Food and Agriculture Organization of the United Nations
Subregional Office for the Pacific Islands

CLIMATE CHANGE AND AGRICULTURE IN VANUATU:
A study of crops and farming system

Prepared by FAO consultant

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ACRONYMS

CCCPIR	Coping with Climate Change in the Pacific Island Region
CEC	Cation Exchange Capacity
DARD	Department of Agriculture and Rural Development
DoF	Department of Forest
DoL	Department of Livestock
FAO	Food and Agriculture Organization
FIS	Fallow Improved System
IRETA	Institute of Research, Extension and Training in Agriculture
LUCM	Land Use Capacity Map
NARI	National Agricultural Research Institute
NDMO	National Disaster Management Office
NEA	Network of Edible Aroids
NGOs	Non-Government Organizations
SPC	Secretariat of the Pacific Community
SPC/GIZ	Secretariat of the Pacific Community/ Deutsche Gesellschaft f'r Technische Zusammenarbeit
UNFAO	United Nations Food and Agriculture Organization
UNICEF	United Nations Children Emergency Funds
UNDP	United Nations Development Programme
VARTC	Vanuatu Agriculture, Research and Training Center

CHAPTER 1:
INTRODUCTION

1.1 Introduction

Vanuatu is identified as one of the most disaster prone countries in the Pacific region. Comprising a national population of 250,000; the country regularly experience natural disasters like flooding, volcanic eruptions, landslides, cyclones, sea level rise, fire and disease outbreaks. The archipelago has 80 inhabited Islands with different degrees of susceptibility and capacity to respond to these natural disasters and impacts of climate-change. At present the country has no quantitative data to qualify the magnitude of susceptibility and capacity to respond to these natural disasters and effects of climate-change. The project selected 12 communities most susceptible to climate-change and natural disasters and quantifies their degree of susceptibility and capacity to respond to them. Component 3.1 of the project considers the capacity of 6 vulnerable communities to produce food under the following scenarios; flood, rising sea level, cyclone, volcanic eruption, drought (shortage of water) and tsunami (Table 1).

Table 1 Selected human security threats and Area Councils and province (From Project Document)

Province	**Selected human threat**	**Selected area/Local Council**
Shefa	1. Tsunami (1)*	Black Sands
	2. Cyclone (2)*	Marae/Finonge
	3. Floods (1)*	Marae/Finonge
Tafea	4. Volcanic eruption (2)*	White Sands (Imaio)
	5. Drought/Water shortage (2)*	Aniwa

***** *Ranking of human security threats related to climate change and natural disasters in Vanuatu according the Project Document. Ranking is from 1 through to 6. 1 denotes the highest level of risk and 6 denote the lowest level.*

The Overall purpose of the project 'Community resilience and coping with climate-change *and natural disasters in Vanuatu 2011*-2013 is to:

"*enhanced short- and long term community resilience and coping with capacity to at least 6 categories of adverse effects of climate-change and natural disasters, with special attention to women, children and other vulnerable groups in Vanuatu and to draw lessons learned in applying the human security concept to the rest of the Pacific Island countries and territories" (Project Document, 2010).*

The purpose of Component 3.1 of the project is to develop and/or recommend strategies for farmers to use as a tool to address adverse impacts of climate change and natural disasters.

The output of Component 3.1 is an *"increased food production and availability"*.

The outcome of the project as stated in the Project Document is:

"the outcome of work should be 'climate smart', promoting agriculture that sustainably increases productivity, is resilient (climate change adaptation), reduce/remove Green House Gases (climate change mitigation), and enhances achievement of food security and development goals".

1.2 Climate Change

Climate change is a reality. It is more so now that ever. It is advancing much faster than previously thought. There are many causes of climate change; some are natural and others anthropogenic. The industrial revolution of the 1800s is considered by some as the culprit of accelerated climate change. The rise of civilization and associated social and economic developments like urbanization, industrialization and intensive agricultural activities all contribute to accelerating climate change. There are many reasons attributed to accelerating climate change, including increasing demand of a growing population and the pattern of its consumption (Hisas, 2011). These activities increased greenhouse gas emissions. Hisas (2011) further suggested lack of full understanding of climate change as another reason for the climate change advancing at this advanced rate.

A good understand of climate change is required to better understand its impacts on environment, economic and health. The geological climate of the past has been intimately studied and scrutinized to better understand the climate of today and that of the future. Simulation models are developed based on these findings and used to predict what the future will be like. Two distinct but important scenarios are postulated using these models. The IPCC's latest report of 2007 utilized these models to project long term impacts of climate change. Using 2020 as the target year, the IPCC (2007) projected changes in climatic factors using past and present data and simulation models and outcomes of these scenarios.

Seven key findings are published in the IPCC (2007). The IPCC postulates that if no rectifying measures are put in place, the globe is likely to face these key issues in 2020.

1. Temperature of the planet would increase by, at least 2.4 ^{o}C above pre-industrial times;

2. Water and climate, two of the three elements of food productions would be most affected by climate change;

3. The tropical region – the region between 30^{o} N and S of the Equator would be the most significantly impacted by climate change as a result of reduced water availability and increased temperature.

4. Pacific Island countries would face severe water shortage due to reduced precipitation. Reduced precipitation would likely lead to intensification of water shortage and change of land use – away from drier areas.

5. Globally, food produced would not be enough to meet the food requirement of an additional 890 million people estimate to inhabit the earth by 2017. This will cause an imbalance in global production and demand. Demand will in most cases outride production. A deficit in major production of major food resources is estimated for the same period. Global wheat production will see a 14 % deficit; 11 % deficit in rice production; and 9 % deficit in maize.

6. Fall in food availability would stimulate an increased in food prices by about 20 %. Triggering an increased in hunger, this would reach one in every five people globally. It is estimated that the current level of global malnutrition is one billion people or one in every seven people are hungry.

It is universally agreed that climate change cannot be stopped. However there are measures available to slow the rate at which it is taking place and issues of food production arising from it.

The first on the list is to reduce greenhouse gas (GHG) emission. Carbon dioxide ($CO_{2)}$ is cited as the main culpit. Current GHG emission is estimated to have exceeded the levels projected as 'safe upper limit' by the IPCC. This would increase the temperature by $1^{o}C$ and with the current steady increase in GHG emission would see an increase of more than 2 ^{o}C (Hisas 2011).

The global community must adapt to climate change. Adaptation in the agricultural sector means implementing actions which adjust practices and processes. For example: altering planting and relocation of crops and livestock activities and using water more efficiently (Hisas, 2011).

Effectively planning for adaptation to climate change is another adaptation strategy. Hisas (2011) suggested that planning ahead means mainstreaming climate change into policies.

Change in dietary habits is another concrete action to fight climate change and food production. In Vanuatu this would mean changing from imported cereal-based food to root crops and legumes.

The key elements of food production are climate, land and water. Climate and water availability are the most important elements. Hisas (2011) noted in the report *'The Impacts of Climate Change on Food Production: A 2020 Perspective* that water availability and climate conditions defined the geography of food production.

In Vanuatu, observations showed that food production is to a large extend dictated by water availability. Food is abundant during t he wet season compared to the dry season. Furthermore, there is limited food supply in dry areas like the flat-plains immediate to the

Yarsu (Tanna) and Benvor and Marum (Ambrym). Similar situation exist in the atoll island of Lau in the Toress Group of islands and northern part of Marae on Emae.

1.3 Climate, climate change and natural disasters in Vanuatu

1.3.1 Current climate and natural disasters

There are two (2) distinct seasons in Vanuatu; the dry and wet season. The dry season is from April through to November. The wet season is from December through to March. Average annual temperature and rainfall closely follow this trend.

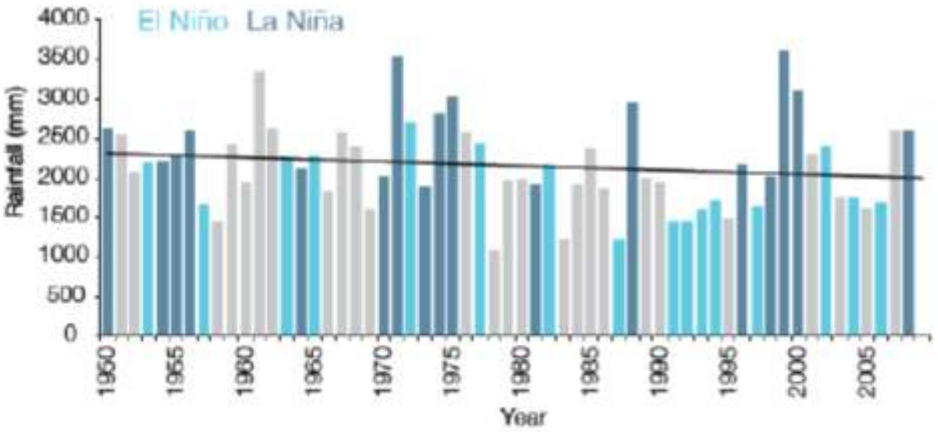
a. Temperature

High average annual temperature readings occur between December and March. The highest reading, about 25 o C occurs between December and March. Maximum temperature at this period is about 30 o C. Minimum temperature is about 24o C. Sea temperature is about 29o C. Both air and sea temperatures begin to drop on March, reaching the lowest readings on July and August. Air and sea surface temperatures warm up again on September. July and August are the coldest months in Vanuatu. Maximum temperature is about 27o C. Minimum temperature is about 20o C. Average temperature is about 24o C. Sea surface temperature is about 26o C. Historical records from a period of 50 years between 1950 and 2005 showed an increase of 0.17o C every 10 years (Australian Bureau of Meteorology and CSIRO, 2011). This trend is in line with the projections made by the IPCC (1998) and 1PCC (2000).

b. Rainfall

Rainfall follows the same pattern as temperature. Rain in Vanuatu is brought by the South Pacific Convergence Zone or Belt. In the South Pacific, the belt begins from the Solomon Islands and stretch to East of the Cook Islands (Fig. 3). Warm temperature warms up the ocean surface, causing the warn current (air) to rise and join the Convergence belt. In the wet season (December – March), this belt moves southward and gets bigger as warm air from the ocean surface gradually joins it. It brings the rain with it as it moves southward.

Vanuatu also receives rain during the wet season when warm air masses hits large land mass (mountains). This is on the south eastern parts of landmasses. The same system also results in low rainfall on the northwest of the same landmass.



Source: http://www.cawcr.gov.au/projects/PCCSP

Figure 1 Average annual rainfalls over a 55 year period from 1950, in Vanuatu

c. Tropical cyclones

The convergence zone and it's warm air current also brings with it tropical cyclones as it moves southward. About 40 tropical cyclones are recorded in Vanuatu since 1972. Not all 40 cyclones hit Vanuatu. Most of these cyclones did come near the country. An average of 2-3 cyclones per season was recorded, although the number of per year varies between 0 and 6.

d. Sea level rise

Increased sea surface temperature is associated with a rise in sea level. The warming sea causes ice gaps in the south and north poles to melt, increasing the volume of the sea. The sea also expands as it warms up. Both actions raise the sea level. The IPCC (2000) projected an annual increased of more than 1 mm. Using simulation models; the IPCC scientists also estimated an increase of 20–30 cm by 2030 and 30–100 cm by the end of this century. In Vanuatu, the Department of Meteorology and Geo-hazards estimated an annual rise of 6 mm.

e. Drought

El Nino brings with it prolonged dry season resulting in drought. Whilst it would be difficult predicting droughts or its intensity, a predicted occurrence of El Nina is an indication that drought is eminent. Drought effects occur in the rain-shallow areas during the normal years (www.meto.gov.vu).

1.3.2 Projected Future Climate and natural disasters

"Utilizing the wealth of traditional knowledge on climate and natural disasters will improve seasonal forecasts and help Vanuatu's people better prepare for extreme events and climate variability. Vanuatu has set a regional precedent in this regard, bringing our tradition, custom and culture to the cutting edge of climate change adaptation." (http://www.nab.vu). The Director of the Department of Meteorology and Geo-Hazards (DMGH) made this statement at the closing of the 'Vanuatu's National Climate Change Summit in 2012.

Projected climate and weather information would help prepare farmers regulate impacts of climate change. Equipped with advanced knowledge on projected occurrence, intensity and duration of rain, drought, cyclone, flood or tsunamis would help farmers develop annual production calendars.

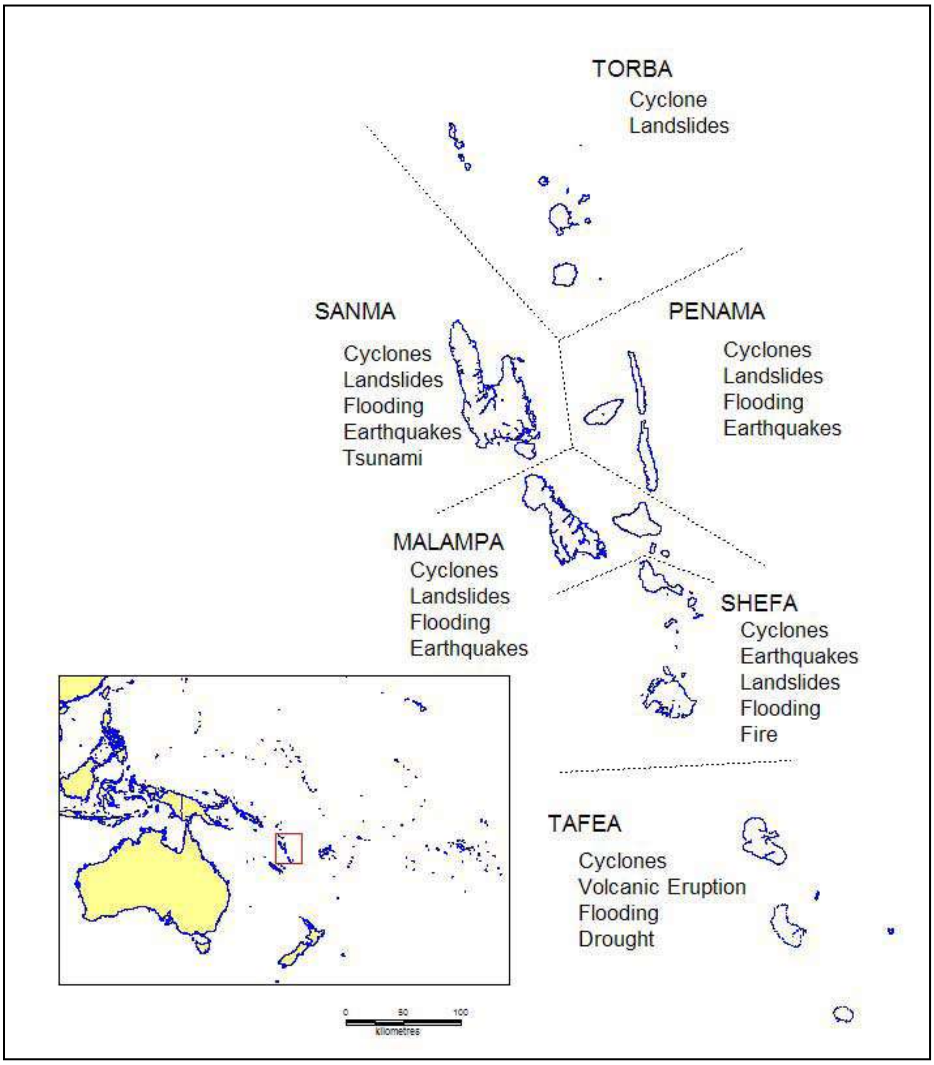
Tropical cyclone coincides with the hot or wet season. The Vanuatu cyclone season is from November through April the following year. According to the DMGH, Vanuatu geographically lies on the route that is occasionally transverse by winds of at least 34 Km/hr (www.meto.gov.vu). January and February have the greatest frequency of cyclones with an average per cyclone season of 2-3 (www.meto.gov.vu).

Flooding is associated with tropical cyclones and La Nina years. Farmers can use information on predicted occurrence of tropical cyclones and La Nina years to produce effective farming programs. This information is made available via a variety of media by the DMGH.

Projected intensification of climate changes would see a continual increased in sea level. The rate of rise from 1994 to 2008 was 3.4 +/-0.4 mm/yr. The projected rise by the end of this century is 7–82 cm (Fig. 8).

1.3 Natural disasters

Figure 2 is a map of Vanuatu. It shows the location of each of the 6 provinces and where impacts of climate change and natural disasters are prominent. The figure shows that Sanma and Shefa are prone to as many 5 types of natural disasters, including cyclone, landslide, flood, earthquake and tsunami. Torba is only prone to cyclone and landslide. Penama and Malampa are each prone is cyclone, landslide, flood and earthquakes. Tafea is prone to cyclone, volcanic eruption, flooding and drought. The common natural disaster is cyclone. This figure does not quantify the magnitude of each type of natural disaster in each province.



Source: Project Document

Figure 2 Location and map of Vanuatu showing distribution of natural disasters

CHAPTER 2:
METHODOLOGY

The Terms of References (TOR) outlined eight (8) principal tasks. The tasks were designed to contribute to output 3.1 of the UNFAO-UNICEF-UNDP project on 'Community resilience and coping with climate change and natural disasters in Vanuatu, 2011 – 2013'. Output 3.1 seeks to increase food production and availability. This study was carried out on four (4) selected study sites. The sites were:

1. Marae and Finonga (Emae, Shefa);
2. Blacksand (Shefa);
3. Imaio (Tanna, Tafea); and
4. Aniwa (Tafea)

2.1 Map of Vanuatu showing selected project communities

The location of the study sites are depicted in Figure 3. The sites were Marae and Finonga on Emae, Blacksand on Efate, Imaio on Tanna and Aniwa.

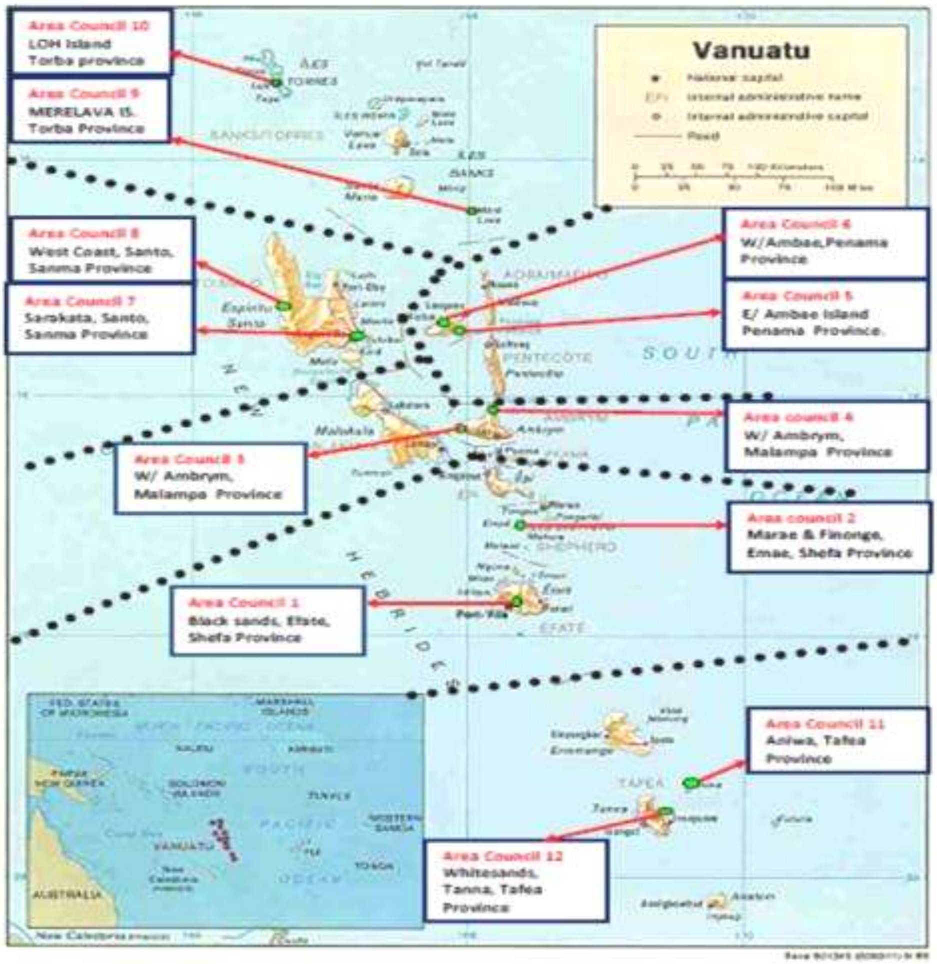


Figure 3 Vanuatu map showing location of the study sites

There were two (2) phases involved in this study. There are outlined below.

Phase 1 consisted of:

1. Identifying crop varieties, farming systems and practices resilient to climate change and major/potential sources of climate resilient crop varieties throughout Vanuatu;
2. Interviewing leading farmers and community authorities;
3. Observing farming systems and practices used;
4. Identifying major root crops and vegetables grown;
5. Identifying and verifying major problems of food production and dietary behaviours;

Phase 2 consisted of:

1. Linking the observations and information collected in Phase 1 to climate change and other natural disasters occurring in the locality;
2. Recommending crop varieties resilient to effects of climate change and other natural disasters; and
3. Recommending suitable farming systems and practices [or climate smart practices] to address limitations of the existing farming systems and practices to address effects of climate change and other natural disasters;

Tools used in this study included, a desk review of literatures made available by the Department of Agriculture and Rural Development (DARD). Literature materials were also sourced from the Department of Meteorology and Geo-Hazards, SPC/GIZ Coping with Climate Change in the Pacific Region (CCCPIR), Vanuatu Agriculture, Research and Training Centre (VARTC), Department of Forestry, Food Technology Section of the Department of Trades and Industry and Department of Livestock. Literature materials were also sourced from the internet.

A visit to the VARTC provided information on past and present studies on root crops and other cash crops in Vanuatu. The visit also included discussions with the Former Director of VARTC, Ms. Mari Melteras.

A further tool used is interview. Both government and NGO personnel knowledgeable in the field of climate change and agriculture were interviewed. A list of persons interviewed is provided in Annex 1.

A last tool employed in this study is field observation. Observations were made on farming systems and practices, crops grown, food production problems, dietary problems and resilient crop varieties and farming systems and practices practiced in each of the study sites.

CHAPTER 3:

CROPS AND THEIR VARIETIES OF SIGNIFICANCE TO THE VANUATU SOCIETY

3.1 Introduction

Chapter three looks at crops and varieties of significance to the Vanuatu society. There are a large number of crops and varieties being cultivated throughout the Vanuatu Islands. However, it is not possible to consider all in this document. Only a handful is selected for this project. Selection is based on socio-economic importance as well as cultural importance and traditional value. The crops and varieties are discussed under four sections including root crops, vegetables, legumes and nuts and seeds. A brief discussion on botanical description, nutritive value, [traditional uses], ecology and agronomy of each crop and variety are also provided.

3.2 Root crops

3.2.1 *Manihot Esculenta* (Manioc)

a. Taxonomy and names of species

Kingdom: Plantae
Order: Malpighiales
Family: Euphorbiaseae
Subfamily: Crotonoideae
Tribe: Manihoteae
Genus: Manihit
Species: M. esculenta
Bionmial name: Manihot esculenta crant

Box 1: Common names

English:Manioc

Bislama:Manioc

Banks(Gauva):Manioc

West Coast Santo:

West Ambae: Manioc

West Ambrym: Maiok

North Ambrym: Meyemer

b. Botanical description

The species ***Manihot esculenta*** comes from the genus Manihot and is native to Southern United States, through Mesoamerica, Northern and South America, and through Brazil, Peru, Bolivia, Paraguay and Argentina (Hershey and Debouck, 2010). It is a perennial crop but commonly used as an annual crop. Depending on the variety, manioc can grow as tall as 10-15 meters. In Vanuatu, the 'sweet' cultivar grows to a height of 2-4 meters. The roots grow just below the ground and may penetrate to a depth of 50-100 centimetres. Depending on the concentration of cyanogenic glucoside in the roots, they are called 'sweet' or 'bitter'. Those containing less than 100 mg per 1000 g of fresh weight are called 'sweet' and those with more 100 g are called 'bitter' (Dufour1988)

c. Roots

The manioc has fibrous roots growing out from the stem. Some of these fibrous root bulk out to form tuberous roots- starch storage organ. Most of the roots continue to function to absorb nutrients. All varieties have cyanogenic glocusides. Both roots and leaves have cyanogenic glucosides. High concentration of cyanide can be lethal to animals and human beings. Lethal dose of HCN for 30 kg adult human is estimated at 0.5 and 3.5 mg/kg of body weight and that for 60 kg adult human is 210 mg (Tewe and Lyayi 1989). Various techniques are available for removing cyanide (Lancaster et al, 1982). Grating, pressing and/or cooking the roots are common techniques used by farmers.

Plate 1 Young manioc plant

d. Nutritive value of manioc

The nutritive value of manioc according to Dignan et al. (1994) is shown in Tables 2 and 3 below. The tables (2 &3) also provide the nutritive value of different processed forms of manioc.

Table 2 Major nutrient composition of cassava in different processed forms (baked, boiled, flour and raw)

Starchy Stables	Measure (g)	Water (g)	Dry Matter (g)	Energy (KJ)	Protein (g)	Total Fat (g)	CHO Avail. (g)	Dietary Fibre (g)	Cholesterol (mg)	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)
Cassava, baked	100	59	41	659	1.4	0.3	38	1.3	0	7	365	32	35
Cassava, boiled	100	65	35	542	0.5	0.2	32	1.5	0	7	289	20	28
Cassava, flour	100	9	91	1430	1.1	0.5	85	3.7	0	4	738	84	74
Cassava, raw	100	63	37	542	0.5	0.2	32	1.5	0	7	302	20	30

Table 3 Vitamins and minerals composition of cassava in different processed forms (baked, boiled, flour and raw)

Starchy Stables	Measure (g)	Water (g)	Dry Matter (g)	Iron Fe (Mg)	Zinc Zn (Mg)	Tot. Vit. A equiv (µg)	Retinol (µg)	β-carotene equiv. (µg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vit. B12	Vit. C	Vit. E
Cassava, baked	100	59	41	2.2	-	T	0	2	0.11	0.05	1	0	53	T
Cassava, boiled	100	65	35	0.2	0.5	T	0	2	0.04	0.02	T	0	18.6	T
Cassava, flour	100	9	91	1	-	T	0	T	0.02	0.03	1	0	0	-
Cassava, raw	100	63	37	0.2	0.5	T	0	2	0.06	0.02	1	0	14.9	T

e. Uses

The starch tubers are used for human and animal consumption. It is a good source energy, an average source of minerals and vitamins and poor source of protein (Tables 2 & 3). The leaves are also consumed by human beings and animals, although, it is not widely used in Vanuatu. The leave has considerable quantity of vitamin C and iron. Other vitamins and minerals are present in moderate to trace amounts (Table 3).

Box 2: Manioc

Use: Staple

Grown in: All islands of Vanuatu

Can be grown in: All Islands of Vanuatu

Suitability to cope with adverse climate effects:

Water requirements: high, medium**, low**

Salt tolerance: high, medium, **low**

Wind tolerance: high, **medium,** low

f. Ecology

The optimal temperature requirement of the manioc is between 25 – 30^{o}C. The manioc plant can tolerate temperatures as low as 12^{o}C and as high as 40^{o}C. It requires an optimal rainfall range of 1000 – 2000 mm. It grows under annual rainfall range of 1000 mm to 3000 mm and can tolerate low rainfalls if [rainfall] is well distributed. The crop tolerates drought, is waterlogged tolerance, and also tolerates shade. Its soil fertility requirement is low. It grows best on light, sandy loams, or loamy sands which are fertile, moist and deep. Manioc grows well on low fertile soils with a wide range texture from sand to clay.

g. Agronomy

Propagation

The manioc is propagated from its stems. There are no buds on the roots therefore cannot be used as planting materials. The Department of Agriculture and Rural Development (DARD) has multiplication plots throughout the provincial centres serving as distribution centres for planting materials of recommended varieties. According to the staffs of the DARD at the Santo Station, there are sufficient planting materials for farmers throughout the nation wanting it.

Crop husbandry

The manioc plant is known in some parts of the world as the 'poor man's crop'. This is because it does not need high fertile soil to grow and produce good tubers. The plant is capable of growing and producing in sub-optimal soil conditions and fertility. Depending on the cultivar, the planting space may range from 1m x 1m to 2m x 2m. Soil preparation for planting include loosening of the soil with a gardening spade, fork or crow-bar and the planting stakes are pushed into the loosen soil. Alternatively stakes can be planting on mounds. Weeding is a necessity in the early days of following planting. Left unattended the weeds would likely smothered the crops. Planting can be done all year round. However, a better growth and tuber formation is attained when planted in the wet season.

Diseases and pests

Globally there is a large number of pests and diseases of manioc reported. These include;

-cassava mosaic disease (CMD) in Africa,

-cassava brown streak disease (CBSD) in India

-bacterial blight caused by *Xanthomonas axonopodis* pv. *Manihotis* in Asia, Africa and Latin America, and

-brown leaf spot caused by *Cercospora henningsii*

In Vanuatu 18 anthropod and fungi diseases are identified as pests for manioc. The anthropods identified are ***Bemisa tabaci, Feresia virgata, Paasissetia nigra***, and ***Tetreanychus neocaledonicus***. Fungal diseases identified are ***Ascochyta sp, Dendryphyiella vinosa, Mycosphaerella henningsii, Periconia manihiticola, Periconia shyamala*** and ***Schizonphyllum commune***.

Although the above anthropod and fungal diseases are identified in Vanuatu, there are of no significant risk to the manioc plant. Insecticides and fungicides, like other farm chemicals are not encouraged in Vanuatu. However, they can be obtained from the Agriculture Supplies or Paradise Agriculture Supplies. Advice must be sought from the Department of Agriculture and Rural Development prior to using them.

Harvest and handling

Depending on the cultivars, the tubers can last up to 3 years in the ground. Typically the postharvest storage life is quite short. Tubers without injuries can last up to a week. Those sustaining injuries during harvest might last for up to 3-4 days. The manioc can be harvested throughout the year. However, depending on the cultivar, it can reach maturity between 2 months and less than 1 year. Left in the ground the starch content increases to a certain point then lignifications takes over, causing it to become woody and hard to prepare for consumption. Two days after harvesting the tubers commerce deteriorating as a result of enzymatic activities. Harvesting in Vanuatu is done manually. At harvest the branches are topped off at 40-60 centimetres above ground. The length is used as a handle when pulling the crop out of the ground.

h. Production, multiplication and distribution of cultivars

There are numerous varieties of manioc found in Vanuatu. Not all varieties are documented. It is safe to say that these varieties differ in their response to climate change. Two major varieties of M. esculenta are produced by the VARTC and multiplied and distributed by the DARD. The M.esculenta. Var. 3 manis is the cultivar recommended by the DARD. There are two types of this cultivar, the white and yellow. Tari Molisale observed that manioc does well under drought and cyclone. Its dwarf status, being of a height of no more than 2 m tall makes it suitable for cyclones. Cyclones tend to uproot tall plants but not those of a lower status. Currently there are sufficient planting materials of these two varieties to supply farmers throughout the archipelago. According to Molisale, demand for these varieties is increasing. This means that more planting materials must be multiplied.

Plate 2 Photo showing mature manioc crops

Plate 3 Photos showing tubers of some varieties of manioc at the DARD

3.2.2 *Impomea botatas* (Kumala)

a. Taxonomy and names of species

Plate 4 Kumala crop at the DARD

***Box 3*: Common Names**

English: Sweet Potato

Bislama:Kumala

Banks(Gauva):Putek

West Coast Santo:

West Ambae: Kumala

West Ambrym: Waso

b. Common names

c. Common cultivars (varieties) in Vanuatu

Kumala is the seventh most important crop in the world after wheat, rice, maize, Irish potato, barley and manioc. It is a native of tropical America. There are many varieties of sweet potato. They vary in many morphological traits. The varieties vary in, type of leaf lobe, number of leaf lobe, shape of central leaf lobe, mature leaf size, mature leaf colour, petiole pigmentation, petiole length and flesh colour.

Common varieties of kumala in Vanuatu are pictorial illustrated below.

Plate 5 Selected hybrid varieties of kumala now being tested in Vanuatu

Plate 6 (a) Baby kumala and (b) Solomon Kumala

d. Botanical description

Belonging the family Convolvulaceae, kumala is a dicotyledonous plant. It is a herbaceous perenniual vine **with** leaves. The leaves are either heart-shaped or palmately lobed. The under ground rubbers are the main starch storage organs. They are soft and vary in colour, with orange, pale and yellow. The kumala cultivars differ in vine tip, pubescence, type of leaf lobes, and number of leaf lobes, mature leaf colour and flesh colour (Fongod et al., 2012).

e. Roots

The plant has fibrous roots growing out of the stem just below the ground. Some of the fibrous roots enlarge to become starchy storage organs. Most other retains their function of nutrient absorption. The edible tubers form clutches at the end of the stem. Adventitious roots also grow out of the vines at the internodes. These roots act as the plant's anchor. In some cultivars, fibrous roots at the vines bulk out to form tubers.

Box 4: Kumala (19 local and 1 exotic variety currently being tested at the VARTC)

Use: Staple

Grown in: Santoi,A & B Islands

Can be grown in: X, Y,Z Islands

Suitability to cope with adverse climate effects:

Water requirements: high, **medium** , low

Salt tolerance: high, **medium**, low

Wind tolerance: high, **medium**, low

f. Nutritive value of kumala

The nutritive value of kumala according to Dignan et al. (1994) is shown in Table 4 and 5 below. Tables 4 & 5 also provide the nutritive value of different processed forms of kumala.

Table 4 Major nutrient composition of sweet potato in different processed forms (boiled and raw)

Starchy Stables	Measure (g)	Water (g)	Dry Matter (g)	Energy (KJ)	Protein (g)	Total Fat (g)	CHO Avail. (g)	Dietary Fibre (g)	Cholesterol (mg)	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)
Sweet potato, orange, peeled, boiled	100	79	21	269	1.9	0.1	14	2.3	0	10	225	26	13
Sweet potato, pale, raw	100	72	28	451	1	0.3	26	1.3	0	3	260	21	26
Sweet potato, white flesh, boiled	100	77	23	313	1.4	0.1	17	2	0	12	182	13	13
Sweet potato, yellow, raw	100	71	29	479	1.2	0.3	27	1.3	0	45	412	36	20

Table 5 Vitamins and mineral composition of sweet potato in different processed forms (boiled and raw)

Starchy Stables	Measure (g)	Water (g)	Dry Matter (g)	Iron Fe (Mg)	Zinc Zn (Mg)	Tot. Vit. A equiv (µg)	Retinol (µg)	β-carotene equiv. (µg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vit. B12	Vit. C	Vit. E
Sweet potato, orange, peeled, boiled	100	79	21	0.5	0.5	960	0	5760	0.02	0.05	1	0	23	4T
Sweet potato, pale, raw	100	72	28	0.9	-	11	0	66	0.14	0.05	1	0	21	5
Sweet potato, white flesh, boiled	100	77	23	0.5	0.4	3	0	17	0.04	0.03	2	0	40	8
Sweet potato, yellow, raw	100	71	29	0.9	-	730	0	4380	0.12	0.05	1	0	30	5

g. Uses

Kumala tubers are consumed by both human beings and animals. The tubers being starch storage organs are excellent source of energy but poor in protein (Table 4). The kumala has moderate to race amounts of vitamins and minerals. Some cultivars are a good source of vitamin A and β-caroteine, but lacks vitamin B12 (Table 5).

h. Ecology

According to Horinor et al. (2007) kumala grows in a wide range of environmental conditions. Bioethics (2004) described its habitat as being marginal areas with poor soil fertility with low moisture. It grows best with average ambient temperature of 24^{o}C. It needs abundant sunlight and warm nights. The plant has an annual rainfall requirement of 750 – 1000 mm with a minimum of 500 mm in the growing season. It is sensitive to drought at tuber initiation stage (50-60 days) after planting. It does not tolerate waterlogging. Excess water in the soil and poor aeration causes root rot; reduce growth of storage roots (Ahn, 1993). Kumala grows well on a variety of soils: well drained, light and medium texture soils with pH range of 4.5 – 7.0.

i. Agronomy

Propagation

Kumala is propagated from the vines and tubers. The vines are mostly used. Tubers can be planted as planning materials because they have buds.

Crop husbandry

Kumala is commonly planted on mounds or ridges. Depending on the culture, land is cleared as a primary forest or it is planted as a second crop on yam gardens. Mounds are created at a spacing of 1 m x 1m. Vines are collected and allowed to dehydrate to allow the leaves to fall off. This may take up to 1 week. The vines are pushed into the mounds and covered. Most cultures plant the kumala crop during the wet season. Weeding is critical before the vines cover the ground.

Diseases and pests

Up to 17 pests and diseases of kumala are found in Vanuatu. The organisms include anthropods, fungi and nematodes. The anthropods identified are ***Agrius convolvuli, Bemisia tabaci, Dialeurora sp*** and ***Euscepes postfasciatus.*** The fungal diseases present in Vanuatu are ***Anthelia rolfsii, Cercopora sp, Elsinoe batatas, Glomerella cingulata, Monilochaetes infuscans*** and ***Pseudocercospora timorensis***. The three (3) nematodes found in Vanuatu are ***Aphelenchus avenae, Helicotylenchus dihystera*** and ***Rotylenchulus reiformis.***

Harvest and handling

Maturity time of kumala ranges between cultivars. It ranges from 2-9 months. Harvesting is done manually. The hands are used to scrap out the mounds to expose the tubers. In heavy soils, a knife or spade is used. Knives and spades are rarely used. When used, extreme care is taken because the tubers are very close to the ground surface. Tubers without injuries can last up to 7 days. Those with injuries; rot after 2-3 days.

h. Production, multiplication and distribution of cultivars

Impomea botatas is growth throughout the Vanuatu islands. It is grown both on the atoll and high volcanic islands. There are two cultivars recommended by the DARD. They are the PNG kumala and baby kumala. Distinction between the two being that the baby kumala has orange flesh and the PNG kumala being white flesh. A number of hybrids are still being studied at the VARTC. Another observation made is that kumala cultivars are specific to islands. That those performing well; both growth and production on one particular island do not perform as well on other islands. It seems that those performing well on some islands would not produce that much well developed tubers on others. Tuber formation seems to differ geographically. There is need to investigate geographical effect on the introduced varieties. However all cultivars distributed showed good adaptation to impacts of climate change.

Plate 7 a-f: Plate showing some varieties of kumala currently being trialled out at DARD, Tagabe

3.1.3 Aroids

The aroids are a subfamily of the family araceae. There are four root crops of the subfamily aroids in Vanuatu. Three of these are commonly used for human consumption. They are ***Colocasia eculenta***, ***Xanthosomia sagittifolium*** and ***Alocasia microrrhiza***. ***Crtysperma chyamissions,*** although used commonly in other Pacific Island countries is rarely consumed in Vanuatu. This makes it a potential root crop that needs exploration.

Colocasia esculenta (taro) and Xanthosoma sagittifolium (taro Fiji)

Both ***C.esculenta*** and ***X.sagittifolium*** do not have a specific growing season. This means they grow around the year in Vanuatu. There are 4 types of ***C.esculenta***, including dry land, mud and wetland. Since 2011 about 4,000 suckers of ***C.esculenta*** has being distributed nationwide. The cultivars distributed are drought resistance. They can resist drought for up to 3 months. The average drought season across Vanuatu is about 1 month. A 3 months drought is on the far extreme. Distribution of both ***C.esculenta*** and ***X.sagittifolium*** is throughout the nation. Cultivars distributed include;

1. Malaysia x Vanuatu hybrid,
2. Malaysia,
3. Indonesia, and
4. Indonesia x Malaysia hybrid.

Box 5: Common names

English:Taro Fiji

Bislama: Taro Fiji

Banks(Gauva):KwetTavit

West Coast Santo:

West Ambae: Taro Viti

West Ambrym: WebierAnvi

North Ambrym: Ober

Alocasia microrrhizos (Navia)

Alocasia micorrhizoma is only consumed by certain cultures in Vanuatu. The plant grows throughout the archipelago. One culture that consumes the ***A.microrrhizos*** is Ambae. An attempt to introduce it on Tanna is met with some resistance (Molisale, 2012). Navia is one of the root crops advocated by the DARD as a crop capable of withstanding the impacts of

Plate 8 Island taro

Plate 9 Taro Fiji

climate change. The DARD attributed its thick leaves and height of not more than 2 m tall as physiological and morphological characteristics making it able to adapt to drought and withstand tropical cyclones. Observation made by the DARD showed that ***A.microrrhizos*** can withstand droughts lasting up to three months**.** ***A.microrrhizos*** is also observed to do well in flooded areas. This might be due to its above ground stem. The giant taro has most of its stem above ground. This morphological character might also be responsible for it not being affected by Papuan beetle. Papuan beetle feeds on underground corm. Its ability to understand tropical cyclones, do well in drought and resist Papuan beetle makes ***A.microrrhizos*** a candidate for food security programme in Vanuatu.

Plate 10 a-d: Taro Crops

a. Taxonomy and names of species

b. Common names

c. Botanical description

Aroids are mostly herbaceous monocotyledonous plants with tuberous roots. The edible tuberous starchy roots are called corms and sometimes rhizomes. The taro is monoceous but some flowers may be hermaphrodite. This means some flowers have both the male and male female parts. Taro grows to height of 1-4 m. ***C. esculenta*** stands at 1-2 meters tall. ***A. microrrhiza*** is about 3-4 meters ***C. sagittifolium*** stands at 2 meters or more tall.

Kingdom: Plantae
Order: Aalismales
Family: Araceae
Subfamily: Aroideae
Tribe: Colocasieae
Genus: Colocasia
Species: C. esculenta (L) schott
Binomial name: Impomea botatas (L) Lam
Trinomial name: Colocasia esculenta esculenta

Plate 11 Taro Fiji plant

d Roots

Most edible cultivars have underground starch storage organs which are enlargements of the stem (***C.esculenta***) called corm or with attachments to the corm called cormels (***X. sagittifolium***). The corm of ***A.microrrhiza*** and ***C.chyamissions*** extends above the ground. The taro has a root system known as superficial and fibrous, radiating primarily from the junction between the corm and petioles.

Box 6: Common names

English: GiantTaro

Bislama: Navia

Banks(Gauva):Navia

West Coast Santo:

West Ambae: Navia

West Ambrym: Navia

North Ambrym: Linovi

e Nutritive value of taro

The nutritive value of edible aroids according to Dignan et al. (1994) is shown in Table 6 and 7 below. The tables (6 & 7) also provide the nutritive value of different processed forms of edible aroids.

Table 6 Major nutrient composition of common aroids

Starchy Stables	Measure (g)	Water (g)	Energy (KJ)	Protein (g)	Total Fat (g)	CHO Avail. (g)	Dietary Fibre (g)	Cholesterol (mg)	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)
Taro, Chinese, raw	100	67	492	1.6	0.1	28	1	0	7	530	9	27
Taro, common, baked	100	64	564	1.2	0.1	33	1.2	0	2	421	48	115
Taro, common, red, boiled	100	72	429	0.9	0.4	24	1	0	1	264	37	114
Taro, common, white, baked	100	60	620	1.4	0.2	36	2.5	0	2	421	54	115
Taro, common, white, boiled	100	75	407	0.9	0.6	22	0.8	0	1	264	34	114
Taro, common, yellow, boiled	100	67	518	0.7	0.4	30	1	0	1	264	44	114
Taro, giant, swamp, baked	100	73	334	0.6	0.2	19	3	0	78	73	198	23
Taro, giant, swamp, boiled	100	78	281	0.5	0.2	16	2.5	0	65	61	165	19
Taro, giant, swamp, raw	100	75	308	0.5	0.2	18	2.8	0	72	67	182	21
Taro, giant, boiled	100	73	375	2	0.1	21	1.7	0	27	243	35	47
Taro, giant, raw	100	70	412	2.2	0.1	23	1.9	0	30	267	38	52
Taro, giant, baked	100	68	448	2.3	0.1	25	2	0	33	290	41	52

Table 7 Vitamins and mineral composition of common aroids in different processed forms (boiled and raw)

Starchy Stables	Measure (g)	Water (g)	Dry Matter (g)	Iron Fe (Mg)	Zinc Zn (Mg)	Tot. Vit. A equiv (µg)	Retinol (µg)	β-carotene equiv. (µg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vit. B12	Vit. C	Vit. E
Taro, Chinese, raw	100	67	33	1	-	13	0	78	0.21	0.05	2	0	13.6	3
Taro, common, baked	100	64	36	1.4	-	11	0	65	0.19	0.06	1	0	11	2
Taro, common, red, boiled	100	72	28	1.1	-	6	0	38	0.09	0.03	1	0	6	2
Taro, common, white, baked	100	60	40	1.6	-	7	0	42	0.13	0.04	1	0	8	3
Taro, common, white, boiled	100	75	25	1	-	6	0	38	0.08	0.03	1	0	5	2
Taro, common, yellow, boiled	100	67	33	1.3	-	6	0	38	0.11	0.03	1	0	7	3
Taro, giant,	100	73	27	0.7	2.3	5	0	33	0.02	0.02	T	0	8.3	2

swamp, baked														
Taro, giant, swamp, boiled	100	78	22	0.6	1.9	5	0	27	0.02	0.01	T	0	7.9	2
Taro, giant, swamp, raw	100	75	25	0.6	2.1	5	0	30	0.03	0.02	T	0	15.7	2
Taro, giant, boiled	100	73	27	0.8	1.5	0	0	0	0.01	0.01	T	0	8.5	2
Taro, giant, raw	100	70	30	0.8	1.6	0	0	0	0.02	0.02	T	0	17	2
Taro, giant, baked	100	68	32	0.9	1.7	0	0	0	0.02	0.02	T	0	9.2	3

f Uses

Edible aroids are used for human and animal consumption. The corm and cormel are rich in energy but poor in proteins. They have moderate amount of potassium but are low in other minerals. The corms of the ***C.esculenta***, ***A. macrorrhiza*** and ***C.chyamissions*** are boiled, baked, roasted and made into laplap or pudding. The corms are also made into chips. The cormel of the ***X. sagittifolium*** has similar uses. The young leaves of the ***C.esculenta*** are also edible. In Vietnam the leaves) of the ***X. sagittifolium*** are used in pig diet as protein replacements for commercially important ingredients like soybean. This makes it a potential animal feed resource in Vanuatu where it is currently not used.

Box 7: Common names

English:Island Taro

Bislama: Island Taro

Banks(Gauva):Kwet Nepetua

West Coast Santo:

West Ambae: Kweta

West Ambrym: Webier Ten

North Ambrym: OberTen

Efate:

g Ecology

Colocasia esculenta var. esculenta: two cultivars of ***C.esculenta***, the dry-land and wet-land cultivars. The dry-land cultivar grows best after rainy season. It requires an annual rainfall of 2500 mm or more. The dry-land cultivar grows well on heavy wet soil and does poorly on dry loose soil. A fertile soil with adequate amount of humus is preferred. The plant requires an average temperature of 21^{o}C for normal production. Yield is poor at high altitudes. In PNG, an altitude of 2,700 m is said to be the maximum elevation. Formation of corm is affected by daylight; promoted by short-days while flowering is initiated by long-day conditions. The most preferable soil pH range is 5.6-6.5.

Xanthosoma sagittifolium: The tannin or taro Fiji is described as a crop of tropical rainforest. It prefers high rainfall with soils with a good amount of moisture. ***X. sagittifolium*** tolerates light shade but will die under heavy shade. ***Alocasia macrorrhiza:*** The giant taro is common throughout the Pacific Islands and the tropics. The crop is common in the Polynesian countries. The giant taro prefers some shade but can tolerate full shade. It grows well in moist, well drained soil. It does well with organic fertilizer.

h Agronomy

Propagation

The giant taro is commonly propagated from its suckers. Offsets growing off the upright stem or rhizome are also used. The stem is also cut into mini-setts and used as propagation materials.

Crop husbandry

The crop can be planted as a sole crop or in a mixed cropping system. It is important to adjust recommended plant spacing when intercropping with giant taro. The leaves of the giant taro expand to cover a wide area when matured. This plant is said to have the largest leave, with a stalk of more than 10 cm and leaf width of up to 2 m.

Diseases and pests

Vanuatu has a number of varieties of taro. However the Pacific disease database has a list of pests and diseases of only the ***C. esculenta*** and ***A. macrorrhizos***. For ***C. esculenta***, 26 pests and diseases are recorded. The anthropods recorded include ***Bemisia leakii, Bemisia tabaci, cocus longulus, Dysmicocus brevipes, Meloidogyne sp, Papuana inermis, Spodopetra litura, Tarophagus proserpina*** and ***Tetranychus marianae***. Fungal diseases recorded are ***Cladosporium colocasiae, Cladosporum oxysporum, Leptosphaeruina chartarum, Neojohnstonia colocasiaem Phoma sp, Phyllosticta colocasiae, Pseudocercospora colocasiae*** and ***Scolecobasidium sp***. Nematodes recorded are ***Helicotylenchus erythrinae, Helicotylenchus mucronatus*** and ***Meloidogyne sp***. The viral diseases of ***C. esculenta*** recorded are ***Oryzavirus Taro reovirus and Potyvirus Taro vein virus.***

Up to 13 pests organisms of ***A. macrorrhizos*** are records. These include fungus and nematodes. The fungi recorded are ***Glomerella cingulata, Mycosphaerella alocasia, Pseudocercospora alocasiicola*** and ***Schizothyrium sp.***

Harvest and handling

Aroids are annual crops. Harvesting in Vanuatu is done manually. The C.esculenta and x. s***agittifolium*** takes up to a year while the ***A. macrorrhizos*** and ***C.chyamissions*** may take more than a year to reach biological maturity. Tools employed in harvesting include spades, stakes or knives. Irrespective of the tool used, carry must be taken during harvesting. Injuries and bruises incurred during harvesting drastically cuts down on the shelf-life. Shelf-life for x. s***agittifolium*** can be prolonged by burying the tubers in the ground. That of *c. esculenta,* ***A. macrorrhizos*** can be prolonged by storing in a dry and properly ventilated room ***C.chyamissions***

3.1.4 Dioscoreas species (yam)

Although the name yam is also used in some parts of the world, including the Americas to include sweet potatos ***(I.botatas)***, Purseglove (1972) restricted the name to only the Dioscorea species. As such I will also confine the term yam, to include this genus only. The genera Dioscorea contain about 600 species (Purseglove, 1972). The edible species of the Dioscorea species common in Vanuatu are the ***D. alata***, ***D. rotundata***, ***D. trifida, D. esculenta, D. cyenensis*** and ***D. nummularia***. The ***D. alata*** originates from Asia, ***D. rotundata*** is from West Africa and ***D. trifida*** comes from tropical America. ***D. cyenensis*** is native of West Africa. ***D. nummularia*** is believed to have originated from southeast Asia. Other species found in Vanuatu and other Pacific countries are D***. bulbeifera*** , ***D. pentaphylla*** and ***D. hispida***.

a. Taxonomy and name of species

Kingdom: Plantae
Family: Euphorbiaceae
Subfamily: Crotonoideae
Tribe: Dioscoreaceae
Genus: Dioscorea
Species: D. alata, D. rotundata, D. trifida, D. esculenta, D. nummularia, D. bulbeifera, D. pentaphylla and D. hispida

Binomial name: Dioscorea alata, Dioscorea rotundata, Dioscorea trifida, Dioscorea esculenta, Dioscorea nummularia, Dioscorea bulbeifera, Dioscorea pentaphylla and *Dioscorea hispida*.

Box 8: Common names

English: Yam

Bislama:Yami

Banks(Gauva):Natam

West Coast Santo:

West Ambae: Tam

West Ambrym: Dom

North Ambrym: Rem

Efate:

Tanna:

b. Botanical description

The yam is a monocotyledonous plant with unground tubers. The tubers are basically starch storage organs. It is an annual plant. Shoots grow out from the tuber during the growing season (wet season) and the tuber dies out and a new tuber or tubers are formed. The plant is dormant during the dry season. Purseglove (1972) suggested that there are over 600 species of yams known. In Vanuatu, about 6 edible species are found with 4 of these being more common than the others. The species are differentiated by the direction in which their vines climb up stakes (right or left). Other guides include presence or absence of spines, aerial tubers and shape of the leaf.

c. Roots, tubers and bulbils

The yam has thick roots that radiate out from the stem (end of the tuber). The roots thinned and branched as they radiate from the stem. The tubers vary in shape, size and form. The following is a summary of the description provided in Purseglove (1972).

D.alata and D.rotundata: Yams of these species mostly occur as single tubers with the occasional 2-3 tubers per stem. The tubers may be globular, enlongated, flattened or branched or lobed.

D.esculenta and D.trifida: These species produce clusters of small tubers attached to the base of the stem. Bulbils are produced on the axils of the leaves of some species.

D.bulbifera: This species of yam produce bulbils or aerial tubers attached to the leave axils. Bulbils are the main starch storage organs in this species. ***D.bulbifera*** is not common in Vanuatu: although it can be found in some cultures.

D.nummularia: Unlike other species of dioscorea, the ***D.nummularia*** takes up to 2-3 years to harvest. The tubers are splinter shaped and grow deep in the soil. Properly maintained, the crop can be harvested annually for up to 8 years. Clusters of tubers are attached to a stem. The stems are spiny at the base. In some cultivars the whole vine is spiny.

D.cyenensis: Purseglove (1972) described the flesh as being pale yellowish in colour. The tubers come in various sizes and forms depending on the cultivar. Tubers of ***D.cyenensis*** have short dormancy and shelf-life. Although it can be harvested in 6 months, it can take up to 1 year to reach full maturity where the dry season is short.

Box 9: Common names

English: Wild Yam

Bislama:Wild Yami

Banks(Gauva):Kwue

West Coast Santo:

West Ambae:

Mouri/Net/Morda

West Ambrym:

North Ambrym: Rem Fir

Efate:

Tanna:

d. Nutritive value

The nutritive value of dioscorea species common in Vanuatu according to Dignan et al. (1994) is shown in Table 8 and 9 below. The tables (8 & 9) also provide the nutritive value of different processed forms of the dioscorea species.

Table 8 Major nutrient composition of common species of the yam

Starchy Stables	Measure (g)	Water (g)	Energy (KJ)	Protein (g)	Total Fat (g)	CHO Avail. (g)	Dietary Fibre (g)	Cholesterol (mg)	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium(mg)
D. trifida, raw	100	81	265	1.5	T	14	1	0	3	350	8	15
Greater yam, raw	100	77	332	2.2	0.1	18	1.9	0	3	318	8	17
Greater yam, baked	100	60	645	3	0	36	0.5	0	6	590	18	19
D.rotundata, raw	100	66	531	1.4	0.1	31	0.6	0	5	361	5	17
Yam, composite, baked	100	72	410	2.5	0.1	22	1.8	0	4	365	9	25
Yam. Composite, boiled	100	77	338	2	0.1	18	1.5	0	3	271	7	20

Table 9 Vitamins and minerals composition of common species of the yam

Starchy Stables	Measure (g)	Water (g)	Dry Matter (g)	Iron Fe (Mg)	Zinc Zn (Mg)	Tot. Vit. A equiv (µg)	Retinol (µg)	β-carotene equiv. (µg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vit. B12	Vit. C	Vit. E
D. trifida, raw	100	81	19	0.5	-	18	0	105	0.08	0.03	1	0	21	3
Greater yam, raw	100	77	23	0.6	0.4	18	0	108	0.05	0.03	T	0	27.6	4
Greater yam, baked	100	60	40	1.2	-	19	0	116	0.12	0.04	1	0	8	5
D.rotundata, raw	100	66	34	0.6	0.2	80	0	482	0.08	0.03	1	0	21	6
Yam, composite, baked	100	72	38	0.8	0.5	19	0	116	0.05	0.03	T	0	22.5	5
Yam. Composite, boiled	100	77	23	0.6	0.4	15	0	90	0.04	0.03	T	0	17.4	4

e. Uses

The yam is a good source of carbohydrate but poor in protein and dietary fibre (Table 8). It is has sufficient quantity of minerals, including sodium, calcium, potassium and magnesium (Table 8). The tuber is low in micro-nutrients (Table 9). The yam is perhaps the most important socio-economic food crop in Vanuatu. It plays a major role in the cultural and traditional functions of the Vanuatu society. Cooking methods include boiling, frying, roosting, baking and made into laplap. In Africa, where the yam originates, it is milled into flour. This potential exists in Vanuatu.

f. Ecology

Purseglove provides a comprehensive description of the ecology of the yam. Below is a condensed version. Readers and farmers must keep in mind that the yam is not native to Vanuatu. This is why it is important to understand the ecological conditions of their origin and ensure that, that of Vanuatu are manipulated to match it.

The yam requires an optimum growing temperature of 25-30^{o}C. It does not grow well at temperatures below 20 ^{o}C. It does not grow well in froze. The yam is a tropical root crop and it grows during the wet season and goes dormant in the dry season. The leaves fall off and the vine dries up. In the growing season, the tubers dies and new tuber(s) are formed. The yam requires about 1000 mm of rainfall annually. Higher amount of rainfall per year is preferred.

g. Agronomy

Propagation

The yam is produced vegetatively from stem cuttings or small tubers. The Department of Agriculture and Rural Development (DARD) advocates the planting of mini-sets as a means of multiplying planting materials. Experiences showed that setts taking from the top of the tuber spouts more quickly and produce higher yields.

Crop husbandry

Cultivation in Vanuatu is smallholder oriented, based on subsistence and shifting cultivation. Land clearing, land preparation and planting is done manually. The yam does best in fresh forested land. Yield is reduced if grown as a second phase crop.

Preparation of land

Fresh forested land is cleared and the vegetation is burnt. In some cultures, the whole garden plot is tilted manually with hand hoes prior to planting. In others, planting holes are dug without tilting the whole garden plot.

Planting

The yam is either planted in rows in completely clearly garden plots or around the stems of trees left standing in the garden. Farmers use one of the two principal systems of planting yams in Vanuatu. In some cultures, holes are drug to a depth of 30-50 cm and the setts/tubers placed in. Loose soil particles are gathered to form mounds over the planted setts/tubers. Alternatively, mounds are built to a height of 30-50 cm and yam setts/tubers are pushed into the mound.

Maintenance

Critical period is from 14 – 20 weeks after planting. Food reserves in the setts/tubers are almost completed. The shoots are growing very rapidly and just before new tubers are formed. Tendering of the vines is important. Vine breakages are often lethal during this stage of growth. Weeding throughout the growing phase is important. Left unattended the weeds would draw nutrients away from the yam crop. Weeding is done manually with a bush-knife. The vines must be staked to prevent sun scoring. Staking also ensures ease of vine trailing.

Planting calendar

The yam is planted at the end of the dry season. Spouting takes place during the wet season. Early planting starts in July. Latest planting is in December. Most farmers carry out planting in the September-October period.

Harvesting and handling

The harvest period is limited. It usually lasted from Match through May. The tubers can be stored for several months if no injuries are incurred during harvesting and storage conditions are adequate. Storage techniques include laying the tubers on raised beds in storage sheds or the open. Adequate ventilation is important. Injured tubers can be kept by cold storage below 10^{o}C. In Africa, the yam is stored by turning it into flour.

Diseases and pests

The Secretariat of the Pacific Community (SPC) website on diseases and pests of the Pacific recorded 8 different diseases of yams in Vanuatu. These include yam scale, anthrocose, banana root nematode, Mycosphaerellales and tylenchina. Anthracnose is the most common. It is a fungal
disease that is easily spread by rain and is more profound in the wet season.

h. Production, multiplication and distribution of cultivars

There are 2 types of yams in Vanuatu; the strong and soft yam. The soft yams found in Vanuatu are ***Dioscorea alata*** (soft yam), ***Dioscorea esculenta*** (sarsau) and ***Dioscorea pentaphylla*** (five-fingered yam, pirita, lena, hipo). The strong or hard yams are ***Dioscorea nummlaria*** (Pacific yam, hard yam, strong yam, puria), ***Dioscorea rotundata*** (white yam, African yam, Martinique yam, six-month yam) and ***Dioscorea trifida*** (African yam). Observations by the DARD indicate 2 local cultivars to be resistance to Anthracnose. The two cultivars are of the species ***D.alata*** and are found on Malo. Although they are also found on other islands they are commonly known as the Malo yams. The 2 yams are known in the Malo language as Daekarai red and Daekarai white.

Plate 12 a-f: Tubers of same yam varieties

3.2 Selected legumes

Legumes are dual purpose plants. They are described by some authors as a cheap-source of protein. Legumes are also used by farmers to replenish the soil. Legumes come in 3 forms; tree legumes, creeping legumes and short plants. There are a number of legume plants existing in Vanuatu. For the purpose of this document I will confine myself to a selected few. I will concentrate on those most commonly used and/or available to farmers throughout Vanuatu.

3.2.1 Family Fabaceae

This family include the genus ***Vigna***, ***Phaseolus, Pisum, Dolicos, Arachis, Cajanus and Psophocarpus.*** Work is confined to the edible species of the above listed genus.

a. Taxonomy and Names of Species

Kingdom: Plantae
Order: Fabales
Family: Fabaceae
Subfamily: Faboideae
Genus: Vigna, Phaseolus, Pisum, Dolicos, Arachis, Cajanus and Psophocarpus

b. Botanical description

Table 10 Brief botanical description of common legumes

Scientific name	Common names	Description
Vigna sinensis, V. unguiculata	Cowpea, black eyed pea. Mable pea	2 types. The climbing and dwarf varieties. The plant has 3-lobed leaves and twining seeds.
Vigna sesquipedalis	Long bean, snake bean, aspaparagus, yardlong bean	They are climbing plants with 3-lobed leaves.
Phaseolus vulgaris	French aricot, kidney or string bean	There are 2 types: the dwarf bushy variety and climbing type.
Phaseolus mungo	Mung bean, black	It is a trailing plant. The creeping plant has green stem with yellow to pale yellow flowers. The seeds are green and black and come in various shapes.
Phaseolus	Mung bean, green	The plant can either be erect or spread out. It has large 3-lobed leaves, yellow flowers and hairy

aureus		pods.
Pisum sativum	Green pea	A creeping plant. It has round green seeds. The pods are also edible.
Dolicos spp. Lalab niger	Lalab bean	Plant is short and twining. It has pale yellow pods, white flowers and seeds.
Archis pypogaea	Peanut	The peanut is a small plant that grows low. Its bears pods underground.
Cajanus cajan	Pigeon pea	The pigeon pea is a shrub that can grow up to 2-4 m high. It has light yellow – red seeds.
Psophocarpus tetragonolobus	Winged bean	A perennial plant: its beans are described as been 4 angled with winds. The flowers are white.

c. Nutritional properties of species

Table 11 Macro- nutrient composition of selected legumes

Legumes	Measure (g)	Water (g)	Energy (KJ)	Protein (g)	Total Fat (g)	CHO Avail. (g)	Dietary Fibre (g)	Cholesterol (mg)	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)	Iodine (mg)
Beans, broad, boiled	100	76	169	6.9	0.5	2	4.2	0	4	225	16	29	
Beans, green, boiled	100	92	69	1.5	0.2	2	2.8	0	3	80	30	17	
Bean, snake, boiled	100	90	94	3.3	0.3	2	3.8	0	1	135	22	25	

Table 12 Micro-nutrient composition of selected legumes

Legumes	Measure (g)	Water (g)	Dry matter)	Iron Fe (Mg)	Zinc Zn (Mg)	Tot. Vit. A equiv (µg)	Retinol (µg)	β-carotene equiv. (µg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vit. B12	Vit. C	Vit. E
Beans, broad, boiled	100	76		1.8	1.1	31	0	185	0.17	0.32	2	0	29	1
Beans, green, boiled	100	92		1.1	0.8	77	0	460	0.03	0.07	T	0	13	T
Bean, snake, boiled	100	90		0.5	0.4	72	0	430	0.03	0.1	1	0	22	-

d. Uses

Legumes are not widely grown by communities in the pilot study sites. However, the genus and species listed about are available in Vanuatu. They are available at the DARD and some commercial outlets including the Agriculture Supplies Store. Legumes are a potential food source for parts of Vanuatu prone to climate change and other natural disasters. Their function as cheap-body-building food and source of vitamins, minerals and fibre makes them an ideal crop and food source. Below are a summary of their uses, (potential uses) and some simple methods of preparing them (Leaflet No. 16, 1991).

Table 13 Brief description of food value, uses and preparation of selected legumes

Scientific name	Common names	Food value, uses and preparation
Vigna sinensis, V. unguiculata	Cowpea, black eyed pea. Mable pea	The cowpea is a good source of protein. The young nods can be used a vegetables and in salads. Matured seeds can be cooked and eaten as vegetables or added to soups and stews.
Vigna sesquipedalis	Long bean, snake bean, aspaparagus, yardlong bean	The pods can be steamed or boiled and eaten as a vegetable. It is a good source of protein.
Phaseolus vulgaris	French aricot, kidney or string bean	Both mature and immature pods are edible. Immature pods can be used in salads. Maturer pods can be steamed and eaten as vegetable. Dried seeds are cooked and eaten as a vegetable or added to soups and

		stews.
Phaseolus mungo	Mung bean, black	Immature pods are used a vegetables.
Phaseolus aureus	Mung bean, green	Immature pods are used a vegetables.
Pisum sativum	Green pea	Mature pods are shelled and cooked. Immature pods are eaten fresh. Cowpea is a good source of protein and fibre.
Dolicos spp. Lalab niger	Lalab bean	Young pods are eaten as vegetables. Mature ones are soaked in water and dried. It is a good source of protein and fibre.
Archis pypogaea	Peanut	Excellent snack for kids. It is a very good source of protein and B vitamins. The peanut can be roasted and eaten as a snack or eaten raw.
Cajanus cajan	Pigeon pea	The young peas are eaten as vegetables. It is a good source of protein.
Psophocarpus tetragonolobus	Winged bean	The pods can be eaten at all stages of maturity. Dried seeds are soaked in water, boiled, then roosted or curried.

Modified from Leaflet No.16(1991)

e. Ecology

Legumes grow on most soil types. They are grown on poor soil to improve them. However some varieties like the cowpeas need deep, rich soil with enough moisture. Some, like the wing bean can grow well under dry conditions. The beans of the family Fabaceae grows in the warm tropics. These make them suitable for Vanuatu. They grow best in temperatures between 16 and 30 ^{o}C. They grow best in the wet season, from November through to March. With sufficient water and watering they can be grown in the dry season. The beans are regularly picked to encourage new flowers. Flowering will slow down if beans are let to get too large on the plants. The peanut requires an annual rainfall of 500 – 1000 mm, It grows best in acidic soil, preferring a pH of 5 – 9.7.

f. Agronomy

Propagation

The family Fabaceae are propagated from seeds.

Crop husbandry

Beans of the genus ***Vigna***, ***Phaseolus, Pisum, Dolicos, Arachis, Cajanus and Psophocarpus*** can be grown in rotation or intercropped with non-legume crops. If planted as part of the crop rotation practice, the land must first be cleared of the previous crop. The vegetation is either burnt or allowed to decompose in the field. Holes are dug to a depth of approximately 3 times the diameter of the seed and planted. Plants are spaced at about 5 – 15 cm apart. Optimal planting time is the wet season. Planting can also be done in the dry season. But continuous watering is necessary to maintain the crop. Mulching can also assist to conserve soil moisture during the dry season. Weeds are also suppressed by mulching. Hand weeding is necessary where there is no mulching.

Diseases and pests

The SPC in its website on diseases and pests of the Pacific recorded the following pest organisms as occurring in Vanuatu. Those of the ***Phaseolus*** species are cotton aphid, ***Mycosphaerelales, Pleosporeales***, pea pod borer and pea pod leafroller. The pest organisms of the ***A.hypogaea*** are ***Tylenchida***, neck rot, ***Polyporales***, pineapple mealybug, ***Dothideales***, root knot nematodes, ***cercospora*** leaf spot of groundnut, late leaf spot of groundnut, peanut rust and reinform nematode.

Harvest and handling

Harvesting of the genus ***Phaseolus*** is in 7 – 10 weeks. The pods of the genus Vigna forms 60 days after sowing. The peanut pods take 120 – 150 days after the seeds are planted to ripen. Aflatoxin, a toxin produced by the fungus ***Aspergillus flavus*** can inflect peanuts if not stored properly.

g. Production, multiplication and distribution of cultivars

Except for distributing ***Dolihos lablab*** and ***Mucuna pruriens*** as fallow crops, the DARD and VARTC are not involved with the distribution of the Fabaceae species. Distribution of the Fabaceae species is left to the seed distributing commercial agencies like the Agricultural Supplies and Agriculture Paradise Supplies. A number of Chinese Retail Outlets in both towns (Port Vila and Luganville) also trade seeds of the Fabaceae species. ***Dolihos lablab*** and ***Mucuna pruriens*** are multiplied and distributed by the DARD. There is sufficient supply of the seeds of both creeping legumes at the DARD. Seeds are collected annually and distributed to interested farmers.

3.3 Fruit

Fruits are a very important source of vitamins, particularly vitamins A, B and C. Some common fruits found throughout the archipelago are citrus, pawpaw, mango and nuts and seeds. Except for a few fruit tree plantations planted mostly on Efate, most fruits currently sold at the 2 urban municipal markets are collected from wild trees. Furthermore, those trees currently supplying the 2 markets and subsistence uses throughout the nation are old trees. However, the DARD has existing programmes to plant new plantations and replant old trees nearing the end of their productive period.

3.3.1 Citrus

a. Taxonomy and names of specie

b. Common names

c. Botanical description

Table 14 A botanical descriptions of common species of citrus.

Common names	Scientific name	Description
Lime		The plant is smaller than lemon. It is also less sour than lemon. The fruits are round and green to yellow in colour.
Sweet Orange	***C x sinensis***	A hybrid of citrus and sinensis, this species is sweet. It is widely grown in the tropical and subtropical climates. Grows well in acidic soils, pH ranging from 2.0 – 4.0.
Grapefruit	***Citrus x paradisi***	A subtropical citrus tree, it can grow up to 5-6 meters tall. The leaves are dark green, long and thin. The flesh varies in colour depending on the variety. It may be white, pink or red.
Lemon	***Citrus x limon***	The tree is may grow to a height of 3-5 meters high. It has sharp thorns on the twigs. The fruit is oval and most varieties have light-yellow peels.
Mandarine	***Citrus reticulata***	The trees may grow up to 7.5 meters tall. It usually has spines, making it thorny. The fruit is bright orange or red-orange when ripe.

d. Uses

There is a wide range of uses of the citrus. Common is it's use as beverage. The peelings of some species, including the lime are used in salad recipes. The citrus also has medial uses. The seeds are a good source of protein, vitamins and minerals.

e. Ecology

Sweet Orange:

The orange plant grows well in places with environmental temperatures ranging from 15.5 to 29^{o}C. The plant needs a lot of sun light and water to grow and produce fruits. The fruits are very sensitive to frost. Although frost is rare in Vanuatu, changes in climate may see occurrences of this event in the future.

Lime:

The lime grows all year round. Its fruits are smaller and not as sour as lemon. The lime grows on mesotrophic or mesoeutrophic soil (Radoglou et al., 2008). It needs fresh or soil which is moderately moist. It prefers soil high in calcium (Jaworski, 1995). It grows optimally on soil with pH 6.2-7.2.

Grapefruit:

The tree grows well in a warm subtropical climate. High humidity cause thinning of the peels. The plant grows on a wide range of soil types although it prefers a mild acidic soil. High salinity reduces water uptake by the root system resulting in reduced yield.

Plate 13 Grafted citrus at DARD Horticulture Nursery, Tagabe

Lemon:

The lemon grows well in soils rich in nutrients. It prefers medium to heavy textured soil. It does well in acidic soil. It grows in subtropical areas.

Mandarin:

The plant grows well at elevation of 370 – 1,500 meters above sea level.
Temperature required ranges from 10 to 35^{o}C. It prefers sandy loan soil with a pH range of 4.5 – 9.0.

f. Agronomy

Propagation

Table 15 Propagation materials of common species of citrus

Citrus crop	Propagation
Sweet orange	Can be grown directly from seeds and asexually propagated by grafting
Lime	Propagated from both its seeds and asexually by grafting.
Grapefruit	Can be propagated from both seeds and vegetatively by grafting.
Lemon	Are grown from seeds and vegetatively by grafting. Some varieties are seedless.
Mandarin	Chiefly propagated from seeds. Current trend is towards vegetative methods, T-budding.

Crop husbandry

Citrus industry is a relatively new industry. In the subsistence sector, the plants are rarely planted. Recently, enterprising farmers are setting up plantation types farms, particularly on Efate.

Land preparation and planting

Land preparation for all citrus trees is similar. The soil must be tilted to allow free drainage of water if grown on heavy and soil draining soils. The roots of the citrus are shallow therefore they do not need deep soils. Mulching is advised to allow roots to grow.

Maintenance

Watering of the young plants is important. The dry soil immediately around the plant must be watered to avoid dehydration during the dry season. Critical period is the first 2 years. Pruning is necessary to keep the plant healthy. Dry branches can serve as entry for pathogenic organisms.

Diseases and pests

Up to 13 pests organisms of the lime are identified in Vanuatu (http://pld.spc.int/pld). They are pink wax scale, drown soft, Helotiales, Tylenchina, palm scale, Seychelles scale, purple scale, tropical grey chaff scale, Parlatoria conerea, renifrom, soursop aphid and citrus snow scale. The phytophthora disease is a concern on Aniwa.

Harvest and handling

Harvesting in Vanuatu is done manually. The fruits are handpicked in both the subsistence and commercial sectors. Injuries during picking are avoided to keep fruits from rotting.

g. Production, multiplication and distribution of cultivars

The DARD has an on-going breeding, multiplication and distribution programme for high value fruit trees including the citrus species. The citrus programme involves making available varieties resistant to certain exotic diseases. Current emphasis is on developing varieties resistance to the Phytophthora diseases of the citrus species. This soil-borne disease favours moist soil and environmental conditions resulting from long periods of rainy season. The DARD grafts and distributes the fruit tree seedlings throughout the archipelago.

3.4 Nuts and seeds

There are a variety of nuts and seeds available in Vanuatu that good sources of protein, energy and B-vitamins. The nuts come from trees like coconut and pandanus. Some common seeds are those of pawpaw, pumpkin and watermelon.

a. Botanical description

Table 16 Botanical descriptions of crop trees from which edible nuts and seeds originate.

Common names	Scientific name	Description
Breadfruit seeds	***Artocarpus edulis***	The breadfruit tree is large and grows up to 20 meters high. Not all varieties contain edible seeds. Some varieties are seedless.
Coconut	***Cocos nucifora***	The coconut is described as tall palm trees with long trunks and crown of leaves. The nuts, which may weight up 1.5 kg grow on stalks which emerge from inside the base of the leaves.
Pandanas nut	***Pandanus tectorius***	The pandanus is a spiky-leaved tree. It comes from the family of palm trees. Pandanus commonly grows on atolls.
Pawpaw seeds	***Carica papaya***	The fruits of the pawpaw grow on short stalks at the base of the leaves. The seeds are contained in the fruit. The tree is an erect tall tree with large green leaves.
Peanut	***Arachis hypogaea***	The peanut is a low-growing small plant with underground pods. The seeds are contained in the pods.
Pumpkin seeds	***Cucurbita species***	The pumpkin is a creeping herd that spreads on the ground surface or climb over dead logs. The seeds are contained in the pumpkin fruits. They are flat oval shaped.
Watermelon seeds	***Citrullus vulgaris***	The seeds are flat and pear-shaped. They are contained in the flesh of the watermelon. The watermelon is a vine that spreads on the ground or climb dead logs.

** Modified from Food technology in Australia, Volume 34(10) October 1982.*

b. Properties of the species

Table 17 Major nutrient composition of edible nuts and seeds

Nuts and seeds	Measure (g)	Water (g)	Energy (KJ)	Protein (g)	Total Fat (g)	CHO Avail. (g)	Dietary Fibre (g)	Cholesterol (mg)	Sodium (mg)	Potassium(mg)	Calcium (mg)	Magnesium(mg)
Breadfruit seeds, roasted	100	50	766	6.2	2.7	34	3.7	0	28	1080	86	62
Melon seeds, coat removed	100	6	2420	25.8	49.7	8	6.7	0	99	-	53	510
Pandanus nut, kernel, dried	100	6	2130	11.7	43.8	19	13	0	289	-	12	192
Pandanus nut, kernel, raw	100	25	1550	15	30	11	46	0	229	-	10	154
Pandanus nut, kernel, roasted	100	68	785	4.1	16.3	7	3.7	0	-	-	4	206
Peanut, kernel & skin, raw	100	5	2310	24.7	47.1	9	8.2	0	1	540	55	160
Pumpkin, seeds, raw	100	4	2320	29.4	40.4	20	5.4	0	18	820	39	270
watermelon, seeds, dried	100	5	2340	22.7	41.2	26	4.2	0	36	606	82	813

Table 18 Micro-nutrient composition of edible nuts and seeds

Nuts and seeds	Measure (g)	Water (g)	Dry Matter (g)	Iron Fe (Mg)	Zinc Zn (Mg)	Tot. Vit. A equiv	Retinol (µg)	β-carotene equiv.(µg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vit. B12	Vit. C	Vit. E
Breadfruit seeds, roasted	100			0.9	1	0	0	0	0.41	0.24	7	0	7.6	-
Melon seeds, coat removed	100			7.4	4	T	0	T	0.1	0.12	1	0	T	-
Pandanus nut, kernel, dried	100			T	2.9	63	0	379	0.48	0.13	5	0	0	6
Pandanus nut, kernel, raw	100			T	2.4	50	0	302	0.38	0.1	4	0	0	1
Pandanus nut, kernel, roasted	100			T	4.2	21	0	103	0.16	0.04	2	0	0	T

Peanut, kernel & skin, raw	100			2.3	3	1	0	4	0.79	0.1	15	0	0	10
Pumpkin, seeds, raw	100			10	6.6	38	0	230	0.23	0.32	2	0	0	20
watermelon, seeds, dried	100			7.7	7	2	0	9	0.22	0.1	3	0	T	17

c. Uses

Table 19 Uses of edible nuts and seeds

Common names	Scientific name	Food value, preparation and uses
Breadfruit seeds	Artocarpus edulis	Very good source of energy, protein and vitamin B_1. Calcium and iron also present. The seeds can be roosted or boiled.
Coconut	Cocos nucifora	The meat can be eaten raw or roosted. Cream squeezed from grated meat can be used in cooking. The meat is a very good source of energy, protein and B-vitamins. Also a good source of calcium and iron. It is also a good source of fibre.
Pandanas nut	Pandanus tectorius	A very good source of energy, protein and B-vitamins. Also adequate in calcium and iron. The nuts can be eaten raw, roasted, cooked or smoked.
Pawpaw seeds	Carica papaya	The seeds contain a good supply of energy. In the form of oil and fat. The fresh seeds can be chopped or mashed and used in salad mixtures. It is a good source of vitamin A and C.
Peanut	Arachis hypogaea	A very good source of protein and vitamins (B). It is rich in oils and fats. Calcium and iron are also present in adequate amounts. The nuts are eaten raw or roasted. They are also used in soups and stews.
Pumpkin seeds	Cucurbita species	The seeds can be cooked, deep-fried and used in soups. A good source of energy, protein and B-vitamins.
Watermelon seeds	Citrullus vulgaris	The seeds contain oils, protein, vitamins and minerals. They are eaten raw. They can be grounded and added to desserts and cakes.

d. Ecology

Nuts and seeds are not plants. They are products of plants. Despite this, a short description of the ecology of the plants from which the selected nuts and seeds are obtained will be provided. A brief overview of the ecological requirement of these nuts and seeds are provided in Table 20.

Table 20 Ecological overview of crop trees from which selected edible nuts and seeds comes from.

Name of plants from which selected nuts and seeds originate	A brief overview of their ecology	Propagating material(s)
Breadfruit	The breadfruit grows well in a variety of soils, including sandy soil. This makes it possible for it to grow on atoll islands or along the coastal lines. It tolerates different climates, but not high winds. Insufficient rainfall can cause the trees to die because of loss of leaves.	Propagated from seeds of ripe fruits and suckers or young shoots
Coconut	The coconut tree prefers abundant sunlight. A regular rainfall of 1500 – 2500mm per year is required for optimal growth and production. The crop grows well on sandy soil and tolerates salinity. The coconut plant needs warm climate and does not tolerate cold. Optimal growth is achieved at an annual mean temperature of 27^{o}C. It tolerates seasonal variation where mean temperature is between 28 and 37^{o}C.	Seeds
Pandanus	The plant is a native of islands throughout the Pacific. It grows along the coastlines. The pandanus grows at elevations as high as 600 meters above sea level. It grows on a wide range of soil, from light to heavy soil.	Seeds
Pawpaw	The pawpaw is a tropical plant that does not tolerate frost. The plant grows in a variety of soils and tolerates salinity.	Seeds
Peanut	Optimal growth is obtained in light sandy loam soil. The plant responds well to an annual rainfall of 500 – 1000 mm. An acidic soil (5.9 – 7) is suitable for growth.	Seeds
Pumpkin	The pumpkin plant grows all year round. It grows on all Pacific islands, including atolls. The vine grows on a variety of soils including sandy soils. It tolerates salinity. It does well in loose rich soil.	Seeds or cuttings

	Old rubbish damping sites are good for pumpkins to grow.	
Watermelon	The watermelon is a creeping plant, described in some botany literature as a vine-like plant or scrambler or trailer. The creeper grows well at an altitude of 1500m. It grows best in lowlands. It needs high temperatures and relatively low rainfall. During the growing season the plant needs a minimum of between 600 and 400 mm of rain. It prefers sandy loan soils.	Seeds

e. Production, multiplication and distribution of cultivars

Seeds of pumpkin and watermelon are widely available in retail outlets in Port Vila and Luganiville. The seeds of the two crops are also accessible from retail outlets in most islands. Coconut seedlings are accessible from the VARTC. The Research Station has an on-going programme that breeds and multiplies improved coconut seedlings. DARD assist is making the seedlings available to interested farmers throughout the nation. Both the VARTC and DARD current have not breeding, multiplying and distributing programme for breadfruit and pawpaw.

CHAPTER 4:
SUSTAINABLE FARMING SYSTEMS AND PRACTICES

4.1 Introduction

In this chapter I will discuss the farming systems available in Vanuatu and are capable of helping crop plants and animals counter the effects of climate change and natural disasters. Discussions will be grouped under two main headings. Farming systems introduced by the DARD with assistance from regional organisations like IRETA, FAO and SPC and those regarded as traditional.

4.2 Improved crop varieties and farming systems

There are 2 primary ways of empowering the crop plant to tolerate the effects of climate change and natural disasters. The first strategy is to breed or introduce novel varieties with physiological and morphological traits that allow them to outperform their wild relatives. The second strategy is to manipulate the farming systems. Observations made by DARD showed that some traditional farming systems respond well to climate change. The DARD is also evaluating other systems advocated by regional institutions like the Institute for Research, Extension and Training in Agriculture (IRETA), Food and Agriculture Organisation (FAO) and the Secretariat of the Pacific Community (SPC).

4.3 Vanuatu Research and Training Centre

The Vanuatu Research and Training Centre (VARTC) is mandated with developing and evaluating new varieties of crops in the country. According to Ms. Marie Melteras, Director of the Research Centre, the institution aims to provide improved planting materials to farmers [throughout Vanuatu]. The Centre has over 50 year's worth of research data on crop plants including yam, taro, kumala, manioc, banana and breadfruit. In collaboration with other research stations, both in the region and globally and organisations like FAO, SPC, National Agriculture and Research Institution (NARI) and International Network of Edible Aroids (INEA), the VARTC aims to improve the quality of food crops in terms of nutrient composition, palatability, traditional value, consumption demand and tolerance to impacts of climate change.

4.4 Climate resilient varieties

The VARTC has over its 50 years life span investigated a range of crops ranging from root crops to tree crops. Included in their priorities are yam, taro, kumala, manioc, banana, breadfruit and coconut. Whereas previous studies were given the primary aim of improving crop plants' ability to tolerate impacts of climate change, current studies are geared toward improving nutrient composition, palatability and traditional value. Plates 14-22 show some crop varieties with the aforementioned traits currently being encouraged in Vanuatu.

Plate 14 A hybrid of taro Fiji

Plate 15 A hybrid of manioc planted on a farm on Ambae

Plate 16 Hybrids of kumala planted under alley cropping system on Santo

Plate 17 Wild yam is a resilient crop. This species of strong yam tolerates drought as well as prolonged wet season. It also grows well in a wide range of soil fertility and conditions

Plate 18 Commercial citrus grafted onto wild relatives of lemon for fungal diseases resistance in DARD, Port Villa

Plate 19 Alocasia macrorrhizos


Plate 20 Local banana variety planted on the volcanic plains of Imaio observed to tolerate volcanic ash


Plate 21 Extension planting materials at the Agriculture Multiplication Plot on Santo

Plate 22 Distribution of introduced planting materials of yam

4.5 Introduced farming systems

Oneil Dalesa, Farming System Officer of the DARD noted that the DARD is currently evaluating the effectiveness of some farming systems. These farming systems have the principal aim of (i) enriching the soil, (ii) conserving moisture, (iii) reducing soil erosion, and (iv) serving as ground cover. Closer analysis of these systems indicated that the issues addressed are actually effects of climate. For example effects of climate change on the soil and plant include, soil erosion (prolonged and heavy rainstorm), loss of soil nutrients (run-offs due to prolonged and heavy rainstorm), conservation of soil moisture (drought and prolonged dry season), ground cover (addition of organic matter and conservation of soil moisture).

4.5.1 Agro-forestry

Agro-forestry combines agriculture and forestry. It is traditionally practiced in Vanuatu. Traditional agroforestry differs from the modern form in a number of ways. Traditionally, agro-forestry seeks to combine useful trees with crop plants. The modern system is an improvement from this form. It aims to make existing farms more productive, protects the soil from degradation and preserves resources, such as the forest. There are many combinations used in agro-forestry. It combines low strata

> ***Box 10: Agro-forestry system***
>
> ***Practiced in****: Sanma (Santo), Province/community.*
>
> ***Could be replicated in****: Other provinces, islands and communities in Vanuatu.*
>
> ***Suitable against****: Landslide, flood, drought, wind, soil nutrient leaching and soil erosion.*

crops like root crops, vegetables and legumes with tree crops. Often leguminous trees and shrubs like gliricidia, dundap and leucaena are used. Another combination is based on the rooting system and nutritional requirement. Crops grown in the systems, if properly selected interrelate and are interdependent on each other. Agro-forestry promotes efficient use of scare resources like land, soil nutrient and soil moisture. A properly designed and structured agro-forestry system also promotes cultural and biological control of pest organisms. The system draws from the interactive benefits of combining trees, shrubs with crops and/or animals. Agro-forestry systems: although many; can be grouped under to two main categories (i) spatial grouping and (ii) time sequence. The forms of agro-forestry available to farmers in Vanuatu are (i) alley cropping (ii) random mixture (iii) alternate rows and (iv) border mixture.

a. Alley cropping

For the last couple of years the DARD has being encouraging farmers throughout the country to adopt this system of cropping. The system involves growing strips of tree crops in a straight line with root crops, legumes or vegetables between the strips. Gliricidia is highly recommended by the DARD as the tree crop (Plate 23). The reasons for recommending gliricidia are,

i. It enriches the soil. Being a leguminous plant, gliricidia traps atmospheric nitrogen and converts it through nitrogen fixing bacteria in the root nodes into the form usable to plants.

ii. It serves as windbreakers during cyclones. The cyclone season in Vanuatu begins December and end April. It is an annual event. This makes annual crop plants like yams, taro, and giant taro and fruit trees susceptible to being uprooted or having their leaves and branches torn off. The cyclone upon hitting the windbreaker reduces its velocity and intensity before reaching the crop plants.

iii. The tap root system of the gliricidia also serves as soil stabilizer. The rooting system holds the soil particles together in crumbs and reduces their chances of being washed off by run-offs.

iv. The prunning serve two purposes. Firstly it is a good ground cover during dry season. Spread on the bare ground, the prunning prevent evaporation of water from the soil. When decomposed, the leaves and branches add organic matter to the soil.

v. Findings at the DARD research plots also showed that Alley cropping; in particular gliricidia prevents rose beetles from damaging crop plants.

Although Alley cropping with gliricidia has many agronomic advantages there is a downside to it. The tape rooting system helps water to infiltrate through the soil: in doing so carry soil nutrients and soil particles with it. Covering the ground with cover crops or mulching will reduce run offs, hence soil nutrient loss and erosion. Decomposed mulch also adds organic matter into the soil. Increased organic matter helps conserve soil moisture content.

Plate 23 Alley cropping system demonstration on Santo

Distribution

Alley cropping is being advocated throughout the country. There are two particular scenarios that warrens alley cropping. It is used where population pressure is high leading to shortage of farmland. Alley cropping is also used in parts of Vanuatu where soil fertility is a problem.

Ability of this system to respond to climate change and other natural disasters

> ***Box 11: Alley cropping***
>
> *Practiced in: Sanma (Santo), Penama (Pentecost, Ambae), Malampa (Malekula), Shefa (Eafte).*
>
> ***Could be replicated in****: Other provinces, islands and communities in Vanuatu.*
>
> ***Suitable against****: Landslide, flood, drought, wind, soil nutrient leaching and soil erosion.*

Prominent characteristics of this system make it suitable to combat certain effects of climate change and natural disasters. Tree crops and leguminous trees like gliricidia and dundap grown in strips serve as windbreakers during cyclones. The strips protect root crops and other crops from being uprooted or the leaves and branches torn. On slopes the rooting system of the strip crops protect soil particles from being washed away during heavy rainstorm. The rooting system can also minimize and prevent landslides. During the dry season the leaves of the tree crops or leguminous trees can provide shade and create a micro-climate within the system. Prunning from the tree crops can also conserve water during the dry period.

b Random mixture

Random mixture or random mixed is practiced widely in Vanuatu. It ensures farmers have all their necessary crops in one garden. There is no systematic arrangement of crop plants in both spatial and time sequence. Traditionally this system serves the principal purpose of providing food source and food types necessary for the farmer's subsistence requirements. An example of this system would include taro, manioc, island cabbage, pawpaw, citrus (orange, lemon, grapefruit or combination of all), and 1-2 coconut trees (Plate 24). Combination of crops used is indicative of the farmer's subsistence requirement and cultural obligations.

Box 12: Random mixture

***Practiced in**: Sanma (Santo), Shefa (Efate).*

***Could be replicated in**: Throughout Vanuatu.*

***Suitable against**: Landslide, flood, drought, wind, soil nutrient leaching, soil erosion, improve soil fertility, management pest organisms and increase food security.*

Plate 24 A random mixed agro-forestry system combining root crops with forestry

Ability of this system to respond to climate change and other natural disasters

Combination of different crop in this system increases food security. A mixture of crop plants means that the farmer is supplied with a wide range of crops throughout the year. Properly designed the farmer can be supplied with protein, vitamins and carbohydrate food sources. A mixture of crop types can also regulate impacts of climate change. Those responding well to long periods of wet season would outperform others during long spells of rain. Similarly: those capable of performing well in droughts. Trap plants can also be included in this system to serve as cultural control of common pest organisms.

4.5.2 Fallow improvement

The traditional system of farming crop plants in Vanuatu is the slash and burnt method. Briefly this method involves clearing of the under growth, followed by removal of the upper canopy trees either by cutting or ringbarking and burning when dried. This system is practiced in collaboration with the fallow system. Soil nutrients decreases during farming as crop plants use the nutrients for growth and production (Fig 1). Fallowing after a year's farming allows regeneration of the forest. Leaves and other debris from the forest decomposed to add organic matter and nutrients to the soil.

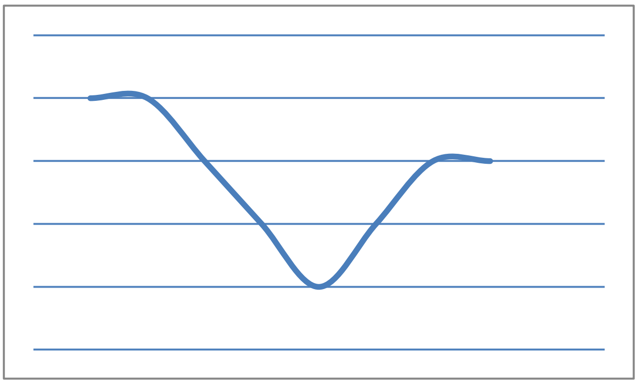


Figure 4: Decline in soil nutrient following gardening and fallow

Box 13: Fallow improvement

Practiced in*: Sanma (Santo); Shefa (Efate); Penama (Ambae, Pentecost).*

Could be replicated in*: Other provinces, islands and communities in Vanuatu.*

Suitable against*: Low soil fertility and condition, drought, wind, soil nutrient leaching and soil erosion.*

Fallowing require substantial amount of time to revamped the soil nutrient. Population pressure shortens the fallow years. The reduced fallow period fails to allow sufficient built up of soil nutrients; resulting in reduced growth and production.

The fallow improvement system [is developed to] address this issue. The system utilizes perennial leguminous plants. Dundap and gliricidia are recommended (Plate 25). Incorporating these plants into the system allows for fallow period to be reduced from the normal fallow duration needed by the traditional fallow system.

Plate 25 Dundap fallow plot

Distribution

Fallow Improved System (FIS) has been introduced throughout the country. Like the traditional fallow system, it is observed to improve soil fertility and soil organic matter in farmlands. Its adaptation and use seem to be population dependent. High population density islands use this system more than larger islands. This makes sense as large islands have a sparse population with access to large amount of land that can be fallowed using the traditional fallow system.

Ability of this system to respond to climate change and other natural disasters

Traditional fallow system requires at least 10 years returning the soil fertility and condition to its former state. This system works well where there is a lot of land and the population is low. Increased or high population density and accompanied land pressure means there is less land to cultivate. Consequently: lesser number of years to fallow the land. In the small islands of Vanuatu the fallow years has being halved. Coupled with climate change the impacts on the soil ecology and crop plants can be significant. Reducing the fallow period decreases the ability of the soil to provide sufficient nutrient elements, conserve water and provide organic matter for soil microorganisms and plants. Reducing the ability of the soil, soil microorganisms and crops plants to perform under impacts of climate change and other natural disasters. The fallow improved system can improve vitality of the soil over the reduced fallow period. This is possible because fallow crops like dundap, giliricidia and creeping legumes hasten the addition of organic matter and soil fertility and condition.

4.5.3 Cover crop

Another improved farming system encouraged by the DARD is known as the ground cover system (method). With ground cover, ***Mucuna prurians*** (Mucuna) (Plate 26) and ***Laplap purpureus*** (Dolichos laplap) are used to cover the soil surface during fallow period. Both are creeping leguminous plants. Although both crops improve soil nutrient and soil moisture, prevent weed emergences and hasten soil nutrient enrichment, farmers prefer ***M.prurians*** over ***L.purpureus***. ***M.prurians*** does not have adventitious roots along its vines making it easy to remove the entire crop at the end of the fallow period. ***L.purpureus*** on the other hand has adventitious roots that anchor the vines to the ground. This makes it difficult to uproot the plant at the end of fallow period. The ***M.prurians*** and ***L.purpureus*** are capable of reducing fallow period to one year or less. Both enriches the soil by (i) converting atmospheric nitrogen into a form that crop plants can use and (ii) release nutrients from their leaves and vines during decomposition.

Plate 26 M.prurians (Mucuna) used as cover crop

Distribution

The ***M.prurians*** is widely distributed in Vanuatu. Greater emphasis is for small densely populated islands requiring shorter fallow periods. Land shortage resulting from population pressure makes it necessary to reduce fallow period. Reducing the fallow period from 10-20 years to a mere 1 year is now a common occurrence. The traditional fallow system cannot be used in such situation. Fallow improved systems are ideal for this situation. Fallow improved system enables the soil to regenerate itself after only 1 year. In some cases it replenished itself in less than 1 year. ***M.prurians*** grows in a wide variety of soil and does best in open field. However it outperforms other crops in a mixture. Often it suffocates other plants in the mixture.

Ability of this system to respond to climate change and other natural disasters

The function of the cover crop as a ground covering mechanism during fallow protects the soil and soil microorganisms from elements of increased and prolong drought and/or wet season. It can also protect soil microorganisms from daily extreme fluctuations in temperature. Organic matter added creates a micro-climate that sustains and protects soil micro-biology from extreme temperatures. During dry season the added organic matter conserves soil moisture. During heavy rainstorms it reduces runoffs.

4.5.4 Vertiver grass

Plate 27 Vertiver grass is tested for its effectiveness in controlling soil erosion by the Department of Forest on a number of locations.

The Vertiver grass grows in bunches (Plate 27). The shoots grow from underground crown making the plant fire-resistant and able to grow in swamp land. The dense rooting system allows it to anchor itself firmly into the ground. This enables it to hold soil particles together reducing soil erosion. These characteristics make them suitable for controlling soil erosion on riverbanks, coastal and on slope lands. The DARD in collaboration with Department of Forest (DoF) are advocating this plant where soil erosion is problematic. Vertiver grass is also known of its mulching quality. The thick bunches makes thick mulching materials.

Box 15: Vetiver grass

***Practiced in**: Tafea (Anityum).*

***Could be replicated in**: Other provinces, islands and communities in Vanuatu.*

***Suitable against**: Soil erosion, low soil fertility and condition, drought, wind and soil nutrient leaching.*

Distribution

The Vertiver grass is being introduced by the DoF and DARD on some islands including Anityum and Efate. On Anityum it is planted on steep lands and coastal land to protect against coastal erosion. On Efate it is planted at the Tagabe Catchment Shed along the Tagabe river bank to protect the bank from being washed away during flooding.

Ability of this system to respond to climate change and other natural disasters

The dense rooting system makes Vertiver grass a suitable crop to protect river banks, coastal and slope lands. On river banks, the dense network of roots holds the soil particles together and makes the soil stable. This reduces soil erosion during flooding. On slopes or steep landforms, the vertiver also stabilizes the soil.

4.5.5 Green manure

Green manure is another strategy used by the DARD. Pruning of gliricidia, dundap, mucuna and other leguminous plants are laid as ground cover (Plate 28). The green leaves, branches and vines serve two functions. Firstly by covering the soil surface, they reduce evaporation. This act helps to conserve and maintain soil moisture. A slow and graduate decomposing leaves and debris provide a source of nutrient that slowing enrich and maintain the soil fertility over time.

Plate 28 Fresh pruning of gliricidia as green manure

Distribution

Green manure is widely advocated in Vanuatu. However its adaptation varies from island to island. It is used mostly where land pressure has risen as a result of population increased. Shortage of cultivated land and the need to reduce fallow period makes it necessary to use green manure.

Green manure

***Practiced in**: Sanma (Santo); Shefa (Efate).*

***Could be replicated in**: Other provinces, islands and communities in Vanuatu.*

***Suitable against**: Low soil fertility and condition and drought.*

Ability of this system to respond to climate change and other natural disasters

During the dry season the green manure can create micro-climate in the soil. This micro-climate can protect the soil micro-flora and fauna from the hush conditions associated with dry season as well as prolonged dry season. Inclusively it can prevent direct impacts of raindrops on the soil during heavy rainstorms. This prevents detachment of soil particles, leading to reduced/arrest of soil erosion and nutrient loss from runoffs.

4.5.6 Intercropping

Intercropping is when two or more crops are grown simultaneously on the same field such that the period of overlap is long enough to include the vegetative stage (Gomez and Gomez,

1983) (Plate 29). Crops are systematically selected in an intercropping system. Legumes like dwarf bean and maize produce interspecific root interactions that promotes yield and nitrogen and phosphorus uptake (Li et al., 1999; Li et al., 2003). Land equivalent ratio, N-fixation and phosphorus acquisition are greater where the legume and non-legume rooting systems intermingle (Li et al,. 2002; Ndakidemi, 2006). These parameters are reduced where the rooting systems are separated completely from each other (Li et al,. 2002; Ndakidemic, 2006).

Plate 29 A strip intercropping system combining Chinese cabbage with dwarf bean

Distribution

The DARD recommended intercropping throughout the archipelago. Reasons for its recommendation are stated above. This system is commonly practiced by semi-commercial farmers in the peripherals areas of Port Vila and Luganville. Market oriented farmers mostly used this system.

Ability of this system to respond to climate change and other natural disasters

Intercropping legumes with non legumes makes it possible to address some effects of climate change and natural disasters. Intercropping coleus plants with crop plants enable the system to tolerate pest organisms. Coleus plants attract insects away from crop plants. Particularly important where climate change causes re-emergence of dormant pests or pest outbreak.

> ***<u>Box 16: Intercropping</u>***
>
> ***Practiced in**: All provinces: Most islands and communities.*
>
> ***Could be replicated in**: Other islands and communities.*
>
> ***Suitable against**: Low soil fertility and condition, drought, wind, soil nutrient leaching, soil erosion and pests and diseases.*

4.5.7 Crop rotation

Crop rotation is when crops are growth successively on the same piece of land over a year or longer period of time. Crops chosen in the rotation are selected so that the soil is not negatively affected. Component crops are selected so that the entire exercise maintains or improves on the soil fertility and condition. Selection can be based on rooting systems, nutrient requirements, and ability to replenish soil fertility or provide some natural preventive measures to natural enemies. Depending on the needed of the farmer or the farming condition, different components can be used. An example of possible combination is given in Plates 30 & 31. Kava, manioc, legumes, leafy vegetables, corn, tomato, kumala, yam and taro are cultivated in the first year (2007). In the second year of rotation, yam, manioc, strap bean, corn, lettuce, capsicum peanut and kumala are planted.

Plate 30 Crop rotation demonstration plot at the Agriculture station, Santo

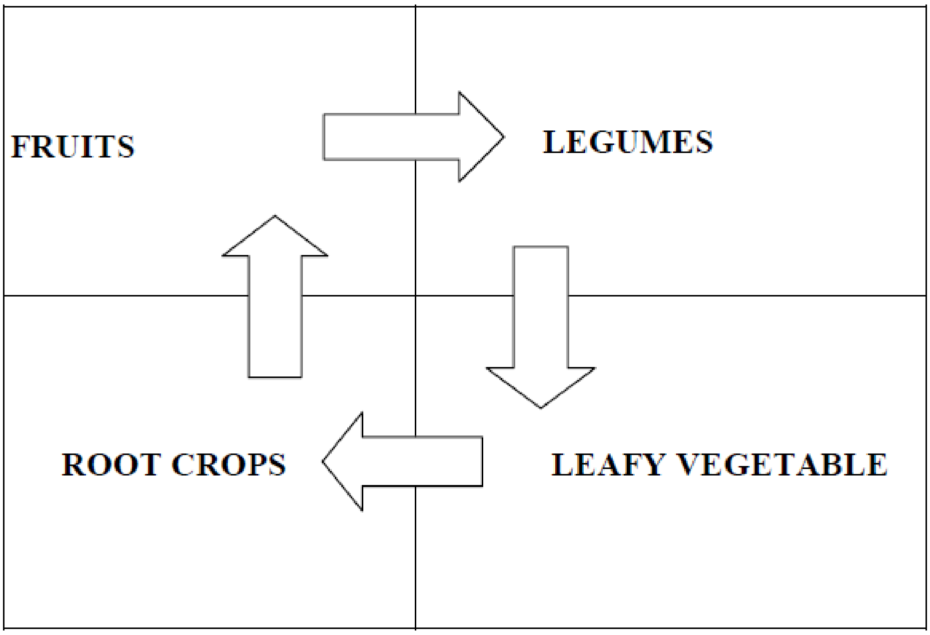


Plate 31 An example of crop rotation programme

Distribution

Crop rotation is a relatively new technology in Vanuatu. This is despite the fact that it has being around for thousands of years. However some simple forms of crop rotation are carried out in certain parts of the country. A properly designed system is now being introduced by the DARD in selected pilot sites.

Ability of this system to respond to climate change and other natural disasters

Inclusion of legumes in the rotation maintains the soil fertility through absorption and conversion of atmospheric nitrogen by microbial organisms in the root nodules. Crop rotation also protects the soil from erosion, salinity and acidity. An ideally designed system can help in controlling insect pests and diseases. It is also proven to control weeds by suppressing their growth and development.

Box 17: Crop rotation

***Practiced in**: Shefa (Efate), Sanma (Santo).*

***Could be replicated in**: Other provinces, islands and communities in Vanuatu.*

***Suitable against**: Low soil fertility and condition, pests and diseases and drought.*

4.5.8 Hydroponic

Hydroponics is a system of farming high value vegetables like tomato and lettuce Plate 32 & 33). The system depends on a culture made of complete fertilize dissolved in water. Crop plants are suspended on the media solution. Nutrient in the media are absorbed by the roots. Coconut husks are filled into individual containers to keep the plants upright. This system has a number of advantages. It would be ideal for small islands, including atolls where land availability is a problem.

Plate 32 Hydroponic trial at the Department of Agriculture and Rural Development Station at Tagabe,

Plate 33 Trialling out fermented vegetation as replacement for commercial fertilizer

Distribution

Although this system of farming has been around for quite sometimes, the DARD has as recently as 2012 attempted to investigate its feasibility. The system is currently being trialled at the DARD station at Tagabe in Port Vila. Farmers were introduced to the system during field visits to the station.

Ability of this system to respond to climate change and other natural disasters

Intrusion of salinity on atoll islands makes it difficult for crop plants that do not tolerate salinity to grow. Hydroponics allows production in such situation. Hydroponic can also allow farmers to produce food crops where the soil is shallow. During dry season, when ambient temperatures are high, hydroponic can enable controlled use of available limited fresh water.

Box 18: Hydroponic

***Practiced in**: Shefa (Efate), Sanma (Santo).*

***Could be replicated in**: Other provinces, islands and communities in Vanuatu.*

***Suitable against**: Low soil fertility and condition, shallow soil, Sandy soil, heavy soil, short fallow period, volcanic ash/eruption, pests and diseases and drought.*

4.5. Aquaculture

Aquaculture is a technique that is being introduced by the Department of Fisheries over the last couple of years (Plate 34). Although it has yet to be widely accepted by farmers throughout the nation, there is potential for it. Tilapia, carp and other freshwater fish species have being introduced and are found to thrive in Vanuatu.

Plate 34 Aquaculture demonstration farm at the Tagabe demonstration unit

Distribution

This system of farming freshwater fishes is gradually spreading throughout the nation. Already it is being set up in the major islands, including Efate, Santo and Malekula. Where there are established, farmers are benefiting both from the cash income generated by the system and protein provided by the fish.

Ability of this system to respond to climate change and other natural disasters

Aquaculture can be an effective method of attaining food security where impacts of climate change caused reduction in marine lives and loss of protein sources. Used in an integrated farming system, it can be the source of protein in the system.

Box 19: Freshwater fish pond

Practiced in*: Shefa (Efate), Sanma (Santo), Malampa (Malekula).*

Could be replicated in*: Other provinces, islands and communities in Vanuatu.*

Suitable against*: Malnutrition and food insecurity.*

4.6 Cultivation/planting/husbandry techniques

There are also cultivation techniques specific to different crop types. These techniques are either developed by the DARD or borrowed and refined from tradition cultivation practices from around the country.

4.6.1 Open pit

> ***Box 20: Open pit***
>
> ***Practiced in**: All provinces, islands and communities.*
>
> ***Could be replicated in**: Throughout Vanuatu.*
>
> ***Suitable against**: Drought and shallow soil*

The open pit is a technique that functions to catch and preserve moisture during dry season (Plate 35). This cultivation practice also encourage built up of organic matter in the open pits as debris fill the pit and gradually decomposed. It is also suitable for sandy or rocky soils. Organic matter is the source of nutrients for the plant. The practice involves digging a 30 cm deep hole and putting the planting material into it. A thin layer of dirt is put into the hole to keep the planting material upright.

Plate 35 An open hole serves as catchment for dews and light rains associate with dry

4.6.2 Hilling or mounding

Hilling is another cultivation practice encouraged by the DARD (Plate 36 (i)-(iv)). Hilling or mounding allows the underground tubers to survive flooding. The hill or mount elevates the plant to heights above the flooded water level. This prevents root rot which is a result of exposure to flooded water. Yam, taro and kumala can be hilled. The crop plants are regularly hilled to prevent exposure of tubers to sun or rain. This system protects the tubers during heavy rainstorm.

<u>*Box 21: Hilling and mounding*</u>

Practiced in: *All provinces, islands and communities.*

Could be replicated in: *Throughout Vanuatu.*

Suitable against: *Low soil fertility, drouht and shallow soil.*

Plate 36 Hilling of (i) Dioscorea spp (ii) Colocasia esculenta (iii) combined hilling and mulching of Impomea botatas (iv) yam in Aniwa

4.6.3 Staking

Staking is a common husbandry practice used in yam cultivation (Plate 37). Vines are trained up the stakes to lift them off the ground. This prevents the vines from crawling on the soil surface. If left on the soil surface, the vines will be burnt when the soil is heated up. Properly constructed stakes would protect the vines from cyclones. Stakes are erected at 1-2 m height to prevent them from being blown over by the cyclone or strong winds.

> **Box 22: Staking**
>
> ***Practiced in***: *All provinces, islands and communities.*
>
> ***Could be replicated in***: *Throughout Vanuatu.*
>
> ***Suitable against***: *hot ground surface, strong winds and cyclone.*

Plate 37 Staking of yam vines

4.6.4 Composting

> ***Box 23: Compost***
>
> ***Practiced in**: Shefa (Efate, Pele); Tafea (Tanna); Sanma (Santo).*
>
> ***Could be replicated in**: All other provinces, Islands and communities.*
>
> ***Suitable against**: Low soil fertility, shallow soil, drought, sandy soil and clayey soil.*

Composting is a technique based on complete breakdown of organic materials by microorganisms (Plate 38). The process of decomposition releases mineral elements contained in the decomposed material into the soil. Composing require specific conditions to take place. Certain elements are needed to create these favorable conditions. The microorganisms involved in decomposition need carbon as their energy source. The microorganisms use nitrogen to grow and reproduce. Oxygen is required for oxidation. Water is necessary to prevent the decomposition environment from becoming anerobic. All elements are supplied via the decomposed materials. A good compose will include all four ingredients. Compose improve soil fertility by adding soil amendments to the soil. Inclusively it adds to the soil physical properties. Compost improves on the soil texture, structure, colour, water holding capacity, porosity and temperature. It also improves on soil micro-and macro-biological activities.

Plate 38 Constructing a compost pit from existing local materials

4.6.5 Liquid fertilizer

Leguminous tree leaves are mashed and made into solutions, fermented and applied to crop plants (Plate 39). In addition to providing soil nutrient elements, the solution also adds water required both by the crop plants and soil microorganisms. The mixture is both carbon and nitrogen substrate for the soil microorganisms. Being acidic it helps to reduce pH in alkaline soils.

> ***Box 24: Liquid fertilizer***
>
> ***Practiced in**: Sanma (Santo).*
>
> ***Could be replicated in**: All other provinces, islands and communities.*
>
> ***Suitable against**: Low soil fertility, shallow soil and drought.*

Plate 39 Liquid fertilizer made from gliricidia leaves

4.6.6 Mulch

Spreading dead or green organic debris onto the soil surface is known as mulching. The mulch is spread around and between the crop plants. Alternative system is to build a low-raised structure around the stem of individual high value crop and filled it with mulch materials (Plate 40). This practice would best suit situations presented with problems like (i) shallow soil. (ii) sandy soil, (iii) soil with a lot of pebbles (small rocks) and (iv) marginal soil.

Box 25: Mulch

Practiced in: *All of Vanuatu.*

Could be replicated in: *All of Vanuatu via and improved system.*

Suitable against: *Low soil fertility, shallow soil, drought, Sandy soil, clayey soil, evaporation, weeds, nutrient loss and soil erosion.*

Plate 40 Mulching of Kava plant

4.6.7 Minimum weeding

This practice is used by farmers on Marae, Finonga, Black Sands and Imaio. On Emae and Black Sand it is used during the dry season as a measure against loss of soil moisture. Both study sites have sandy soil. It ensures that the soil is covered as much as possible during the dry season. Which means soil particles are loose and moisture in the soil pores are easily exposed to the heat of the sun. At Imaio, it is used on slopes (Plate 41). The roots of the weeds help keep the soil particles together thereby assisting to reduce the amount of soil particles being eroded during the rain. Soil nutrient elements are also protected this way.

Box 26: Minimum weeding

***Practiced in**: All of Vanuatu.*

***Could be replicated in**:*

Throughout Vanuatu.

***Suitable against**: Drought, evaporation, loss of soil moisture and surface run-off.*


Plate 41 Minimum weeding on slope at Imaio & Marae: A strategy to reduce soil erosion and loss of soil nutrients

4.6.8 Grafted citrus

Citrus species have also been affected by climate change. An observed effect according to Jean Mac (2012) is increased incidence of pest organisms of citrus. Introduced varieties like volca, citrance and flying dragon currently used in Vanuatu are not resistant to these organisms. The wild variety is resistant to these organisms but do not produce as much fruits as the imported ones.

Box 27: Grafted citrus

***Practiced in**: Shefa (Efate); Sanma (Santo, Malo, Aore); Malampa (Malekula); Penama (Ambae); Tafea (Tanna).*

***Could be replicated in**: All provinces, islands and communities where this is not practiced.*

***Suitable against**: Pests and diseases, salinity and food insecurity.*

Grafting introduced varieties onto the wild varieties is a technique that ensures that the product is both resistant to pest organisms and produce more fruits than the wild varieties (Plate 42). The DARD has in recent years carry out a programme to draft and distribute resistant varieties to farmers all over Vanuatu.

Plate 42 Wild variety of mandarine and lemon are used as rootstock for grafting with imported varieties - volca, citrance and flying dragon

4.6.9 Multiplication of banana

The frequency and intensity of cyclones have increased over recent years as a result of climate change. For example, in the last 40 years, there have been a total of 94 cyclones passing through the vicinity of Vanuatu averaging 2-3 cyclones per year. The actual number varies between years, with as many as 6 in some years.

> ***Box 28: Multiplication of banana***
>
> ***Practiced in***: *DARD encouraging this practice but farmers have yet to adopt it.*
>
> ***Could be replicated in***: *All of Vanuatu.*
>
> ***Suitable against***: *Food insecurity and natural disasters (flooding, landslide, earthquake).*

Cyclone destroys and disrupts the normal growth of crop plants by uprooting the plants, tearing up the leaves, breaking off the branches and making the plants unstable. This may cause a decreased in availability of planting materials during the planting season. Often planting materials are moved from elsewhere to address the shortage. This exercise is often expensive because of the huge cost of transportation.

One way to ensure that planting materials are made available to all farmers and at an affordable price is to multiply the planting materials from available; limited sources of planting materials on-site. Banana stem can be multiplied by sectioning it into many parts and allowed to regenerate from existing growing points (buds). This technique has been recently used and advocated by the DARD.

4.6.10 Silage for pigs during drought

Silage is being around for many years. In many parts of the world it is used as a means of preserving animal feed. It is also used by some cultures in Vanuatu to preserve food, particularly breadfruit for cyclone or other natural disasters. It is also highly nutritive. Silage can be made from many food materials, including those available to farmers throughout Vanuatu. The Climate Field School at Pele Island has trialled out a recipe developed and introduced by the NARI Project (Plate 43).

Plate 43 Silage prepared and kept inside a rubbish pin to ferment

Silage can be advocated as a measure against drought and cyclones. Surplus food collected during time of plenty can be turned into silage and stored for use during drought and after a cyclone. This is possible because silage is found to have long shelf-life.

4.6.11 Cross breeding of exotic and local breeds of livestock animals

Main livestock species farmed in the study sites include cattle, pig and chicken and goat. Most of the species farmed are introduced. Introduced from temperate countries and perform sub-optimally in the Vanuatu situation. Recent increased in ambient temperature, rainfall and humidity negatively affect the performance of these animals. Performance in hush environments can be optimised using improved farming practices (FAO, 1988; Eminger, 1991; Rollin, 1995). The Department of Livestock (DoL) advocates the use of hybrids (crossing of exotic and local breeds) as a way to address impacts of climate change on animal performance. Recommended crossing is between the tropical and temperate breeds. In cattle, recommended crossings are Charolais x Brahman, Limousine x Brahman and Simmental x Brahman. Some commercial farms also use Black

> ***Box 29: Cross-breeding***
>
> ***Practiced in**: All provinces.*
>
> ***Could be replicated in**: All of Vanuatu via an improved system.*
>
> ***Suitable against**: Drought, rainy season and pests and diseases.*

Angus x hybrid of Brahman x Limousin. The Pele Field School of Climate Change is trialling out hybrids of Large White x Local. Preliminary results indicate positive responses to impacts of climate change. There is still nothing done to identify the best breeds or breed mixture of chicken with the best response to climate change. However observations in all study sites showed chickens of mixed parentages of exotic and local breeds performing better that their local relatives (Plate 44). The crossing of temperate and tropical breeds as a means to adapt livestock animals to hush environmental conditions (Plate 45) created by climate change is support by (Esminger, 1991).

Plate 44 Chicken is a primary source of protein for rural communities.

Plate 45 Pig is an alternate source of protein from subsistence farmers in rural settings

4.6.12 Processing of food materials to increase food shelf-life and feeding value for livestock animals

Most food materials are high in water. The high water concentration does not allow food to be kept for a long period of time. Cyclones and prolonged and frequent rainstorms create favourable conditions for microbial growth. These include those responsible for increasing the rate of food decomposition. Cyclones also uproot root and tree crops and break and tear the branches and leaves of tree crops. All above stated scenarios leads to reducing availability of food materials for livestock animals. Prolonged dry season and drought also create food shortages. Projected increased in global warming resulting in increased in intensity, frequency of cyclones, rainstorms and droughts will increase and continue to increase the magnitude of food shortage and effect of food shortage on livestock production unless strategies are put in place to reduce their impacts.

> ***Box 30: Increased shelf-life and feeding value of animal feed***
>
> ***Practiced in****: Not practiced in Vanuatu.*
>
> ***Could be replicated in****: All of Vanuatu.*
>
> ***Suitable against****: Drought, rainy season and cyclone.*

A number of strategies can be used to address this situation. A practical strategy is to dehydrate food materials and store them during time of plenty for use during the above mentioned scenarios. Dicing or cutting the food materials into small pieces, drying them under the sun (Plate 46) and storing them in properly ventilated rooms can increase their shelf-life.

Plate 46 Processing good materials for monogastric animals as a means of improving self-life and feeding value. This also ensures food availability during droughts and periods of food shortage

CHAPTER 5:
AGRICULTURE AND CLIMATE CHANGE:
Case studies of selected communities

5.1 Introduction

Chapter 5 looks at case studies of selected communities in the South and Central parts Vanuatu. The communities selected are Imaio on Tanna, Blacksand on Efate and Marae and Finonga on Emae. These communities represent two provinces, Tafea and Shefa. They are also representative of in-land and coastal villages and farmlands. The communities represent farming problems across the Vanuatu archipelago.

Tables 21 and 22 provides description of the communities selected for the 'community resilience and coping with climate change and natural disasters project. Table 21 gives the coordinates of the islands, land area, highest points and geological nature. The islands are located between the following coordinates, 16 00 S and 167 00 E. The islands vary in altitude as well as land mass. Aniwa is the lowest lying island at 42 meters at its highest point above sea level. The highest point on Loh Island is 155 meters above sea level. Except for Aniwa, which is a raised atoll, all other islands involved in the project are volcanic.

Table 21 Geographical description of the study islands

Study Islands	Province	Coordinates	Land Area	Highest point	Geological Classification
Loh	Torba	13^{o}20'24"S 166^{o}38'40'E	11.9 km²	155 m	Volcanic
Santo	Sanma	15° 15′ 0″ S, 166° 50′ 0″ E	3955.5 km^2	1,879 m	Volcanic
Ambae	Penama	15^o 30' 167^o 167'E	399 Km^2	1,496 m	Volcanic
Ambrym	Malampa	16°15′S 168°7′E	677.7 Km^2	1,334 m	Volcanic
Emae	Shefa	17°4′S 168°24′E	32 Km^2	644 m	Volcanic
Efate	Shefa	17^{o}40'S 168^{o}25"E	899.5 km^2	647 m	Volcanic
Tanna	Tafea	19°30′S 169°20′E	550 km^2	1,084 m	Volcanic
Aniwa	Tafea	19^{o}25'14" 169^{o}36'00"E	8 km^2	42 m	Raised coral atoll

Table 22 provides an overview of demography, source of livelihood, food production and major crops and livestock animals produced in the study sites. Both genders are represented equally in the study sites with about 51 % population being affected being male and 49 % being female. Small-holder farming (agriculture and fishery) is the principal source of livelihood. Formal employment is confined to the population residing in communities on/or proximal to the country's two urban centers (Port Vila and Luganville). Food production system is primarily subsistence and semi-commercial. Semi-commercial is more prevalent in study communities proximal to Port Vila and Luganville. Major stable crops are kumala, manioc, taro (esculenta, taro Fiji, giant taro) and yam. Breadfruit is another staple food crop. Chicken is the principal poultry reared. Pig is the principal livestock. Goats are cattle are also produced but at a low concentration than chicken and pig.

Table 22 Demographic and farming overview of the study communities

Province	Study site	Population		Area	Source of livelihood (source of income)	Food production	Major crops	Major livestock
		Male	Female					
Torba	Loh	86	83		Small-holder Agriculture and Fishing	Subsistence farming oriented[1]	Kumala; Taro Fiji; Island Taro; yam; Breadfruit	Chicken; Pig
	Merelava	489	470		Small-holder Agriculture and Fishing	Subsistence farming oriented,	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana; Breadfruit	Chicken; pig
Shefa	Emae	612	588		Small-holder Agriculture and Fishing	Subsistence farming oriented	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana; Breadfruit; Banana	Chicken; pig
	Mele	2042	1961		Formal employment; Small-holder Agriculture and Fishing	Semi-commercial agriculture[2]	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana; Breadfruit	Chicken; Pig; Cattle
	Blacksand	3572	3431		Formal employment; Small-holder Agriculture and Fishing	Semi-commercial agriculture	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana;	Chicken
Tafea	Whitesand	4307	4138		Small-holder Agriculture	Semi-commercial farming	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana;	Chicken, Pig, Cattle; Goat
	Aniwa	275	264		Small-holder Agriculture and Fishing	Subsistence farming oriented	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana;	Chicken; Pig
Sanma	West Santo	1698	1631		Small-holder Agriculture and Fishing	Subsistence farming oriented	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana;	Chicken; Pig; Goat; Cattle
	Sarakata East	369	354		Formal employment[3]; Small-holder Agriculture	Subsistence farming oriented	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana;	Chicken

[1] Subsistence farming oriented: farming firstly for subsistence consumption and the surplus sold for cash income.
[2] Semi-commercial farming: Up to half or more 50 percent of the garden produce is earmarked and exchanged for cash income or traded for other form of goods and services.
[3] Formal employment: refers to rendering of service or labour in return for cash income. That includes earning wages or salaries

Province	Study site	Population		Area	Source of livelihood (source of income)	Food production	Major crops	Major livestock
		Male	Female					
	Sarakata North	271	261		Formal employment; Small-holder Agriculture	Subsistence farming oriented	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana;	Chicken; pig
Malampa	North Ambrym	1869	1795		Small-holder Agriculture and Fishing	Subsistence farming oriented	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana;	Chicken; pig; Cattle; Goat
	West Ambrym	1474	1416		Small-holder Agriculture and Fishing	Subsistence farming oriented	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana;	Chicken; pig; Cattle; Goat
Penama	East Ambae	1061	1019		Small-holder Agriculture and Fishing	Subsistence farming oriented	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana;	Chicken; pig; Cattle; Goat
	West Ambae	2129	2046		Small-holder Agriculture and Fishing	Subsistence farming oriented	Kumala; Taro Fiji; Island Taro; yam; Manioc; Banana;	Chicken; pig; Cattle; Goat
Total		20254	19457					

5.2 Emae Island: Central Vanuatu

5.2.1 Situation analysis

Emae: Issue of prominent as identified by the "Climate Resilient and Coping with Climate Change Project" is flooding. Compounding this, there is shortage of farmland due to population pressure, shallow top soil, sandy soil and soil erosion. Shortage of water, sea level rise and cyclone are additional environmental problems faced by the people of Marae and Finonga (Figure 5).

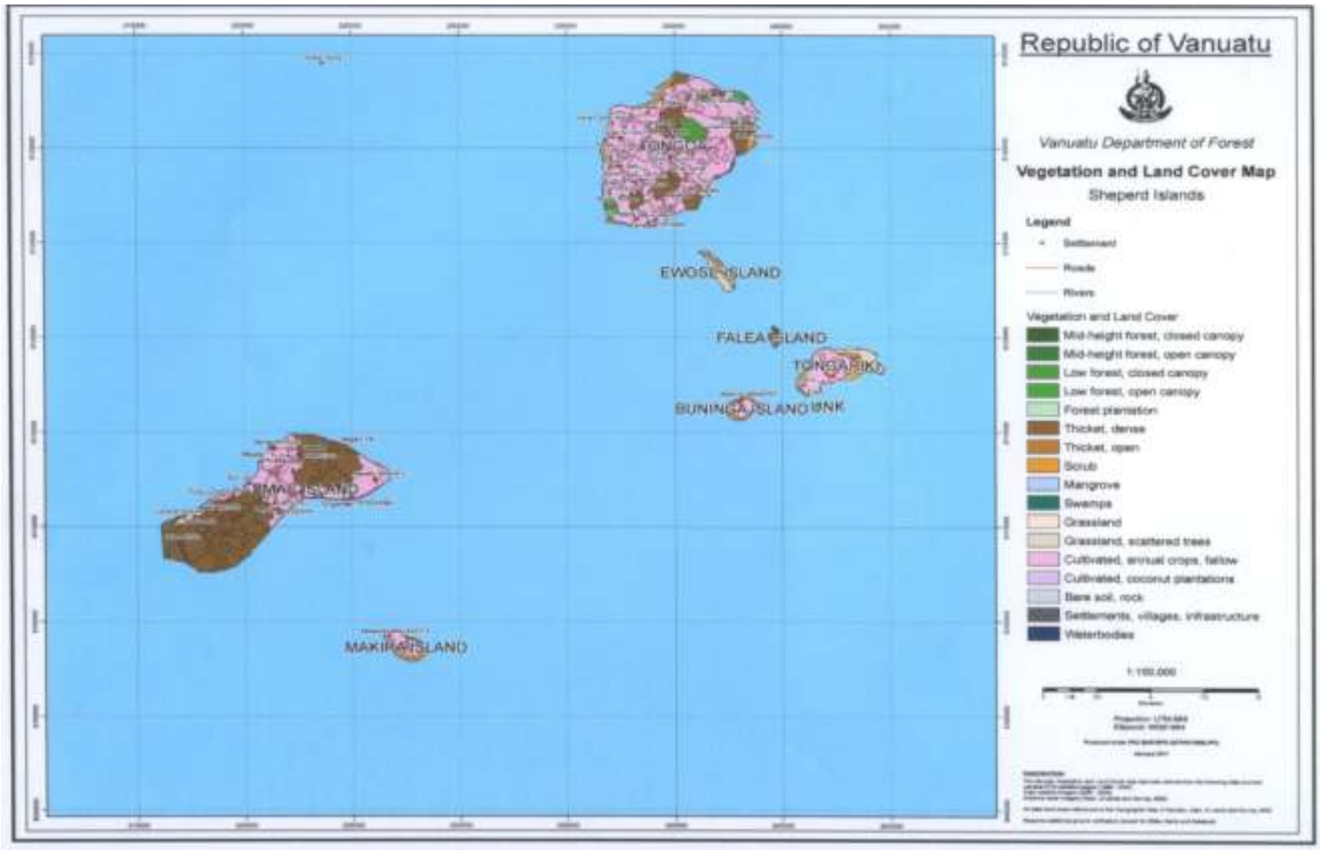


Figure 5 Map of Emae Island showing Marae and Finonga (Dept of Forest)

5.2.3 Agro-ecological Feature

Agro-ecological constraints found on Marae and Fionoga can be categorized into 4 groups. These include;

1. sandy soil,
2. shallow soil,
3. drought,
4. decreased soil fertility,
5. soil erosion, and
6. pests and diseases.

5.2.5 Location of farm land

Both Marae and Finonga are coastal villages. Both villages are built on sandy soil with a watertable of 4-5 m. This makes them prone to flooding and sea level rise (Plate 1). The Marae community has its farmland approximately 100m from the coastline. The farmland is silty sand clay with a depth of 40 cm. The parent rock is only 40 cm below the soil surface. The depth of the soil is shown in Plate 47.

Plate 47 Depth of soil farmed by the people of Marae is less than 40 cm.

The shallow soil presents a number of problems. Firstly only shallow rooted crops can be grown. The nature of the soil and shallow depth does not encourage moisture conservation. The light brownish colour of the soil also indicates poor or lack of humus and organic matter, an indication of low soil fertility.

5.2.4 Seasonal Periods

Two distinct seasons occur on Emae (Figure 6). The dry season is from August through to December. The wet season starts December and ends June. Drought resulting from long

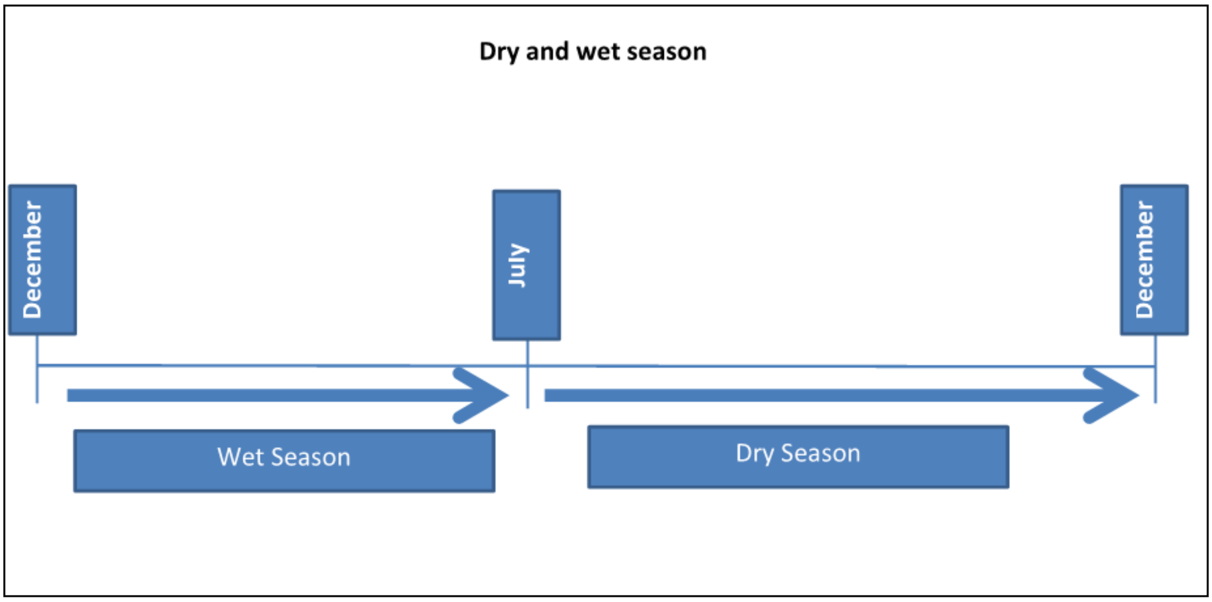


Figure 6 Typical dry and wet season on Emae

periods of dry season is becoming more frequent than previously. Farmers indicate that the average dry season has increased to 3- 5 months. Rainfall distribution and intensity during the wet season has also shown some changes. Farmers observed frequent short periods of heavy rainfalls resulting in flash flooding during the wet season than previously.

5.2.6 Principal root crops

Principle root crops grown on Emae are manioc, taro Fiji, yam, kumala and banana. Ranking of these stable starchy food by people interviewed is based on their importance in the diet of the people. However ranking differs between households. On average the following ranking is identified:

1. manioc,
2. kumala,
3. banana,
4. yam, and
5. taro (Fiji).

This list and ranking is indicative of the ability of the crop plant to tolerate the production conditions prevalent at Emae. Manioc, kumala and banana seem to have a certain degree of tolerance to sandy soil and drought. Yam and taro (Fiji) on the hand have little tolerance to these two elements. Diet composition is influenced by type of food available.

Table 23 Common root crops and their cultivars on Emae

Root Crop	Cultivar	
	#	Name (local names)
Manioc	2	White manioc
		Yellow manioc
Kumala	3	White Flesh
		Yellow Flesh
		Pink Flesh
Banana	4	Malele
		Apple Banana
		Lady’s Finger
		Chinese Banana
Yam	4	6-manis
		Africa
		Wild yam
		Soft yam
Taro (Fiji)	3	Red skin (strong)
		White skin (strong)
		White skin (soft)

5.2.8 Principal Vegetables

Limited vegetable and vegetable types are grown on the pilot sites on Emae. One reason would be that agro-ecological conditions such as lengthy dry season and sandy soil do not create a suitable growing condition for vegetables. Vegetables grown during the wet season are;

1. island cabbage,
2. tomato,
3. bean, and
4. sushut.

This resulted in lack of, hence deficiencies of vitamin in the diet during prolong dry season.

5.2.9 Farming System Practiced on Emae

Fallow is the main farming system practiced on Emae. Recent increased in human population has resulted in shortage of available arable land for cultivation. Land pressure has already caused changes in the farming system. Where pressure is intense, farmers are now continuously farming the land. This has resulted in a decrease in soil fertility. A prominent indication of this is drops in yield over the last 5 years. This problem is intense where land is continually cultivated. It is less intense where farmers still practice fallow systems. Fallow system is only practised by farmers with enough plots of land.

Farmers on Emae have developed and adopted a number of cultivation techniques that reduce the risk of drought on food crops. Some of these practices are discussed below.

(i) Mounding and Staking

Mounding is used on Emae as a farming technique to conserve soil moisture. This technique is quite important during the dry season. It is also useful where soil is shallow. Mounding is an artificial way of increasing the total depth of the soil. Staking keeps the vines off the ground. A good strategy is to keep the vines from being burnt by the hot soil surface. The dark colour of the soil particles absorbs and retains. Direct exposure of the sun rays on bare soil makes it hot.

(ii) Ground Cover

Protecting the ground surface from direct exposure to sun helps reduce evaporation. This helps conserves soil moisture during long period of sun and dry season. A number of techniques are recommended by the DARD. The strategy adapted on Emae is based on the same principle although the actual technique used differs. Undergrowth comprising mainly ***Lecucena leucephera*** are used a ground cover. ***Lecucena leucephela*** is the primary shrub at Marae (Plate 48). The lecucena leucephela also traps atmospheric nitrogen and converts it with the help of nitrogen fixing bacteria into the form used by crop plants. In doing so, it improves the fertility of the soil. Weeding is not encouraged during the dry season. All weed serves as ground cover.

Plate 48 Leucena leucephela as ground cover

(iii) Colocasia esculenta Planted in Pits

C. esculenta are planted in open pits (Plate 49). Pits are dug to a depth of about 40 cm. The pits allows for dews to collect at night. It also allows for debris (leaves and branches) to collect. Over time the debris will decompose to form soil particles.

The pits allow dews to collect at night. The drew supplies water to the plant during the day. Organic debris also collects in the pit and decompose to form soil particles.

Plate 49 Taro planted in pits as a means to conserve water and build up organic matter

(iv) Tuber morphology

The morphology of a number of root crops, particularly their shape makes it possible to cultivate them on shallow soils.

Yam: Two local varieties of yams are suitable for shallow soils. The tubers of the *'Tupuk'* a local variety grows horizontally. The *'Tupuk'* is borrowed from Epi. The *'Malakekua'* is also a variety that does not require deep soil. The tuber is C-shaped. The curving allows the tuber to grow upward stead of downward. This makes it ideal for shallow soils.

Navia: The stem of the navia grows upward instead of downward. The upward growth allows it to be grown on shallow soils.

(v) Adoption of early maturing cultivars

Intensified and prolonged dry season forced farmers to shift from late to early maturing root crop varieties. According to farmers on both study sites, this practice ensures that crops matured and are harvested before the dry season intensified. Early varieties allow planting at the end of the wet season and harvest at the beginning or middle of the dry season. Examples of early varieties utilized are pictorially illustrated below (Plate 50 & 51).

(i) Kumala Varieties

Plate 50 Early maturing variety-pink fleshed kumala, harvested after 3 months

(ii)Taro varieties


Plate 51 Some varieties of taro available in Vanuatu

(vi) Adopting of food crops resistance to drought

Both the Marae and Finonga community have adopted a number of drought resistant crop varieties. Past experiences show that some crops and crop varieties perform better than others during prolonged dry season. These observations assisted the communities to select drought resistant varieties. Plates 53 are pictorial illustrations of drought tolerance crops and crop varieties used on Emae.



Plate 53 Early maturing kumala (pink, yellow and orange flesh) if established before dry season can withstand the drought.

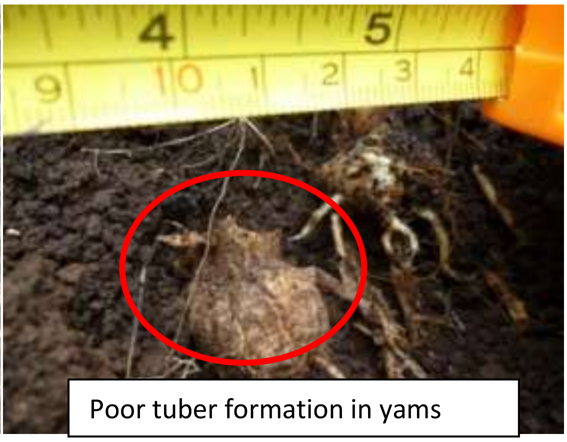
5.2.10 Effects of drought on food crops

Drought has a devastating effect on crop plants. The effects of drought are more pronounced when crop plants are planted very close to the dry season. The time period between planting and onset of the dry season does not allow sufficient time for the plants to establish themselves before dry season commences. Below are some pictorial example of the effect of drought on kumala, yam, corn, banana and taro Fiji on Emae Island (Plate 54).

Drying up of yam vines

Drying up of kumala vines

Stunt growth and drying up of kumala leaves



Poor tuber formation in yams

Yellowing of leaves in corn

Stunt growth in kumala

Plate 54 : Effects of drought in pictures

5.2.11 Early maturing varieties

A number of early maturing crop varieties have being introduced over the last 10 years. Two cultivars of kumala have being introduced into the community of Marae. The orange flesh kumala is introduced from Tanna (Southern Vanuatu) and white flesh kumala from Port Vila. Both cultivars take 3 months to reach maturity. These early maturing varieties are supplied by the Vanuatu National Disaster Office (NDMO) after Cyclone Prima in 1993 .

5.2.12 Planting Calendar

Planting season for both Marae and Finonga depicts that of the island of Emae. Responses from farmers on both pilot study sites showed no change in planting calendar as far as they can remember. However, some crop plants can now be grown throughout the year compared to past experiences. The following table (Table 1) provides a summary of the present growing season for principal food crops.

Table 24 Traditional planting calendar of principal root crops on Marae and Finonga, Emae Island

Name of Crop	Planting Calendar		Comment(s)
	Planting Season	Harvest Season	
Yam	July - October	May-June	Yam on Emae is planted between July and October. It can be planted as late as December. Planting between July and October gives the plant sufficient time to establish itself before the wet season. Also yam dominancy is naturally broken during this period. Planting at this period also ensures that the plant is strong and able to withstand anthracnose disease during the wet season.
Kumala	March - June	October - December	Kumala can be grown throughout the year. However tuber formation is poor during wet season. Hence planting November-February does not allow for good tuber formation. Vegetative growth is high. Planting March to June allows the plant to establish itself before the onset of dry season on August. The plant needs the dry season for tuber formation.
Manioc	Feb - March	June	Feb – March is the optimum planting period. This is prior to the dry period. The end of the wet season provided sufficient time for the plant to establish itself before the onset of the dry season. The plant need the dry season for tuber formation. Although Feb – March is the optimum planting months, manioc can now be grown throughout the year. Farmers observed greater vegetative growth and poor tuber formation if the manioc is planted during the wet season.
Taro Fiji	Feb - March	Feb – March	Taro is best planted just before the onset of the dry season. This is from February through to March. The end of the wet season provides sufficient time for the plant to establish it's rooting system. Farmers on both pilot study sites observed good tuber formation during the dry season compared to

			the wet season. Planting at the start of the wet season encourage vegetative growth at the expense of tuber formation.
Banana	All Year Round	All Year Round	Banana grows well in both pilot study sites. Farmers observed that banana grows well throughout the year. However recently some farmers observed rotting of banana bunches during prolonged dry season. This occurs early during the formation of the banana bunch. This problem is intense in farm land with shallow soil. The Marae community's principal farmland is located some 100 m from the coastline. The soil depth is only 40 cm.

5.2.13 Food Preservation

The average shelf life of root crops on Emae is given in Table 25. This is where no preservation technique is used to prolong the crop's shelf. Manioc has the shortest shelf life. Shelf life is further reduced if injuries are inflicted during harvest. Injuries are a route for micro-organisms leading to accelerated deterioration.

Table 25 Average shelf life of selected crops when no preservation is carried out

Name of Crop	Duration of shelf-life
Kumala	1 week
Banana	1 week
Manioc	3 – 4 days
Yam	>1 month
Taro	1 week

Two preservation techniques are used on Emae. Baking and burying the food crop under the ground. Baking involves peeling the crop and baking it in an earth oven. The baked root crops are securely stored away in storage bags or containers for future use. Burying involves individually wrapping each food crop in thick layers of leaves and burying them in holes dug on the ground. The holes can be dug inside the kitchen or in the garden. The tubers are dug out when they are needed. Burying can prolong the shelf life by as much as one month, similarly baking.

5.2.14 Typical diet

The typical diet of Marae and Finonga is deficient in vitamin. Greens like island cabbage, Chinese cabbage, English cabbage and lettuce do not grow well on the sandy soil prevalent on Marae and Finonga combined with prolonged dry season. Farmers indicate that most of these greens are no longer grown because of their poor performance.

A typical diet comprises mainly root crops like manioc, kumala, taro Fiji, banana and yam. The primary protein sources are land crab, fish, chicken, goat meat and pork . There are locally available sources of vitamins on Emae worth investigation. Responses from the both communities indicated knowledge of the potential use of these plants as sources of vitamin. Irrespective of this, the communities are not using them. Some potential sources of vitamins are provided below (Table 26).

Table 26 Potential sources of vitamin

Potential Source of Vitamin	Comment(s)
Wild Cabbage	This plant is widely used as hedges by both communities. It is drought tolerance. The top of the plant (young leaves) can be stir-fried with canned beef or tuna. It can be lethal if not properly prepared. Preparation procedures include dehydrating the leaves in the sun prior to cooking. Spread the picked leaves under the sun for a whole day prior to cooking. Alternatively, the leaves are dipped in hot (boiled) water (Plate 62)
Manioc leaves (young leaves)	Commonly used by other communities in the Pacific, there is abundant of manioc tops on Emae. The tops can be picked, dipped in hot water and cooked in various ways. A common method is to stir-fry with canned beef or tuna. Manioc is drought tolerant (Plate 58).
Kumala leaves	Same procedure as manioc leaves.
Nalalas leaves	Abundant in both communities, nalalas is used a hedges. This means all families have access to this crop. The tops can be boiled, stir-fried, baked or boiled with root crops. It can also be cooked with laplap. Nalalas respond well to prolonged dry season (Plate 56& 57).
Breadfruit leaves	Breadfruit adapts well to drought and low fertile soil. This makes it an ideal crop for small islands during droughts. The young leaves can be cooked in coconut milk. It can also be cooked with other root crops and in laplap. (Plate 55)
Dry land taro leaves	The dry land taro does well under dry conditions. The leaves are edible and are eaten by some cultures in the Pacific. It is a potential source of vitamin on Emae. (Plate 59)

These sources are recommended based on observation of their responds to drought, low soil fertility and low soil moisture content. They are also observed to grow well on sandy soils. This list is not exhaustive. The author believes there are other potential greens on Emae worth investigation.

Plate 55 Nalalas leaves

Plate 56 Breadfruit leaves

Plate 57 Nalalas leaves

Plate 58 Manioc leaves

Plate 59 Taro leaves

Plate 60 Sushut leaves

Plate 62 Wild cabbage tree leaves

Plate 61 Pumpkin Leaves

Plate 63 Fish and shellfish are main sources of protein on Marae

Plate 64 Chicken is a source of protein on Marae and Finonga

Plate 65 Land crab is a main source of protein on Marae and Finonga

Plate 66 Goat as a source of protein for both Marae and Finonga

5.2.15 Recommended suitable crops and cropping systems/practices

Table 27 is a compilation of farming systems and practices recommended for agro-ecological constraints identified at Marae and Finonga on Emae. Crops recommended for each of these agro-ecological constraints are also provided. The recommendations are based on the crop's morphological and physiological characteristics and agro-climatic requirements. This table is applicable elsewhere in the country where the specific listed agro-ecological constraints occur.

Table 27 Crops recommended to counter agro-ecological constraints identified at Blacksand

Agro-ecological problems	Recommended farming systems/practices	Recommended crop types
Sandy soil/rocky /Sandy loam	1. Cover crop 2. Add compost 3. Mulching 4. Minimum weeding 5. Raised bed	• Carrots • Radishes • Leafy greens (adequate soil moisture) • Sweet potatoe • Breadfruit • Lettuce • Runner beans • Yam • Taro • Manioc • Cabbage • Citrus • Corn • Watermelon • Pumpkin • Cucumber • Banana
Shallow soil	1. Cover crops using Mucuna prurians and laplap purpureus 2. Intercropping 3. Open pits 4. Compositing 5. Liquid fertilizer 6. Mulching 7. Minimum weeding	• Citrus • Corn • Watermelon • Pumpkin • Cucumber • Sweet potatoe • Manioc
Drought	1. Hydroponics 2. Mixed cropping 3. Mulching	• Taro (Colocaisia esculenta); Alafua Sunrise, Talo Niue

	4. Compost 5. Liquid fertilizer	• Allocasia macrorrhiza • Sweet potato-4 varieties are drought tolerant • Manioc • Mango (up to 8 months) •
Decreased soil fertility	1. Strip planting 2. Agroforestry 3. Cover crops (creeping legumes) 4. Minimum weeding 5. Compost 6. Liquid fertilizer 7. Mulching 8. Crop rotation 9. Mixed cropping	• Mucuna Pruiens • Dolichos lablab • Gliricidia sepium • Erythrina variegata • Fabaceae (edibles) • •
Soil erosion	1. Contour planting 2. Strip planting 3. Agroforestry 4. Cover crops (creeping legumes) 5. Minimum weeding 6. Terracing	• Leuaena leucocephala • Gliricidia sepium • Erythrina variegata • Mucuna Pruiens • Dolichos lablab • Forestry (timber) species •
Pests and diseases	1. Integrated pests management	• Integrated cropping system allows combination of different crop species. - Include plants/crops with natural repellents against diseases organisms; crop rotation ensures that a crop species is not planted in the same plot for 2 or more consecutive cycles thus removing substrates for pathogens of that species.

5.2 Tanna Island: Southern Vanuatu

5. 2.1 Situation analysis

Tanna: Issue of prominent as identified by the "Climate Resilient and Coping with Climate Change Project" is volcanic eruption. Compounding this, there is shortage of farmland due to population pressure, shallow top soil, sandy soil, landslide, soil erosion and loss of soil fertility. Cyclones and destruction of gardens by livestock animals (pigs and cattle) are additional environmental problems faced by the people of Imaio, on Tanna (Figure 7).

5. 2.2 Agro-ecological constraints at Imaio, Tanna

Agro-ecological constraints prominent on Imaio include the following;

1. volcanic eruption and ashes
2. sandy soil,
3. slope land,
4. shallow soil,
5. landslide,
6. soil erosion,
7. loss of soil fertility,
8. drought, and
9. pests and diseases.

5. 2.3 Location of study site

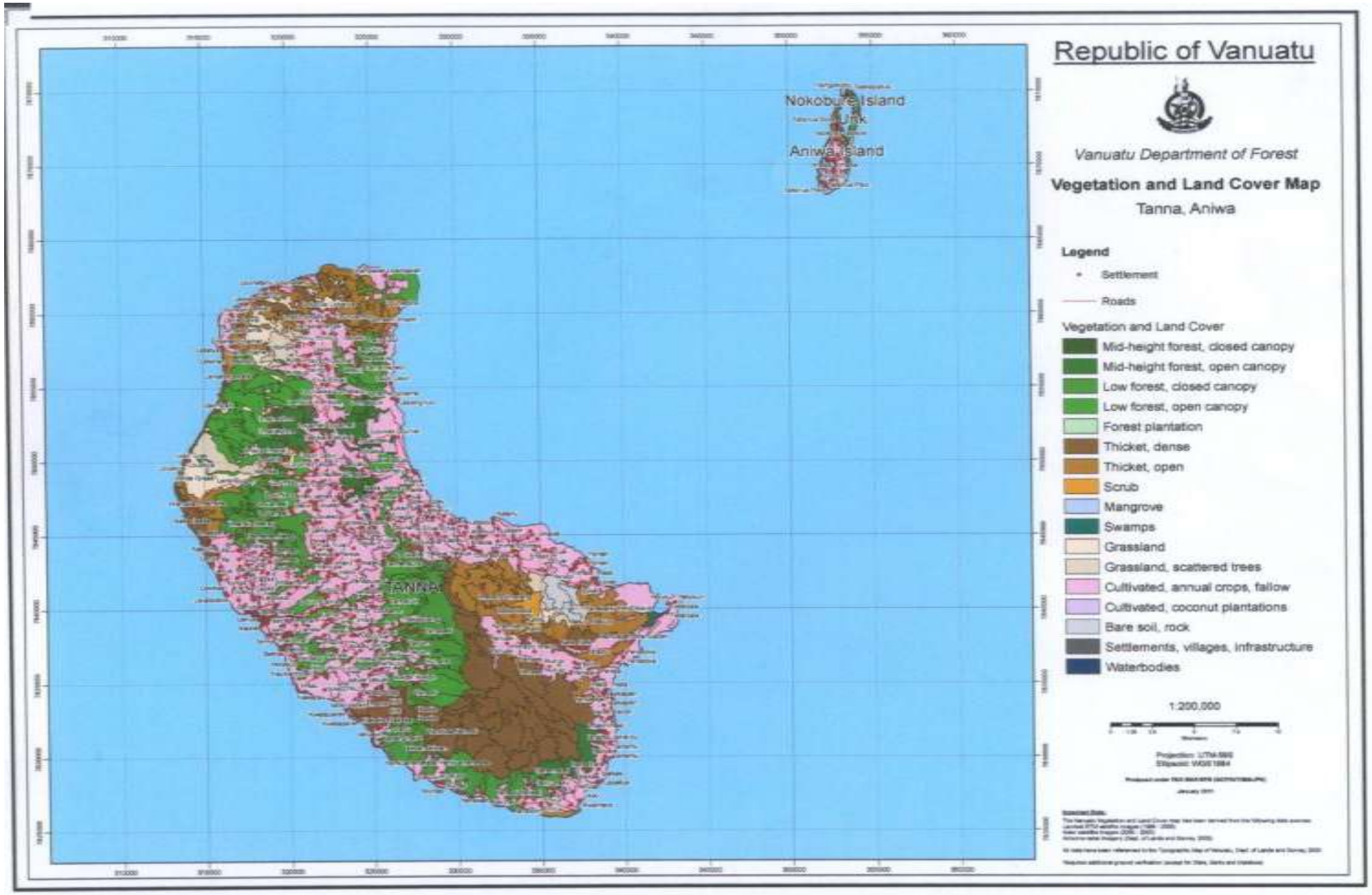


Figure 7 Map of Tanna showing Imao village (Dept of Forest)

5. 2.4 Seasonal Periods and Planting Calendar

Tanna, like other islands in Vanuatu has two distinct seasons (Chart 1). Unlike other islands, Tanna has a 14-months calendar year. The Tannese calendar centres on the yam. It has the modern day 12-months plus the month of May divided into 2 months. The first begins 1st of May and end 15th of May. The second starts the 16th of May and ends 31st of May. May being the harvest season; is also the most important month of the year. The month is divided into harvesting and sacrificing month. The first being the harvesting month: with the second being the sacrificing month.

The Tannese calendar year is described below (Table 28). Each month is related to natural occurrences. The table shows that Tannese people rely heavily on nature to plan their annual farming activities.

Table 28 Tanna annual calendar

Tannese Calendar	Modern Calendar	Significances
Nahua Asuas	January	Little bird and animal activities. Rain and cyclone season. North east trade wind brings the cyclone
Nhua Matua/Asul	February	Little bird and animal activity. Rain and cyclone season. Fruits (Nandau) ready for picking. North east trade wind brings rough or calm seas
Varitam	March	Vegetative re-growth. Reef covered with brown seaweeds. Nakavika fruits ready for picking. North east trade wind brings rough or calm sea. Rain and cyclone season still on.
Iatnus	April	Harvesting of new yam. Orange, mandarin, sugarcane and nakatambol ready for picking. North east trade wind brings rough or calm sea. Last month of rain season
Sil-Mos	May	Best yams and fruits selected for offerings to the gods. North east trade wind brings rough or calm sea
Iapakilpakil	June	Last harvest and selection of yams for subsistence and custom ceremonies. Mango begins fruiting season. West trade wind brings rough or calm seas. Start of dry season
Mauk-Mai	July	Clearing of new garden sites. Trees including Natavoa, banyan and blue water begin losing leaves. Beginning of dry season. Nights become cold
Mauk-U	August	Preparation of land for new garden (ploughing etc). Start of breeding season for birds. North trade wind brings cold nights
Mauk-Via	September	Beginning of yam growing season. Emerging of yam vines. Yam staking.. Trees begin growing

		new leaves. South east trade wind. End of dry season.
Mauk-Ilo	October	Yam at peak growth. Stakes, poles and beds are fully covered with yam vines. Trees began growing new leaves. Start of rain season. Small sporadic rains
Tamitam	November	Period of food shortage. Heavy reliance on banana and manioc. Nantau and Nakavika starts flowering. Start of cyclone season.
Katik-Makos	December	Period of food shortage. Population revisits old gardens sites for root crops; manioc, taro, taro Fiji. Mango and namambe begins flowering

Translated from a ppt presentation by Willie Iau, Principal Agriculture Officer, TAFEA province.

5. 2.5 Location of Farmland: Topography

Imaio is located in the Whitesands area of Tanna. The village was once located at the foot of the Yarsu, on the banks of the once flourishing Lake Seawe. The lake has since dried up. The gigantic eruption of the 1800s displaced the people to their current location. The village, comprising a few nakamals is located on the only available flat plain less susceptible to direct spewing of volcanic ashes from the mouth of the Yarsu. The gardens are along the mountain slopes (Plate 68). Recent and frequent landslides have also added to reducing total arable land.

Plate 67 The rugged terranes (hills) of Imaio village-also the farmland

Plate 68 a. Shallow soil b. Soil is mostly gravely (small pebbles) and has a thin layer of humus

Being on the slope, the fertile soil and large amount of soil are continuously subjected to being washed down the slope. This makes the soil at the top of the slope quite shallow (Plate 69 a) and infertile (Plate 69 b): incapable of supporting and sustaining food crops. This has forced farmers to move and restrict gardening to the lower parts of the slope, greatly reducing arable land.

5. 2.6 Principal root crops

Root crops available to the community are influenced by the volcano and its impacts. Only root crops with some degree of tolerance to volcanic ash and acid rain are grown by the community. The community is restricted to:

1. taro,
2. manioc,
3. kumala,
4. taro Fiji, and
5. banana.

Ranking of these food crops in terms of their importance to the daily diet of the typical Imaio family is also in the same order. Yam, once the centre of cultural and traditional activities in the community is now a rare sight.

5. 2.7 Principal vegetables

Vegetables are a rare sight at Imaio. This is due to the unpredictable occurrence of volcanic ashes. The community has protected itself from the disappointments and heartaches generated by loss of vegetable crops to volcanic ashes and acid rain by not growing vegetables. Although island cabbages can be seem sprouting in random gardens.

Apart from island cabbage, Chinese and English cabbages do grow well in the volcanic soils. The community also noted that legumes like beans do flourish on the land. The reason they are not cultivating them is to protect themselves from the disappointments of losing the cropto volcanic ash and acid rain.

5. 2.8 Planting Calendar

Table 29 Traditional planting calendar

Name of Crop	Planting Season	Harvest Season
Taro	March, August , December	All year round
Manioc	August	December
Kumala	September - March	December – May
Taro Fiji	All year round	All year round
Banana	All year round	All year round

Taro (***C.esculenta***), being the primary starchy food crop has a unique planting calendar. The calendar year is divided into 3 planting seasons. The first is in March. This is referred to as a small planting period: where only a small plot of land is cultivated. This is followed by the main planting season in August. The final planting takes place in December. This strategy ensues that taro is available and harvested all year round.

Kumala ***(I.botatas)*** is planted at the end of the ***C.esculenta*** harvest season. This is so that the kumala vines are planted in the harvested plot(s) of taro. In fact the vines are usually planted in the holes left by the harvested taro crops.

Taro Fiji ***(X.*** s***agittifolium)*** is planted together with the ***C.esculenta***. There are 2 ways in which the Imaio villagers lay-out their taro plot. The lay-out ensures conservation of soil nutrients and reduces soil erosion. The ***X. sagittifolium*** is planted as a boundary around the ***C.esculenta*** or at the bottom of the garden plot to stabilise the soil on slope lands. This strategy also shows that ***C.esculenta*** is regarded to be more important than *X.* ***sagittifolium***.

5. 2.9 Food Preservation Technique

Food crops do not keep well in their natural stage. Like other cultures in Vanuatu, food harvested or collected is quickly prepared and consumed to avoid spoilage. Food is rarely preserved. It is only preserved when there is abundant or when there is a natural disaster. Micro-organisms quickly set in after harvest and decomposition takes place. To avoid hastening decomposition, the Imaio farmers, like other cultures in Vanuatu makes it a priority during harvest to avoid injuring the tuber or fruit. An uninjured food crop may last for a couple more days that the injured ones.

Like other cultures on Tanna, farmers have more than one planting season spread out through the year. There is the main planting season and the mini-planting season. The 2 planting seasons ensures that there is food in the gardens ready to be harvested throughout the year.

5. 2.10 Recommended crops and and cropping systems

The following table (Table 30) has a list of farming systems and practices recommended for the agro-ecological constraints identified at Imao, on Tanna. The table also has crops recommended for each of the agro-ecological constraints. The recommendation is based on the crop's morphological and physiological characteristics and agro-climatic requirements. This table can be used elsewhere in the country where the specific listed agro-ecological constraints occur.

Table 30 Crops recommended to counter agro-ecological constraints identified at Imao, Tanna

Agro-ecological problems	Recommended farming system(s)/practices	Recommended crop types
Volcanic eruptions and ashes	1. Diversification of root crops. This system would ensure that atleast one would .. 2. Sustainable breeding root crops 3. Promoting food security by planting banana	4. Fast maturing crops 5. Banana 6. Manioc 7. Kumala 8. Colocasia esculenta 9. Allocasia marorrhiza 10. Xanthosoma sagittifolium
Sandy silt/gravel	1. Cover crop 2. Add compost 3. Mulching 4. Minimum weeding	1. Carrots 2. Radishes 3. Leafy greens (adequate soil moisture) 4. Sweet potato 5. Breadfruit 6. Lettuce 7. Runner beans 8. Yam 9. Taro 10. Manioc 11. Bracssica species 12. Citrus 13. Corn 14. Watermelon 15. Pumpkin 16. Cucumber 17. Banana 18. Colocasia esculenta 19. Allocasia marorrhiza 20. Xanthosoma

		sagittifolium
Slope land	1. Intergrated alley cropping 2. Land restoration and farming using vetiver grass 3. Contour farming	1. Leuaena leucocephala 2. Gliricidia sepium 3. Erythrina variegata 4. Mucuna Pruiens 5. Dolichos lablab 6. Forestry (timber) species
Shallow soil	1. Cover crops using Mucuna prurians and laplap purpureus 2. Intercropping 3. Open pits 4. Compositing 5. Liquid fertilizer 6. Mulching 7. Minimum weeding	1. Citrus 2. Watermelon 3. Pumpkin 4. Cucumber 5. Sweet potatoe 6. Manioc
Landslide	1. Contour planting 2. Agroforestry 3. Terrace with leucaena leucocephala	1. Root crops 2. Fabaceae 3. Forest species 4. Leafy vegetables
Soil erosion/loss of soil fertility	1. Contour planting 2. Strip planting 3. Agroforestry 4. Cover crops (creeping legumes) 5. Minimum weeding 6. Terracing	1. Mucuna Pruiens 2. Dolichos lablab 3. Gliricidia sepium 4. Erythrina variegata 5. Fabaceae (edibles)
Drought	1. Hydroponics 2. Mixed cropping 3. Mulching 4. Compost 5. Pit planting	1. Taro (Colocaisia esculenta); Alafua Sunrise, Talo Niue 2. Allocasia macrorrhiza 3. Xanthosoma sagittifolium 4. Sweet potato-4 varieties are drought tolerant 5. Manioc 6. Mango (up to 8 months)
Pests and diseases	Intergraded pests management	Integrated cropping system allows combination of different crop species. -Include plants/crops with natural repellents against diseases organisms; crop rotation ensures that a crop species is not planted

		in the same plot for 2 or more consecutive cycles thus removing substrates for pathogens of that species.

5. 3 Aniwa, Southern Vanuatu

5. 3.1 Situation analysis

Aniwa: The issues identified by the "Climate Resilient and Coping with Climate Change Project" are drought and water shortage. This situation is further aggregated by water logging during the rains. Aniwa has primarily clay soil. The heavy soil reduces the rate at which water seeps through the soil after the rains. The stagnant movement of water after a rainstorm is also aggregated by the island's flat topography. Another problem evident in Aniwa is the drying up of orange trees. A disease caused by the phytothora fungus. A number of environmental conditions suit the growth of this fungus, including a well aerated and moist soil. Oranges become more susceptible when their roots are stressed or damaged in saturated or dry soil. Drainage restricted by heavy clay soil with shallow water table provide ideal conditions for fibrous root infection and build up of Phytohthora propagules (Graham and L.W. Timmer, 1994; Graham et al, 1998; Ahmed et al, 2012).

5. 3.2 Agro-ecological constraints on Aniwa

Agro-ecological constraints found on Aniwa can be categorized into 4 groups. There are;

1. clay soil,
2. drought,
3. reduced fallow period,
4. water logging after a rainstorm,
5. decreased soil fertility, and
6. pests and diseases.

5. 3.3 Location of study site

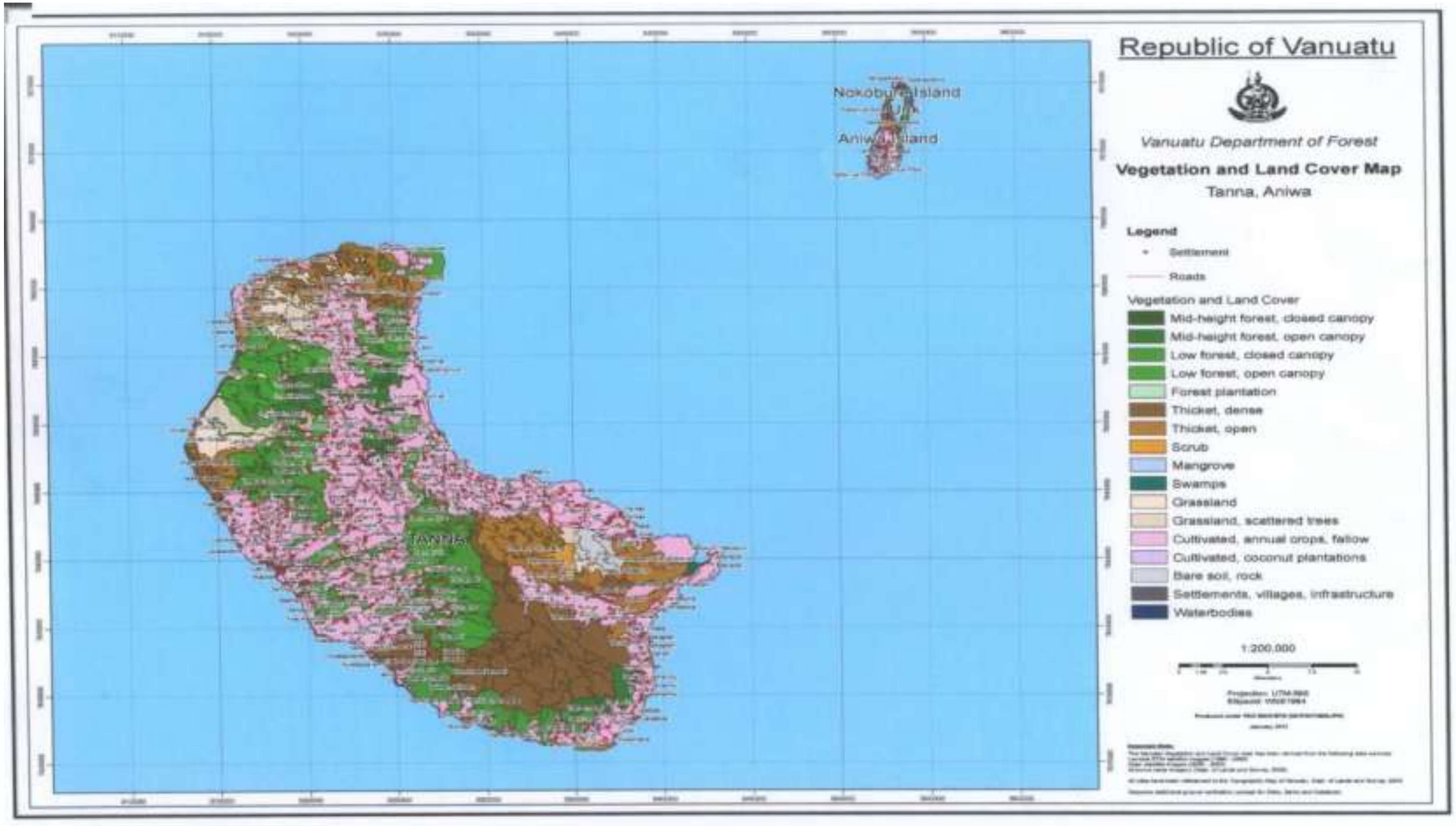


Figure 8 Map of Aniwa Island (Dept of Forest)

5. 3.4 Principal root crops

The types of root crops planted on Aniwa is to a large extend dictated by it environmental conditions, including the soil type. The soil type in Aniwa is predominantly clay. The root crops grown, in a ranking order are;

1. manioc,
2. banana,
3. taro Fiji,
4. kumala, and
5. yam.

The root crops and their varieties grown on Aniwa are tabulated in Table 31. Another crop of importance in the diet of the typical Aniwa family is breadfruit.

Table 31 Common roots and their varieties grown in Aniwa

Root crop	Varieties
Manioc	1. White flesh 2. Yellow flesh
Banana	1. Apple banana 2. Malele
Taro Fiji	1. Red skin 2. White skin
Kumala	1. Yellow flesh 2. Red skin, White Flesh 3. Purple flesh 4. Orange flesh
Yam	1. Strong yam 2. Soft yam

5. 3.5 Principal vegetables

Like Imaio on Tanna, vegetables are a rare sight on Aniwa. The growing of vegetables on the island is limited by drought and water shortage. A handful of vegetable species, particularly leafy vegetables with some ability to withstand drought are grown. Island cabbage seems to do fine as long as there is sufficient soil moisture. Chinese cabbage is also grown during the wet season. Edible ferns are alternative sources of vegetables. The ferns, like in all islands on the archipelago, grow along valleys and creeks.

5. 3.6 Seasonal periods and planting calendar

Like the rest of Vanuatu, Aniwa has 2 distinct seasonal periods, the dry and wet season. Planting is done during the wet season to utilize the rains. Harvesting is done at start of the dry season. Land clearing and preparation are done during the dry season. This allows farmers to utilise the sun's heat to dehydrate the cleared vegetations. Planting is done at the beginning of the rain season to fully use the rains. Crops like the yam are planted in the middle or towards the end of the dry season to utilize the heat to break their dormancy. This also ensures that the new crop is established before the rains, which often brings with it anthracnose disease. The rains come as early as November. In some years, it may come as late as January. The dry season is from May through October. The rain coincides with the cyclone season.

The Aniwa planting calendar is provided in the table below (Table 32). The calendar shows that the most important crops are grown all year round; manioc and banana. These two crops provide the bulk of the Aniwan diet. Kumala has two planting seasons. The first planting is done in August – September and the second is in March. This approach ensures that kumala is available most of the year. Kumala also makes up a large part of the Aniwan diet. Crops that are confined to certain months of the year only makes up a small part of their diet. These are crops like taro Fiji and Chinese cabbage.

Table 32 Main crops grown on Aniwa and their planning calendar

Name of Crop	Planting Season	Harvest Season
Manioc	All years round	All year round
Banana	All year round	All year round
Taro Fiji	October - December	October - December
Kumala	2 planting seasons First planting: August – September Second planting: March	First harvest: December – January Second harvest: July – August
Yam	July - August	April – June
Breadfruit	All year round (main season July – August)	All year round (main season July – August)

5. 3.7 Food preservation techniques

Root crops and vegetables do not last long. Exposed to environmental conditional, micro-organisms quickly invade the food materials and began the process of decomposition. Injuries incurred during harvesting provide entry points for these micro-organisms. The table below (Table 33) is an indication of the shelf-life of food materials common in the Aniwan kitchen.

Table 33 Shelf-life of food materials in Aniwa

Crop product	Shelf-life
Taro Fiji	2 -3 weeks
Manioc	2 days
Kumala	1 week
Yam	> 1 month
Breadfruit	< 1 week
Namabe	4 -5 months
Banana	1 – 2 weeks

There are also ways in which the community preserves materials during time of surplus to be used when food availability is low. One technical involves preservation of banana. Briefly, the banana fruits are grated and washed in the sea. The grated product is hanged and allowed to dry (wind dried). This product can last for 6 months.

5.3.8 Recommended crops and and cropping systems

A list of farming systems and practices recommended for agro-ecological constraints identified on Aniwa are provided in the following table (Table 34). The table also includes crops recommended for each of these agro-ecological constraints. The recommendations are based on the crop's morphological and physiological characteristics and agro-climatic requirements. This table is applicable elsewhere in the country where the specific listed agro-ecological constraints occur.

Table 34 Crops recommended to counter agro-ecological constraints identified at Aniwa

Agro-ecological problems	Recommended farming system(s)/practices	Recommended crop types
Clay soil-heavy soil	1. Compost 2. Mulching	1. Bracassia species 2. Citrus 3. Watermelon 4. Cucumber 5. Taro (Colocasia esculenta. 6. Allocasia marorrhiza 7. Xanthosoma sagittifolium
Drought	1. Hydroponics 2. Mixed cropping 3. Pit planting 4. Mulching 5. compost	1.Colocasia esculenta 2.Allocasia marorrhiza 3.Xanthosoma sagittifolium
Reduced fallow period	1. Cover crops 2. Green manure	1. Mucuna pruiens 2. Dolichos lablab

	3. Intercropping 4. Crop rotation 5. Compost 6. Pit planting	3. Gliricidia sepium 4. Erythrina variegata
Waterlogging following heavy rainstorm	1. Raised beds 2. Agroforestry	1. Citrus 2. Watermelon 3. Pumpkin 4. Cucumber 5. Sweet potatoe 6. Manioc
Low soil fertility	1. Agroforestry 2. Cover crops (creeping legumes) 3. Minimum weeding 4. Crop rotation with legumes 5. Alley crop with gliridia/erythrina/ leucaena	1. Mucuna Pruiens 2. Dolichos lablab 3. Gliricidia sepium 4. Erythrina variegata 5. Fabaceae (edibles)
Pests and diseases	Integrated pests management	Integrated cropping system allows combination of different crop species. -Include plants/crops with natural repellents against diseases organisms; crop rotation ensures that a crop species is not planted in the same plot for 2 or more consecutive cycles thus removing substrates for pathogens of that species.

5. 4 Blacksand, Efate Central Vanuatu

5.4.1 Situation analysis

Prominent issues at Blacksand, Efate are tidal wave, flooding and overpopulation. The area referred to as Blacksand is a low land area lying only a few meters above sea level. This makes it very prone to tidal wave, even though the recent history has made no mention of its occurrence. Flooding is another natural event presenting eminent disaster to the community. The recent flooding remembered by residents is dated in the 1990s.

5. 4.2 Agro-ecological constraints at Blacksand on Efate

Agro-ecological constraints identified at Blacksand are listed below. There are;

1. sandy soil,
2. low fertility,
3. reduced fallow period,
4. drought,
5. pest and diseases, and
6. high water table (leading to waterlogging during heavy rainstorm.

5. 4.3 Location of the study site

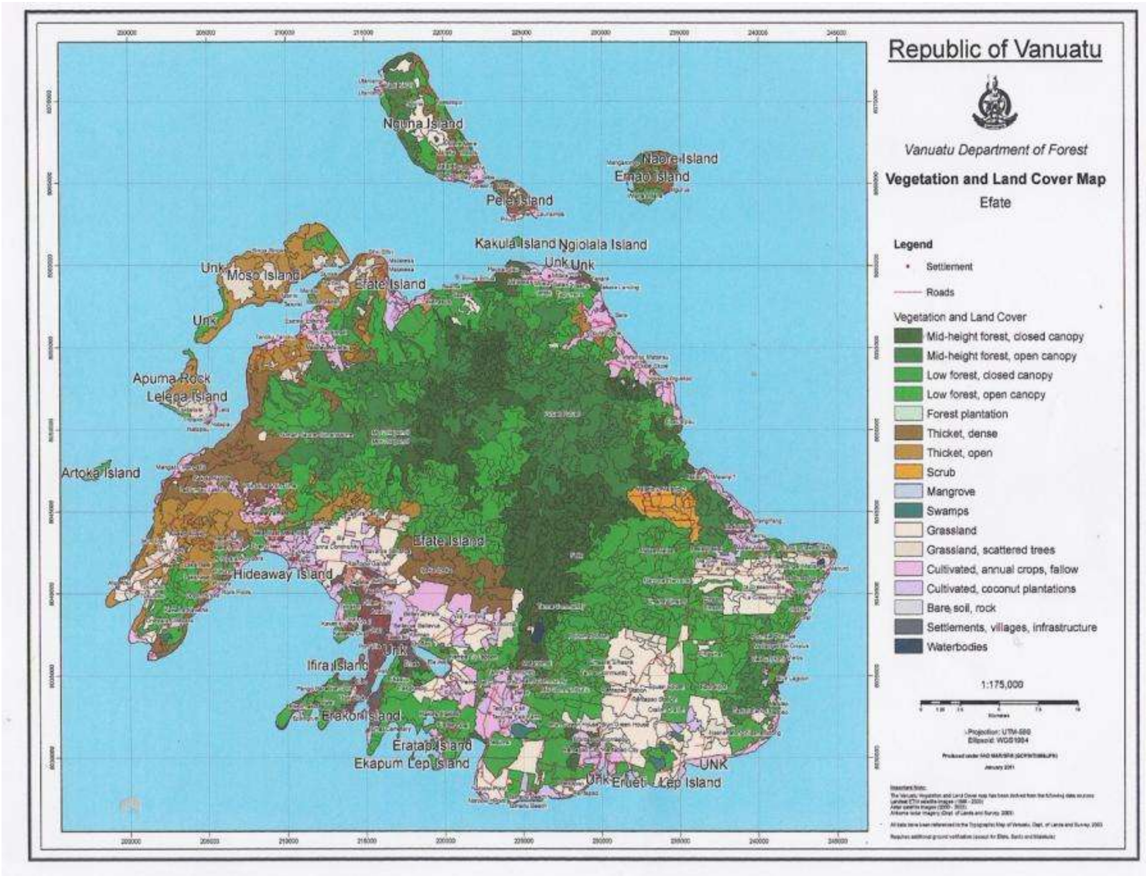


Figure 9 Map of Efate Island: Central Vanuatu (Dept Forest, Vanuatu)

5. 4.4 Principal root/starchy crops

Selection of root crops grown by the community is influenced by the nature of the soil, including its ability to carry the root crop to maturity. It is also influenced by the culture and diet of the individuals. The Blacksand community is made up of cultures from throughout Vanuatu. The root crops identified in the food gardens are given below in a ranking order.

Ranking of the root/starchy crops are carried below. Ranking is based on two (2) things. The proportion of daily diet the root/starchy crop makes up. The second is the area of the garden allocated to the crop. The ranking is as follows:

1. manioc,
2. banana,
3. kumala,
4. taro (Fiji),
5. yam,
6. taro ***(esculenta)*** and
7. wild yam.

Table 35 Root/starchy crops and their varieties grown at Blacksand

Root crops	Varieties
Yam	1. Strong yam (Wailu) 2. Soft yam (Salemona)
Taro (Fiji)	Red skin 1. Short tubers and strong flesh 2. Long tubers and soft flesh White skin 1. Strong flesh 2. Soft flesh
Manioc	1. Yellow flesh 2. White flesh
Kumala	1. Yellow flesh 2. Orange flesh 3. White flesh 4. Purple flesh 5. Purple and white flesh
Taro ***(esculenta)***	Dry land taro
Banana	1. Lady finger 2. Apple banana

5.4.5 Principal vegetables

The diet of the typical Blacksand Family contains some vegetables. Although it is safe to say that the daily consumption very much does not meet the daily nutritional requirement. The primary reason being that the gardens are too small in area and do not have the capacity to produce the daily requirement. The daily consumption can be supplemented from the Vegetable Market in Port Vila, except that the purchasing power of the typical family does not carter for it. Vegetables found in the gardens are;

1. island cabbage,
2. bean (dwarf and snake bean),
3. Chinese cabbage, and
4. English cabbage.

5.4.6 Farming systems

The farming system practiced at Black Sand is shifting cultivation, based on 1 year semi-fallow system. The system is a bastardised version of shifting cultivation. Households are allocated on average 3 plots each of less than 5 – 6 square meters each by the land lords. One plot is rested each season whilst the others are farmed. During fallow, crops like cassava and annuals like banana are kept to continue to supply food resources for the family. Cropping system used is intercropping. There is no evidence of cropping with leguminous plants to maintain soil fertility. Typical crops planted are;

1. yam,
2. taro (Fiji),
3. taro (esculenta),
4. kumala,
5. corn,
6. Island cabbage,
7. banana,
8. manioc, and
9. pumpkin

5.4.7 Planting calendar

The following planting calendar is developed from information gathered during the field survey. It is a typical planting calendar and does not necessarily mean that planting by all farmers is strictly governed by it. In most cases, planting coincide with the wet season. However, some farmers interviewed suggested that it is becoming more necessary that food crops are planted out of season. For example, kumula are now being planted off season to supplement diets throughout the year. This might be a result of climate change, in particular the spread of rains over the year.

Table 36 A typical planting calendar for farmers at BlacksandTable 36

Crop plant	Planting season	Harvest season
Taro (Fiji)	January - March	January
Taro (esculenta)	June – July)	June – July
Manioc	All year	All year
Yam	April - July	April – July
Banana	All year	All year
Kumala	May - July	August - November
Wild yam	All year	All year

5.4.8 Food preservation

Except for the yam, most food crops are harvested when needed. This eliminates the need to store or preserve them for future use. Unlike other pilot study sites, Blacksands is an outgrowth of the Port Vila Municipality. Members from most households are employed in Port Vila. As such most households use their gardens to supplement food sourced from retailers and the Vegetable Market in Port Vila. The following table (Table 37) provides the shelf-life of some food crops at Black Sand.

Table 37 Shelf-life of some food crops at Blacksands

Food crop	Shelf-life
Taro (Fiji)	< 1 months
Yam	> 2 months
Kumala	1 months
Wild yam	> 1 months
Manioc	1 week
Taro (esculenta)	> 1 months
Banana	1 week

Burying surplus root crops to preserve them is the most common method of preservation. Food tubers like wild yam and taro are wrapped in green leaves and buried. Food materials are only buried for preservation when there are surplus. Otherwise food is kept (preserved) in the garden and harvested only when they are needed for consumption or to perform cultural obligations.

5.4.9 Recommended crops and cropping systems

Farming systems and practices recommended for agro-ecological constraints identified at Blacksand on Efate are listed in the following table (Table 38). Crops recommended for each of these agro-ecological constraints are also supplied. The recommendations are based on the crop's morphological and physiological characteristics and agro-climatic requirements. This table is applicable elsewhere in the country where the specific listed agro-ecological constraints occur.

Table 38 Crops recommended to counter agro-ecological constraints identified at Blacksand on Efate

Agro-ecological problems	Recommended farming system(s)/practices	Recommended crop types
Sandy soil	1. Cover crop 2. Add compost 3. Mulching 4. Minimum weeding	1. Carrots 2. Radishes 3. Leafy greens (adequate soil moisture) 4. Sweet potato 5. Breadfruit 6. Lettuce 7. Runner beans 8. Yam 9. Taro 10. Manioc 11. Bracssica species

		12. Citrus 13. Corn 14. Watermelon 15. Pumpkin 16. Cucumber 17. Banana 18. Colocasia esculenta 19. Allocasia marorrhiza 20. Xanthosoma sagittifolium
Drought	1. Hydroponics 2. Mixed cropping 3. Pit planting 4. Mulching 5. compost	1. Colocasia esculenta 2. Allocasia marorrhiza 3. Xanthosoma sagittifolium
Reduced fallow period	1. Cover crops 2. Green manure 3. Intercropping 4. Crop rotation 5. Compost 6. Pit planting	1. Mucuna pruiens 2. Dolichos lablab 3. Gliricidia sepium 4. Erythrina variegata
High watertable leading to waterlogging following heavy rainstorm	1. Raised beds 2. Agro-forestry	1. Citrus 2. Watermelon 3. Pumpkin 4. Cucumber 5. Sweet potatoe 6. Manioc
Low soil fertility	1. Agro-forestry 2. Cover crops (creeping legumes) 3. Minimum weeding 4. Crop rotation with legumes 5. Alley crop with gliridia/erythrina/leucaena	1. Mucuna Pruiens 2. Dolichos lablab 3. Gliricidia sepium 4. Erythrina variegata 5. Fabaceae (edibles)
Pests and diseases	Intergrated pests management	Integrated cropping system allows combination of different crop species. -

		Include plants/crops with natural repellents against diseases organisms; crop rotation ensures that a crop species is not planted in the same plot for 2 or more consecutive cycles thus removing substrates for pathogens of that species.

CHAPTER 6:
CONCLUSION AND RECOMMENDATIONS

This chapter deals with recommendations deem appropriate for agro-ecological constraints identified in this report. The agro-ecological constraints are common to all study sites and are representation of food production problems existing throughout the archipelago.

6.1 Conclusion

Strategies recommended must be sustainable and resilience to climate change. Many small island states have looked to traditional knowledge as a way forward. Combining traditional knowledge with science is another option. However, we must not become too romantic with traditional knowledge. We must make calculated decisions when implementing traditional knowledge. We must be mindful of where and when to use it. We must also be mindful of when, where and how to combine it with science.

Two categories of recommendations are provided; general and specific recommendation. The categories of recommendations are discussed below.

6.2 Recommendations

6.2.1 General recommendations

1. The Department of Agriculture and Rural Development and other line agencies representing the government in collaboration with non-government organizations must provide awareness on climate change and its impacts in Vanuatu across the full range of stakeholders. Climate change–agriculture interactions must be included in planning and on-going agricultural development programs.
2. The government through relevant agencies must develop strategies, policies and measures to reduce the impacts of climate change on agriculture. These include developing, improving and implementing technology appropriate strategies, techniques and practices and monitoring and evaluating them.
3. The government through relevant agencies must collect valid and comprehensive agricultural data at appropriate local and national scales. These data must allow national, regional and international institutions to engage in analysis and make projections, development, improvement and implementation of climate-smart strategies and policies.
4. The government through the Vanuatu Agricultural Research and Training Center (VARTC) must include climate change as a high priority research question; expand its knowledge on

climate smart farming systems and climatic tolerance/sensitive crops of importance to Vanuatu and its islands through national researches. Conduct basic husbandry and production researches, improve understanding of the complex relationships between climate change and agriculture and understand how these links can impact on food production and security.

5. The government to increase its capacity and capacity building by developing institutional arrangements for knowledge sharing at national, regional and international levels; improve education and training; encourage programmes of action and government/private sector partnerships; and transfer knowledge of adaptation options on climate change and agriculture issues and concerns.
6. The government through the Vanuatu Meteorology and Geo-Hazards Department to improve and strengthen national climate forecasts. In addition, to strengthen partnership between meteorology and agriculture to improve and strengthen awareness of the use and uses of climate forecast information.

   The Vanuatu government through relevant agencies to address resource needs by facilities and funding for capacity building, interdisciplinary research and national assessments.
7. A long term strategy would be to develop Land Use Capability Map (LUCM) for the whole country. The map is to define all physical factors impacting on agriculture. The physical factors would be an expansion of those included in the VANRIS. Specifically, localities prone to effects of climate change (sea level rise, flooding, drought) and natural disasters (landslide, earth quake, tidal wave). This would give the government and NGOs a clear indication of susceptible areas and what to do to alleviate constraining factors of production resulting from climate change and natural disasters.
8. Soil tests and fertilizer trails in addition to Cation Exchange Capacity test (CEC) would provide a better understand of soil fertility and how best to address it. Soil test and fertility trails will identify soil nutrients that are lacking. CEC test will provide information on the soil's water-holding capacity and ability to hold nutrients at a certain soil depth. Appropriate strategies can then be implemented to rectify the problem(s). Soil pH can be corrected in accordance with CEC results.
9. Education and training through public awareness programmes and demonstration are important components to addressing the effects of climate change and natural disasters. Relevant government agencies must combine efforts with NGOs to deliver effective education and training programmes. Trainings must be tailored to address specific problems identified. Farmers must be involved with on site demonstration(s). Farmers will be more interested if they can see actual/tangible results on the demonstration plot.

6.2.2 Specific recommendations

Recommendations are given for each of the agro-ecological constraints identified. They are focused on improving agricultural production in;

1. sandy soil,

2. shallow soil,
3. saline soil,
4. drought,
5. low soil fertility,
6. soil erosion and leaching,
7. slope land,
8. landslide,
9. heavy clay soil and waterlogging,
10. decreased fallow period,
11. volcanic eruption and ashes, and
12. **12.** pest and diseases.

a. Sandy soil

Prominent characteristics of sandy soils are poor structural stability, poor nutrient holding capacity and cation exchange capacity (Blanchart et al, 2007). Crop performance in sandy soil is limited by these features. Performance can be improved by implementing compost, creeping crops, mulching and crops natural or adapted to sandy soil.

Compost can be added into the sandy soil to improve its performance. Applying 5-8 cm thick good quality compost to the sandy soil and digging into the top 15 – 20 cm of the soil is an option. A list of probable compost materials are provided in Table 2 (6.2.2 Shallow soils). Farmers can also add organic matter through crop plants planted.

Creeping crops (kumala, pumpkin, watermelon) and legumes (mucuna, lablab) adds organic matter through decomposed leaves and vines. However, organic matter added this way is a slow process and can take many years to produce sufficient organic matter.

Circular, square or rectangular boxes can be constructed around the stem of high value crops like kava and filled with compost. The compost will slowly add organic matter to the soil when decomposed. This practice is quite time consuming and requires a high amount of labour. It can be expensive if the farmer uses sawn timber to construct the apparatus. An alternative and cheaper method includes heaping of compost materials around the stem of the high value crop and coving it with coconut shells or short logs of wood. Banana stems can also be used to cover the heaped compost.

A further alternative is to select and use crops that grow natural or adapt to this soil condition. Literature search of tropical crop plant species and varieties adapted to sandy soil yielded very little information. This demonstrates the need for government research institutions (VARTC, DARD) to prioritize studies in this area. As a way forward relevant government agencies need to catalogue crop plants native or adapted to sandy soil (particularly Atolls and Low-lying Islands) and determine physiological and morphological characteristics enabling them to perform well in sandy soil.

East and Dawes (2009) recommended a number crop plants for sandy and shallow soils. The recommendation was made for South Tarawa, Kiribati. Relevant government agencies in Vanuatu can investigate their viability in the Vanuatu context. The list is provide below (Table 39)

Table 39 Trees, shrubs, vegetables and root crops recommended for sandy and shallow soils according to East and Dawes (2009)

Trees	**Vegetables**
Breadfruit	Chinese broccoli
Pawpaw	Chinese cabbage
Lime and Indian lime	English cabbage
Coconut palm	Bell pepper
Common fig	Watermelon
Native fig	Pumpkin
Beach mulberry	Cucumber
Banana	Tomato
Pandanus	Eggplant
Shrubs	Sweet corn
Sugar cane	Maize
Chaya	**Root crops**
Hibiscus	Taro (C.esculenta0
	Sweet potato

b. Shallow soil

This problem is common to all project study sites. Shallow soil is prominent on atoll and low-lying islands. In high volcanic islands, it occurs on certain parts only. Recommendations include increasing the top soil and organic matter by implementing cover crop, compost and mulch.

Farmers are also encouraged to implement shallow rooted crop plants and plants with morphological traits allowing them to grow on shallow soils.

Farmers can utilize a number of crop types and crop varieties as cover crop on farmlands with shallow soil. Cover crop help conserve moisture as well as add organic matter and humus to the soil. Adding humus and organic matter over time will gradually increase top soil. Implementation of legumes as cover crop will also add nitrogen to the soil via nitrogen fixing bacteria inhabiting the root nodules. Most creeping leguminous plants are good cover crops. ***D. lablab*** and ***M. pruriens*** are two most commonly available creeping legumes in Vanuatu. ***M. pruriens*** is preferred over ***D. lablab*** because its vines can easily be removed when matured. The vines of the ***M. pruriens*** lack adventitious roots unlike the ***D. lablab***. Adventitious roots on the vines of the ***D. lablab*** anchors them to the soil making it difficult to remove when matured.

Compost and mulch are other practices which can add soil particles to the top soil. Over time soil particles will gradually add to the top soil layer. They can also retain and conserve moisture; important features during drought. Humus and organic matter produced by compost and mulch are substrates for soil microorganisms. Materials used have a great impact on how well a compost works. A balanced carbon to nitrogen ratio is recommended. Some recommended materials are listed in Table 40. Compost can be added into the soil in 3 ways; (i) dig the compost into the soil; (ii) heaped around the crop plant's stem; and (iii) added into planting holes.

Table 40 Compostable materials

Material	**C/N**	**Material**	**C/N**
Fruits	N	Leaves	C
Fruit peelings	N	Manure	N
Feathers	N	Vegetable scraps	N
Grass clippings, dry	C	Hedge trimmings[4]	C or N
Grass clippings, fresh	N	Sawdust[1]	C
Garden debris, dry	N	Seaweed, fresh	N

[4] Hedge trimmings, saw dusts and weeds are hard to compost; needs some treatment to enhance decomposition process

Garden debris, fresh	C & N	Weeds[1]	N

Modified from http://web.extension.illinois.edu/homecompost/materials.cfm

Crop plants with shallow rooting system perform comparatively better than deep rooted ones in shallow soils. Soil depth measurements on Emae and Imaio showed the depth of the top soil on both sites to be less than 30 centimeters deep. Similar situation exist in Tegua and other atoll and low-lying islands in the Banks and Toress Group of Islands and the Shepherds Group. The shallow rooting system allows the plants to use nutrients from decaying leave debris breaking on the soil surface. Table 41 provides a list of shallow rooted crop plants. This list is not exhaustive.

Table 41 Shallow rooted crop plants

Shallow rooted leafy vegetables	**Shallow rooted creeping legumes**	**Shallow rooted root/starchy crops**
Lettuce	Dwarf bean	Manioc
Chinese cabbage	Snake bean	Taro Fiji
English cabbage	Mung bean	Giant taro
Tomatoes	Chickpea	Kumala
Carrot	pea	Irish potato
Eggplant	Lablab	Banana
Island cabbage	Runner bean	Wild yam
Shallow rooted creeping vegetables	Common bean	**Shallow rooted cereals**
Water melon	Wing bean	Sweet corn
Pumpkin	**Shallow rooted leguminous shrubs**	Maize
Cucumber	Pigeon pea	Sugarcane
Sushut	pawpaw	

Raised bed and mound increased soil deep in shallow soils. These techniques would best suit root crops like the yam. The added depth artificially created by the raised mound provides space (depth) needed by the tuber to develop and expand, both vertically and horizontally. Mounds are built from soil and compost materials. The materials are heaped into a mound and yam tubers pushed into it. The mounds can be as big as one meter high and wide. Vegetables can be grown on raised beds. The beds are also of soil and compost. The dimensions can vary depending on the situation and farmer's preference. Mulching is applied on the bed's exposing surface to reduce direct contact of radiation, thus evaporation.

c Salinity

Salinity is problematic on atoll islands such as that those in the northern part of the country and low-lying islands in the Shepherds Group. Observations in the Bank Group of Islands showed that a number of crop varieties have developed some tolerance to salinity (Dalesa, 2012). However, there are no formal catalogue of these crop types and varieties. The government, through the VARTC and DARD is recommended to identify such crop types and varieties and their magnitude of tolerance or prove their tolerance. Recommendations on salinity tolerance crop types and varieties can then be recommend for atolls and low-lying island; but only after testing it/them in that location.

Low-lying island nations like Kiribati, Tuvalu, Marshall Islands, Tonga, Maldives and the Caribbean are already faced with salinity. These countries have built up technical knowledge in this area that can be useful to Vanuatu. The VARTC and DARD can test these innovations and recommend them to Vanuatu farmers if found to be effective in the local situation.

Future increased in sea level will required more specific strategies. Salinity is the result of built up of salts like sodium, magnesium, calcium, chloride, carbonate, sulfate and other salts in the root zone. As this increases, these salts will have to be removed to allow the rooting system to continue to absorb necessary nutrient ions. The salts can be flashed out by leaching and drainage. Although this technique is expensive at present, it must be considered an option in the future when salinity in atolls and low-lying islands intensified.

Shannon (1997) suggested; (i) gradual improvement of salt tolerance of crops through conventional breeding and selection, (ii) introgression[5] of crops with their wild progenitors, which may already possess salt tolerance; (iii) domesticating wild species that currently grow in saline environments by breeding and selection for agronomic characteristics.

d Drought

The government through the Department of Meteorology and Geo-Hazards to establish and make available and accessible [warning] systems farmers can use to plan farming activities in advance. Such system can allow farmers to prepare in advance for prolonged dry seasons. Knowing when there will be a drought and how long it may last would help farmers decide on how much water they would need to reserve for it.

[5] Transfer of genes (gene flow) from one species to another.

Several strategies are suggested in Reilly et al. (2003). Some adaptation techniques they proposed are planting dates, shift in varieties, change on crop types and farm inputs.

Planting dates: Vanuatu has two main seasons, dry (cold) and wet (hot) season. Traditional farming calendar is based on these two seasons. Planting dates are scheduled in accordance with these two seasons. Planting adjustments must be made to coincide with the occurrence and duration of the dry season. Planting must be programmed such that crops take advantage of the rains at the beginning of the rainy season. Crops like the yam must be scheduled such that the crop established itself and is able to fight the anthracnose disease comes the rains. The planting date of the kumala must be programmed such that it utilizes the dry season for tuber development and maturation.

Shift in varieties: Some crops traditionally grown in Vanuatu are hardy and able to tolerate drought. Not all varieties of a crop species do well against drought. There is at present lack of complete information on crops and crop varieties tolerant to drought. The government through the VARTC and DARD need to catalog all food crops and their varieties existing in Vanuatu. The institutions must then investigate the capacity of these varieties to tolerate drought. This type of study is currently being done on selected varieties at the VARTC. However, more crop species and varieties need investigation. Recommendation must be based on this catalogue. Similar studies must be carried out by the Department of Livestock to identify drought tolerate strains of livestock animals.

Change on crop types: Some crops are tolerant to drought while others are not. Those that are tolerant show different magnitude of tolerance. Presently we have very little knowledge of the conventional farm crops' degree of tolerance to drought. Although observation shows that crops like navia, dryland taro and wild yam tolerate drought. The government through the VARTC and DARD must include drought tolerance as a priority research question. The government must establish a catalogue of drought tolerance crops and if possible create an ex-/in-situ conservation of genetic materials where farmers can have access to them. Further research must be taken to determine the magnitude of tolerance for these crops and the information catalogued. Furthermore this information must be made user-friendly, available and accessible to farmers throughout Vanuatu.

According to Johnson et al (2000) deep rooted crop plants does better in droughts because they are able to draw water and nutrients from deep within the soil during water stress and dry periods. Literature search on crop plants in Vanuatu with the ability to draw water and nutrients from sources deep in the soil produce no results. In this regard, it would be recommended that the VARTC and DARD conduct relevant studies and catalogue such crop plants. This list can be made available and accessible to farmers as a strategy to combat drought. Kell (2011) suggested breeding crop plants with deep roots as a strategy. This strategy can be a future option for the VARTC and DARD to think about.

Farm inputs: In the conventional sense, farm inputs include finance and capitals like inorganic fertilizers, herbicides and farm tool and implements that the farmer uses in the farming process. In this regard, I will define farm inputs to include organic matter. A good amount of organic matter in the soil can help conserve soil moisture during drought.

Farming practices: The government through DARD and other line agencies must advocate through awareness and demonstration plots that compost, mulch and cover crop 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.

e. Soil erosion and leaching

Soil erosion and leaching are identified in all pilot study sites. The washing away of soil particles is a serious problem on slopes and deforested land. Washing away of the top layer (top soil) means that there is little or no soil left to support crop plants. The top layer of the soil must be rebuilt if the degraded land is to support crop production. There are a number of ways the farmer can do this. Some recommended strategies are briefly discussed below.

The vertiver grass morphologically has thick dense rooting system and grows in thick butches. The dense network of rooting system serves as a barrier preventing soil particles from being washed away by running water during rainstorms. The rooting system also helps give the soil structure and stability. Planted in rows along slope or hilly land, the vertiver grass will help reduce soil erosion. The leaves of vertiver grass can be cut and laid out on the soil as mulch. Covering the soil surface protects it from directly being impacted by droplets of rain. This keeps the droplets from detaching the soil particles or destabilizing the soil structure.

The falling droplets of rain gather acceleration and weaken the soil structure and detach the soil particles when it comes in contact. The weaken soil structure and detached soil particles and nutrients are easily washed away by running water to lower elevation or lagoons or the ocean. Covering the soil surface with crops or weeds serves as barriers which reduces the impact of the falling droplets of rain on the soil and keep the soil particles intact.

Replanting of trees in deforested land is another option. Both commercial tree crops and ornamental trees can help. Sandalwood, pine and whitewood are examples. Ornamental trees can add value to the land as well as protecting it from soil erosion.

f. Low soil fertility

Low soil fertility is one of the causes of low food production and food insecurity. Many soil become degraded as a result of burning and over-cropping. Strategies applied to improve soil fertility must be targeted at adding organic matter to the soil and protecting it. There are a number of ways available and accessible to small-holder farmers with limited resources.

Covering the soil surface with cover crops is recommended as a soil fertility improvement strategy for situations with slope, sandy soil, shallow soil and areas with short fallow period. Combined with crop rotation this practice can be an effective tool to improving and maintaining soil fertility and conditions.

The cover crop can be dug into the soil as green manure at the end of each cropping cycle. Being legume the crop can also add nitrogen into the soil through nitrogen fixing bacteria in the root system. The decomposed leaves and vines add organic matter to the soil. Rotating the food crop with cover crop gives the soil time to replenish itself with organic matter and soil amendments to support another cycle of food crop.

Creeping legumes are the recommended cover crops. There are a number of creeping legumes available and accessible to farmers throughout Vanuatu. Glycine is widely used a livestock feed in Vanuatu and can be sourced from throughout the nation. This crop can be planted on islands or parts of Vanuatu where there are no ***D. lablab*** or ***M. prurines*** seeds.

Compost and mulch can also improve soil fertility. Like cover crop they are cost-effective. Both compost and mulch draws from waste organic materials. They enriched the soil by adding organic matter. Compost and mulch can be applied in all scenarios in the country. It can be applied on high volcanic and atolls islands. They can be used on slopes as well as flat lands. They are applicable in sandy and shallow soils.

Farmers with the capacity to use inorganic fertilizers can be advised to us it. However soil tests and soil fertility trials must be carried out to determine exact nutrients that are deficient. Rate application would need to be advocated as a measure against leaching and downstream effect.

Alley cropping with nitrogen fixing trees and shrubs is another option. Gliricidia, calliandra, erythrina and leucaena are recommended nitrogen fixing alley trees and shrubs. The branches and leaves can also be prunned and left along the alleys to decompose and add nutrients to the soil, conserve soil moisture and reduce evaporation from the soil.

g. Decreased fallow period

Decreasing fallow period is identified in all project sites. Population pressure resulting from high population density and shortage of arable land is the key contributing factor to shorter fallow period. Fallow can only sustain soil fertility if the land is given sufficient time (years) to add organic matter and soil nutrients. Traditionally, agricultural lands were allowed to fallow for 5-7 years to improve degraded soil. Increasing population over the last couple of decades has resulted in drastic slashed in fallow period to about 2-3 years: in some cases to only a year. Systems and practices must be developed to improve soil fertility and sustain food production over a shorter period (number of years) that the traditional [fallow] system. There are a number of strategies available, both locally and from other countries.

Brush and hoe method is described by Dola (2011). This technique is used widely on Malata province in the Solomon Islands. Brush and hoe method is a modification of the slash and burnt method. It is an improvement of the slash and burnt method. Unlike the slash and burnt, brush and hoe forbids burning of the vegetation brushed. Trees are debarked and the skin used as organic matter. The vegetation cut are collected and heaped in rows as mulches. Where there is too much vegetation to use as organic matter, the materials are placed on the side of the garden and added into the field when needed. This practice avoids burning of organic matter as in slash and burn. By not burning organic matter the farmer is also reducing the amount of carbon dioxide produced and emitted into the atmosphere when the vegetation is burnt.

h. Landslide land and slope land

This problem is common on hilly and mountainous islands with steep slopes. It is particularly intense where the forest cover is removed as a result of deforestation. It is also a problem on places where heavy pressure is placed on the land (slope) as a result of high population pressure. Of the study project sites, this problem is identified on Tanna, Ambrym and Ambae. This problem is intensifying in places where it is already a problem and occurring in new sites. Increased rainfall frequency and intensity as a result of climate change is attributed to this problem. The projected increased in frequency and intensity would only result in increased occurrence and intensity of this problem. There are a number of strategies to correcting it. Strategies must be targeted at preventing landslides from occurring. There are a number of ways to doing this.

Reforesting slopes after deforestation is a recommended measure. Reforestation will ensure that the land is covered with crop plants. The leaves of the forest trees will reduce the impact of the falling droplets of rain on the soil surface. The roots of the forestry crops will hold the soil particles together and give stability to the soil structure.

Forestry crops with dense rooting system and also those with deep rooting system can be planted at the bottom of the slope hold the soil particles to together. Planted at the bottom of the slope, the dense and deep rooting system will act as barriers preventing the soil particles from being washed down into the creeks, gullys or rivers. Bamboo species with dense rooting systems is one of the recommended species. Erythrina is also a recommended species because of its dual purposed. The erythrina has a deep rooting system and serves as a leguminous plant. Other flora species with these traits can also be used to prevent landslides.

i. Heavy clay soil and waterlogging

Clay soil is also known as heavy soil. Unlike sandy soil, clay soil holds rich concentrations of nutrients, which makes it potentially fertile if treated properly. It also holds water well. However, clay soil is heavy to dig and cultivate, drains slowly, leading to waterlogging. It losses structure and forms puddle and is compacted when worked on when wet. Waterlogging causes yellowing of leaves, root rot and dead. Clay soil is identifies on a number of the project sites, including Aniwa in the northern part of Vanuatu. The Sarakata basin is also prominently of clay soil. Strategies implemented must be targeted at improving drainage or crop plants adapted to clayey soils.

There are a number of ways to improve drainage in heavy soils. The most cost-effective strategy for small holder famers is to raise beds to assist drainage and reduce waterlogging. The structure of the raised beds can be built from bamboo, waste timber or woods and sticks collected from the forest. Alternatively the beds can be raised without a wooden structure. The farmer can dig a different type of soil elsewhere to the fill up the raised bed.

Digging plenty of bulky organic matter such as manure or compost is another option. The organic matter or compost helps improve drainage. Adding organic mulches around the stem of tree crops including high value crops is another option. This technique is recommended for permanent tree cops. Dig the mulch to about 7.5 cm deep. To prevent the mulch causing stem and root rot in crop plants, best to leave a gap of 7 cm between the stem and mulch. In addition to improving drainage and adding nutrients to the soil, organic matter also improves retention of soil moisture.

Additionally, the website http://apps.rhs.org.uk/advicesearch/Profile.aspx?pid=305 also recommends breaking up the bottom and sides of planting holes as a measure to enhance free drainage. Accumulation of water in the planting pit can result in root rot.

Crops suitable for heavy soil include ginger, cassava, kumala and taro. Many other crop types do grow well in this type of crop as long as drainage is sufficient or improved.

j. Volcanic eruption and ash

Prevalent on Tanna and Ambrym, this natural disaster is ranked by the Project on 'Community Resilience, Climate Change and Adaptation and Coping with Natural Disasters' as the 3rd most hazardous disaster Vanuatu communities are prone to. The effects of volcanic eruption are not confined to areas proximal to the volcanoes. Subsequently, the effects are immediate and may last for several months. The effects of volcanic eruptions and ashes are multiply and multifacet, affecting crop plants, livestock, drinking water, health and infrastructures. Sometimes taking up to several years for communities to recover from the impacts

There is no immediate solution to the effects of volcanic eruptions and the ashes spewed during eruptions. The most effective strategy is to build up the community's resilience and ability to rebound from it. Whilst there is no one solution, there are avenues available to farmers. There are also practices that Vanuatu can adapt from other Pacific Island countries with similar problem. A strategy is to combine available techniques.

Hardy varieties or those that tolerate volcanic ashes are recommended. A visit to Imaio village at the basin of the Yarsu volcano identified certain crop varieties with tolerance to volcanic ash. For example, a species of banana (unknown name) showed good resilience to volcanic ash. A detailed study to identify and catalogue crop plants tolerant to volcanic ash is to be conducted in volcanic ash prone islands.

Volcanic eruption and ash spewing is not a daily occurrence. In fact it takes place at certain times of the year. Unfortunately there is very little knowledge, both traditional/historical and scientific in this field. A strategy would therefore be to catalogue and build up historical and chronological events and combine with scientific knowledge to predict occurrence (seasonal) of volcanic eruptions. Equipped with a predicted calendar of events (volcanic eruptions) farmers can develop with assistance from the DARD planting calendars specific to localities and based on early maturing crop plants.

Increasing food security by crop diversification is another recommended strategy. Crop diversification means that a garden has more than one crop species. The principal behind this; is that when one crop is destroyed by volcanic ashes, one or more species with tolerance to volcanic ash would still provide food and cash income for the family. This strategy would reduce risk placed on food sources and cash income.

Kitchen gardening, or backyard gardening refers to planting of food crops, particularly vegetables and legumes around the home. A kitchen garden can be effectively protected from the volcanic ashes if it can be covered with plastic sheets during volcanic eruptions and ash spewing. Kitchen gardens can also serve as emergency gardens during or after volcanic eruptions and ash fall outs. Families can use food crops from the kitchen gardens when it becomes difficult to venture out into the deep forest gardens during volcanic eruptions and ash spewing.

Hydroponic is an alternative farming practice that allows high value crops to be cultivated on solutions rather than soil. This system also allows crop plants to be grown inside of a specially constructed shed. The shed ensures that the roof protects the crops from falling volcanic ashes and acid rain. Growing the crops in media solutions remove the need to grow crops on the soil hence removing the crops from the risk of exposure to volcanic ashes and acid rain.

In a similar manner to hydroponic, greenhouse allows production of crops inside a specially built shed. The roof of the greenhouse protects the plants from falling volcanic ashes and acid rain. Raising the platforms above the ground surface protects the crops of acid or sulphur contained in the volcanic soil.

k. Pests and diseases

There are a number of ways to tackle pests and diseases. A strategy is to use crops and crop varieties resistant to pests and diseases occurring in the locality of interest. A number of native plants and crop plants have developed resistance to specific pest and disease organisms. An example is the resistance of ***A. microrrhizos*** to Papuan beetle. Other aroids like ***C. esculenta*** and ***X. sagittifolium*** are susceptible to this pest. Where this beetle is present, it would be advisable for farmers to cultivate ***A. macrorrhizos.***

Changes in climate, particularly toward long periods of wet season create favorable conditions for the ***Phytophthora*** diseases of the citrus. Thedisease has already inflicted devastating harm on the orange industry on Aniwa. Grafting that sweet Aniwa orange onto wild lemon root stock would provide a grafted plant capable of withstanding it. Wild lemon is observed to resistance to the ***Phytophthora*** disease.

Pathogenic organisms require moisture as a pre-requisite to reproducing, growing and multiplying. Take way moisture and these proteins are denatured. Planting calendar can be manipulated so that these organisms do not have the conditions necessary for their survival. Planting yams at the end of the dry season to allow the crop to establish itself before the rainy season is an example. This would ensure that the yams are able to tolerate anthranose when the rain comes.

Weeds like ***M.peltata*** and ***Cassia tora*** are also of economic importance. Not only do they smother crop plants, they also deprive them of nutrients and water. Although there are herbicides commercially available, famers in most rural outsets lack the purchasing power to purchase them. The best strategy therefore would be to develop management methods based on planting calendar and manual weeding or running grazing livestocks through the batch. A further combination would include grazing livestock and manual weeding plus burning of the weeded weeds. Burning would ensure that seeds are also gotten rid of.

Traditional practices of planting repellant and trap plants in the garden are also suitable strategies. Repellant plants planted in rows around the garden or in the midst of the crop produce pheromones repulsive to insect pests. Traps plants planted around the garden or between rows of crop plants attract pest organisms to them. Although there are such plants being growth by farmers throughout the nation, present knowledge on them is limited. The DARD and VARTC would be advised to survey, test and catalogue a list of both repellant and trap plants recommended for Vanuatu.

Mixed cropping is another technique to counter loss of food security due to pest and disease organisms. This strategy is based on the principle that pest and disease organisms are crop specific. That certain organisms will only attack a certain crop family or species. A combination of difference crop families and species will ensure that when a pest or disease organism strikes, food security will not be drastically affected. That the family will still have other crops as sources of food and/or cash income.

Rotating crops around a number plots allow at least one plot to fallow in a growing season. Crop rotation also ensures that one crop species is not planted in the same field in 2 or more consecutive years. The break in the cycle removes food substrates for pest organisms. The withdrawal of food substrates will cause starvation and eventual death.

The seaweed is plentiful in coral atolls where there is a lagoon. In the Solomon Islands the seaweed is collected, processed and used as both a soil amendment and to control common pest organisms. According to Sui (2011) seaweeds are collected and placed in a bucket. 5 litters of water is added to the seaweed. The mixture is thoroughly mixed and the bucket covered with a lid and allowed to ferment for 2 weeks. The solution is strained and the decomposed seaweed is applied as mulch or used in compost. Half a cup of the seaweed solution is extracted and mixed with three-quarters of a cup of fresh water. This solution has dual purposes. It is used as organic fertilizer or natural pesticide.

The chilly plant is easily accessible throughout the Vanuatu archipelago. The fruits of the chilly have properties that repel common pest organisms. Kabu (2011) of the Kastom Gaden Association in the Solomon Islands described how the solution is made and applied to infested gardens. The fruits (chilly) are collected and measured using a coconut shell. The content of the coconut shell is tipped into a bag and thoroughly mashed. The mashed material is poured into 5 liters of soapy water or water and thoroughly mixed. The solution is strained and rested overnighted. It is sprayed onto infested garden the following morning.

Tomato leave solution is made of chopped tomato leaves boiled in fresh water for 2 minutes and rested overnight. This technique is used in the Solomon Islands. Briefly tomato leaves are collected, cut in half and boiled in a pot for 2 minutes (Aloatu, 2011). The solution is poured into a container and stored overnight. It is ready for use the following morning. This natural pesticide is recommended for pests of the brassica family.

Strict garden management is another technique of controlling pest organisms. Well drained soil prevents pools of water to be collected after a heavy rainstorm. Moisture provides the ideal condition of pathogenic proliferation. Without moisture the protein bodies will dehydrate and eventually died off. Raised beds provide similar conditions to well-drained soil. Raised beds can be used in clayey soil or heavy soil where water does not easily drain. Physically hand-picking harmful insects and plants is another strategy. The harmful insects and plants are burnt or dehydrated in the sun and/or burnt.

The plant protection section of the Department of Bio-security must expand service it provides to remote islands and communities. This service is currently confined to certain parts of Vanuatu. The service provided must include identification of pest and disease organisms and advices and recommendations on cost-effective ways to manage them. A policy to regulate the movement of plants and animals between islands within Vanuatu must be developed and gazette by the government.

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ANNEX-1: Crops and extreme events calendar

(i) Root crops

Season		**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Extreme Events	Drought												
	Flood												
	Cyclones												
	Fire												
	Landslide												
	Volcanic Eruptions												
Root crops	**Root crops**												
	Manioc	All year round											
	Kumala	Harvest							Planting & Development				
	Taro												
	Island taro			Planting	Growth & Development								Planting
	Taro fiji	Growth & Development											December
	Navia	All year round											
	Yam												
	Soft yam	Growth & Development				Harvest			Planting				Growth & Development
	Strong yam	All year round											

(ii) Legumes and vegetables

Season		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
	Drought												
Extreme Events	Flood												
	Cyclones												
	Fire												
	Landslide												
	Volcanic Eruptions												
	Legumes/Vegetables												
	Bean	All year round											
	Tomato						Plant	Growth & Development		Harvest			
Legumes/ Vegetables	Round cabbage							Planting		Harvest			
	Chinese cabbage							Planting		Harvest			
	Island cabbage	Planting							Planting				Planting
	Carrot	Planting. Growth & Development & Harvest											
	Pumpkin	All year round											
	Water melon	Harvest							Planting		Growth & Development		Harvest
	peanut	All year round											
	Wild fern	All year round											

(iii) Fruit trees

Season		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Extreme Events	Drought												
	Flood												
	Cyclones												
	Fire												
	Landslide												
	Volcanic Eruptions												
Fruit trees Vegetables	**Fruit trees**												
	Breadfruit												
	Orange					Harvest							
	Mandarin					Harvest							
	Grape fruit	All year round											
	Mango							Flowering					Harvest
	Nakatambol					Harvest		Flowering					
	Naus	Harvest						Flowering					
	Nakavika				Flowering			Harvest					
	Avocado	Flowering			April								
	Nangai							July					December
	Namambe	Flowering											Harvest
	Nantaou	Flowering						July					
	Pawpaw	All year round											
	Navel	All year round											
	Sousoup	All year round											

ANNEX-2 : List of people consulted

Name	Occupation	Contact	Address
Willie Kalia	Farmer	(678)5934722	Marae Village, Emae island
Annie Meto	Farmer		Marae Village, Emae island
Song James	Farmer		Marae Village, Emae island
Jimmy DeMarae	Farmer	(678)56914407	Marae Village, Emae island
Abel John	Farmer	(678)599065	Finonga, Emae Island
Graham Matan	Farmer	5440741	Finonga, Emae Island
Ronald Avenus	Farmer	5446020	Finonga, Emae Island
Willie Ben Temert	Assistant Agriculture Officer	(678) 7713686/5606274	West/North Ambrm
Edward Hendry Lekel	Farmer	(678) 7788569	East Guava, Banks Island
Antoine Ravo			Department of Agriculture and Rural Development, Port Vila , Vanuatu
Kaltuk Kalomor	Senior Livestock Laboratory Officer		Department of Livestock, Port Vila
Tari Molisale	Root Crop Officer		Department of Agriculture and Rural Development, Luganville, Vanuatu
Oniel Dalesa	Farming System Officer		Department of Agriculture and Rural Development, Luganville, Vanuatu
Wllie Iau	Principal Agricultural Officer		Isangel, Tanna , Tafea Province
Lesly Jonah	Farmer		Blacksand , Efate, Vanuatu
Daniel Samson	Live and Learn Officer		Tanna, Tafea Province
Jimmy Tes	Live and Learn Officer		Santo, Sanma Province
Isso T			SPC/GIZ Vanuatu Climate Change Project, Vanuatu
Clive Garae	Farmer	(678) 7787336	East Ambae, Ambae
Camden Molisa	Farmer	(678) 7792705	Olboi Village, West Cost Santo, Santo