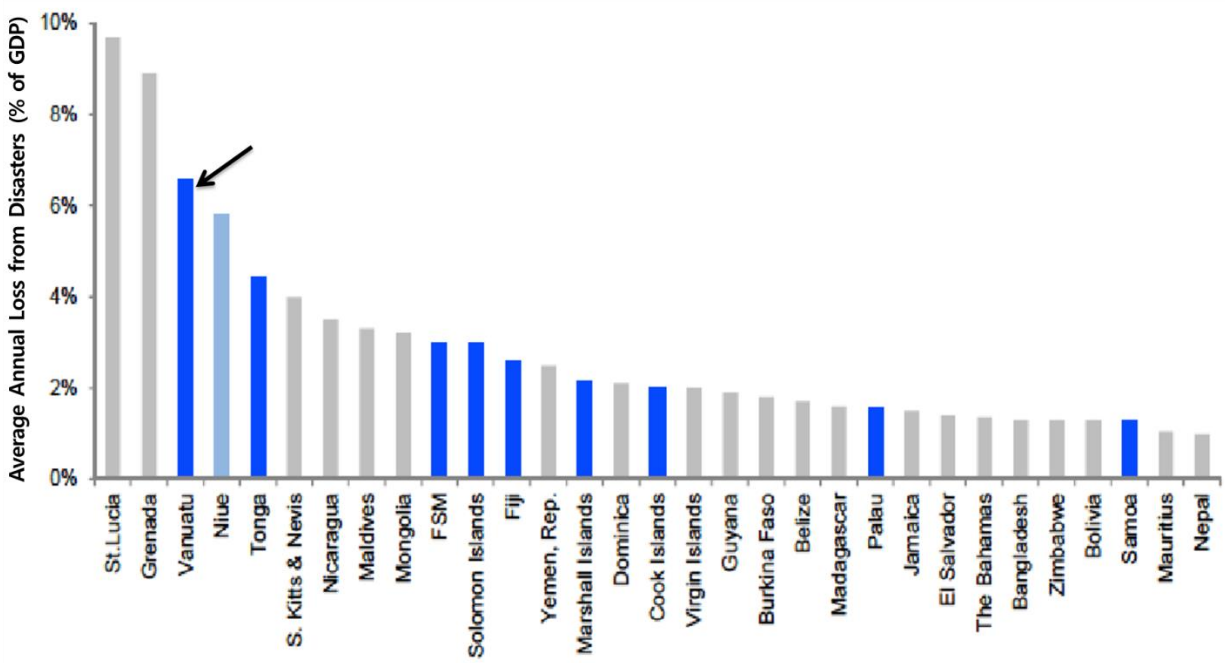

Figure 2. Estimated average annual losses from natural disasters (% of GDP) (Sources: Mahul, 2013).

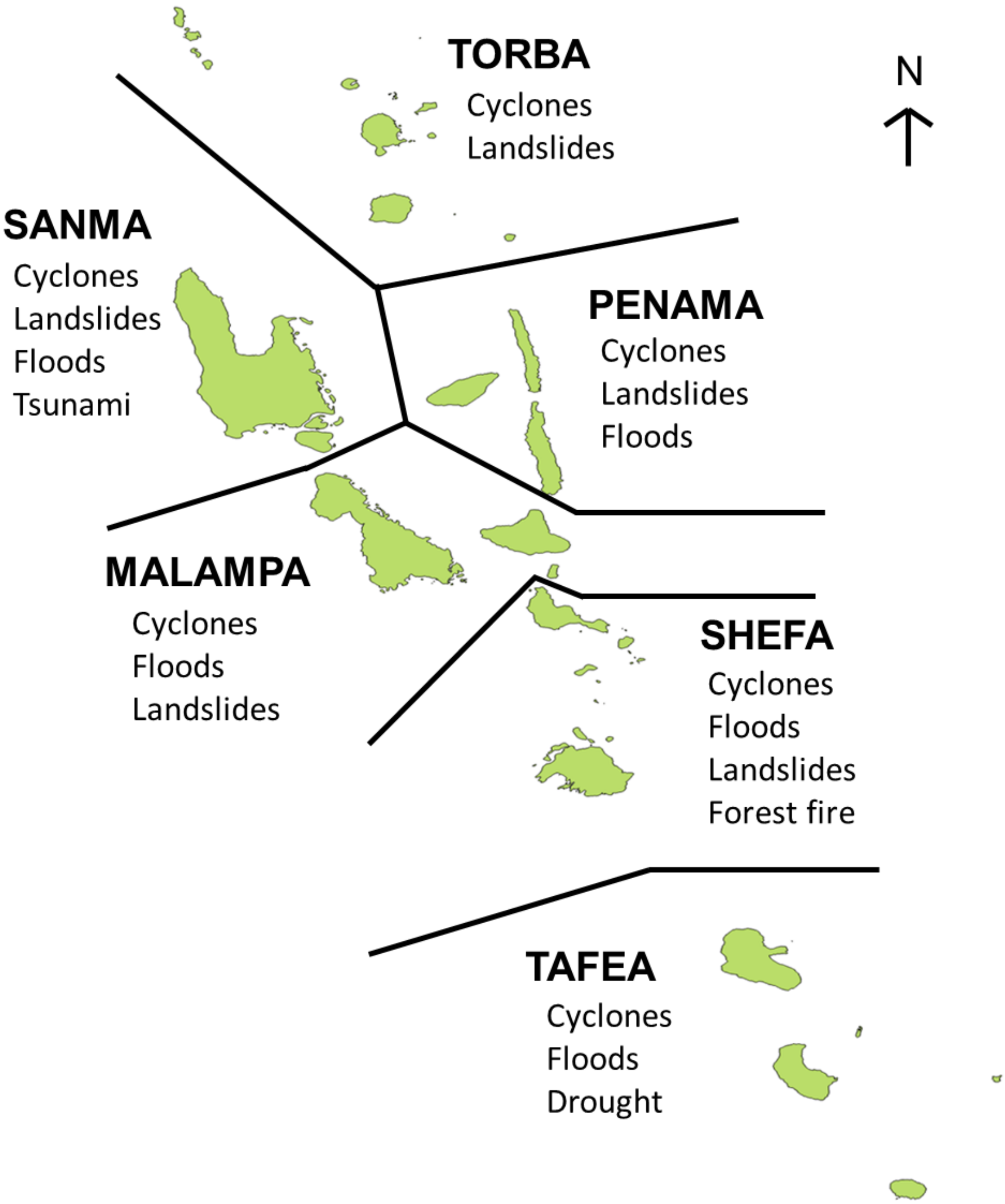

Figure 3. Distribution of extreme weather and climate events among the Provinces of Vanuatu (Adopted and modified from the source: FAO, 2013)

As a direct effect of altered rainfall and temperature patterns, climate change is projected to multiply the risks of extreme weather and climate events over the next decades (IPCC, 2013). Impacts from the extreme events will be inequitably spread throughout the islands; especially in the agriculture sector, predicted severe damage includes contamination of water resources, loss of crops or livestock, increased susceptibility to pests and diseases, and destruction of agricultural infrastructure, such as irrigation systems (Chung, 1996).

As Das et al. (2003) explained that extreme weather and climate events have direct and indirect effects on agriculture. Direct effects result from the physical damage on crops, animals, and trees caused by the extreme hydro-meteorological event. These effects range from short-term temporary damage to complete crop loss. Within hours of their occurrence, extreme events cause acute damage to agriculture in terms of total or partial destruction of farm buildings, machinery, equipment, means of transport and storage, as well as damage to crop land, irrigation works, reservoirs, and destruction of crops ready to harvest.

Loss of perennial crops, such as banana trees or forests, has long-term consequences on the ability to regenerate income. Floods make arable land unsuitable for agricultural production until water is drained, while cyclones might completely wash out arable land or permanently increase salinity through storm surges and flash floods.

Extreme weather and climate events also cause indirect damage; this refers to the loss of potential production due to disturbed flow of goods and services, lost production capacities, and increased costs of production. Indirect effects also include the evacuation of people in the event of cyclone-induced landslides, disruption of households, and stress-induced sickness (Sivakumar, 2008). Such indirect effects manifest progressively, because of lower income, decreased production, environmental degradation and other factors related to the disaster (Das et al., 2003).

Extreme weather and climate events and their impact on agriculture in Vanuatu are discussed below. Definitions of selected extreme weather and climate events are provided in Box 1.

Box 1. Definition of Selected Extreme Weather and Climate Events

Drought is the consequence of a natural reduction in the amount of precipitation over an extended period, usually a season or more in duration. Drought is not a purely physical phenomenon, but instead, it is an interplay between natural water availability and human demand for water supply. For example, agricultural drought is caused when there is insufficient soil moisture for average crop or range production. This condition can arise, even during average precipitation, due to soil conditions or inadequate agricultural management practice.

Flood is the condition that occurs when water overflows the natural or artificial confines of a stream of other body of water, or accumulates by drainage over low-lying areas. A flood is a temporary inundation of normally dry land with water, suspended matter and/or rubble caused by overflowing of rivers, precipitation, storm surge, tsunami, waves, failure of water retaining structures, groundwater seepage, and water backup in sewer systems.

Tropical cyclone is a rapidly rotating storm system in the tropics, characterized by a low-pressure center, a closed low-level atmospheric circulation, strong winds, and a spiral arrangement of thunderstorms that produce heavy rains. Depending on its location and strength, a tropical cyclone is referred to by different names, including hurricane, typhoon, tropical storm, cyclonic storm, tropical depression or simply, cyclone.

Heat wave is a prolonged period of excessively hot weather, which may be accompanied by excessive humidity. The term is relative to the usual weather in the area, so temperatures that are considered normal for people from a hotter climate can be considered a heat wave if they are outside the normal pattern for a cooler area.

Droughts

Droughts are common in Vanuatu and are predicted to become more extreme as the change in weather pattern intensifies (McGregor and McGregor, 1999). Rainfall in the wet season provides most of water supply to the smaller islands of Vanuatu. However, El Niño conditions in this part of the Pacific can shift rainfall patterns, causing significant decrease in rainfall and leading to drought conditions. Droughts are especially damaging in the more remote islands lacking sufficient rainwater harvesting/storage capacity to withstand dry periods, as is the case with most of the southern islands.

The latest El Niño events, which resulted in dry conditions in Vanuatu, occurred in 1982/83, 1991/92, 1994/95, and 1997/98. The worst period of drought in Vanuatu was registered in 1993, between two consecutive El Niño years, causing significant declines in agricultural productivity and exports. More frequent El Niño events could increase the intensity and occurrence of drought. The National Adaptation Program of Action, notes the special vulnerability of the western region of Tanna to drought, with significant negative impacts on both, agricultural productivity and the all-important tourism sector (NACCC, 2007).

Agricultural drought is defined as a reduction in moisture availability below the optimum level required by a crop during different stages of its growth cycle, resulting in impaired growth and reduced yield. Most parts in Vanuatu experience a normal dry season from May through October, which cropping patterns have adjusted to and depend on. In some years, the dry season can be pronounced and extended; thereby, subjecting agricultural activities to severe pressure. Occasional severe drought, as has occurred in Vanuatu a few times over the last decades (1978, 1983, 1993, 1997), can cause not only shortage of food, but also shortage of planting material for rehabilitation in the next season.

During drought, short-term impacts on agriculture include water shortage for agriculture purposes, which rapidly affects health, production, and reproductive capacity of animals; slow growth and low yields from food crops; low productivity from home gardens for subsistence farmers, leading to food insecurity; and increased risk of fires due to prolonged dryness.

Floods

Floods are also common in Vanuatu and are predicted to become more intense similar to droughts, under conditions of climate change and variability. Flooding in Vanuatu is highly associated with tropical cyclones and heavy rainfall over a short time period during La Niña years. Combined with poor farming practices, flooding is responsible not only for heavy and immediate crop losses, but also for soil erosion and nutrient loss from agricultural land, creating favorable conditions for the spread of pests and diseases, further threatening land stability. Additionally, flooding leads to pollution of ground water sources and coastal areas; thereby, endangering the health of rivers and marine life in or around river mouths.

Tropical cyclones

Vanuatu is one of the most tropical cyclone (TC) prone areas in the Pacific. According to the Vanuatu Meteorology and Geo-Hazards Department (VMGD), geographically, wind speed in Vanuatu is at least 34 km/hr. January and February have the greatest frequency of TCs, with average 2–3 TCs per cyclone season (www.meteo.gov.vu). In total, 124 TCs have affected Vanuatu since 1939; 45 of them were categorized as having hurricane force winds (>120 km/h).

Between 1990 and 1999, Vanuatu experienced more cyclones than any other PIC, at an annual average of 2.6. Among the most devastating TCs to strike Vanuatu, Uma, in 1998, caused an estimated US$ 150 million in damage and loss of 50 lives. More recently, in March 2015, TC Pam struck Vanuatu as an extremely destructive Category 5 cyclone. As a result, an estimated 65,000 people were evacuated; approximately, 17,000 buildings were damaged or destroyed and the cyclone destroyed crops on a large scale; thereby, compromising the livelihoods of at least 80% of the rural population. Low-income victims suffered during the post-disaster period due to reduced income and food source scarcity. Among all agricultural households located in the disaster area, 50% have lost all or part of their crops.

The magnitude of the damage depends on the cyclone intensity and path. Damage to crops and vegetation tends to increase exponentially with wind speed; for example, a 4-fold difference in severity of damage is observed between 180 and 90 km/hr winds. The rapid upward spiraling air in a cyclone can cause extremely heavy rain, particularly when the system is forced to rise over mountains. Low atmospheric pressure during TC storms can raise the sea as high as 2 m, causing engulfment of low-lying areas and considerable seashore damage.

Short-term impacts of TCs on agriculture include wind damage to agricultural crops and forest trees, such as uprooting, tearing up leaves, breaking off branches and making plants unstable; decreased availability of planting material for the following season; erosion of coastal areas due to wave surges and flooding; damage to crops from salt spray and rising sea levels; intrusion of groundwater sources by salt water; destruction of farm shelters and rainwater storage facilities; loss of animals due to falling trees and buildings; damage to coral reefs; outbreaks of pests and diseases; and low fish catch.

2 Climate services to agricultural climate risks

2.1 Climate smart practices and technologies for coping with extreme weather and climate events

Table 1. Climate products and services and related climate-smart practices and technologies recommended to cope with extreme weather and climate events and resulting damages.

<table>
<tr><th rowspan="2">Extreme weather and climate events and resulting damages</th><th rowspan="2">Drought</th><th colspan="2">Flood/Heavy Rain</th><th>TC</th><th>Tsunami</th><th rowspan="2">Pest & Disease</th></tr>
<tr><th>Soil erosion</th><th>Water logging</th><th>High winds</th><th>Salinity</th></tr>
<tr><td colspan="7">Climate Products and Services Required</td></tr>
<tr><td>Early-warning system</td><td>✓</td><td colspan="2">✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Vulnerability mapping</td><td>✓</td><td colspan="2">✓</td><td>✓</td><td>✓</td><td></td></tr>
<tr><td>Decision support tools</td><td>✓</td><td colspan="2">✓</td><td></td><td></td><td></td></tr>
<tr><td>Dynamic cropping calendar</td><td>✓</td><td colspan="2">✓</td><td></td><td></td><td>✓</td></tr>
<tr><td>Climate information</td><td>✓</td><td colspan="2">✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="7">Climate-Smart Practices and Technologies</td></tr>
<tr><td>Resistant/tolerant crops and varieties</td><td>✓</td><td></td><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Deep root systems</td><td>✓</td><td>✓</td><td></td><td>✓</td><td></td><td></td></tr>
<tr><td>Shallow root systems</td><td></td><td></td><td>✓</td><td></td><td></td><td></td></tr>
<tr><td>Adjust planting dates with dynamic cropping calendar</td><td>✓</td><td></td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td>Improve irrigation systems</td><td>✓</td><td></td><td></td><td></td><td>✓</td><td></td></tr>
<tr><td>Agroforestry</td><td>✓</td><td>✓</td><td></td><td>✓</td><td></td><td></td></tr>
<tr><td>Enhance ground cover with organic matter</td><td>✓</td><td></td><td>✓</td><td></td><td></td><td></td></tr>
<tr><td>Open pit</td><td>✓</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Raising beds/hilling</td><td></td><td></td><td>✓</td><td></td><td></td><td></td></tr>
<tr><td>Staking</td><td></td><td></td><td></td><td>✓</td><td></td><td></td></tr>
<tr><td>Improving land use and physical planning mechanisms</td><td></td><td>✓</td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td>Removing salt</td><td></td><td></td><td></td><td></td><td>✓</td><td></td></tr>
<tr><td>Mixed cropping</td><td></td><td></td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td>Biocontrol materials</td><td></td><td></td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td>Integrated pest management</td><td></td><td></td><td></td><td></td><td></td><td>✓</td></tr>
</table>

2.1.1 Drought

- Climate Products and Services Required

1) Drought early warning system: Knowing the probable occurrence and duration of droughts would help agricultural stakeholders to plan the amount of water to be stocked as reserve, the crops or varieties to plant, cropping measures to implement, etc.

2) Location-specific drought risk map: Based on high resolution historical data on hazard, exposure, and vulnerability, location-specific drought risk maps can be produced. These drought risk maps can be used for drought management, both proactively prior to drought occurrence together with the drought early warning information, and reactively responding to the drought after the impacts have occurred.

3) Decision support tools for climate smart irrigation: Based on measurement and forecasting of evapotranspiration or soil moisture information, climate smart irrigation can be practiced for individual crops in a specific manner. The use of decision support tools using meteorological and cultural information as inputs will facilitate climate smart irrigation practice of agricultural stakeholders.

4) Dynamic cropping calendar: A cropping calendar is a tool that provides timely information about planting, sowing, and harvesting periods of locally adapted crops in specific agro-ecological zones. It also provides information on the sowing rates of seeds and planting materials, and the main agricultural practices. The dynamic cropping calendar supports farmers and agriculture extension in taking informed decisions on crops and their sowing period based on given agrometeorological information, such as weather and climate forecasts.

5) Climate information: Historical climate analyses of past drought events at the village, province, and national levels; weather and climate forecasts for drought monitoring and outlook over the next months.

- Climate-Smart Practices and Technologies

1) Drought-tolerant crops and varieties

Some crops traditionally grown in Vanuatu are relatively tolerant to drought, compared to others (FAO, 2010; 2013). Not all varieties of a crop can tolerate drought. For example, yam is quite tolerant to an extended dry period. This is especially true for wild yams that are protected by trees in a forest. Taro will not survive a prolonged dry spell, but taro Fiji, which is more tolerant to water stress, can be planted in drier areas. Kumala is reasonably drought tolerant if there is adequate rain at the time of planting; although well-distributed rain enables its harvest in three months, it requires six months to reach maturity under drier conditions. Cassava can grow at any altitude where land is cultivated in Vanuatu; abundant rain is a requirement for this crop; however, it can withstand prolonged drought, except at the time of planting. Young kava will not tolerate an extended period of drought, making the planting of kava outside the wet season highly risky. Coconut palms are relatively drought resistant, as evidenced by their ability to produce in a harsh atoll environment; however, prolonged dry periods delay drupe production. Similarly, breadfruit survives in prolonged droughts. Cocoa, with its deep root, is quite drought tolerant, but like other crops, cocoa will eventually be affected by extreme, extended drought conditions.

In Vanuatu, there is very little information on conventional crops and varieties in terms of their degree of tolerance to drought. Therefore, it is one of the priority research areas for the Vanuatu government to establish a list of drought-tolerant crops and their varieties existing in Vanuatu, and if possible, it would be beneficial to create a genetic material and nursery bank that farmers can have access to during emergency situations. Further research should investigate the magnitude of tolerance of those crop varieties. Like cocoa, deep rooted crop plants do better under drought because they are able to draw water and nutrients from deeper within the soil during water stress and dry periods (Johnson et al, 2000). Therefore, the Vanuatu government should consider breeding crop plants with deep roots (Kell, 2011). Once the information on drought tolerant crops and varieties is listed, extension workers can provide recommendations based on this information.

2) Planting date

Crop planting dates in Vanuatu are scheduled based on the onset or duration of two distinct seasons: dry (cold) and wet (hot). Planting date adjustments using a dynamic cropping calendar based on climate information can be made to coincide with the onset and duration of the dry season. Planting date should be adjusted, so that crops such as taro, yam, and vegetables take advantage of the rains at the beginning of the rainy season. The planting date of kumala can also be adjusted, such that it utilizes the dry season for tuber development and maturation.

3) Improving or building village irrigation systems

Improving existing irrigation systems or building new irrigation systems for villages is required to cope with agricultural drought. High risk areas shown on the location-specific (high resolution) drought-risk map generated based on historical climate and drought data, are normally targeted. There are two possible types of irrigation systems in the context of the Vanuatu agriculture sector.

First is a run-off rainwater harvesting system for irrigation, in which rainwater flowing on the ground is collected into a tank below the surface of the ground. The tank is constructed using bricks and cement. During storage, it is important to incorporate efficient and effective water conservation methods to reduce evaporation; similarly, it is important adopt efficient irrigation techniques to maximize water use efficiency.

Another irrigation system makes use of groundwater pumping for irrigation. In many parts of Vanuatu there are substantial amounts of underground water. This large amount of water provides a large storage buffer to sustain seasonal variations in rainfall. During severe droughts, the groundwater reservoir is expected to provide sufficient water for agricultural use, although impacts on the ecological biophysical environment should be considered. However, low lying islands are the exceptional for this groundwater pumping system because the fresh water lens is thin and salt intrusion may become a problem. In this case, the run off rainwater harvesting system can be considered as an alternative.

Community irrigation systems should be upgraded or built using an approach that enables participation of most community members in all steps of implementation, which will improve the community ownership necessary for sustainable long-term performance of the irrigation systems. Education programs, including proper use of climate products, such as drought monitoring (risk) information, seasonal climate forecasts, and ENSO forecasts, will also ensure efficient and effective water use and management by means of the village irrigation systems during future events.

4) Drought-tolerant traditional farming practices and systems

Traditional food gardens in Vanuatu, which involve small plots surrounded by forest (i.e. agroforestry), are drought resistant, being able to conserve moisture and protect crops from desiccating winds (McGregor and McGregor, 1999). The Ni-Vanuatu community have great knowledge about drought-tolerant local crops passed down over multiple generations. Although the magnitude of drought tolerance varies among species, drought tolerant crops in Vanuatu include yam (especially wild yam), taro Fiji (compared to swamp taro), kumala, coconut palm, cocoa, and cassava. On the contrary, swamp taro, kava, and vegetables are known to be drought susceptible, to avoid during prolonged dry spells.

Agroforestry combines low strata crops such as root crops, vegetables, and legumes, with trees. Leguminous trees and shrubs such as gliricidia (quickstick) and leucaena (white leadtree) can be advantageous. Agroforestry promotes efficient use of scare resources like land, soil nutrients, and soil moisture. Leguminous trees enrich soil by fixing nitrogen. In agroforestry, trees serve as wind breaker barriers that protect crops when cyclones strike. Additionally, the litter from pruning trees serves as good ground cover during the dry season preventing soil water evaporation and adding organic matter to the soil when decomposed, which in turn helps conserve soil moisture content. Well-designed agroforestry can also provide cultural and biological pests and disease control.

Ground cover systems with compost, mulch, and cover crop also reduce the impact of drought on crop performance. All three farming practices reduce direct exposure of the soil surface to sunlight or heat from the sun. The humus and organic matter produced and added to the soil will increase its (soil) capacity to retain and conserve soil moisture during drought.

Open pit is a traditional cultivation practice that functions to catch and preserve moisture during dry seasons. This practice also helps build up organic matter in the open pits as the debris filling the pit gradually decomposes. Minimum weeding is used during the dry season as a measure against loss of soil moisture.

2.1.2 Flood

- Climate Products and Services Required

1) Flood (excessive rainfall) early warning system: Knowing the amount of rainfall that will occur over the next hours or days would help agricultural stakeholders decide on actions preventing possible damage from excessive rainfall and consequential floods in certain agricultural areas.

2) Location-specific flood-risk map: Based on high resolution historical data on hazard, exposure, and vulnerability, a location-specific flood-risk map can be produced. This flood-risk map can be used both, to prevent damage from flooding by the flood early warning system, and to enable timely reaction to damage from flooding after impacts have occurred.

3) Climate information: Climate information provides critical insight, including historical climate analyses for past flood events at the village, province, and national levels. Various temporal scales of weather and climate forecasts are necessary for flood monitoring and very short- to long-term predictions are needed for tactical and strategic decisions.

- Climate-Smart Practices and Technologies

1) Soil erosion control plants

Floods can cause serious soil erosion and leaching. At extremely high flow during floods, underwater vortexes are formed by large volumes of rapidly rushing water, which cause extreme local soil erosion. Soil erosion (a form of degradation) will result in little or no soil left to support crop plants. Soil erosion control plants are effective in helping prevent the washing away of soil layers due to flooding in soil erosion-prone sites located in flood vulnerable areas. Forestry crops with dense and deep rooting systems can be planted at the bottom of slopes to hold soil particles together. When planted at the bottom of the slope, the dense and deep rooting system will act as a barrier preventing the soil particles from being washed down.

Bamboo species with dense rooting systems are one of the recommended plants for soil erosion control in Vanuatu. *Erythrina* has a deep rooting system also, and serves as a leguminous plant. The vetiver grass has a thick, dense rooting system, and thus, is traditionally planted in rows along slopes to reduce soil erosion. The blades of vetiver grass can be cut and laid out on the soil as mulch. Covering the soil surface protects it from directly being impacted by rain drops. Similarly, covering the soil surface with crops or weeds serves as a barrier which reduces the impact of a heavy rainfall on the soil and keeps the soil particles intact.

2) Agroforestry

Agroforestry in flood prone areas is another option to reduce potential damage from floods. Agroforestry combines low strata crops with trees. Both commercial trees and ornamental trees can help. Sandalwood, pine, and whitewood are good examples. The tap roots of the trees will hold the soil particles together and reduce the chances of being washed away by run-off water. The rooting system can also minimize and prevent landslides. The leaves of the forest trees will reduce the impact of the falling droplets of rain on the soil surface. Ornamental trees can add value to the land in addition to protecting it from soil erosion.

3) Raising beds and adding organic mulches

Flooding causes waterlogging (the saturation of soil with water), especially in heavy clay soil. Thus, if high-risk areas identified on the location-specific flood-risk map are prominently composed of heavy clay soil, waterlogging should be addressed, as it can result in root rot and crop failure. Strategies implemented include improving drainage or planting crops adapted to clay soils. Crops suitable for heavy soils in Vanuatu include ginger, cassava, kumala, and taro.

The most cost-effective strategy for smallholder famers to improve drainage in heavy clay soils is to raise beds to aid drainage and reduce waterlogging. The beds can be constructed using bamboo, wood, or sticks collected from the forest. The farmer can use a different type of soil obtained elsewhere to fill the raised bed.

Additionally, hilling or mounding allows the underground tubers of root crops to survive flooding. The hill or mount elevates the plant to heights above the flooded water level. This prevents root rots, which result from exposure to waterlogging. Yam, taro, and kumala can be hilled.

Utilizing bulky organic matter, such as manure or compost also helps improve drainage. Adding organic mulches around the stem of tree crops is another option. This is recommended for permanent tree crops. In addition to improving drainage and adding nutrients to the soil, organic matter also improves retention of soil moisture.

4) Increasing top soil after soil erosion damage

Shallow rooted crops are superior to deep rooted ones in shallow soils that were affected by soil erosion caused by flooding. The shallow rooting system allows the plants to use nutrients from decaying leaf debris on the soil surface. To improve the top soil layer of a shallow soil, cover crop, compost, and mulch can be used. Cover crops help conserve moisture as well as add humus and organic matter to the soil. Addition of humus and organic matter periodically, will gradually improve the top soil over time. The use of legumes as cover crops will also add nitrogen to the soil. Most creeping leguminous plants are good cover crops. *Dolichos lablab* and *Mucuna pruriens* are the two most commonly available creeping legumes in Vanuatu (FAO, 2013). Compost and mulch are other practices that can aid in adding soil particles to the top soil.

2.1.3 Tropical Cyclone

- Climate Products and Services Required

1) Tropical cyclone (TC) early warning system: A TC early warning system generally has two levels of alerts issued by the national meteorological service to certain national areas threatened by the imminent approach of a TC. This simply notifies the local population and civil authorities to make appropriate preparations for the TC, including evacuation of vulnerable areas when necessary. Some early warning systems include sectoral impact forecasts based on the magnitude of the TC. This impact-based forecast requires extensive knowledge of sector-specific vulnerability and exposure, which allow risks of impact forecasted and warnings issued targeting those exposed to TC.

2) Location-specific TC-risk map: Based on high resolution historical data on hazard, exposure, and vulnerability to TC, a location-specific risk map can be produced. This risk map can be used for short- and long-term practices and planning both, to reduce damage from TC utilizing the information from a TC early warning system and to timely react to resulting damage immediately after a TC has struck.

3) Climate information: Historical climate analyses of past TC events at the village, province, and national levels; weather and climate forecasts for TC monitoring and outlook over the next months.

- Climate-Smart Practices and Technologies

1) Cyclone-tolerant crops

Many crops in Vanuatu are susceptible to cyclones, particularly yams, taro, and kava planted in food gardens. Nevertheless, diverse integrated cropping systems have evolved over the centuries, which provide a high degree of tolerance to natural hazards like cyclones. Therefore, it is necessary to learn from and build on the strength of traditional systems to mitigate the impact of natural hazards.

Certain crops, such as taro Fiji, are more tolerant to wind than swamp taro. Island cabbage, particularly if cut before the cyclone, will bear again within six weeks. Aboveground sections of bananas may collapse, but the main rootstock is seldom destroyed and suckers will reappear to fruit within six months. Post-cyclone pruning accelerates recovery. Traditionally, wild yams, arrowroot, and elephant yam act as disaster and hunger foods, indicating that these crops survive well during natural hazards such as cyclones. Cassava is tolerant to strong winds if the tops are cut before the cyclone. In the case of kumala, its low and spreading growth habit makes it quite tolerant to high wind. South Pacific coconut varieties have evolved in cyclone prone environments and therefore, have adapted to survive the strongest of winds.

2) Cyclone-tolerant traditional cropping practices and systems

Although annual crops such as yam, taro, and giant taro, and some fruit trees are susceptible to tropical cyclones, and get uprooted, or their leaves and branches tear off. Agroforestry practices could increase their tolerance level to strong winds, and the trees used in agroforestry would serve as windbreakers during cyclones. Upon striking the windbreaker trees, a violent gust of wind from cyclones is often reduced in velocity and intensity before reaching the crop plants.

Staking is a traditional husbandry practice used in yam cultivation in the Pacific (personal communication). Vines are trained up the stakes to keep them above the ground. This prevents the vines on the heated soil surface from getting burnt; in addition, the strong stakes would also protect the vines from cyclones. Stakes are erected 1–2 m high to prevent them from being blown over by the cyclone strong winds.

Heavy rainfall from tropical cyclones causes waterlogging. As mentioned in the previous section, drainage to avoid waterlogging can be improved by raising beds. Additionally, hilling or mounding allows the underground tubers of root crops to survive flooding. Adding plenty of bulky organic matter, such as manure or compost is another option. The organic matter or compost helps improve drainage.

Cover crop, compost, and mulch can be used to improve the shallow top soil layer caused by soil erosion due to heavy rainfall accompanying tropical cyclones. Periodical addition of humus and organic matter will gradually improve the top soil over time.

2.1.4 Tsunami

- Climate Products and Services Required

1) Tsunami early warning system: A tsunami early warning system is used to detect tsunamis in advance and issue warnings to prevent the loss of lives and damage. It is made up of two equally important components: a network of sensors to detect tsunamis and a communications infrastructure to issue timely alarms to permit evacuation of the people from coastal areas.

2) Location-specific tsunami-risk map: Based on high resolution historical data on hazard, exposure, and vulnerability to tsunamis, a location-specific risk map can be produced. This risk map can be used for short- and long-term practices both, to reduce damages from tsunami, together with the early warning system, and to timely react to resulting damages from tsunami impacts.

- Climate-Smart Practices and Technologies

1) Salinity-tolerant plants and cropping systems

Tsunamis can increase soil salinity by bringing salt sea water in coastal land, where farming is taking place. In this case, planting salinity-tolerant crops will help to reduce damages from the salt water inundation due to tsunamis. However, a list of salinity-tolerant crops and varieties available does not exist. The Vanuatu government is recommended to identify such crops and varieties and the magnitude of their salinity tolerance or import verified salinity-tolerant crops and varieties from other Pacific countries. Recommendations on salinity-tolerant crops and varieties can then be given to atolls and low-lying island farmers. There are several plant species known for their salinity tolerance in Vanuatu. Paw-paw and coconut trees grow in a variety of soils and tolerate salinity well. Pumpkin also tolerates salinity.

Hydroponics can be an alternative cropping system for high salinity soils on atoll islands, where salinity susceptible crop plants are difficult to grow. Hydroponics is a system that uses a liquid culture medium on which crop plants grow, physically supported in a variety of ways.

2) Removing salt from the soil

Due to sea water influx into the land during tsunamis, salts accumulate in the root zone. These salts must be removed to allow the rooting system to continue to absorb necessary nutrient ions. The salts can be flushed out by leaching and drainage. In particular, good drainage allows salts to be washed out of the soil. Although this technique is currently expensive and time intensive, it must be considered as an option in the future, when salinity in atolls and low-lying islands will increase.

3) Improving land use and physical planning mechanisms

Land use and physical planning based on accurate assessment of the possible impacts of climate change and sea level rise provides a powerful tool for reducing vulnerability to the detrimental effects of climate change. Planning mechanisms can be used to direct or regulate all new investments in infrastructure and agriculture outside hazard zones to minimize vulnerability, reduce repair costs, and decrease disruption of economic activities. This includes planning of farmland starting, at a certain minimum distance from the coastal line to fundamentally decrease the level of exposure to sea water intrusion. It also includes regulating the extraction of freshwater from coastal aquifers when the salt concentration of the fresh water exceeds a certain threshold level. Such policies would eventually reduce the vulnerability of coastal communities and reduce the need to replace infrastructure under incidences of salt water intrusion.

2.1.5 Pest and Disease

- Climate Products and Services Required

1) Pest and disease early warning and spray decision support tool: A pest and disease early warning system is a decision support tool that helps agricultural stakeholders to assess the risk of outbreaks of economically damaging crop pests and diseases. Using information about the weather, the crop, and/or pathogenic agents, warning systems advise agricultural stakeholders when they need to take an action - usually to apply a pesticide spray - to prevent pest or disease outbreaks and avoid economic losses. If the warning system uses a seasonal climate forecast, the risk of pest or disease epidemics over the next season can be predicted; this will enable the agricultural stakeholders to implement strategic management actions to control the high risk of pests or diseases.

2) Climate information: Historical climate analyses of past pest and disease outbreak events at the village, province, and national levels; weather and climate forecasts for monitoring of pest and disease epidemics, and outlook over the next months.

- Climate-Smart Practices and Technologies

1) Resistant crop and varieties

Cultivation of crops and crop varieties resistant to pests and diseases incident in the locality of interest is one of the most effective ways to tackle pests and diseases. Many native plants and crops have developed resistance to specific insect pests and pathogens. An example is the resistance of giant taro to Papuan beetle. Other aroids such as taro and taro Fiji are susceptible to this pest. When there is a high risk of infestation by this beetle, farmers should be advised to cultivate giant taro rather than taro or taro Fiji. Wild lemon is observed to be resistant to diseases caused by *Phytophthora* spp. in citrus that harm the orange industry in Vanuatu. Thus, using the wild lemon root stock for grafting would benefit orange orchards and larger plantations with a natural control of the disease.

2) Dynamic Planting Calendar to avoid pest and disease favorable conditions

Pathogenic organisms require moisture as a pre-requisite to reproducing, growing, and multiplying. A dynamic planting calendar based on weather and climate information can be developed to avoid the favorable conditions necessary for the outbreak of pathogens on crops. For example, yams can be planted at the end of the dry season so that the crop is established before the rainy season; thus, mature yams will be able to tolerate anthracnose, a group of fungal disease, during rains.

3) Traditional cropping systems to mitigate pest and disease outbreaks

Mixed cropping is one of the traditional cropping systems to mitigate pest and disease outbreak. This strategy is based on the principle that most pests and diseases are crop specific (host specific). Therefore, a combination of different crops will ensure that when a pest or a pathogen strikes, non-host crops will survive. This is consistent with the belief that diversification of root crops will help in increasing the resilience of agriculture systems to climatic extremes in Vanuatu.

Crop rotation ensures that one crop species is not planted in the same field for more than two consecutive years. Breaking the continuity of monoculture removes host plants for the existing pests and pathogens for the next season; thus, reducing the likelihood of any pandemic pest or disease outbreak during the crop rotation cycles.

4) Biocontrol materials

In the Solomon Islands, seaweeds are collected, processed, and used both as an organic fertilizer and a controlling material of common insect pests. Chilli pepper is commonly found in Vanuatu. The fruits of the chilly-pepper have chemicals that repel common insect pests. The content of the coconut shell and tomato leaves are also well known for their natural pesticide activity.

7) Integrated Pest Management

Integrated pest management (IPM) is another popular technique of controlling pests with environment-friendly and thus, sustainable practices. IPM uses integrated measures to reduce the potential risk of pest or disease outbreaks. A combination of various measures, including, the use of crops and cultivars of known pest and disease resistance traits, pest repellants and trap-plants, and adopting multi-cropping and agroforestry, is a good example of IPM.

In the context of Vanuatu, IPM practices may include removing any ideal conditions for pathogenic proliferation, such as pools of water on raised beds. Well-drained soils prevent the formation of water pools after a heavy rainstorm. Regular surveillance for harmful insects, disease incidence, and weeds is another strategy. Upon detection of any of these, Vanuatu government will need to provide crop protection services, including identification of insect pests and diseases and necessary advice and recommendations on cost-effective ways to manage them, which is definitely an area requiring capacity building.

2.2 Climate services for agriculture components in the Van-KIRAP

The Van-KIRAP (or Van CIS RDP) project will directly support generation of and application of climate products and services in decision-making in the agriculture sector through key development policies, planning and project processes. A comprehensive suite of tailored climate products and services will be developed in partnership with target Next/End-users, and deployed in real-time operational situations for the agriculture sector, as part of the case studies. These case studies will provide the framework for ensuring that climate services are mainstreamed into the decision-making process by the key decision-makers themselves.

To produce desired climate services to impact decisions of agricultural stakeholders it is crucial to guarantee a productive coordination among and within the organizations involved. Thus, strengthening the existing units is important to ensure that climate products and information is integrated in their coordination mechanism. The strengthened coordinating unit should have representation from all potential stakeholder groups, which will be identified to facilitate development of potential tailored content of climate, agriculture and allied sector information and advisory.

For example, within the coordinating unit, the role of the VMGD should be to produce seasonal downscaled forecasts; while, the Ministry of Agriculture needs to ensure that advisories issued to farmers are reached in user-friendly manner. Local universities need to collaborate with the Ministry of Agriculture to package the content in a comprehensive fashion. Media and research organizations must work on communicating information on the seasonal forecast advisory. Research organizations need to develop the capacity of the met agency and extension systems to ensure delivery of tailored information. NGOs must provide information from the ground-up on whether the seasonal forecast was accurate and useful to farmers. They also need to encourage confidence in scientific information among farmers. Farmers' organizations need to mobilize farmers to use advisories.

The project will support the capacity of agricultural communities to plan for and make decisions on the best adaptation pathways, via training and resource support, such as climate services and planning decision-support tools. The project will develop a suite of new climate services delivered through multiple formats/platforms tailored to the specific needs of target Next/End-users in the agriculture sector. The combination of targeted climate service support for these key Next/End-users will facilitate enhanced awareness of the risks of climate change and increase broad adoption of climate services at different levels of government and within local communities to make better "climate-smart" decisions in relation to climate adaptation and disaster-risk reduction.

The scope of the proposed activities for the climate services for agriculture under the Van-KIRAP project addresses the baseline condition in Vanuatu and priority climate products and service gaps and needs identified. These activities reinforce delivery of key climate services for agricultural decision-makers at all levels in Vanuatu (from national and provincial government to local community scale). The proposed set of activities will be delivered by the APEC Climate Center under the supervision by the two Executing Entities (SPREP and VMGD).

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