REPUBLIC OF VANUATU

TECHNOLOGY NEEDS ASSESSMENT ADAPTATION REPORT

Date of Submission: July 2020

Supported by;

TECHNOLOGY NEEDS ASSESSMENT REPORT:
CLIMATE CHANGE ADAPTATION TECHNOLOGIES IN AGRICULTURE AND WATER SECTOR REPORT

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Foreword

The existential threat posed by climate change is undisputable for small Pacific island nations such as Vanuatu. The increasing concentrations of carbon dioxide in the atmosphere places humanity on a dangerous pathway. There is the urgent need for drastic global actions. According to the World Meteorological Organization's 2019 report, the past five years and the past decade (2010 – 2019) have been the warmest on record. The World Economic Forum's Global Risks 2019 Report rates the failure of climate change mitigation and adaptation amongst three of the top five risks. The reduction and stabilization of atmospheric GHG concentrations is critical. Adaptation to the impacts of climate change is therefore essential and requires a series of measures. It will be of utmost importance that the transfer of or access to environmentally sound technologies is a focus within Vanuatu's development agenda. Promoting the transfer of such technologies to developing countries is in close alignment with Article 4.5 of the United Nations Framework Convention on Climate Change (UNFCCC). More specifically the Poznan Strategic Programme (PSP) on the transfer of technologies, adopted at the 14th Meeting of the Conference of Parties to the UNFCCC in Poland in 2008, is meant to facilitate funding to developing countries for assessing their needs for environmentally sound technologies. Vanuatu has greatly benefited from the Technology Needs Assessment (TNA) process, undertaken as part of the PSP. The priority sectors for Vanuatu which have been assessed under the TNA are the Agriculture and Water sectors for adaptation. I am therefore pleased to present the Climate Change Adaptation Technologies in Agriculture and Water Sector Report. This Report has been prepared in consultation with relevant stakeholders and I would like to take this opportunity to convey my heartfelt appreciation for their collaboration and their contributions. I wish to further highlight that the Report recognizes the vulnerability of Vanuatu to the impacts of climate change. The Report's recommendations reflect our national development priorities. The technologies recommended in the TNA for the priority sectors are meant to chart a pathway for enhancing climate change adaptation for Vanuatu. My deepest gratitude also to the UNEP DTU Partnership and the University of the South Pacific for their technical support and most importantly as well to the Global Environment Facility (GEF) for its financial support towards this project.

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Acknowledgements

Technology Needs Assessment Project implemented in collaboration with the United Nations Environment Program, Climate Technology Centre & Network (CTCN) and UNEP/DTU (https://unepdtu.org/) partnership as a part of the strategic program on technology transfer, is an encouraging step in Vanuatu's progress towards climate change adaptation and mitigation.

For Vanuatu, the ongoing Technology Needs Assessment (TNA) project is an excellent and timely opportunity to accelerate environmentally friendly technology transfer that should become the basis for Vanuatu to reach its' determined GHG emission reduction targets and promote low carbon and climate resilient development of the country.

The Vanuatu Department of Climate Change (DOCC) hopes that the Technology Needs Assessment (TNA) project will serve as a key step towards addressing our climate change concerns by providing an assessment of the priority technology requirements. My special thanks are due to the members of the respective Expert Working Groups on Adaptation (Agriculture and Water sectors) and all other experts who contributed to the TNA process. I would also like to thank the numerous other ministries, divisions of the government, non-government and private sector experts who took time out of their busy schedule to meet with our consultants and provide data and information.

Lastly, I extend my gratitude to the Global Environmental Facility (GEF) for providing financial support. I also thank the UNEP Division of Technology, Industry and Economic for their technical support and guidance.

Mike Sam Waiwai
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Executive Summary

The Pacific Ocean state of Vanuatu is extremely vulnerable to the impacts of climate change. Given Vanuatu's geographical location, the country is regularly exposed to climatic disaster risks such as cyclones, droughts, flooding and storm surges. Furthermore, Vanuatu is categorized as a least developed country whereby its' economic status is critically susceptible to impacts from climate change and associated disaster risks.

The main objective of Technical Need Assessment (TNA) Project is to prioritize the most relevant and effective application of prioritized technologies in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change. Selected sectors for the TNA process came about as a result of stakeholder discussions through the National Advisory Board on Climate Change and Disaster Risk Reduction (NAB) platform. These discussions were also informed by desk research undertaken by the TNA national team of Vanuatu's respective development and climate change priorities. .

Being a Small Island Developing State, fresh water and agriculture are key sectors for the socio-economic development of Vanuatu. With Vanuatu going through intense periods of droughts, increasing severe tropical cyclones and water salinization, the detrimental impacts of climate change and climate variability are already being felt on water supply and agriculture. Adaptation in the water sector is, therefore, of very high importance particularly with respects to health and sanitation needs. Since agriculture, especially the production of vegetables is highly dependent on rain and is already impacted negatively by climate change and climate variability, adaptation in the agriculture sector is also covered by the TNA project.

The choice of priority sectors in the TNA project is consistent with national development priorities, while taking into account the inherent vulnerabilities of climate change impacts on an island state. The sectoral consideration in the climate-development nexus of Vanuatu is clearly revealed in its Second National Communication under the UNFCCC, and articulated in the country's National Sustainable Development Plan. The TNA project brings complementarity in terms of nationally determined contributions.

In sum, this TNA report has assessed the technology needs for adaptation in the water and agriculture sectors. A multi-stakeholder process, inclusive of two stakeholder workshops and series of bilateral meetings, has been embraced for the identification and prioritization of technological options using a Multiple Criteria Analysis (MCA) framework. Local stakeholders and sector experts collaboratively discussed and agreed upon the respective criteria and weights from which adaptation technologies were scored. All relevant information for prioritizing technologies was provided in Technology Fact Sheets. The criteria proposed by UDP TNA Guidebook were used and indicators were defined by local stakeholders.

The technologies that have been retained for developing the Technology Action Plan (TAP) are summarized below for each sector:

SECTOR	TECHNOLOGIES RETAINED FOR TAP
AGRICULTURE	• Crop diversification and new varieties • Agro-forestry • Farmer Field Schools
WATER	• Rainwater harvesting from roof tops • Water Safety Plans • Flood Hazard Mapping

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Abbreviations and Acronyms

CTCN	Climate Technology Centre and Network
DTU	Technical University of Denmark
EPM	Ecological Pest Management
FFS	Farmer Field Schools
GoV	Government of Vanuatu
HWTS	Household water treatment and safe storage
INM	Integrated Nutrient Management
MCA	Multi Criteria Analysis
MCC	Ministry of Climate Change
NAB	National Advisory Board on Climate Change and Disaster Risk Reduction
NAPA	National Adaptation Programme for Action
NDC	Nationally Determined Contributions
NEPIP	National Environment Policy and Implementation Plan
NSDP	National Sustainable Development Plan
RCPs	Relative Concentration Pathways
SOPAC	South Pacific Applied Geoscience Commission
SPREP	Secretariat of the Pacific Regional Environment Programme
SNC	Second National Communications
SSTs	Sea Surface Temperatures
TFS	Technology Factsheet
TNA	Technology Needs Assessment
UDP	UNEP DTU Partnership
UNFCCC	United Framework Convention on Climate Change
VANGO	Vanuatu Association of Non-Government Organizations
VBRC	Vanuatu Business Resilience Council
VCAN	Vanuatu Climate Action Network
VCAP	Vanuatu Coastal Adaptation Project
VSTP	Vanuatu Sustainable Tourism Policy
WSP	Water Safety Plans

National Circumstances

The archipelago nation of Vanuatu is located in the Melanesian region of the South Pacific Ocean between 12° and 23° north latitude and 166° and 173° east longitude, covering an expanse of approximately 1,300 kilometers (km). Over eighty islands, covering a total land area of 12,233 square kilo-meters (km2) with just over 2.5 thousand kilometres of coastline and an exclusive economic zone of 680,000 km2 make up the country (Figure 1). The largest of the islands, Espiritu Santo and Malekula cover 50% of the country's land mass and harbour the majority of Vanuatu's population.

Figure 1: Map of Vanuatu

Vanuatu gained independence in 1980 from the UK and France. It is a member of the international organizations such as Commonwealth, Pacific Islands Forum, World Trade Organization, UN, ADB and the World Bank.

Vanuatu has a population of 272,459 (2016). The annual growth rate of 2.14% has been declining in the recent years[1]. Seventy-five per-cent of the population live in rural areas[2] and approximately 26.6% of the population is between 15-29 years of age. Approximately 80% of the population in Vanuatu engages in subsistence agriculture, which contributed to about 27% to Vanuatu's gross domestic product (GDP) in 2017[3]

The country's economy is primarily based on small-scale agriculture, which provides a livelihood for two thirds of the population, while fishing, offshore financial services and tourism support the economy[4].

[1] *https://data.worldbank.org/country/Vanuatu*
[2] *Mini Census Report (Post TC Pam), 2016.*

[3] *CIA World Factbook*
[4] *World Bank, (2011). 'Vulnerability, Risk Reduction, and Adaptation to Climate Change: Vanuatu', Climate Risk and Adaptation Country Profile*

Vanuatu's climate varies with latitude, from wet tropical in the northern islands, which receive over 4,000 millimeters (mm) of annual rainfall to the dryer subtropical in the southern extremes of the archipelago, where annual average rainfall measures at 1,500 mm.

Average temperatures range from 21°C to 27°C, and unlike many of the Pacific island nations, seasonal temperatures in the capital city of Port Vila exhibit high variability with summertime highs exceeding 30°C and minimum temperatures often reaching below 20°C.
Seasonal and inter-annual variations in climate are driven by changes associated with the El Niño Southern Oscillation (ENSO), which affect every aspect of the climate in the Pacific. Cyclones are common during the warm months of November to April, although two recent cyclonic events were experienced outside of the traditional cyclonic season.

Almost 74% of the land area in Vanuatu is covered by natural vegetation, with around one third covered by forest. Vanuatu's total land area is about 12,336 km^2 with more than 36.1% (440,000 hectares) covered by tropical forest. Vanuatu has some 108 known species of amphibians, birds, mammals and reptiles; of these, 21.3% are endemic, meaning they exist in no other country, and 13% are threatened. Vanuatu is also home to at least 870 species of vascular plants, of which 17.2% are endemic. There are around 1000 vascular plants of which 150 are endemic and 700 species of bryophytes including many Invertebrates species (butterfly, bees, flies, ants and termites etc.) One of the best-known invertebrate species in Vanuatu is the coconut crab. There is a repertoire of 121 bird species, some of which are rare or vulnerable and around 30 species of Reptiles and Amphibians. The region is rich in sea life, with more than 4,000 species of marine molluscs. But these habitats are under increasing pressures from invasive creeper, tree and aquatic species. A large proportion of Vanuatu's forests are secondary due to reasonably high forestry impacts during colonial times.

Chapter 1 Introduction

This report documents the first step in the technology needs assessment process to determine the technology priorities for Vanuatu's adaptation to climate change and evaluate alternative technology options for adaptation. After the priorities were established the Multi-Criteria Analysis (MCA) methodology was used to evaluate and prioritize the alternative technology options.

The Ministry of Climate Change Adaptation received financial support from the Global Environment Facility /Technical University of Denmark partnership to conduct the Technology Needs Assessment for Vanuatu.

This section looks at the existing policies and plans relevant to the process, and looks at the vulnerability of Vanuatu with emphasis on the agriculture and water sector, and the sector selection process.

1.1 About the TNA project

The Technology Needs Assessment (TNA) Project is a global project that is implemented by UNEP and UDT partnership. The project is into its third phase. Vanuatu is one of 23 countries participating in the third phase of the project which started in 2018. The TNA project[5] assists developing countries, which are Parties to the United Nations Framework Convention on Climate Change (UNFCCC), to determine their technology priorities for greenhouse gas emission reduction and adaptation. For Vanuatu in particular this project will significantly contribute to Vanuatu's efforts in implementing its' climate change policy priorities especially aspirations as stated by its' Nationally Determined Contributions. Moreover, the TNA project will also enhance processes relative to the country's national adaptation communications efforts. Ultimately through the project, Vanuatu will be able to utilize and build capacity where the application of appropriate climate technologies is concerned within the most vulnerable development sectors.

[5] https://tech-action.unepdtu.org/

1.2 Existing national policies related to technological innovation, adaptation to climate change and development priorities

There are currently a number of significant policies, strategies and frameworks that are relevant for Vanuatu's context where climate change is concerned. These documents are outlined below such as:

i. **National Sustainable Development Plan (NSDP) 2016 -2030**: The NSDP or the People's plan serves as the country's highest-level policy framework. The NSDP acknowledges the importance of a balance the 'three pillars' of sustainable development, encompassing society, environment, and the economy. In line with the three pillars, the plan outlines 15 national sustainable development goals.

   The third target of the environment pillar (ENV 3) addresses the climate change links stating that they seek to build "A strong and resilient nation in the face of climate change and disaster risks posed by natural and man-made hazards".

   In addition to the NDSP, the government of Vanuatu published a monitoring and evaluation framework in which they outline on how they want to measure progress towards reaching the development goals. The document provides information on the baseline situation of each indicator and the aspired measurable target by 2030. Some objectives for the ENV 3 goal are, for example a 100% mainstreaming of CC and disaster risks in public policies, budgets, and legislation by 2030, as well as a 100% coverage of all provinces by a multi-hazard warning system.

ii. **Vanuatu Climate Change and Disaster Risk Reduction Policy 2016 - 2030**: This flagship policy document is the key strategy of Vanuatu to cope with and mitigate risks, including climate change induced risks. It was jointly developed by the government and the Secretariat of the Pacific Community in 2015. The strategic Goal outlined in the document is to achieve 'resilient development', which is further described to incorporate "activities that enable and strengthen capacities to absorb and quickly bounce back from climate and/or disaster shocks and stresses". This overarching goal intents to drive planning, decision-making, programming and project delivery across government and its partners.

The document consists of a range of measures based on sustainability, accountability, collaboration, equity, community focus, and innovation. It addresses the six strategic priorities of: (i) governance; (ii) finance; (iii) knowledge and information; (iv) climate change adaptation and risk reduction; (v) low carbon development; and (iv) response and recovery.

The objectives of these strategic priorities, which are further specified by proposed actions in the document, are:

i. to enhance strategic frameworks and institutional structures to deliver effective climate change and disaster risk reduction initiatives in a coordinated, integrated and complementary manner;
ii. to ensure that adequate resourcing is available for climate change and disaster risk reduction activities, build financial capacity to manage resources, and enable access to increased international funding;
iii. to meet stakeholders' needs for climate change and disaster risk knowledge and information, and improve communication-related interventions that empower appropriate climate and disaster risk management actions;
iv. to integrate and strengthen climate change adaptation and disaster risk reduction initiatives across national, provincial and local levels, and across all sectors;
v. to expand sustainable development opportunities that reduce carbon emissions and simultaneously contribute to resilient livelihoods and wellbeing; and
vi. to strengthen and build capacity in the areas of disaster preparedness, planning, response and recovery.

The document, further, outlines options and pledges to enable a gender and socially inclusive process in delivering the outlined actions and reaching the objectives. Despite the long initial time-frame of the plan until 2030, it is perceived as being a living document with a periodic review every three to five years in order to reflect changing framework conditions and developments.

iii. **The National Water Policy 2017 – 2030**: identifies the need for effective planning and coordination amongst key water sector stakeholders where Vanuatu's vulnerability to various disaster risks are anticipated to increase with climate change.

The policy specifically highlights the gap in long-term prediction, planning and investment to respond to changes in the supply of rain, ground and surface water resources to secure sufficient safe water in the face of changes in water demand from agricultural, industrial and municipal users.

iv. **National Water Strategy 2008-2018**: The National Water Strategy calls for sustainable and equitable access to safe water and sanitation for the people of Vanuatu to support improved health and promote social and economic development. It explicitly recognizes that climate related changes could be expected to limit the future availability of potable water, constrain its productive use and impact negatively on Vanuatu's pristine natural environment.

v. **National Agriculture Sector Policy**: this policy document was developed and completed in2015. One of the areas of focus of the policy is the strengthening of the agricultural sector's resilience to climate change. This policy highlights the importance of mainstreaming climate variability, climate change and disaster risk reduction using adaptation and mitigation strategies in all agricultural practices, initiatives and development. The role of water for irrigation to enhance sustainability and productivity of farming systems is moreover underscored in the agriculture sector policy.

vi. **National Livestock Policy 2015-2030**: This Policy framework guides the development of the livestock sector to realise the vision that "the livestock sector is modern, sustainably managed to benefit all its stakeholders, contribute to greater socio-economic development, and in its endeavours ensures sound environmental and climate proofing practices, including, achieving a national cattle herd of 500,000 heads by year 2025".

The policy identifies a lack of knowledge of climate change and adaptation options a constraint and dedicates chapter 8 of the policy to outline desired progress in the field of climate change adaptation and disaster reduction for the livestock sectors.

vii. **Vanuatu National Fisheries Sector Policy 2016-2031**: This policy provides a high-level framework to fulfil the vision to promote a "healthy and sustainable fisheries sector for the long term economic, social and food security for the current and future generations of the Republic of Vanuatu. One (objective Nr.5) out of eight identified priority objectives of the policy address "climate change and disaster risk reduction" and intents to investigate the impacts of environmental and climate change on fisheries resources and habitats.

To achieve this objective the policy outlines three strategic actions for the fishery sector in the field of or relevant to climate change adaptation: (i) undertake baseline assessments marine environment for long term climate change monitoring; (ii) implement mitigation and adaptation and disaster risk reduction activities in readiness for natural disasters; and (iii) strengthen community-based management through co-operative approach.

viii. **Vanuatu Forest Policy (2013-2023):** Guided by Vanuatu's Department of Forestry, this Forest Policy 2013-2023 was developed building up on and updating the 1997 National Forestry Policy. The policy was developed in an integrative manner, involving a range of stakeholders in its development. The Forest Policy also draws clear linkages towards climate change mitigation and adaptation through presenting clear directives and implementation strategies. The policy, for example, targets to: "Integrate climate change adaptation issues into forestry sector planning and activities". The strategies outlined to achieve this directive include:

- Develop forestry-related climate change adaptation demonstration projects including concerns for food security, soil stabilization, water management, and coastal erosion.
- Raise awareness of stakeholders on forestry climate adaptation opportunities in Vanuatu and develop related materials.
- Liaise, collaborate and share expertise with relevant government and non-government organizations (national, regional and international) to assist local efforts to adapt to climate change.
- Introduce and promote climate change resilient tree species and varieties.
- Maintain and enhance food security through agro-forestry systems.
- Identify and seek financing for novel and promising forestry adaptation projects and programs.
- Rehabilitate watershed and water catchment areas to secure water supplies.
- Systematically assess and continuously monitor the impacts of climate change on forest systems.
- Zone development activities and undertake land use planning to minimize site-specific climate change impacts.
- Develop and regularly update a database of climate change adaptation information in the Vanuatu forest sector and
- Identify, prioritize and implement appropriate and effective strategies for the forestry sector to adapt to climate change.

ix. **National Environment Policy and Implementation Plan (NEPIP) 2016–2030**: The NEPIP is an overarching policy for the sustainable conservation, development and management of the environment of Vanuatu, and aims to: i) provide for the co-ordination of related activities; ii) promote the environmentally sound and safe management and conservation of the natural resources and environment of Vanuatu; and iii) outline the operational matters necessary to implement i) and ii) above. The NEPIP outlines 5 key goals of which one is directed to climate change: "[to build] a strong and resilient nation in the face of climate change and disaster risks posed by natural and man-made hazards." The associated policy objective is to support the implementation of 'Vanuatu Climate Change and Disaster Risk Reduction Policy 2016 – 2030'.

x. **National Ocean Policy 2016**: Vanuatu's maritime jurisdiction comprises 98% of the nation and includes living and non-living marine resources that contribute significantly to the country's economy, that are fundamental to the wellbeing of its citizen. This policy acknowledges the nations dependency on its ocean and intents "to conserve and sustain a healthy and wealthy ocean for the people and culture of Vanuatu, today and tomorrow". The policy outlines actions for six thematic areas, namely: (i) marine spatial planning and marine protected areas; (ii) fisheries management; (iii) marine tourism; (iv) marine transport; (v) deep sea mining; (vi) climate change and disaster risk reduction. The actions identified under the last category six on climate change include to: (i) promote and support efficient, effective Climate Change & Disaster Risk Reduction efforts using Ecosystem-based Approaches; (ii) facilitate and enhance appropriate measures to manage Climate Change & Disaster Risk Reduction knowledge & information; and (iii) promote and support an efficient, effective Low Carbon & Mitigation Approaches & Strategies to ensure safety, security and protection of the marine environment.

xi. **Vanuatu Sustainable Tourism Policy 2018 – 2030:** The Vanuatu Sustainable Tourism Policy (VSTP) provides a guiding framework and direction for the Government of Vanuatu (GOV) and all stakeholders to develop their tourism sector in a sustainable manner. The collective vision of the VSTP is to "To protect and celebrate Vanuatu's unique environment, culture, kastom and people through sustainable and responsible tourism."

Vanuatu's main sustainable tourism goals are:

a. To develop and manage a sustainable and responsible tourism industry.
b. Visitors connect with Vanuatu's environment, culture and its people.
c. Sustainable and responsible tourism products and services developed, supported, and marketed to attract responsible high-value tourists.
d. Tourism that enhances, conserves and protects the environmental and cultural resources of Vanuatu.

e. Sustainable and responsible tourism brings improved income and well-being for Vanuatu and its people.

xii. **National Gender Equality Strategy 2015-2019**: The mission of the policy is "to promote equal rights, opportunities and responsibilities among men and women and to eliminate all forms of discrimination and violence against women and girls." The strategy clearly highlights in one paragraph the differentiated vulnerability of women to climate change due to the fact that more women than men (49% and 41% respectively) are involved in the subsistence economy (Vanuatu National Statistics Office 2011), which makes them more susceptible to poverty, climate change, disasters and other livelihood stresses

xiii. **National Adaptation Programme for Action (NAPA)**: The objective of the NAPA was to develop a country-wide programme of immediate and urgent project-based adaptation activities in priority sectors, in order to address the current and anticipated adverse effects of climate change, including extreme events. Vanuatu's NAPA proposed five priority projects in the fields: (i) agriculture and food security (preservation/ processing/ marketing, modern & traditional practices, bartering); (ii) water management policies/ programmes (including rainwater harvesting); (iii) sustainable tourism; (iv) community based marine resource management programmes (modern & traditional, aqua-culture); and (v) sustainable forestry management. For the forestry sector, the NAPA highlights the importance of forests to local communities and for their significance to the country's cultural heritage.

xiv. **Nationally Determined Contributions**: The NDC, lays out adaptation and mitigation strategies to increase climate resilience. The Government of Vanuatu highlights that it belongs to the Small Island Developing States, which recognised by the UNFCCC and IPCCC as most vulnerable countries towards climate change impacts, while having contributed marginally to global greenhouse gas emissions.

Regardless, Vanuatu's NDC (which was submitted in 2016 to the UNFCCC) sets targets to achieve an ambitious mitigation contribution with a transitioning to close to 100% renewable energy in the electricity sector by 2030. This contribution would reduce emissions in the energy sector by 72Gg by 2030. Emissions in this sector were around 130 Gg in 2010 but are expected to rise to 240 Gg by 2030 (3% per annum). Furthermore, it aims to reduce emissions in all sectors, except agriculture and forestry, by 15%.

The forestry sector mitigation will be attended to as part of the existing REDD+ program and the mitigation in the agriculture sector will depend on cooperative programs with other nations. This contribution is based on using the best available data.

The outlined adaptation targets in the NDC resemble the adaptation priorities and related project ideas, outlined in Vanuatu's NAPA (2007) and Vanuatu Climate Change and Disaster Risk Reduction Policy 2016 – 2030.

xv. **Meteorology, Geological Hazards and Climate Change Act 2016**: The Act replaces the Meteorology Act of 1989 given more recent institutional developments within the atmospheric and geological sciences in Vanuatu. This particular Act provides additional powers for the establishment and functions of the Geo-Hazards Department and the Department of Climate Change. The National Advisory Board on Climate Change and Disaster Risk Reduction (NAB) is legislated for under this Act with provisional requirements for the NAB's establishment, composition and functions.

xvi. **Disaster Risk Management Act 2019**: recently endorsed by the Vanuatu parliament, this Act supersedes the National Disaster Act of 2000. The 2019 Act sets out the following objectives:

a. to establish the necessary institutions and mandates for effective disaster risk management in Vanuatu, including an integrated approach to disaster risk reduction and climate change adaptation, disaster preparedness, response and recovery, at the national, provincial, and municipal level;

b. to ensure the development and implementation of disaster risk management policies, strategies and plans at national, provincial and municipal levels;

c. to support a whole-of-society approach to disaster risk management through education awareness, capacity building and training of elected officials, Government employees, the private sector, non-governmental organizations and communities that are also gender responsive and respectful of indigenous and traditional knowledge systems;

d. to support a whole-of-government approach to disaster risk management, especially the integration of disaster risk reduction and climate change across the different sectors and through all levels of Government, through information-sharing, cooperation and joint planning, as appropriate;

e. to govern the declaration of emergencies in disaster situations;

f. to ensure disaster response operations are coordinated and effective;
g. to facilitate the entry and coordination of international humanitarian assistance when required during disaster situations; and
h. to establish an Emergency Fund.

1.3 Vulnerability assessments in the country

There are a number of key documents highlight Vanuatu's climate vulnerability, which include the NAPA, Second National Communications, and Vanuatu Risk Profile report. Vulnerability assessments formed the core of these documents.
The "Profile of Risks from Climate Change and Geo-hazards in Vanuatu (2014)", outlines the major climate change impacts and geo-hazards for Vanuatu, which corroborate and build on Vanuatu's 2007 National Adaptation Programme of Action (NAPA).
The Risks Report describes the activities and results of the risk profiling activity. The sectors considered in this assessment to be most vulnerable for climate change are: Agriculture (crops, cattle and sustenance), Fisheries (freshwater, coastal, deep sea, aquaculture), Forestry (including mangroves and production forest), Tourism (cruise-ships, hotels), Transport (road, ferries, and air), Infrastructure (utilities [energy, water, and sanitation], houses, offices, and industry) and Health.

Both the NAPA and Second National Communications (SNC) emphasize Vanuatu's extreme vulnerability to climate change given its' geographic and socio-economic situation. Similarly, to the Risk Profile report, sector vulnerabilities with respects to agriculture, fisheries, forestry, tourism, transport and infrastructure, and health were undertaken.
Respective sector vulnerabilities, particularly from the SNC, are outlined as follows:

A. Agriculture

Due to the large amount of the population, around 80%, being dependent on subsistence agriculture the climate change impacts pose a tremendous risk to Vanuatu's agriculture sector and food security.

Agricultural activities in Vanuatu are particularly susceptible climate change induced changes in precipitation patterns (as most cropping practices are rain-fed), extreme rain or drought events, salinization processes, increases in evapotranspiration, seasonal variations, and reduction in fresh-water availability. Prolonged and intense rainfall, for example, damage seedlings and encourage conditions that promote diseases and pests. Droughts, on the other hand, cause added thermal stress on plants. Projected temperature increases may reach the maximum heat tolerance thresholds of crops and induce heat stress and crop failure, especially in traditional crops like cassava, taro, and yam. Communities on Torres islands, South Santo, South Malekula, Central Pentecost, Epi, Erromango, Aniwa and Aneityum in particular reported impacts from increased temperatures and droughts on declining crop yields and lowered livestock productivity during the 2015 – 2016 El Niño period.

Inundations with saltwater and salinization of soils and freshwater lenses poses additional risks to coastal and low-lying farms. These climatic impacts are exacerbated by soil erosion and loss of soil fertility due to improperly managed deforestation and environmental degradation.

Furthermore, anthropogenic and demographic pressures through migration/urbanization, loss of social cohesion and culture and over use of natural resources (fishing, poor land management practices) are exerting unsustainable pressures on the fragile resources with associated loss of ecosystem services.

This demands adaptive responses from the industry, the government, and local people to reach a paradigm shift in resilient livelihood choices and production patterns.

B. Fisheries

The fisheries sector is of high importance for the country for income generation and as a food source, particularly for fisher communities. Climate change poses a significant threat towards Vanuatu's fisheries and marine life. The changing ocean temperature regime can lead to migration of fish populations and habitat impacts.

Changes in ocean circulation patterns, furthermore, may affect the aquatic food web as species seek conditions suitable for their lifecycle. Climate-induced ocean acidification processes could impact the marine environment through deficiency in calcium carbonate, affecting shelled organisms and coral reef calcification. The reduction of coral reefs (e.g. due to acidification or temperature-driven coral bleaching) can lead to reduced fish and invertebrate populations which naturally seek shelter or raise their offspring in reef habitats. Naturally occurring extremes in sea surface temperatures (SSTs), exacerbated by climate change, have already been observed to have indirect and direct impacts on demersal fish and invertebrates.

In 2015-2016, high SSTs resulted in mass fish mortality, likely due to the lowered oxygen concentration at higher sea temperatures. On the islands of Torres, Pentecost (particularly villages of Bwatnapni, Igi and Levetnabal), Epi, Aneityum and Erromango) there have been observed coral bleaching events with associated reductions in local fish stocks. Changing precipitation patterns, ocean temperatures, and habitats can, further, influence fish and invertebrate physiology i.e. metabolism, growth, reproduction. High temperatures may also induce growth of aquatic micro and macrophytes, which often lead to habitat degradation and oxygen depletion. Coastal marine ecosystems, can furthermore be impacted through enhanced sedimentation due to soil erosion from agricultural and forestry practices, intense cyclones or storms that cause physical damage, or extreme rainfall events leading to flash floods and landslides such as in the case of Torres and Epi islands.

The projected alterations to habitats are expected to have the greatest effects on coastal fish and invertebrates given their high sensitivity to food and shelter quality changes they obtain from coral reefs, seagrasses, mangroves and intertidal flats. Potential impacts include reduced diversity and abundance of fish and invertebrates as their food resources decline, and mortality rates increase due to greater predation as structurally complex habitat is lost.

C. Forestry

With a total of 36% of Vanuatu’s landmass the forest coverage is high and makes the country a net carbon sink. Forests, as fisheries, always been an integral part of lives of the people of Vanuatu and contribute to the welfare and economic development. There are limited assessments been done on the effects of climate change on the forestry in Vanuatu.

However, drawing on relevant impact projections it can be expected that climate-induced changing precipitation trends, temperature and seasonal variability, and intensified extreme weather events create significant additional stress to many tree species and biodiversity of Vanuatu’s forests. This can lead to changed ecosystem composition and decline in plant density or migration of some species.
In its National Forest Policy (2013-2023) Vanuatu acknowledges the need to adapt to climate change and targets to “integrate climate change adaptation issues into forestry sector planning and activities”. However, the enforcement of regulations is hindered by the fact that all forests are privately owned, whereas the constitution demands from landowners to manage their land in a way that “safeguards the national wealth, resources and environment in the interests of the present generation and of future generations”.

D. Tourism

With a contribution of around 40% to Vanuatu's GDP (in 2014), tourism is one of the most important economic sectors with the highest growth potential for the nation. Climate change could, however, be a threat to the industry and its growth potential. This is acknowledged in Vanuatu's Strategic Tourism Action Plan 2014-2028. The industry is likely being impacted through a reduced attractiveness as a tourist destination due to loss of destination habitats such as coral reefs (e.g. due to thermal bleaching) and reduced biodiversity. Further, tourism infrastructure that is located close to the shoreline is now under threat through coastal erosion and storm surges, both intensified and caused by cyclones and sea level rise (see above).

Increasing temperatures is further leading to increasing cooling costs and/or heat stress for tourists. And more variable rainfall can lead to drought and water shortages for tourists. It is inevitable to consider climate change in tourism development planning processes in order to enhance the sectors resilience and enable a sustainable sectoral growth.

E. Transport & Infrastructure

Almost all major services, settlement and tourism infrastructure in Vanuatu are coastal. This focus on the coastal zone makes the populations extremely vulnerable to sea level rise, erosion and inundation. Transportation is pivotal for the country's prosperity and further development. Air and sea are the predominant modes of transportation in Vanuatu. There are 29 airports (5 paved and 24 unpaved) and two main ports and terminals across the different islands. Developed road systems only exist on larger islands, whereas most roads are being located in proximity to the coasts. The existing road system comprises a total 1,894 km of roadways (111 km paved and 1,783 km unpaved). The inter-island transportation is already impacted by extreme climatic events frequently interrupting air and shipping services. Like the road systems most human settlements and man-made infrastructure is located in close proximity to the shoreline. The main commercial centres of Port Vila and Luganville, are located on the perimeter of the major islands. The location of existing infrastructure close to the coast enhances its susceptibility and vulnerability to climate change impacts, such as coastal erosion, storm surges, cyclones, sea level rise, extreme rainfall and landslides. Primary and secondary local roads on the islands of Santo (south), Malekula, Pentecost and Epi are observed to generally experience flooding during episodes of heavy rain. Where bridge or river crossings exist, such structures undergo severe erosion and get washed away given from heavy flooding.

Pavements or footpaths are furthermore likely to be impacted by temperature variations or precipitation. Heavy rainfall trends have contributed to the inaccessibility of footpaths on the islands of Aneityum and Erromango.

Community structures such as schools, churches and airports have been observed to be increasingly affected or threatened by sea level rise and coastal erosion e.g. on Torres, Santo, Pentecost, Epi, Aniwa, Aneityum and Erromango islands.

F. Health

Climate change effects on human health are both direct and indirect, and are expected to exacerbate existing health risks, especially in the most vulnerable communities, where the burden of disease is already high.

Extreme weather and climate events such as tropical cyclones, storm surges, flooding, and drought can have both short and long-term effects on human health, including drowning, injuries, increased disease transmission, and health problems associated with deterioration of water quality and quantity. Vanuatu’s climate is conducive to the transmission of vector borne diseases such as malaria, dengue, filariasis, and schistosomiasis. A Commonwealth study revealed that during a period where Vanuatu experienced five cyclones, incidence of malaria preceded that of the previous year (Howes et al, 2018).

Ciguatera fish poisoning (CFP) occurs in tropical regions and is the most common non-bacterial food-borne illness associated with consumption of fish. Distribution and abundance of the organisms that produce these toxins, chiefly dinoflagellates of the genus Gambierdiscus, are reported to correlate positively with water temperature.

Vanuatu has been identified as one of the countries with high incidences of CFP, a trend closely associated with the enabling factor of increasing SSTs (Nurse et al, 2014).

Other direct climate change impacts related to intensified cyclones that could damage existing health infrastructure or hinder transportation of injured or sick people, as well as damage critical water and energy supply infrastructure affecting the people’s health.

G. Water security

Freshwater supply in Vanuatu has always presented challenges. On high volcanic and granitic islands, small and steep river catchments respond rapidly to rainfall events, and watersheds generally have restricted storage capacity. On porous limestone and low atoll islands, surface runoff is minimal, and water rapidly passes through the substrate into the groundwater lens. Rainwater harvesting is also an important contribution to freshwater access. Rapidly growing demand, land use change, urbanization, and tourism are already placing significant strain on the limited freshwater reserves.

These issues also occur on a background of decreasing rainfall and increasing temperature. Severe water shortages were particularly observed and reported in most islands of Vanuatu during the 2015 -2016 El Niño period.

More specifically for the islands of Torres, Malekula, Santo, Pentecost, Epi, Erromango, Aniwa and Aneityum, gravity feed and rainwater harvesting systems encountered low flow rates or depleted water storage.

Extreme events such as cyclones also aggravate Vanuatu's already delicate water resource situation. Tropical Cyclone Pam, one of the more intense cyclones to occur in the southern hemisphere, hit Vanuatu in 2015. The cyclone caused widespread damage including to community water infrastructure for example affected gravity feed systems in Central Pentecost.

Moreover, Vanuatu's NAPA through a multi-criteria approach identified 11 key adaptation strategies listed below:

1. Agriculture & food security (preservation/processing/marketing, modern & traditional practices, bartering)
2. More resilient crop species including traditional varieties
3. Land use planning and management (modern & traditional agricultural practices, early warning including traditional systems)
4. Water management policies/programmes (including rainwater harvesting)
5. Sustainable forestry management
6. Community based marine resource management programmes (modern & traditional/aqua-culture)
7. Mainstream climate change considerations into infrastructure design and planning (modern & traditional, EIA)
8. Sustainable Livestock farming and management
9. Develop Integrated Coastal Zone Management (ICZM) programmes, including mangroves & coastal flora management plan.
10. Sustainable tourism
11. Vector & water borne disease activities (modern & traditional)

More recently in 2018, Vanuatu developed a draft Country Program as part of a GCF Readiness activity outlining climate investment priorities up to the year 2030. The GCF Country Program, identified 43 priority projects in total for Vanuatu's pipeline, 23 of which are classed as top priority (Pipeline A). Under pipeline A, there are 12 adaptation and 4 mitigation proposal ideas and 7 GCF readiness proposal ideas.

The top ten (10) priorities are namely adaptation projects or concepts within in the following sectors:

1. Water security
2. Community based adaptation
3. Agriculture
4. Livestock
5. Health
6. Farm production data and food security
7. Education
8. Fisheries
9. Infrastructure (roads and bridges)
10. Ecosystem

In addition, the Second National Communications outlines Vanuatu's institutional arrangements where climate adaptation governance is concerned particularly the role of the National Advisory Board on Climate Change and Disaster Risk Reduction (NAB) and the Ministry of Climate Change (MCC) in guiding, coordinating and implementing

Whilst a number of vulnerability assessments and adaptation activities have been implemented or on going, the country's Second National Communications and National Sustainable Development Plan (NSDP) point to significant research gaps as summarized below:

- Community and participatory risk assessment methodologies needs to be promoted with a direct link to appropriate activities and planning at the sub national and local levels.
- Understanding what's needed (particularly at the community level) to build the socio-economic capacity to adapt and to manage disaster risks. A better understanding of the differential nature of vulnerability within the country's high-risk geographic regions is needed. Analyses of sector impacts must be complemented by social, economic and political assessments of vulnerability and resilience.
- Water supply and demand studies need to be conducted across the country. A limited understanding of how water supplies will be impacted by rising temperatures hampers response to climate change in the water sector.

- Modelling of storm-surge zones, taking into consideration possible sea-level rise. Planning mechanisms can subsequently be used to direct all new investments in infrastructure, housing construction, and agriculture outside this zone to minimize vulnerability, reduce repair costs and decrease disruption to economic activities.
- Detailed assessments of climate change impacts and risks across a variety of sectors are required in order to develop sound response strategies, in particular focusing on food security, water resources, and coastal resources.
- Little to no work has been done to downscale climate models to individual islands. Realistically it may not be possible to derive more accurate climate change information due to the small size of these islands. However, more work needs to be done to address the "island dilemma". New information should be made available in an accessible, credible, and useful format at the island scale.
- Establishing a robust observation network is a critical first step towards addressing potential cyclone risks.
- Applied research assistance is required to properly establish an island-specific and robust baseline from which to gauge projected changes and impacts.

- Comprehensive vulnerability maps identifying the locations of high vulnerability could support disaster planners in preparing communities for worst case impacts as well as in helping local communities take an active role in identifying appropriate response mechanisms.

1.3.1 Gender linkages to adaptation

Climate change impacts both men, women, children and the poor differently given the various vulnerability elements that interact with these groups of people.

According to the Vanuatu National Statistics Office (2016), more women than men (49% and 41%, respectively) are involved in the subsistence economy, and there are more female headed single parent households with children, grandchildren or extended family members compared to men. Women consequentially are more vulnerable and face higher poverty risks as a result of climate change in areas of food security, energy access and water scarcity.

Women play significant roles or contribute to a number of development sectors. In agriculture particularly, it has been observed and documented that women are actively engaged in subsistence farming along with the marketing of agricultural produce. The majority of vendors, approximately 98 percent, in markets around Vanuatu are women. Additionally, women are key resource managers especially when it comes to household or community water resource management. Where water resources have been successfully managed, it has been observed of women's particular lead or proactive roles in community water committees.

Given differential climatic impacts and women's engagement within the core development sectors of agriculture and water, it is therefore imperative that adaptation efforts address or consider the important role of gender as well.

1.4 Sector selection

Vanuatu, as many Small Island Developing States (SIDS), is affected by and is extremely vulnerable to climate change. The susceptibility of the country to climate change impacts is shaped by its geographic and socio-economic characteristics. Particularly, the small size and remoteness in conjunction with large parts of the population living in poverty and key infrastructure being located in particularly exposed areas exacerbate Vanuatu's vulnerability. Considering a wide range of natural hazards, Vanuatu ranked first out of 171 countries in the World Risk Index 2017 indicating their high susceptibility towards natural hazards.

Climatic and natural hazards impacts are demonstrably significant on climate sensitive sectors such as agriculture, health, water, tourism and infrastructure. Given the significance of agriculture and water on livelihoods, these two sectors are the focus of this adaptation technologies prioritization exercise.

a. Agriculture

Agriculture continues to be of major importance to the population of Vanuatu, the vast majority of which relies on subsistence production. In rural areas, 97 percent of households are engaged in vegetable crop production, 85.6 percent manage livestock,73.9 percent are engaged in cash cropping, and of these, 6–9 percent grow spices. A majority of households, 57.8 percent are engaged in the fishing industry, 55.8 percent are engaged in forestry activities and 51.3 percent of households are engaged in value adding activities (VNSO, 2016). Men and women play quite different roles in agricultural production, processing and marketing.

Of Vanuatu's total land area of 1 223 178 hectares, only 492 177 hectares – 40 percent of the total area – consist of good agricultural land, amounting to 10.4 hectares per household. Only one-third of the cultivable customary land area is presently being farmed (Department of Agriculture and Rural Development, 2015). Although agriculture is the primary activity for the majority of the population, only about one-third of production is commercial, resulting in the sector's relatively low share of GDP, while the majority of economic activity is in the services sector, largely driven by tourism.

The agricultural sector's contribution to GDP was severely impacted by TC Pam in 2015, with a decrease in the value of agricultural sector output by 16 percent and a decrease in the constant price value of animal production by 58 percent in from 2014 to 2015. Likewise, commodity exports decreased.

Agriculture is predominately rain fed and can be a water intensive sector; therefore vulnerable to the predicted impacts of climate change.

b. Water

In Vanuatu, both ground and surface water are used for domestic purposes. In urban areas the main water source is shallow aquifers whereas in rural areas various sources are used such as bores, wells, springs, rivers and rainwater catchments.

On high volcanic and granitic islands, small and steep river catchments respond rapidly to rainfall events, and watersheds generally have restricted storage capacity. On porous limestone and low atoll islands, surface runoff is minimal, and water rapidly passes through the substrate into the groundwater lens. Rainwater harvesting is also an important contribution to freshwater access.

Urban water supplies are provided by UNELCO (a private company) in Port Vila and Public Works in Luganville, Isangel and Lakatoro. All rural supplies are donor-funded and designed and delivered by either the drilling section or rural water supply (within DGMWR). Rural water supplies are operated and managed by the local community

Rapidly growing demand, land use change, urbanization, and tourism are already placing significant strain on the limited freshwater reserves.

These pressures also occur with a background of decreasing rainfall and increasing temperatures.

1.4.1 An overview of expected climate change and its Impacts in Sectors Vulnerable to Climate Change

As one of the most highly exposed countries in the world to disaster risks4. Vanuatu is vulnerable to a range of climate variability, storm surge, landslides, and droughts and flooding. Some of these climate related risks include the following: by 2040, daily temperatures will increase from 1995 levels by 1.2°C; sea level rise will continue and accelerate thus risks of coastal inundation will be high when combined with storm surges and high seas; ocean acidification may degrade 80% of coral reefs within 20 years;• extreme temperatures will reach higher levels and become more frequent; extreme weather events, including cyclones and storms, will increase in intensity but not necessarily in frequency; dry periods will last longer; and extreme rainfall will be more frequent and intense thus Vanuatu will be susceptible to erosion and flooding due to expected periods of intense rainfall (SPREP 2016).

The main climate change hazards for Vanuatu include tropical cyclones (with high winds and wave energy, heavy rain flooding, extended periods without rain causing drought, rising sea levels threatening coastal environments and property, as well as sea temperature increase and ocean acidification putting pressure on highly valuable coastal ecosystems and resources (including coral reefs, fisheries and impacts on livelihoods and tourism) (SPREP 2016)

Climate projections, under all different Relative Concentration Pathways (RCPs) derived from the Australian Bureau of Meteorology and CSIRO (2014) report further outline expected climate change impacts as follows:

- El Niño and La Niña events will continue to occur in the future, but there is little consensus on whether these events will change in intensity or frequency.
- Annual mean temperatures and extremely high daily temperatures will continue to rise.
- Mean annual rainfall could increase or decrease with the model average indicating little change, with more extreme rain events.
- Incidence of drought is projected to decrease slightly under the high emission scenario and stay approximately the same under the other emissions scenarios.
- Sea level will continue to rise.
- Ocean acidification is expected to continue.
- The risk of coral bleaching is expected to increase.

- Wet season wave heights and periods are projected to decrease slightly, with no significant changes projected in the dry season.
- Tropical cyclones are projected to be less frequent but more intense.

Expected Sectoral Impacts

i. *Agriculture*

Agricultural production systems and conditions are expected to change under a changing climate. There has been observed impacts from increased temperatures and droughts on declining crop yields and lowered livestock productivity within communities on Torres islands, South Santo, South Malekula, Central Pentecost, Epi, Erromango, Aniwa and Aneityum, These impacts were particularly more profound impacts during the 2015 – 2016 El Niño period (Vanuatu Coastal Adaptation Project 2015)

Projected temperature increases may reach the maximum heat tolerance thresholds of crops and induce heat stress and crop failure, especially in traditional crops like cassava, taro, and yam. Under an A2 high emissions scenario, Pakoa (2016) demonstrated that Sakius and Tarapatan taro yields showed declining trends where rainfall projections are concerned for the years 2030, 2055 and 2090 respectively. Similarly, temperature projections indicated reductions in crop yields for both species of corn for 2030, 2055 and 2090 in a high emissions scenario (Pakoa 2016).
When variables (temperature, rainfall and CO_2) were combined, crop studies on taro yield showed continued increases from the year 2030, 2055 and 2090 under A2 high emissions scenario (Pakoa 2016).
The Secretariat of the Pacific Regional Environmental Programme (2015) also highlights the impacts of climate change on the agricultural sector, which entail reduction in crop yields and damage from cyclonic activity, increases in evapotranspiration rates, changes in growing seasons and reduction in water availability. In particular, for smaller islands, sea level rise has been reported to impact agriculture, through salt water intrusion of ground water. There is further documentation of increased incidences of pests and diseases, both established and of new incursions (SPREP 2015).

A summary of climate impact study results on various stable crops, by Taylor et al (2016) with relevance to Vanuatu, are outlined below in Table 1.

Table 1. Climate impacts on select stable crops

Crop	Climate change/climate variability impact in recent decades	The impact of climate change over the next two to three decades (2030–2050)	The impact of climate change beyond 2050
Sweet Potato	El Niño-Southern Oscillation (ENSO)-induced droughts have had a major impact on production	Impact on tuberisation and yield will be greatest in those countries where rainfall is already high, and where temperature is currently around 32°C. Impact on pests and diseases is unclear — possibly increased pressure from sweet potato scab *Overall production assessment impact: moderate*	Increasingly serious impact in areas where there is currently high rainfall and temperatures, especially with high emissions scenario. The impact on pests and diseases is unclear. *Overall production assessment impact: moderate to high*
Cassava	No clearly discernible direct impact	Impact is expected to be minimal, but extreme rainfall events could cause problems with waterlogging. Cyclone intensity could cause lodging problems which would affect growth. Possible yield benefits from eCO_2 *Overall production assessment impact: insignificant to low*	Extreme rainfall and cyclone events would be likely to increase lodging and waterlogging problems. It is unclear how cassava pests and diseases will be impacted. Possible yield benefits from eCO_2 *Overall production assessment impact: Low to moderate*
Crop	**Climate change/climate variability impact in recent decades**	**The impact of climate change over the next two to three decades (2030–2050)**	**The impact of climate change beyond 2050**
Aroids	For taro ENSO-induced droughts and cyclones have adversely affected taro production.	Taro leaf blight (TLB) pressure could increase. Problems with other pests (armyworm) and diseases (Pythium) could also increase. In locations where rainfall levels are currently a constraint, there is possibility to grow taro. Increased intensity of cyclones could cause damage depending on stage of crop growth. For cocoyam and giant taro — impact is expected to be minimal. For swamp taro — increasing losses from	Very high temperature increases (>2°C) could affect production. Cyclones will continue to cause damage. A continued spread and increase of TLB and other taro pests and diseases would also be expected. For cocoyam and giant taro — temperature (>2°C) would be a constraint to productivity. Swamp taro could disappear from atoll environments. Taro — possible yield benefits from eCO_2

		saltwater intrusion are likely. Taro — possible yield benefits from eCO2 *Overall production assessment impact: taro (low to moderate), cocoyam (insignificant), swamp taro (moderate to high), giant taro (insignificant).*	*Overall production assessment impact: taro (moderate to high), cocoyam(low), swamp taro (high), giant taro (low),*
Yams	Impact from ENSO-induced droughts and cyclones. No clearly discernible direct impact on wild yams	Impact from increased intensity of cyclones would be expected and increased rainfall likely to increase incidence and spread of anthracnose. *Overall production assessment impact: wild yam (insignificant) domesticated yams (moderate to high)*	Projected temperature rise could affect bulking and therefore yield. Damage from cyclones would occur and increasing rainfall levels would intensify anthracnose problems. *Overall production assessment impact: wild yams (low) and domesticated yams (high)*
Rice	No information available.. Globally, rising temperatures, especially at night have caused yield losses of 10–20% in some locations	Increasing temperature expected to decrease rice yields and overall rice production in tropical locations. Rice production likely to become even less viable in terms of productivity *Overall production assessment impact: moderate to high*	Severe global shortages in rice available for export. The high price of imported rice expected to enhance the comparative advantage of Pacific Island rice production and other staple food crops *Overall production assessment impact: high*
Crop	**Climate change/climate variability impact in recent decades**	**The impact of climate change over the next two to three decades (2030–2050)**	**The impact of climate change beyond 2050**
Breadfruit	Apparent changes in fruiting patterns due to changes in rainfall	Expected to be minimal though cyclone damage likely to increase *Overall production assessment impact: insignificant to low*	Expected to be minimal though higher temperatures could reduce fruiting and fruit quality. Cyclone damage will worsen with increased intensity of cyclones. Possible increase in pest and disease problems *Overall production assessment impact: low to moderate*
Aibika/bele/island cabbage	No apparent impact from any change	Minimal impact likely from increasing temperature, but changes in rainfall will increase pest and disease problems. Increase in frequency and	More problems with pests and diseases from increased rainfall *Overall production assessment impact: low to moderate*

		intensity of drought will affect growth. *Overall production assessment impact: low*	
Banana	Cultivation at higher altitudes with warmer temperatures	Favour cultivation in currently sub-optimal locations and at higher altitudes. Higher temperatures could affect flowering and fruit filling. Higher temperatures could increase pest and disease. Increase in cyclone damage *Overall production assessment impact: low*	Increased pest and disease pressure (Fusarium wilt, nematode and weevil) is likely though the enhancing impact of rainfall on BLDS could be lessened by higher temperature. The heat stress effect on flowering and fruit filling would increase, as would cyclone damage. Overall production assessment impact: low to moderate

ii. Water

The quality and availability of water is expected to be substantially impacted given the increasing trend of daily temperatures, uncertain precipitation, extreme rainfall and heatwaves. Projected increases where sea level rise is concerned equates to increased salt water intrusion into shallow ground water lenses and surface water (SPREP 2016). SPREP (2015) further highlights the future impacts on the water sector from events such as cyclones, drought and sea level rise.

Extreme events such as cyclones will have more profound impacts, especially with projections for intense cyclones under the different emission scenarios or RCPs (BOM and CSIRO 2014). The major concern will be for those communities that solely depend on rainwater, with uncertain rainfall trends going forward into the future.

1.4.2 Process and results of sector selection

The sector selection process began with a national stakeholder consultation through the platform of the National Advisory Board of Climate Change and Disaster Risk Reduction (NAB)[6], which identified water and agriculture as the priority adaptation sectors for Vanuatu. This initial consultation with the NAB, and with advice from the consultant, was informed by an analysis of the policy landscape which entailed the NSDP, NDC and other frameworks These two sectors were generally chosen given their respective significance and contributions to the livelihoods and economic development of communities in Vanuatu.

Agriculture especially is the mainstay of the country's economy. Eighty percent (80%) of Vanuatu's population are based in the rural areas by which agriculture forms a core part of local subsistence economy.

Furthermore, the sector water provides vital linkages to sustaining Vanuatu's agriculture based subsistence economy as well as its' critical role in health and broader socio economic development.

Both agriculture and water are climate sensitive, hence the necessity to utilize appropriate technologies to enable adaptation of these sectors to future climatic impacts.

After the NAB's recommendation on the two sectors, the TNA team (Assistant project coordinator and consultant) met with sector technical working to advance the prioritisation process. At follow-up meetings[7] of the national TNA team and the sectors, the decision by the NAB and background of the project was relayed to the respective sector technical working groups for their feedback and validation.

From a broad development perspective, food security, natural resource management and infrastructure were identified as priority sectors in the NSDP. While the NDC identified as adaptation priorities the agriculture and water sectors.

The National Climate Change and Disaster Risk Reduction Policy, the Second National Communication to the UNFCCC and the NDC list agriculture and water as the main sectors vulnerable to climate change.

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[6] The NAB is the principal body responsible for policy, program and project oversight where climate change and disaster risk reduction. This body has representation from all government departments (at director level), Vanuatu Climate Action Network (VCAN), Vanuatu Chamber of Commerce and Industry (VCCI) through its' Business Resilience Committee and the Vanuatu Association of NGOs (VANGO).

[7] Four follow-up meetings overall; 2 meetings with the agriculture sector technical working group and 2 meetings by the water sector technical working group

Chapter 2 Institutional arrangement for the TNA and the stakeholder involvement

Climate change policy formulation and implementation namely rests with the Ministry of Climate Change, the National Advisory Board on Climate Change and Disaster Risk Reduction (NAB) and the Department of Climate Change.

The NAB is the supreme policymaking and advisory body for all disaster risk reduction and climate change programs, projects, initiatives and activities. The NAB develops DRR and CC policies, guidelines and positions, advises on international and regional DRR and CC obligations, facilitates and endorses the development of new DRR & CC programs, projects, initiatives and activities, acts as a focal point for information - sharing and coordination on CC/DRR, as well as guides and coordinates the development of national climate finance processes. Moreover, the MCC was established in 2013 comprising of departments and agencies such as the Department of Climate Change, Department of Energy, Department of Environment, Vanuatu Meteorology & Geo-hazards Department and the National Disaster Management Office. Of these aforementioned MCC entities, the Department of Climate Change was set up very recently by the Vanuatu government in 2018 under the Meteorology, Geological hazards and Climate Change Act of 2016.

2.1 National TNA team

The TNA project in Vanuatu utilized the National Advisory Board on Climate Change and Disaster Risk Reduction (NAB) as the project's Steering Committee to provide overall oversight and approval requirements. The NAB sits under the Ministry of Climate Change (MCC) with representatives from various ministries, non-government organizations and the private sector.

The Chair of the NAB and officially the National Coordinator, is the Director General to the Ministry of Climate Change. The Department of Climate Change is the operational focal point and assists the Director General in executing the role of the TNA coordinator and day to day activities of the project.

The National TNA Project Steering, which essentially is the NAB, is comprised of representatives from the following agencies or entities:

- Government Departments: Environment, Meteorology, Disaster Management, Environment, Energy, Agriculture, Forestry, Lands, Infrastructure, Water Resources, Foreign Affairs, Lands, Finance and National Planning.
- Vanuatu Association for Non-Government Organizations (VANGO) and Vanuatu Climate Action Network (VCAN)
- Vanuatu Business Resilience Committee (VBRC)

All climate change initiatives and projects in the country fall under the oversight of the NAB. The NAB comprises of a number of working groups as well which include climate finance, mitigation, project screening and international negotiations. Under the TNA project, two adaptation technical working groups were established respectively for the agriculture and water sectors.

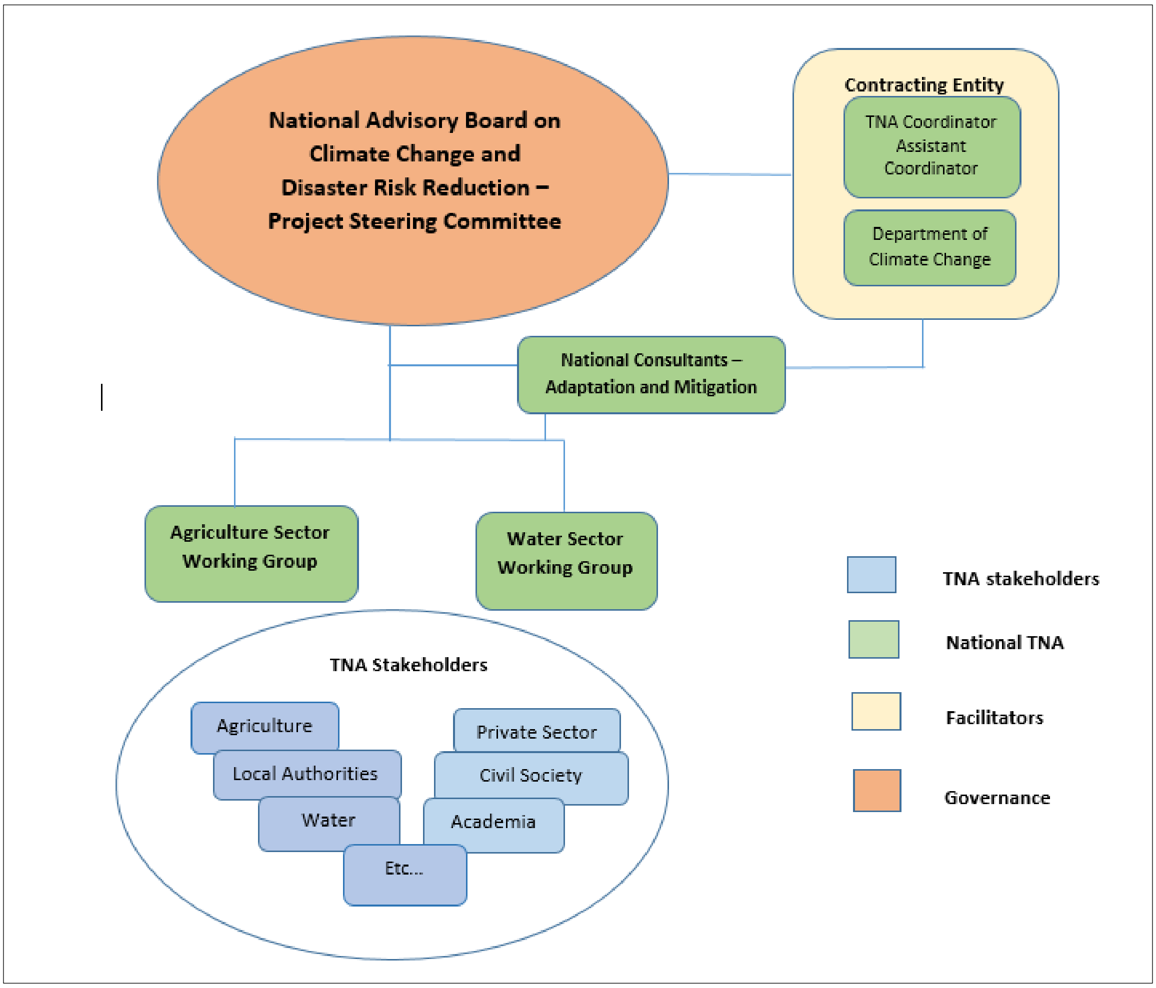

Figure 2. TNA project organizational structure, Vanuatu

2.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

Prior to engaging with stakeholders in this prioritization exercise, a stakeholder mapping exercise was undertaken by the Assistant Coordinator and the consultant which identified primary stakeholders (mainly technical staff) from the following agencies:

- Departments of agriculture, water, climate change, health, local authorities and women's affairs
- National Youth Council, Vanuatu Business Resilience Council, University of the South Pacific

All stakeholders were identified based on their ability to implement the project or influence the outcome of the project. The list of stakeholders can be found in the Annex.

Two workshops, which were led by the Adaptation consultant and the Assistant Coordinator, were held with stakeholders. The first workshop was held on 11th July 2019 with the Water sector technical working group and second workshop on 12th July 2019 with the Agriculture sector technical working group.

During the workshops, stakeholders were introduced to the TNA process and the Multi-Criteria Analysis Methodology. Fact sheets on the alternative technology options were presented and discussed with stakeholders at the workshop. Experts on the technology options led the discussion and provided information on the status of the technology option in Vanuatu. The workshops were namely geared to have stakeholders develop and provide feedback on criteria categories. Similarly, the workshops allowed for sector technical working groups to collectively discuss and agree by consensus on weights to be assigned to each criteria. Costs, implementation feasibility and political categories were those which generated much discussions.

Subsequent to the respective workshops, participants were emailed asking them to assign scores to the criteria category. Some stakeholders completed the process on their own while others requested guidance from the consultant.

It should also be noted that sensitivity analysis was undertaken with emphasis on gender considerations. This was done to further unpack social and economic related criteria.

Any resulting major difference in scores may equate to differing opinions where gender and adaptation technologies is concerned.
Individual scoring for each technology was aggregated and the results sent to participants for their review and subsequent comments prior to finalizing the results

Tables 2 and 3 provide detailed information on the engagement by different stakeholders from the Agriculture and Water sectors.

Table 2. Stakeholder identification (Agriculture Sector)

KEY STAKEHOLDERS/ Organizations	INTEREST (institutional, political, personal)	INFLUENCE	MOST RELEVANT
Departments of Agriculture	Institutional	High) During the discussion of the workshop, some participants showed influence at the topic/technologies being discussed	High The participants are relevant to some extent with the project. They can lead the discussion during the MCA process
Department of Climate Change	Institutional	High Participants demonstrated some influence in the selection of technologies for initial discussions	High Participant is able to link up this project with other climate change processes in country and also have the ability to lead discussions
Non-Government Organization	Institutional	Medium Participants were only able to provide useful information on the application of certain technologies	Medium Information provided by the stakeholder that can be contribute in shaping the MCA process
Private Sector (Farmers Support Association)	Personal, Institutional	High Showed some influence in discussion of topics	Medium Some information provided contributed to shape MCA process
Academia (Vanuatu Agriculture College)	Personal, Institutional	High Showed some influence in discussion of topics	High Some information provided was able to shape MCA process
Youth Representative (350.org)	Personal	Low Superficial discussion or contributions to the MCA process	Medium Ability to contribute to the MCA process discussions

Table 3. Stakeholder identification (Water Sector)

KEY STAKEHOLDERS/ Organizations	INTEREST (institutional, political, personal)	INFLUENCE	MOST RELEVANT
Department of Water	Institutional	High) During the discussion of the workshop, some participants showed influence at the topic/technologies being discussed	High The participants are relevant to some extent with the project. They can lead the discussion during the MCA process
Department of Climate Change	Institutional	High Participants demonstrated some influence in the selection of technologies for initial discussions	High Participant is able to link up this project with other climate change processes in country and also have the ability to lead discussions
Department of Local Authorities	Institutional	Medium Participants were only able to provide useful information on the application of certain technologies	Medium Information provided by the stakeholder was useful to informing the MCA process
Department of Health	Institutional	Medium Showed some influence in discussion of topics	Medium Some information provided was able to shape MCA process
Private Sector (Vanuatu Business Resilience Council)	Institutional	High Participants demonstrated some influence in the MCA process	Medium Some information provided was able to shape MCA process
Youth rep (Vanuatu Youth Council)	Political	Low Minimal information provided in the MCA process	Low
Non Government Organization	Institutional, Personal	Medium	Medium
Academia (University of the South Pacific)	Institutional, Personal	High Participants demonstrated some influence in the MCA process	High The participants are relevant to some extent with the project. They are able to lead the discussion during the MCA process

2.3 Consideration of gender aspects in the TNA process

Integration of gender aspects in the TNA process was carried out at various stages. Within the NAB (TNA Project Steering Committee), there is the Department of Women's Affairs which is a key or permanent sitting member. The Department of Women's Affairs has extensive knowledge and the mandate on issues with respects to gender issues.

Additionally, prior to forming the two sector technical working groups, the stakeholder mapping process was undertaken, which highlighted the need to include institutions with gender analysis capacity. In these respects, it was vital to involve the Department of Women's Affairs and the Vanuatu National Youth Council in both sector-working groups for their expert guidance or inputs. Furthermore, other non-government agencies, which have a dedicated gender programs or projects, were also considered for consultation. For example, Care International has a dedicated gender program hence were consulted particularly with respects to agriculture sector technologies.

When undertaking initial background analysis of policy document or frameworks emphasis was also on the social development aspect of a sector and related technologies. Whilst this was a more generic assessment, when engaging with sector experts it was further necessary to ensure that participation of these stakeholders should at best involve women.

From the 17 stakeholders that were part of the consultation process, 40 percent were women (Annex II). Furthermore, it was essential to ensure gender aspects were well catered for during the scoring and weighting process of criteria for technology prioritization. Accordingly, in undertaking sensitivity analysis, an additional 5 percent in weight value was added to the existing social criteria. Refer to Annex III.

Chapter 3 Technology prioritisation for Agriculture

3.1 Key climate change vulnerabilities in Agriculture

Due to the large amount of the population, around 80%, being dependent on subsistence agriculture the climate change impacts pose a tremendous risk to Vanuatu's agriculture sector and food security. Agricultural activities in Vanuatu are particularly susceptible to climate change induced changes in precipitation patterns (as most cropping practices are rain-fed), extreme rain or drought events, salinization processes, increases in evapotranspiration, seasonal variations, and reduction in fresh-water availability.

Prolonged and intense rainfall, for example, damage seedlings and encourage conditions that promote diseases and pests. Droughts, on the other hand, cause added thermal stress on plants. Communities on the islands of Torres, South Santo, South Malekula, Central Pentecost, Epi, Erromango, Aniwa and Aneityum in particular reported impacts from increased temperatures and droughts on declining crop yields and lowered livestock productivity during the 2015 – 2016 El Niño period.

Inundations with saltwater and salinization of soils and freshwater lenses poses additional risks to coastal and low-lying farms. These climatic impacts are exacerbated by soil erosion and loss of soil fertility due to improperly managed deforestation and environmental degradation. Furthermore, anthropogenic and demographic pressures through migration/urbanization, loss of social cohesion and culture and over use of natural resources (fishing, poor land management practices) are exerting unsustainable pressures on the fragile resources with associated loss of ecosystem services.

3.2 Decision context

Sixty percent (60%) of the Vanuatu population rely on agricultural activities as the basis of household incomes and livelihoods, and it accounts for around 23% of GDP. Almost all agriculture activity is micro-scale subsistence based, for household consumption or sale at local markets. A considerable number of households maintain a household garden for household consumption 33 690 out of 33 879 households. Most household gardens in Vanuatu are less than a hectare in size. Women are particularly dependent on agriculture with 49% being involved (compared to 41% for men).

Key crops cultivated include fruits and vegetables as well as coffee, vanilla, kava and pepper. Livestock is also kept and there are a few small hold farmers across livestock, coffee and

coconut producers. Additionally, over 80 percent of Vanuatu's export commodities derive from agricultural produce e.g. copra, kava, cocoa, vanilla and beef.
Agricultural production (and market activity) is highly exposed and vulnerable to drought and cyclone impacts in particular. With projections for more intense or regular climatic impacts, there is also the associated the increasing disaster risk outlook on agriculture and food security in general.

The decision as to which sectors to focus on stemmed from an initial literature review of existing climate change and development frameworks.
The Vanuatu Agriculture sector policy expresses strategic objectives to achieve sustainable management of agriculture, chief amongst this is the need to minimize risks such as climate change and disasters. Strategies identified to respond to climate variability and climate change encompass technologies with respects to sustainable crop management, sustainable farming systems, soil management, planning for climate change, sustainable water management and capacity building.

With the impact of climate change and variability in mind, Vanuatu's NAPA proposed specific adaptation technologies such as food preservation/value chain addition, production of resilient crop varieties and sustainable livestock management.
The Project Steering Committee considered the various climate issues and development issues at hand especially its' significance on agriculture.

Accordingly, the TNA team and Project Steering Committee on that note decided on agriculture to be a priority sector as a focus for this technology prioritization exercise.

Agriculture technologies were mainly prioritized ability to improve the resilience of farming/production systems and the livelihood of farmers. Technologies to be considered were especially prioritized according to those which were already used in Vanuatu, were based on national priorities and knowledge on ease of adoption of technologies in the local context.
Pre-screening was conducted through discussion with the relevant stakeholders in technical working group meetings, and a short-list of eleven (11) most appropriate technologies were retained from an initial list of eighteen (18) technologies.

Technology factsheets were produced namely by gathering information from the climate techwiki and CTCN databases. Adaptation technologies information for the agriculture sector locally was limited. Similarly, information with respects to costs and benefits was also limited or unavailable locally.

Given the paucity of locally appropriate information on the technologies, utilization of expert judgement was therefore the preferred option to facilitate the prioritization exercise.

The technology factsheets were circulated prior to the stakeholder workshop and were further discussed at the workshop or bilaterally via meetings. Stakeholders also provided information on the status of each technology in Vanuatu and where available historical information about technologies, which have been used in Vanuatu.

Technology criteria and weights were discussed collectively and agreed upon by way of consensus among. Scores and results for technologies were undertaken and distributed to participants.

3.3 Overview of existing technologies in Agriculture

Research on agriculture adaptation technologies was firstly undertaken to come up with a pre-selection list from which the prioritization process will stem from. This assessment was done to determine which technologies are currently in use or have the potential to be utilized in Vanuatu.

Table 4 below provides an overview of the status of existing technologies in Vanuatu.

Category	Adaptation technologies	Status of technology in country
Planning for Climate Change and Variability	Climate Change Monitoring System	Presently being implemented needs to be reinforced.
	Seasonal to Inter-annual Prediction	Currently implemented by the Meteorology Department
Sustainable water use and management	Sprinkler and Drip Irrigation	Its adoption by small scale farmers is low due to high initial investment.
	Rainwater Harvesting	Technology implementation in some areas but needs to be reinforced.
Soil Management	Slow-forming Terraces	Implemented in some locations. Needs to be encouraged to other locations.
	Conservation Tillage	Low implementation level

	Integrated Nutrient Management	Low implementation level
Sustainable Crop Management	Crop Diversification and New Varieties	Actually implemented by Department of Agriculture. Needs to be reinforced and upscaled.
	Biotechnology for Climate Change Adaptation of Crops	Low level of implementation
	Ecological Pest Management	Implementation in few location, needs reinforcement
	Seed storage	Currently implemented but requires encouraging to all levels
Sustainable Farming Systems	Mixed Farming/Integrated Farming	Low level of implementation.
	Agro-forestry	Currently implemented. Needs reinforcing
Capacity Building and Stakeholder Organisation	Community-based Agricultural Extension Agents	Implemented by the Agriculture Department. Requires strengthening
	Farmer Field Schools	Low implementation

3.4 Adaptation technology options for agriculture and their main adaptation benefits

Technologies selection was guided by general recommendations from a number of key documents and current climatic challenges faced by the agriculture sector. A pre-selection list of 15 possible adaptation technologies was identified. These technologies were selected mainly to improve resilience of small-scale farmers and resilience of farming systems or production.

Eleven technology options for agriculture sector adaptation were identified and agreed upon by the TNA team members. Factsheets for the approved technologies were prepared and circulated to stakeholders for review and feedback.

The fact sheets provided a description of the technology, its potential to contribute to adaptation to climate change and the status of the technology in Vanuatu. Estimated cost and benefits of the technology options was provided where available. Refer to Annex I for the fact sheets. Brief summaries of the technologies and their respective contributions to adaptation are provided below:

Agro-forestry is an integrated approach to the production of trees and of non-tree crops or animals on the same piece of land. The crops can be grown together at the same time, in rotation, or in separate plots when materials from one are used to benefit another. This technology can improve the resilience of agricultural production to current climate variability as well as long-term climate change through the use of trees for intensification, diversification and buffering of farming systems. Trees have an important role in reducing vulnerability, increasing resilience of farming systems and buffering agricultural production against climate-related risks.

Community-based agricultural extension agents describes the services that provide rural people with the access to knowledge and information they need to increase productivity and sustainability of their production systems and improve their quality of life and livelihoods. The technology contributes to climate change adaptation and risk reduction by building the capacity of communities to identify and select appropriate strategies in response to observed impacts of climate variability on local livelihoods.

Crop diversification and new varieties is a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses. Breeding new and improved crop varieties enhances the resistance of plants to a variety of stresses that could result from climate change. These potential stresses include water and heat stress, water salinity, water stress and the emergence of new pests – stresses which are common in Vanuatu.

Drip irrigation is based on the constant application of a specific and calculated quantity of water to soil crops. The system uses pipes, valves and small drippers or emitters transporting water from the sources (i.e. wells, tanks and or reservoirs) to the root area and applying it under particular quantity and pressure specifications. Drip irrigation technology can support farmers to adapt to climate change by providing efficient use of water supply. Particularly in areas subject to climate change impacts such as seasonal droughts, drip irrigation reduces demand for water and reduces water evaporation losses (as evaporation increases at higher temperatures).

Ecological Pest Management (EPM) is an approach to increasing the strengths of natural systems to reinforce the natural processes of pest regulation and improve agricultural production.

EPM is a biotechnology belonging to the denominated ‘clean’ technologies which combines the life cycle of crops, insects and implicated fungi, with natural external inputs (i.e. bio-pesticides) that allows a better guarantee of good harvesting even in difficult conditions of pests and diseases that emerge with the temperature and water level changes (increase of relative atmospheric humidity and runoff) typical of climate change.

Farmer Field Schools (FFS) look to reinforce the understanding of farmers about the ecological processes that affect the production of their crops and animals, through conducting field learning exercises such as field observations, simple experiments and group analysis. The knowledge gained from these activities enables participants to make their own locally specific decisions about crop management practices. To cope with this increased climate change trends and climate variability, a farmer will need a greater understanding of the processes that affect the performance of the different production systems they manage and undergo constant experimentation and adaptation of these production systems.

Integrated farming system (Mixed Farming) is an agricultural system in which a farmer conducts different agricultural practice together, such as cash crops and livestock. The aim is to increase income through different sources and to complement land and labour demands across the year. Mixed farming technology contributes to adaptation to climatic change because the diversification of crops and livestock allows farmers to have a greater number of options to face the uncertain weather conditions associated with the increased climate variability. Mixed farming can also give a more stable production because if one crop or variety fails, another may compensate.

Integrated Nutrient Management (INM) aims to integrate the use of natural and man-made soil nutrients to increase crop productivity and preserve soil productivity for future generations. Rather than focusing nutrition management practices on one crop, INM aims at optimal use of nutrient sources on a cropping-system or crop-rotation basis. INM can have positive effects on crops under harsh climatic conditions especially the resulting effect of considerable soil erosion and the depletion of nutrient stocks.

Seed storage helps ensure resource poor farmers, households and communities, food security until the next harvest and commodities for sale can be held back so that farmers can avoid being forced to sell at low prices during the drop in demand that often follows a harvest. Seed storage enables the preparation for droughts and hunger and malnutrition. Seed storage provides an adaptation strategy for climate change by ensuring feed is available for livestock and seed stock is available in the event of poor harvests due to drought.

Slow-forming terraces are constructed from a combination of infiltration ditches, hedgerows and earth or stone walls. This technology decreases superficial water run-off, increasing water infiltration and intercepting the soil sediment. Slow-forming terraces are called as such because they take between three and five years, and possibly even ten years, to fully develop. This technology facilitates adaptation to climate change by optimising water use. This is particularly relevant in areas where there is uncertainty about future rainfall patterns, as in the case for Vanuatu. Climate variability also affects the soil, since heavy rainfall coupled with poor soil management give rise to landslides and mudslides.

Sprinkler irrigation is a type of pressurised irrigation that consists of applying water to the soil surface using mechanical and hydraulic devices that simulate natural rainfall These devices replenish the water consumed by crops or provide water required for softening the soil to make it workable for agricultural activities. The technology can support farmers to adapt to climate change by making more efficient use of their water supply. This is particularly appropriate where there is (or is expected to be) limited or irregular water supply for agricultural use.

3.5 Criteria and process of technology prioritisation

Two steps were used to arrive at a shortlist of technology options for adaptation in the agriculture sector. The first step consisted of pre-screening most likely implementable adaptation technologies from the long-list of identified technologies. The second step consisted of developing technology factsheet (TFS) for each of the short-listed technologies, and establishing the criteria and indicators for technology prioritization using MCA.

The pre-screening was conducted through discussion with a wide group of stakeholders in technical working group meetings, and a short-list of ten most appropriate technologies, from an initial pre-screening list of fifteen (15 technologies) were retained based on national priorities and knowledge on ease of adoption of technologies in the local context.

A focus group[8] workshop was convened to guide stakeholders through the process of determining criteria category and weights. The criteria selected were based from the UNEP MCA guidance on adaptation technology (2015) and sector expert views. Criteria categories selected were financial costs, economic, social, environmental, climatic, institutional and political. Stakeholders collectively decided upon and agreed that weights would range from 0 – 100, with a high value score assigned to a criterion which was most preferred, and a lower

[8] Consisting of representatives namely from the Agriculture department and Department of Climate Change

value score assigned to a criterion with a lower preference. Weights were collectively discussed and averaged out to be used for the scoring exercise.

Costs and policy alignment (national policy coherence) were matters that generated much discussions and were highly regarded as of importance therefore were accorded more weight by stakeholders. This was followed by the environmental, climate and social criteria as priorities that were also placed with considerable weighting. Refer to Table 5 below.

It was agreed that performance scores were to be standardized using a Linkert scale between 0 (lowest score) to 10 (highest score) based on the expected merits of the technology.

There were some discussions on public financing needs, especially given limited data, with respects to establishment and maintenance costs for the technology options. Performance scoring where costs are concerned was therefore to be anchored to a Linkert scale between 0 (most costly) and 10 (least costly).

Technology fact sheets (TFS) were produced for each short-listed technology. The TFS contain relevant information on the technical aspects of the technology implementation, including its installation, operation and maintenance, efficiency, cost, and the benefits / opportunities, as well as the barriers for each short-listed adaptation technology.

Table 5. Performance criteria, assigned weights and scoring scale

Criteria category	Criteria	Weight (%)	Scale
Institutional/ implementation barrier	Ease of implementation	9	0 – very low/difficult 10 – very high/easy
	Use and maintenance /replicability	8	0 – very low/difficult 10 – very high/easy
Costs or Public financing needs	Capital to set up and operational costs to utilize the technology (resources, skills, infrastructure.)	16	0 – very low/difficult 10 – very high/easy
Economic	Catalyzing private investment	5	0 – very low/difficult 10 – very high/easy
	Improving farmer income and ability to reinvest	8	0 – very low/difficult 10 – very high/easy
Environmental	Contribution of the technology to protect and sustain ecosystem services	13	0 – very low/difficult 10 – very high/easy
Climate-related	Enhancing resilience against climate change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts)	13	0 – very low/difficult 10 – very high/easy

Social	Contribution to social and sustainable development (benefit to society, poverty reduction)	13	0 – very low/difficult 10 – very high/easy
Political	Coherence with national development policies and priority	15	0 – very low/difficult 10 – very high/easy
	Total	100	0 – very low/difficult 10 – very high/easy

Bilateral meetings were also held with key stakeholders to discuss the status of the technologies in Vanuatu, and to acquire technical information to estimate the cost and implementation feasibility of the adaptation technologies.

3.6 Results of technology prioritisation

A major challenge in the prioritization of technology options was limited data to ascertain costs and benefits. Expert views were therefore relied upon to discuss the merits of individual technologies in their relevance to reducing vulnerability to cyclones, prolonged dry periods and salinization.

Emphasis was given to technologies with the potential to contribute to adaptation to the extreme events, prolonged dry periods and salinization. Much discussion also revolved around the cost implications of a technology and whether implementing a technology will contribute to broad development or sector development objectives such as poverty reduction and gender mainstreaming.

The performance of each technology was rated individually by stakeholders and with scores aggregated in order to determine ranking. The weight assigned to each criterion was multiplied by the score value (0-10) that each technology was assigned. The scores for each technology options were aggregated and the technology receiving the highest score was consigned high priority. Refer to MCA calculator, Annex III.
The results of the MCA exercise were further examined to assess sensitivity of technology ranking and to perceive if the resultant rankings were logically positioned. Namely sensitivity analysis was undertaken, with respects to, ensuring gender considerations were adequately considered. On that note an additional 5 percent in weight value was added to the social performance criteria weight.

The overall ranking of the adaptation options was finally agreed by all stakeholders and technical expert based on the sensitivity analysis. The results are summarized in Table 6.

Table 6. Summary of results

Ranking priority	Adaptation technologies for the agriculture sector
1	Crop diversification and new varieties
2	Agro-forestry
3	Farmer Field Schools
4	Ecological Pest Management
5	Integrated Farming System / Mixed farming
6	Seed storage
7	Drip irrigation
8	Integrated Nutrient Management
9	Community based agricultural extension agents
10	Sprinkler Irrigation
11	Slow-forming Terraces

In all, the top three (3) prioritized adaptation technologies are:

1. **Crop diversification and new varieties**: a technology that entails the introduction of new cultivated species and improved varieties of crop. This technology enhances the tolerance of plants to a variety of stresses that could result from climate change and climate variability. These stresses include water and heat stress, water salinity, emergence of new pests and extreme events such as cyclones.

2. **Agro-forestry**: an integrated approach to the production of trees and of non-tree crops or animals on the same piece of land.
   Agro-forestry can improve the resilience of agricultural production to current climate variability as well as long-term climate change through the use of trees for intensification, diversification and buffering of farming systems. Additional such an approach provides co-benefits as a carbon sink and enhances the retention of soil moisture.

3. **Farmer Field Schools**: to strengthen the understanding of farmers about the ecological processes that affect the production of their crops and animals, through conducting field learning exercises such as field observations, simple experiments and group analysis. Importantly FFS provide a platform for farmers to understand the relationship between crops, livestock and meteorological factors – agro meteorology. This knowledge will

assist farmers to prepare well to reduce risks of short term and long-term climate change on production. FFS is an effective training mechanism that can reach multiple small-scale farmers with knowledge and technical content to assist each former adapt to their own unique circumstances.

Chapter 4 Technology prioritisation for Water sector

4.1 Key climate change vulnerabilities in Water

Impacts of climate variability and change on water resources are evident on most of Vanuatu's islands. Water temperatures remained relatively constant from the 1950s to the late 1980s. This was followed by a period of more rapid warming (approximately 0.09°C per decade from 1970 to present). Furthermore, the intensity and frequency of days of extreme rainfall are projected to increase.

Most of Vanuatu's urban centres and outer islands are dependent on ground water for drinking, given the limited availability of surface water. On high volcanic and granitic islands, small and steep river catchments respond rapidly to rainfall events, and watersheds generally have restricted storage capacity. On porous limestone and low atoll islands, surface runoff is minimal, and water rapidly passes through the substrate into the groundwater lens. Rainwater harvesting is also an important contribution to freshwater access. Rapidly growing demand, land use change, urbanization, and tourism are already placing significant strain on the limited freshwater reserves.

These issues also occur on a background of decreasing rainfall and increasing temperature. Severe water shortages were particularly observed and reported in most islands of Vanuatu during the 2015 -2016 El Niño period. More specifically for the islands of Torres, Malekula, Santo, Pentecost, Epi, Erromango, Aniwa and Aneityum, gravity feed and rainwater harvesting systems encountered low flow rates or depleted water storage.
Extreme events such as cyclones also aggravate Vanuatu's already delicate water resource situation. Tropical Cyclone Pam, one of the more intense cyclones to occur in the southern hemisphere, hit Vanuatu in 2015. The cyclone caused widespread damage including to community water infrastructure for example affected gravity feed systems in Central Pentecost.

4.2 Decision context

Water is accessed in most islands of the country in a number of ways, either via individual supply systems, rural community managed systems, public entity (Public Works Department managed) system or by a collective private sector run reticulated system.

Urban water supplies are provided by UNELCO (a private company) in Port Vila reaching over 90% of the population and by the Public Works Department in Luganville, Isangel and Lakatoro via a reticulation system servicing about 60% of the entire population with generally reliable and clean water, generally sourced from aquifers.

Other rural water supplies are operated and managed by the local community and is either sourced from groundwater via open wells and bores, from surface water sources, or rainwater collection with storage in ferro-cement or polyethylene tanks. Demand for irrigated water is extremely low and limited to a few small horticultural sites.

In these rural areas there is a range of different problems with the delivery of safe drinking water including intermittent supply caused by drought or damaged infrastructure, contaminated water and competing uses for drinking water causing conflict in communities.

Water in the context of catchment management and flooding is also an issue. Several catchments are prone to flooding (such as the Jordan River catchment in Santo and the La Cole River catchment on Efate) causing damage and disconnecting major populations to the main centres. This means that population are denied access to general services and local communities are not able to trade or sell their produce in the local markets. The damages to crops and infrastructures caused by flooding during tropical cyclone Pam contributed to the USD450K in loss and damages.

Changing climate trends associated with the recent El Niño phenomenon have also revealed that rainwater dependency and a lack of storage undermine the security of a sufficient quantity of water.

The decision as to which sectors to focus on stemmed from an initial literature review of existing climate change and development frameworks which included the National Water Policy, the NAPA and other policy frameworks stated in section 1.2.

The Vanuatu National Water Policy in particular seeks to achieve and align its' strategic objectives for sustainable development via safe and sufficient, accessible and affordable, reliable and sustainable source of water for all.

Vanuatu’s NAPA proposed water management policies or programmes such as integrated water resource management, including rainwater harvesting as specific adaptation technologies.

The Project Steering Committee considered the various climate issues and development issues at hand especially its’ significance on the water.

Accordingly, the TNA team and Project Steering Committee decided on water to be a priority sector as a focus for this technology prioritization exercise.

Water technologies were mainly prioritized on their ability to improve the resilience of domestic water supply, availability of water for households’ livelihoods and tourism. Technologies to be considered were especially prioritized according to those which were already used in Vanuatu, were based on national priorities and knowledge on ease of adoption of technologies in the local context.

Pre-screening was conducted through discussion with the relevant stakeholders in technical working group meetings, and a short-list of ten (10) most appropriate technologies were retained from an initial list of thirteen (13) technologies.

Technology factsheets were produced namely by gathering information from the climate techwiki and CTCN databases. Adaptation technologies information for the agriculture sector locally was limited. More specifically, information with respects to costs and benefits was also limited or unavailable locally. Given the paucity of locally appropriate information on the technologies, utilization of expert judgement was therefore the preferred option to facilitate the prioritization exercise.

The technology factsheets were circulated prior to the stakeholder workshop and were further discussed at the workshop or bilaterally via meetings. Stakeholders also provided information on the status of each technology in Vanuatu and where available historical information about technologies, which have been used in Vanuatu.

Technology criteria and weights were discussed collectively and agreed upon by way of consensus among. Scores and results for technologies was undertaken and distributed to participants.

4.3 Overview of existing technologies in Water Sector

Initial research on water adaptation technologies was undertaken to come up with a pre-selection list from which the prioritization process will stem from. This assessment was done to determine which technologies are currently in use or have the potential to be utilized in Vanuatu.

Table 7 below provides a summary of adaptation technologies in the water sector.

Adaptation technologies	Status of technology in country
Desalination	Currently implemented on 2 islands
Domestic water supply during drought	Low implementation
Flood hazard mapping	Implementation mainly on the two urban centres of Port Vila and Luganville. Needs to be reinforced in other growth areas.
Flood warnings	Implemented by the Meteorology Department but requires strengthening.
Household water treatment and safe storage	Implemented in some localities but needs reinforcement
Leakage management in piped systems (urban)	Currently implemented but needs improvement especially in Luganville and other provincial centers
Post-construction support for water supplies	Currently implemented by Department of Water Resources and partners but also needs improvement.
Rainwater harvesting from rooftops	Implemented by both government and non-government stakeholders in most provinces of Vanuatu. However needs reinforcement.
Solar groundwater extraction	Low level of implementation
Water Safety Plans (WSPs)	Implemented in a number of communities or provinces as Drinking Water Safety and Security Plans (DWSPs). Needs reinforcement.
Hydro panels	Still in trial stage on Tanna island.

4.4 Adaptation technology options for water and their main adaptation benefits

General recommendations were firstly drawn from a number of key documents and current climatic challenges faced by the agriculture sector to guide selection of technologies.
A pre-selection list of thirteen (13) possible adaptation technologies was identified. These technologies were selected mainly to improve resilience and safety of domestic water supply and improvement of household livelihoods.

Ten technology options for water sector adaptation were identified and agreed upon by the TNA team members. Factsheets for the approved technologies were prepared and circulated to stakeholders for review and feedback.

The fact sheets provided a description of the technology, its potential to contribute to adaptation to climate change and the status of the technology in Vanuatu. Estimated cost and benefits of the technology options was provided where available. Refer to Annex I for the fact sheets.

Brief summaries of the technologies and their respective contributions to adaptation are provided below:

Desalination is the removal of sodium chloride and other dissolved constituents from seawater, brackish waters, wastewater, or contaminated freshwater. This technology can greatly aid climate change adaptation, primarily through diversification of water supply and resilience to water quality degradation. Diversification of water supply can provide alternative or supplementary sources of water when current water resources are inadequate in quantity or quality.

Domestic water supply during drought referred to as tubewells which consist of a narrow, screened tube or casing driven into a water-bearing zone of the subsurface. The term tubewell is sometimes used synonymously with borehole. Aids especially in times of extreme weather events such as droughts.
or
Flood hazard mapping is an exercise to define those coastal areas or flat plains which are at risk of flooding under extreme conditions. The approach has benefits for risk informed development planning, emergency management/response and raising awareness for flood hazard risks.

Flood warnings is a system purposely established detect and forecast threatening flood events so that the public can be alerted in advance and can undertake appropriate responses to minimize the impact of the event. The technology is a highly important adaptive measure where protection through large scale, hard defenses, is not desirable or possible.

Household water treatment and safe storage (HWTS) or point of use (POU), drinking water treatment and safe storage provides a means to improve the quality of their water by treating it in the home. HWTS increases resilience to water quality degradation by enabling users to improve water quality at the point of use especially where the degradation of water quality is expected to be one of the key impacts of climate change on water resources and water supply.

Leak management methods can prevent or reduce leakage volume and leak detection technology can improve the ability of water utilities to respond quickly and repair leaks. Detection and repair of leaks in water systems is an important part of comprehensive strategies to reduce pressure on existing water resources. Reducing water use in municipal systems also contributes to climate change mitigation by decreasing greenhouse gas emissions.

Post construction support for water supplies (PCS) consists of a range of capacity building, technical assistance or institutional strengthening activities to improve the success and sustainability of community-managed water systems. Increasing the resilience of the growing number of rural, community-managed piped water supplies is one of the major challenges of climate change adaptation. Community-managed water supplies are typically more vulnerable to extreme weather events and less able to assess water resource sustainability than utility-managed systems.

Rainwater harvesting from rooftops (RWH) systems include: (1) a catchment surface where precipitation lands; (2) a conveyance system of gutters and pipes to transport and direct the water; and (3) containers to store the water for later use.

The technology is beneficial to climate adaptation by (a) diversification of household water supply; and (b) increased resilience to water quality degradation. It can also reduce the pressure on surface and groundwater resources (e.g. the reservoir or aquifer used for piped water supply) by decreasing household demand.

Solar ground water extraction is a typical solar powered pumping system consisting of a solar panel array that powers an electric motor, which in turn powers a bore or surface pump.

The technology enables the utilization of groundwater which is not easily affected by variation in rainfall and provides mitigation benefits as well where there are offsets in greenhouse gas emissions.

Water Safety Plans (WSPs) are described collectively as a systematic and integrated approach to water supply management based on assessment and control of various factors that pose a threat to the safety of drinking water. WSPs contribute to climate change adaptation at the catchment level primarily through increased resilience to water quality degradation. The WSP approach allows for water suppliers to be flexible and responsive to changing input parameters.

4.5 Criteria and process of technology prioritisation

Two steps were used to arrive at a shortlist of technology options for adaptation in the water sector. The first step consisted of pre-screening most likely implementable adaptation technologies from the long-list of identified technologies. The second step consisted of developing technology factsheet (TFS) for each of the short-listed technologies, and establishing the criteria and indicators for technology prioritization using MCA.

The pre-screening was conducted through discussion with a wide group of stakeholders[9] in technical working group meetings, and a short-list of ten most appropriate technologies were retained based on national priorities and knowledge on ease of adoption of technologies in the local context.

A focus group workshop was convened to guide stakeholders through the process of determining criteria category and weights. The criteria selected were based from the UNEP MCA guidance on adaptation technology (2015) and sector expert views. Criteria categories selected were financial costs, economic, social, environmental, climatic, institutional and political. Stakeholders jointly discussed and agreed that weights would range from 0 – 100, with a high value score assigned to a criterion which was most preferred, and a lower value score assigned to a criterion with a lower preference. Weights were collectively discussed and averaged out to be used for the scoring exercise.
While climate parameters were critical when it comes to adaptation technology costs, policy alignment (national policy coherence) and social criteria were matters that generated much discussions. These three criteria classes were highly regarded therefore were accorded more weight by stakeholders.

[9] Stakeholders included the Department of Water Resources, Department of Local Authorities, Department of Health, Department of Climate Change, private sector, NGO and the academia

This was followed by the environmental criteria as priorities that were also placed with considerable weighting. The waste management implication for technologies such as desalination triggered much debate between stakeholders. Refer to Table 8 below.

It was agreed that performance scores were to be standardized using a Linkert scale between 0 (lowest score) to 10 (highest score) based on the expected merits of the technology. There were some discussions on public financing needs, especially given limited data, with respects to establishment and maintenance costs for the technology options.

Performance scoring where costs are concerned was therefore to be anchored to a Linkert scale between 0 (most costly) and 10 (least costly). Table 8 below shows criteria category and weights.

Technology fact sheets (TFS) were produced for each short-listed technology. The TFS contain relevant information on the technical aspects of the technology implementation, including its installation, operation and maintenance, efficiency, cost, and the benefits / opportunities, as well as the barriers for each short-listed adaptation technology.

Table 8. Performance criteria, assigned weights and scoring scale

Criteria category	Criteria	Weight (%)	Scale
Institutional/ implementation barrier	Ease of implementation	6	0 – very low/difficult 10 – very high/easy
	Use and maintenance /replicability	6	0 – very low/difficult 10 – very high/easy
Public financing needs	Cost to set up and operate the technology (resources, skills, infrastructure..)	17	0 – very low/difficult 10 – very high/easy
Economic	Catalyzing private investment	3.5	0 – very low/difficult 10 – very high/easy
	Improving household income and ability to reinvest	3.5	0 – very low/difficult 10 – very high/easy
Environmental	Contribution of the technology to protect and sustain ecosystem services	15	0 – very low/difficult 10 – very high/easy
Climate-related	Enhancing resilience against climate change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts)	9	0 – very low/difficult 10 – very high/easy
Social	Contribution to social and sustainable development (benefit to health, poverty reduction)	19	0 – very low/difficult 10 – very high/easy
Political	Coherence with national development policies and priority	21	0 – very low/difficult 10 – very high/easy
	Total	100	0 – very low/difficult 10 – very high/easy

Bilateral meetings were also held with key stakeholders to discuss the status of the technologies in Vanuatu, and to acquire technical information to estimate the cost and implementation feasibility of the adaptation technologies.

4.6 Results of technology prioritisation

Limited data to ascertain costs and benefits posed a major challenge in the prioritization of technology options. Experts in that regard provided perspectives to the merits of individual technologies relative to their relevance to increasing resilience of domestic water supply to climatic hazards (such as prolonged dry periods, cyclones and salinization).

Emphasis was also given to technologies with the potential to contribute to development objectives such as poverty reduction, health and gender mainstreaming. Cost implications of a technology and whether implementing a technology will contribute to broad development or sector development objectives promoted much discussions.

The performance of each technology was rated individually by stakeholders and with scores aggregated in order to determine ranking. The weight assigned to each criterion was multiplied by the score value (0-10) that each technology was assigned. The scores for each technology options were aggregated and the technology receiving the highest score was consigned high priority. Refer to MCA calculator, Annex III.

The results of the MCA exercise were further examined to assess sensitivity of technology ranking and to perceive if the resultant rankings were logically positioned. Namely sensitivity analysis was undertaken, with respects to, ensuring gender considerations were adequately considered. On that note, an additional 5 percent in weight value was added to the social performance criteria weight.

The overall ranking of the adaptation options was finally agreed by all stakeholders and technical expert based on the sensitivity analysis. The results are summarized in Table 9.

Table 9. Summary of results for water adaptation technologies

Ranking priority	Adaptation technologies for the water sector
1	Rainwater harvesting from roof tops
2	Water Safety Plans
3	Flood hazard mapping
4	Solar groundwater extraction
5	Domestic water supply during drought
6	Flood warnings
7	Household water treatment and safe storage
8	Post construction support for water supplies
9	Leakage management in piped systems
10	Desalination

Overall, the top three (3) technologies are:

1. **Rainwater harvesting from roof tops**: the collection of rainwater from roof top catchments. Beneficial adaptation aspects of this technology include (a) diversification of household water supply; and (b) increased resilience to water quality degradation. It can also reduce the pressure on surface and groundwater resources (e.g. the reservoir or aquifer used for piped water supply) by decreasing household demand and has been used as a means to recharge groundwater aquifers. Another possible benefit of rooftop RWH is mitigation of flooding by capturing rooftop runoff during rainstorms.

2. **Water Safety Plans**: described collectively as a systematic and integrated approach to water supply management based on assessment and control of various factors that pose a threat to the safety of drinking water. WSPs contribute to climate change adaptation at the catchment level primarily through increased resilience to water quality degradation. The WSP approach allows for water suppliers to be flexible and responsive to changing input parameters

3. **Flood Hazard Mapping**: an exercise to define those coastal areas which are at risk of flooding under extreme conditions. As such, its primary objective is to reduce the impact of coastal flooding. The technology provides benefits for risk informed development planning, emergency management/response and raising awareness for flood hazard risks.

Chapter 5 Summary and Conclusions

This TNA report has outlined and reviewed the multi-stakeholder process that has been put in place in Vanuatu to prioritize adaptation sectors, as well as identifying climate change technologies for the priority sectors. The sectors that have been retained for the TNA project are: agriculture and water.

Multi-criteria analysis (MCA), including sensitivity analysis of scores and weights, was used to prioritize and rank technologies. The results are summarized as follows:

Sector	Technologies retained for the next phase
Agriculture	• **Crop diversification and new varieties** • **Agro-forestry** • **Farmer Field Schools**
Water	• **Rainwater harvesting from roof tops** • **Water Safety Plans** • **Flood Hazard Mapping**

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Annex I: Technology Factsheets for selected technologies

Agriculture

Agro-forestry factsheet

Introduction

Agro-forestry is an integrated approach to the production of trees and of non-tree crops or animals on the same piece of land. The crops can be grown together at the same time, in rotation, or in separate plots when materials from one are used to benefit another. Agro-forestry systems take advantage of trees for many uses: to hold the soil; to increase fertility through nitrogen fixation, or through bringing minerals from deep in the soil and depositing them by leaf-fall; and to provide shade, construction materials, foods and fuel. In agro-forestry systems, every part of the land is considered suitable for the cultivation of plants.

Perennial, multi- purpose crops that are planted once but yield benefits over a long period of time are given priority. The design of agro-forestry systems prioritises the beneficial interactions between crops, for example trees can provide shade and reduce wind erosion. And act as a buffer zone to extreme wind damages during cyclones for farming activities. According to the World Agro-forestry Centre, “agro-forestry is uniquely suited to address both the need for improved food security and increased resources for energy, as well as the need to sustainably manage agricultural landscapes for the critical ecosystem services they provide”. Agro-forestry is already widely practiced on all continents.

Technology characteristics

Country specific applicability and potential

- Capacity: existing institutional and technical capacity to implement the technology either through government agencies such as the Department of Agriculture, Department of Forestry and NGO or private sector partners.
- Scale of application: community to provincial. Can be applied within both rural and urban settings.
- Time horizon- Short to long term application of technology.

Status of technology in country

- Agro-forestry is currently implemented as a core program of the Department of Agriculture and Department of Forestry. Implementation covers only select islands or on community sites.

Climate change adaptation benefits

Agro-forestry can improve the resilience of agricultural production to current climate variability as well as long-term climate change through the use of trees for intensification, diversification and buffering of farming systems. Trees reduces vulnerability, increasing resilience of farming systems and buffering agricultural production against climate-related risks. Trees are deep rooted and have large reserves, and are less susceptible than annual crops to inter-annual variability or short-lived extreme events like droughts or floods. Thus, tree-based systems have advantages for maintaining production during wetter and drier years. Trees improve soil quality and fertility by contributing to water retention and by reducing water stress during low rainfall years. Tree-based systems also have higher evapo-transpiration rates than row crops or pastures and can thus maintain aerated soil conditions by pumping excess water out of the soil profile more rapidly than other production systems if there is sufficient rainfall/soil moisture. Trees act as nutritional pump, making soil nutrients and minerals in the lower depths of soil profiles available to shallow rooting systems for annual crops, especially out traditional staple crops and vegetables. Agroforestry can be integrated with food crops and animal, of which farmers can benefit from the integrated systems during harsh weather conditions.

Most of the tree species used are readily available for farmers who may need technical advises on setting up the different structures (alley cropping system; integrated farming systems; contour planting; fallow improvement systems; life- fencing or border planting) of their suitable choices.

Trees reduces the impacts of extreme weather conditions such as droughts or torrential rain. Research has also demonstrated that the tree components of agro-forestry systems stabilize the soil against landslides and raise infiltration rates. This limits surface flow during the rainy season and increases groundwater release during the dry season.

Agro-forestry can also play a vital role in improving food security providing means for diversifying our agricultural production systems

Benefits to economic / social and environmental development

Agro-forestry can also play a vital role in improving food security through providing a means for diversifying production systems.

Furthermore, Vanuatu's Sector policies places emphasis to sustainable farming practices of which captures agro-forestry as a promotional activity for sustainable farming practices.

Financial Requirements and Costs

- Typical agro-forestry costs can range from USD 10, 000 to 80, 000

Community – based agricultural extension agents Factsheet

Introduction

Agricultural extension' describes the services provided to rural communities, with the access to knowledge and information they need to increase productivity and sustainability of their production systems, and improve their quality of life and livelihoods.

The community-based rural agricultural extension model is based on the idea of providing specialised and intensive technical training to one or two people in a community who then promote a variety of appropriate technologies and provide technical services with occasional support and review from a supporting organisation This model is demand-based in that the providers of service are contracted directly by farmers' groups or communities to deliver information and related services that are specified by farmers. These models have generally experienced a high degree of success in terms of discovering or identifying productivity enhancing technologies, which are then widely adopted. They have also been able to do so at relatively low cost.

In general there are five stages to implementing the rural extensionists model:

Stage 1: Creating a Space for Public Debate and Institutional Coordination

Stage 2: Establishment of Training Centre

Stage 3: Training Rural Extension Agents

Stage 4: Ongoing Technical Support and Evaluation

Stage 5: Knowledge Refresher Courses

Technology characteristics

Country specific applicability and potential

- Capacity: technical capacity exists to roll out this technology. Will require expanding this technical expertise to other non-government actors and private sector.
- Scale of application: suitably applied at community or provincial level.
- Time horizon- Short to long term application of technology.

Status of technology in country

- Extension officers are currently deployed within provincial centres of Vanuatu. However, depending on size of provinces that they serve and available operational budget, delivery services is rather mixed.

Climate change adaptation benefits

The community-based rural extension model contributes to climate change adaptation and risk reduction by building the capacity of communities to identify and select appropriate strategies in response to observed impacts of climate variability on local livelihoods. The model promotes a rural outreach programme that provides assistance to many communities that would otherwise not receive technical support services. As a result of these services, farmers have generally been able to increase crop and livestock production.

The agents are more conscious and adapted to the social and environmental welfare of the community, hence will provide more appropriate advice and direction on different climate change issues to their respective communities.

Benefits to economic / social and environmental development

The community based extension model has positive effects on family health and food security. In addition, rural extensionists have been instrumental in supporting local communities to develop affordable new products for local markets.

Vanuatu’s National Sustainable Development Plan (NSDP) highlights the importance of extension services to improve primary sector production. Additionally, the Agriculture Sector Policy underscores the need to utilize extension services in order to improve build capacity of the agriculture sector workforce, including women or youth, and expand coverage of agriculture information.

Financial Requirements and Costs

External financing will usually be required support training schools for agricultural extension. When the training is carried out by local organisations and farmer facilitators, initial start-up costs may be moderate, but the running costs will be much lower.

Globally costs range from $1200 to train an extension agent on an annual basis or $112 – 117 per person in the case where refresher trainings are provided.

<u>Crop diversification and new varieties Factsheet</u>

Introduction

The introduction of new cultivated species and improved varieties of crop is a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses. Crop diversification refers to the addition of new crop varieties or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities.

Technology characteristics

Country specific applicability and potential

- Capacity: institutional and technical capacity in country. Currently the Department of Agriculture and the Vanuatu Agricultural Research and Technical Centre (VARTC) have dedicated programs utilizing the technology
- Scale of application: suitable for community to national level implementation within either urban or rural settings. May need to be complimented by specific crop modelling assessment or field trials due to different island climatic conditions.
- Time horizon- Short to medium term application of technology.

Status of technology in country

- Technology is substantively employed by the Department of Agriculture and stakeholders in several communities or islands of Vanuatu through the establishment of demo plots which act as multiplication and redistribution sites within provincial centers.

Climate change adaptation benefits

Breeding new and improved crop varieties enhances the resistance of plants to a variety of stresses that could result from climate change. These potential stresses include water and heat stress, water salinity, water stress and the emergence of new pests – stresses, and cyclones which are common in Vanuatu.

Elite varieties are developed to resist harsh conditions to ensure that agricultural production can continue and even improve despite uncertainties about future impacts of climate change.

The aim of crop diversification is to increase crop availability and choice, so that farmers are not dependent on a single crop to generate their income and create food security. Mono-cropping (use of one crop type) exposes the high risks in the event of unforeseen climate events that could severely impact agricultural production, such as emergence of pests and disease infestation, and the sudden onset of frost or drought.

Benefits to economic / social and environmental development

Vanuatu's National Sustainable Development Plan (NSDP) emphasizes the necessity to improve food production systems via traditional and modern approaches. More specifically the Agriculture Sector Policy underlines the importance of diversifying food crops and introducing new crops to foster food production resilience.

Diversification of agricultural production can increase natural biodiversity, strengthen the ability of the agro-ecosystem to respond to these stresses, reduce the risk of total crop failure and also provides producers, especially women and youth, with alternative means of generating income.

Financial Requirements and Costs

Costs of farmer experimentation are generally low, but results may only have local applicability. Capital investment will relate to the purchase of new seed varieties (if not available 'wild' locally) and labour time. Where farmers are implementing a project initiated by an external agency, capital costs for training, technical experts and field staff, on farm trial equipment (an experimental plot may be established), and site visits may also be required.

Financial requirements of diversification revolve around the costs involved in researching the species to be planted and training in the management of diversified systems. Preliminary feasibility and market research need also to be considered in the financial requirements. Infrastructure (such as transport and storage) and marketing costs should also be considered.

Adaptability is very likely, when the crop varieties introduce clearly satisfies the farmers' farming needs.

Drip irrigation Factsheet

Introduction

Drip irrigation is based on the constant application of a specific and calculated quantity of water to soil crops. The system uses pipes, valves and small drippers or emitters transporting water from the sources (i.e. wells, tanks and or reservoirs) to the root area and applying it under particular quantity and pressure specifications. The system should maintain adequate levels of soil moisture in the rooting areas, fostering the best use of available nutrients and a suitable environment for healthy plant roots systems. Managing the exact moisture requirement for each plant, the system significantly reduces water wastage and promotes efficient use. Comparatively, surface irrigation, 60 per cent water use efficiency, sprinklers systems which can provide 75 per cent efficiency, drip irrigation can provide as much as 90 per cent water-use efficiency. In recent times, drip irrigation technology has received particular attention from farmers, as water needs for agricultural uses have increased and available resources have diminished. In particular, drip irrigation has been applied in arid and semi-arid zones as well as in areas with irregular flows of water (or in zones with underground water resources that rely on seasonal patterns such as river-flow or rainfall).

Technology characteristics

Country specific applicability and potential

- Capacity: some institutional and technical capacity in country namely within the Department of Agriculture and private sector
- Scale of application: suitable for community to national level implementation within either urban or rural settings that have good access to a reliable water source.
- Time horizon- Short to medium term application of technology.

Status of technology in country

- Technology is still in the early phases of deployment by the Department of Agriculture. Trial plots have been established within the Department of Agriculture premises for further research.

Climate change adaptation benefits

Drip irrigation technology can support farmers to adapt to climate change by providing efficient use of water supply for especially cropping farms. Particularly in areas subjected to climate change impacts such as seasonal droughts, drip irrigation reduces demand for water and reduces water evaporation losses (as evaporation increases at higher temperatures). Scheduled water application will provide the necessary water resources directed to the plants when required. Fertilizer application is more efficient since it can be applied directly through the pipes.

Drip irrigation is more appropriate where there is limited or irregular water supply for agricultural use. The technology uses less amount of water than sprinkler irrigation, since water is applied directly to the crops, according to plant requirements. Furthermore, the drip system is not affected by wind or rain (as is the sprinkler technology).

Benefits to economic / social and environmental development

The Agriculture Sector Policy places importance and highlights water irrigation as a means to the productivity of farming systems. More broadly the NSDP calls for appropriate technologies in food production to ensure food security needs are met.

Secondary benefits from improved crop productivity through the application of drip systems include income generation, employment opportunities and food security particularly for vulnerable groups e.g. women, youth, people with special needs.

Financial Requirements and Costs

The technology is widely variable, however the cost of a drip irrigation system ranges from US$ 800 to US$ 2,500 per hectare depending on the specific type of technology, automatic devices, and materials used as well as the amount of labor required. Capital costs for a small solar powered system can cost up to VT2.4 million vatu (US$ 2200 approx.). Financing for equipment may be available from financial institutions via leasing operations or direct credit. Farmers usually cover installation, design and training costs that represent about 30 to 40 per cent of final costs depending on the size of the land, characteristics and shape, crops, and particular technology applied.

Ecological Pest Management (EPM) Factsheet

Introduction

EPM is an approach to increase the strengths of natural systems to reinforce the natural processes of pest regulation and improve agricultural production. Also known as Integrated Pest Management (IPM), this practice can be "defined as the use of multiple tactics in a compatible manner to maintain pest populations at levels below those causing economic injury while providing protection against hazards to humans, animals, plants and the environment. IPM is thus ecologically-based pest management that makes full use of natural and cultural processes and methods, including host resistance and biological control. IPM emphasises the growth of a healthy crop with the least possible disruption of agro-ecosystems, thereby encouraging natural pest control mechanisms. Chemical pesticides are used only where and when these natural methods fail to keep pests below damaging levels".

The basis of this natural method of controlling pests is the biodiversity of the agroecological system. This is because the greater the diversity of natural enemy species, the lower the density of the pest population, and as diversity of natural enemy species decreases, pest population increases

The key components of an EPM approach are:

- Crop Management
- Soil Management
- Pest Management

Technology characteristics

Country specific applicability and potential

- Capacity: institutional and technical capacity in country especially by the Farm Support Association (FSA) and Department of Agriculture.
- Scale of application: suitable for community to national level implementation within either urban or rural settings.
- Time horizon- Short to medium term application of technology.

Status of technology in country

- Technology has been implemented by farmers, Agriculture Department and the FSA for more than 20 years.

Climate change adaptation benefits

EPM is a biotechnology belonging to ‘clean’ technologies which combines the life cycle of crops, insects and implicated fungi, with natural external inputs (i.e. bio-pesticides) that allows a better guarantee of quality and quantitative food production, even in difficult conditions of pests and diseases emerging with the temperature and water level changes (increase of relative atmospheric humidity and runoff) typical of climate change.

Thus, it is a biotechnology for facing uncertainty caused by climate change. EPM contributes to climate change adaptation by providing a healthy and balanced ecosystem in which the vulnerability of plants to pests and diseases is decreased. By promoting a diversified farming system, the practice of EPM builds farmers’ resilience to potential risks of climate change, such as damages to crop yields caused by newly emerging pests and diseases.

Benefits to economic / social and environmental development

The Agriculture Sector policy places priority on protecting crops from pest and diseases through the application of appropriate management strategies including management of pests as a climate change adaptation measure.

In agricultural production systems where the environment is relatively free of polluting elements (such as pesticides), and pests and diseases are becoming progressively more aggressive, conditions for EPM development are better. This is because there is no need to ‘clean’ the environment first in order to conduct research into which biological controllers are required. When EPM is used, farmers including vulnerable groups such as women or persons living with special needs, can benefit from the opportunity to sell their goods as healthy organic products that can fetch a higher market price.

Financial Requirements and Costs

A dedicated program (period of up to 5 years) with extensive training of personnel or extension officers can cost up to USD 6.6 million. On the other hand, generated benefits due to reduced production costs and increased yields amounted to USD 1.8 million.

Farmer Field Schools Factsheets

Introduction

Overall, field schools look to reinforce the understanding of farmers about the ecological processes that affect the production of their crops and animals, through conducting field learning exercises such as field observations, simple experiments and group analysis. The knowledge gained from these activities enables participants to make their own locally specific decisions about crop management practices. Although FFSs were initiated as a training process for pest control in field crops, the principles have now been adapted to all agricultural production systems from livestock to coffee production.

Technology characteristics

Country specific applicability and potential

- Capacity: institutional and technical capacity exists within the Department of Agriculture and Vanuatu Agricultural Research and Technical Centre to roll out the technology.
- Scale of application: suitable for community to national level implementation within either urban or rural settings.
- Time horizon- medium to long term application of technology.

Status of technology in country

- There has been low application or use of this technology. Field schools to date have been run as a donor project activity.

Climate change adaptation benefits

Climate change brings many complex and unpredictable changes that affect the viability and management of farming systems. Not only are there trends in the change of temperature and rainfall, but also increased climate variability especially in the duration and intensity of the seasons. This affects a whole range of conditions relating to the performance and management of different farming systems, from planting time, to flowering, to the prevalence of different pests and diseases. To cope with this increased variability farmer will need a greater understanding of the processes that affect the performance of the different production systems they manage and undergo constant experimentation and adaptation of these production systems.

More so even than the agronomic knowledge that farmers acquire from participating in farmer field schools, the habits and abilities of constant adaptation are essential for farmers to be able to cope with climate change.

Benefits to economic / social and environmental development

Vanuatu's Agriculture Sector policy identifies field schools as means to upskill workforce within the agriculture sector.

Farmer field school processes empower farmers, both individually and collectively, to more effectively participate in the processes of agricultural development. The 'empowerment' impacts of the FFS oriented training have resulted in widespread and lasting developmental impacts, such as continued learning, increased social and political skills, especially for women, to enable improved agro-ecosystem management.

Financial Requirements and Costs

FFS programs have generally been funded by donor agencies such as the EU, World Bank and FAO. The cost of conducting a season-long field school for 25 farmers has ranged from $150 to $1,000 depending on the country and the organisation. In some cases, the graduates of FFS have saved $40 per hectare per season by eliminating pesticides without any loss of yield. In other cases, graduates did not experience any savings because they were not previously using any pesticides. However, their yields increased by as much as 25 per cent as a result of adopting other practices learnt during the FFS, such as improved varieties, better water management and enhanced plant nutrition.

The conceptual and methodological problems associated with assessing the impact of IPM field schools have resulted in disagreements among experts about the advantages of this intervention. One widely circulated paper written by World Bank economists has questioned the benefit of 'sending farmers back to school'. By contrast, a meta-analysis of 25 impact studies commissioned by FAO concluded that in the majority of studies there were substantial reductions in pesticide use and in a number of cases of increased yield due to training.

Integrated farming system (Mixed Farming) Factsheet

Introduction

Mixed farming is an agricultural system in which a farmer conducts different agricultural practice together, such as food crops and livestock. The aim is to increase income through different sources and to complement land and labour demands across the year.

Mixed farming systems can be classified in many ways. They can be based on land size, type of crops and animals, geographical distribution, market orientation, and so on. Three major categories are distinguished here.

On-farm mixing refers to mixing on the same farm, and between-farm mixing refers to exchanging resources between different farms. On-farm mixing enables the recycling of resources generated on a single farm.

Between-farm mixing can be used to resolve waste disposal problems where by crop farmers use waste from animal farms for fertiliser.

Multiple cropping or keeping different types of animals together. For example, grain-legume association can provide grain with nitrogen. With plant inter-cropping farmers can utilize small space available by selecting plants and cropping formations that maximise the advantage of light, moisture and soil nutrients. Examples of mixed animal systems include chicken-fish production where chicken waste serves as fish fodder.

Creating a diversified system which some components exist as independent units. In an integrated system, maximum use is made of resources, making the system highly interdependent.

This system maximizes production with minimum land area.

Technology characteristics

Country specific applicability and potential

- Capacity: institutional and technical capacity exists within the Department of Agriculture, Vanuatu Agriculture College and Vanuatu Agricultural Research and Technical Centre to roll out the technology.
- Scale of application: suitable for community to national level implementation but especially fitting within urban settings that have limited land space.
- Time horizon- medium to long term application of technology.

Status of technology in country

- Technology has initially kick-started in 2-3 locations. Basically these initial pilots will also aid to ascertain the technology's feasibility and replicability.

Climate change adaptation benefits

Integrated farming system or Mixed farming technology contributes to adaptation to climatic change because the diversification of crops and livestock allows farmers to have a greater number of options to face the uncertain weather conditions associated with the increased climate variability. Mixed farming can also give a more stable production because if one crop or variety fails, another may compensate. Livestock represents a means by which families can save and invest in the future. Livestock is a walking bank of assets that can be sold during periods of need such as if crops fail due to drought or flooding.

The system encompasses the purpose of food security (Availability, Accessibility, Stable and Use), as each systems support each other, with efficient use and waste management, where livestock waste are managed to support plant production.

Benefits to economic / social and environmental development

The Agriculture Sector Policy places emphasis on farming systems which will enhance food security and livelihoods. More broadly the NSDP calls for appropriate technologies in food production to ensure food security needs are met.

This technology also allows greater food security and improved household nutrition levels, an aspect that is particularly beneficial to vulnerable groups i.e. women, children, elderly and people with special needs. In addition, farmers can generate a surplus of some products that can be sold at market. Among other benefits, this technology also allows farmers to grow fodder for livestock and poultry. An additional benefit of mixed crop–fish culture systems is that the fish may help reduce populations of existing and emerging disease vectors such as mosquitoes.

Financial Requirements and Costs

As for most cases, to estimate the costs of implementing this technology the cost of farming inputs (e.g infrastructures; tools; equipments; chemicals and machines) must be considered.

The main financial needs are associated with credits for the acquisition of inputs, investment in training and in the dissemination of this technology. Investment is needed to obtain necessary qualitative and quantitative micro-climate information for managing the synchronisation of mixed crop cycles (phenologies).

Integrated Nutrient Management (INM) Factsheet

Introduction

The aim of Integrated Nutrient Management (INM) is to integrate the use of natural and man-made soil nutrients to increase crop productivity and preserve soil productivity for future generations.

Rather than focusing nutrition management practices on one crop, INM optimizes the use of nutrient sources on a cropping-system or crop-rotation basis. This encourages farmers to focus on long-term planning and make greater consideration for environmental impacts.

INM relies on a number of factors, including appropriate nutrient application and conservation and the transfer of knowledge about INM practices to farmers and researchers. Boosting plant nutrients can be achieved by a range of practices covered in this guide such as terracing, alley cropping, conservation tillage, intercropping, and crop rotation. Given that these technologies are covered elsewhere in this guidebook, this section will focus on INM as it relates to appropriate fertiliser use. In addition to the standard selection and application of fertilisers, INM practices include new techniques such as deep placement of fertilisers and the use of inhibitors or urea coatings that have been developed to improve nutrient uptake.

Technology characteristics

Country specific applicability and potential

- Capacity: institutional and technical capacity exists within the government, academia, NGO and private sector to roll out the technology.
- Scale of application: suitable for community to national level wide implementation.
- Time horizon- medium to long term application of technology.

Status of technology in country

- Technology traditionally has been implemented although only in select locations.

Climate change adaptation benefits

Harsh climatic conditions are a major cause of soil erosion and the depletion of nutrient stocks. By increasing soil fertility and improving plant health, INM provides sufficient supply in major soil nutrients such as phosphorus, nitrogen and potassium, enhances plant growth and production by:

- Gaining a considerable influence on the susceptibility or resistance of plants towards many types of pests and diseases

  Exploring a larger volume of soil in order to access water and nutrients, and improving root development for plants to access water from deeper soil layers. With a well-developed root system, crops are less susceptible to drought
- Along the coastal areas, where there is increasing coastal erosion activities, hence increase saline conditions from salt sprays, plants can be supplemented with potassium to maintain normal growth
- With appropriate potassium fertilisation, plants can improve its tolerance to colder conditions

Benefits to economic / social and environmental development

The Agriculture Sector Policy places emphasis on soil improvement technologies to facilitate sustainable farming practices. More broadly the NSDP calls for appropriate technologies in food production to ensure food security needs are met.

INM empowers farmers, including women, by increasing their technical expertise and decision-making capacity.

It also promotes changes in land use, crop rotations, and interactions between forestry, livestock and cropping systems as part of agricultural intensification and diversification.

Financial Requirements and Costs

The main cost associated with Integrated Nutrient Management relates to the purchase and distribution of inorganic fertilisers. Costs can be affected by factors such as geographical landscape, market conditions (i.e. import and export trade balances), transport infrastructure, policy environment and fertilizer demand.

Organic fertilisers provide a low-to-no-cost technology for improving soil fertility as long as they can be produced and used within a relatively close distance.

Seed storage Factsheet

Introduction

Seed security is key to household food security among resource poor farmers in developing countries. Good storage helps ensure household and community food security until the next harvest and commodities for sale can be held back so that farmers can avoid being forced to sell at low prices during the drop in demand that often follows a harvest. While considerable losses can occur in the field, both before and during harvest, the greatest losses usually occur during storage. Therefore the basic objective of good storage is to create ideal environmental conditions that protect the product and maintain its quality and its quantity, reducing product loss and financial loss.

Seed storage enhances domestic security and maintains value prior to sale. Farmers may not accept improvements, which incur costs when storing primarily for home consumption because an improvement in the quality of a food produced for home consumption does not achieve a higher monetary value for the farmer.

Technology characteristics

Country specific applicability and potential

- Capacity: institutional and technical capacity exists within the government, academia, NGO and private sector to roll out the technology.
- Scale of application: suitable for provincial to national level wide implementation.
- Time horizon- medium to long term application of technology.

Status of technology in country

- Technology implementation is still low and requires upscaling.

Climate change adaptation benefits

Seed storage contributes to preparations for droughts and hunger and malnutrition. Seed storage provides an adaptive strategy for climate change, by ensuring feed is available for livestock and seed stock is available in the event of poor harvests due to drought

Efficient harvesting can reduce post-harvest losses and preserve food quantity, quality and the nutritional value of the product. The establishment of safe storage for seeds and reserves of food and agricultural inputs are used as indicators of adaptive capacity in the agriculture sector.

Benefits to economic / social and environmental development

The Agriculture Sector Policy places emphasis on the establishment of plant material centres to enhance access to planting materials and improve food security. More broadly the NSDP calls for improved access to appropriate technologies for food production and food storage.
The establishment of safe, long-term storage facilities ensures that grain supplies are available during times of drought and is especially beneficial for vulnerable groups such as women, elderly and people with special needs. It is important to be able to store food after harvest so as not to be compelled to sell at low prices. Appropriate storing techniques can prolong the life of foodstuffs, and/or protect the quality, thereby preserving stocks year-round.

Financial Requirements and Costs

Costs requirements vary between storage methods. If the produce is for consumption, rather than sale, then investing large amounts in a new technology will not prove cost-efficient. On the other hand, if the amount of food for sale increases, then the investment can be paid back over time. Calculating the existing profit and potential profit with new technology is useful for businesses to estimate this payback period. The amount people are prepared to invest in new technology may depend partly upon who owns the equipment and facilities. In some cases, farmers will invest in a new technology if they have total ownership of it while in other cases, storage may be collectively owned and so costs can be shared. Access to credit is often dependent on where people live, educational levels and on being able to raise collateral. Adopting new storage methods for low-income farmers will be possible if they are given assistance with literacy and numeracy, and possibly some kind of group training.

Slow Forming Terrace Factsheet

Introduction

Slow-forming terraces are constructed from a combination of infiltration ditches, hedgerows and earth or stone walls. This technology decreases superficial water run-off, increasing water infiltration and intercepting the soil sediment. Slow-forming terraces are called as such because they take between three and five years, and possibly even ten years, to fully develop.

Slow-forming terraces can be built where the land is marginally to steeply inclined and where the soil is sufficiently deep to create a drag effect. This leads to the formation of steps as sediment accumulates due to rainfall and natural gravity. Level ditches are traced and excavated along the contour line of a slope and then an embankment of earth, stones or plants is constructed at regular intervals. Eroded soil accumulates in these buffer strips every year and terraces slowly form. To avoid intensive rains breaking buffers strips, a one to two per cent inclination is recommended.

Technology characteristics

Country specific applicability and potential

- Capacity: institutional and technical capacity exists within the Agriculture Department and agriculture training entities.
- Scale of application: suitable for locations or islands with steep terrains
- Time horizon- medium to long term application of technology.

Status of technology in country

- Technology implementation is still low and requires upscaling.

Climate change adaptation benefits

This technology facilitates adaptation to climate change by optimising water use. This is particularly relevant in areas where there is uncertainty about future rainfall patterns, as in the case for Vanuatu. Climate variability also affects the soil, since heavy rainfall coupled with poor soil management give rise to landslides and mudslides.

In this respect, slow-formation terraces reduce soil erosion and, consequently, the danger of large landslides occurring. Terraces also provide a method for regulating the micro-climate for agricultural production.

By capturing the sun's heat in the rock walls, terraces absorb heat during the daytime and release this nightly helping to create a slightly warmer internal micro-climate which can prolong the growing season and allow for crop diversification.

Benefits to economic / social and environmental development

The Agriculture Sector Policy places emphasis on soil improvement technologies to facilitate sustainable farming practices. More broadly the NSDP calls for appropriate technologies in food production to ensure food security needs are met.

Financial Requirements and Costs

The most costly component of terrace construction is labour which will depend on average local daily wages. The time required to construct a slow-forming terrace will depend on available manpower, the type of soil and the time of year. The basic tools required (such as picks and shovels) usually belong to the farmer and can be used at no extra cost. Once built, annual maintenance costs are minimal. Research indicates that two people can build 7m² of wall in one day. Assuming a common size terrace wall of dimensions 1.8m high and 50m long, two people could restore an entire terrace in two weeks, or build an entirely new one in a slightly longer period of time. In a project in northern Peru, an initial investment of $350/ha was required with $86/ha per annum for maintenance.

Planting of contour hedgerows or grass strips are considerably cheaper to establish, but they require continuous management afterwards.

Water Sector

Desalination Factsheet

Introduction

Desalination is the removal of sodium chloride and other dissolved constituents from seawater, brackish waters, wastewater, or contaminated freshwater. Approximately 75 million people worldwide rely on desalination and that number is expected to grow as freshwater resources are stressed by population growth and millions more move to coastal cities with inadequate freshwater resources. Desalination is most widely used in arid regions; more than half of the world's desalination capacity (volume) is located in the Middle East and North Africa.

Technology characteristics

Country specific applicability and potential

- Capacity: limited institutional and technical capacity to both install and implement the technology.
- Scale of application: preferable for small islands and coastal locations
- Time horizon- medium to long term application of technology.

Status of technology in country

- Technology currently established on 3 islands – Ambae, Aniwa and Uripiv islands

Climate change adaptation benefits

Desalination can greatly aid climate change adaptation, primarily through diversification of water supply and resilience to water quality degradation. Diversification of water supply can provide alternative or supplementary sources of water when current water resources are inadequate in quantity or quality.

Desalination technologies also provide resilience to water quality degradation because they can usually produce very pure product water, even from highly contaminated source waters.

Increasing resilience to reduced per capita freshwater availability is one of the key challenges of climate change adaptation. Both short-term drought and longer-term climatic trends of decreased precipitation can lead to decreased water availability per capita.

Vanuatu in particular faces regular periods of droughts, with projections of increasing variability in rainfall events. These climatic trends are occurring in parallel with population growth, land use change, and groundwater depletion; therefore, rapid decreases in per capita freshwater availability are likely. However, the large energy demands of current desalination processes will contribute to greenhouse gas emissions and could set back climate-change mitigation efforts.

Benefits to economic / social and environmental development

Access to an adequate supply of freshwater for drinking, household, commercial and industrial use is essential for health, well being, and economic development. Furthermore health and economic benefits will be advantageous for vulnerable groups such as women, children and people with special needs . In many settings, desalination processes can provide access to abundant saline waters that have been previously unusable.

Financial Requirements and Costs

Some of the factors reported to have the greatest influence on the cost per m3 include: the cost of energy, the scale of the plant, and the salt/TDS content of the source water. Capital costs of construction are clearly a major consideration as well, but are almost entirely site-specific.

The cost of membrane desalination decreases sharply as the salt concentration decreases. Seawater, on average, contains about 35,000 mg/L TDS; brackish waters, at 1000-10,000 mg/L, can be treated much less expensively (Greenlee et al., 2009). The costs per volume to desalinate brackish water using Reverse Osmosis (RO) have generally been reported to range from $0.26-0.54/m3 for large plants producing 5000-60,000 m3/day and are much higher ($0.78-1.33/m3) for plants producing less than 1000 m3/day. Cost per volume for seawater RO are reported to be $0.44-1.62/m3 for plants producing more than 12,000 m3/day. Units installed on Ambae (65kW solar powered, 100 tonne) and Aniwa (diesel powered 10 tonne) amounted to a collective cost of $4 million (VT400, 000, 000 approx.) in capital costs.

Thermal methods (generally used to desalinate seawater) are subject to the same economies of scale. Costs for thermal desalination plants were reported to be $2-2.60/m3 for 1000-1200 m3/day and $0.52-1.95/m3 for plants producing more than 12,000 m3/day.

Climate change adaptation strategies must consider not only future climate forecasts but also future technological development. The costs associated with desalination continue to decline incrementally as technological efficiency improves.

Domestic water supply during drought Factsheet

Introduction

Tubewells consist of a narrow, screened tube or casing driven into a water-bearing zone of the subsurface. The term tubewell is sometimes used synonymously with borehole. However, boreholes are more specifically defined as tubewells penetrating bedrock, with casing not extending below the interface between unconsolidated soil and bedrock. Tubewells can often be installed by hand-auguring; boreholes require a drilling method with an external power source. The choice of technology and drilling method depends on the cost, resources, groundwater table, desired yield and other factors.

A hand-powered or automated pump is used to draw water to the surface or, if the casing has penetrated a confined aquifer, pressure may bring water to the surface. The salient features of tubewells include: (1) plastic or metal casing (usually 100-150 mm diameter); (2) in unconsolidated soils, a "screened" portion of casing below the water table that is perforated; (3) a "sanitary seal" consisting of grout and clay to prevent water seeping around the casing; and (4) a pump to extract the water. Detailed information on tubewell construction options can be found in references including, for example, online resources from WaterAid and UN FAO.

Technology characteristics

Country specific applicability and potential

- Capacity: limited institutional and technical capacity to install tubewells or boreholes
- Scale of application: preferable for locations with substantive groundwater resources
- Time horizon- short term to medium term application of technology.

Status of technology in country

- Application of this technology has increased after impacts from Tropical Cyclone Pam (Category 5) in 2015 and the ensuing El Niño period from 2015 – 2016 especially in the provinces of Shefa and Tafea. These provinces were directly impacted by Cyclone Pam and the subsequent drought event.

Climate change adaptation benefits

A warmer climate is highly likely to result in more frequent drought. Vanuatu is expected to face a wide range of rainfall conditions in particular under a high emissions scenario, along with more intense cyclones. Deep tubewells, usually defined by engineers as those that penetrate at least one impermeable layer, generally have much greater resilience to drought than traditional water supplies including springs, hand dug wells and surface water sources. In many regions, groundwater is the only perennial source of water supply. However, a more nuanced understanding of drought is needed to formulate a proper response.

Benefits to economic / social and environmental development

Vanuatu's National Sustainable Development Plan (2016 – 2030) and the Vanuatu National Water Policy (2017 – 2030) emphasizes the strategic policy objectives of:

- ensuring safe water services for all
- protecting community water sources
- building community natural resource management capacity
- reducing communicable diseases
- strengthening local authorities to enable decentralised service delivery
- strengthening physical planning to meets the need of a growing population

Discontinuity of water supply during drought can halt economic development and hinder human health and well-being. For Vanuatu it is critical to ensure safe and adequate water needs particularly during drought periods and in extreme events such as cyclones. Access to groundwater prevents reliance on poor quality alternative supplies and reduces expenditures for bottled and vended water.

Financial Requirements and Costs

The costs of drilling new boreholes vary widely depending many factors. However, costs will generally cover incorporating (i) mobilisation/demobilisation, (ii) drilling, (iii) casing and completion, and (iv) development and test pumping (Carter et al., 2006). Repairing damaged wells can cost far less (sometimes by three or more orders of magnitude) than drilling new boreholes.

<u>Flood hazard mapping Factsheet</u>

Introduction

Flood hazard mapping is an exercise to define those coastal areas which are at risk of flooding under extreme conditions. As such, its primary objective is to reduce the impact of coastal flooding. However, mapping of erosion risk areas may serve to achieve erosion risk reduction. It acts as an information system to enhance our understanding and awareness of coastal risk. Geographic Information Systems (GIS) are frequently used to produce flood hazard maps. They provide an effective way of assembling information from different maps and digital elevation models. Using GIS, the extent of flooding can be calculated by comparing local elevations with extreme water levels.

Technology characteristics

Country specific applicability and potential

- Capacity: Flood hazard mapping may be difficult to undertake at the community level due to the need for complex numerical modelling for the forecast of extreme water levels, storm surges and wave heights. The required expertise and modelling capacity is unlikely to be locally available, especially in developing countries like Vanuatu. As such, it may be necessary to enlist the help of external organisations. This type of mapping has been accomplished generally via national programmes.
- Scale of application: most suitable to be undertaken at the national level
- Time horizon- medium to long term application of technology.

Status of technology in country

- Technology was applied mainly to the two urban areas of Port Vila and Luganville. Flood hazard mapping was namely funded from donor programs such as the Global Facility for Disaster Reduction and Recovery (GFDRR). Mapping infrastructure and data currently sits within the Department of Climate Change and the Department of Lands.

Climate change adaptation benefits

Flood hazard maps can be used by developers to determine if an area is at risk of flooding, and by insurers to determine flood insurance premiums in areas where flood insurance exists.

Identification of those areas at risk of flooding will help inform emergency responses. For example, areas that are likely to require evacuation can be identified, and evacuation routes can be planned and clearly signposted so local communities are made aware in advance of an emergency. The identification of flood risk areas will also help in the location of flood shelters for evacuees.

Identification of flood risk areas is likely to help in the planning of a more effective emergency response. It is essential that certain infrastructure, such as electricity supplies, sewage treatment, etc., and services, such as the emergency services, continue to function during a flood event. The creation of flood hazard maps will therefore allow planners to locate these elements in low risk areas so that they can continue to serve during an extreme event. Flood hazard mapping will allow quantification of what is at risk of being flooded such as the number of houses or businesses. This will help identify the scale of emergency and clean-up operations. The creation of flood hazard maps should promote greater awareness of the risk of flooding. This can be beneficial in encouraging hazard zone residents to prepare for the occurrence of flooding. In order to achieve this however, local authorities must ensure that emergency procedures are established, and that information about what to do in the event of a flood is made available to the general public.

In the longer-term, flood hazard maps can support planning and development by identifying high risk locations and steering development away from these areas. This will help to keep future flood risk down and also encourages sustainable development. In order for this to occur, the consideration of flood hazard maps must be integrated into planning procedures.

Benefits to economic / social and environmental development

Vanuatu’s National Sustainable Development Plan (2016 – 2030) and the Vanuatu National Water Policy (2017 – 2030) emphasizes the strategic policy objectives of:

- ensuring safe water services for all
- protecting community water sources
- building community natural resource management capacity
- reducing communicable diseases
- strengthening local authorities to enable decentralised service delivery
- strengthening physical planning to meets the need of a growing population

Flood hazard mapping seeks to achieve strategic objectives of the National Climate Change and DRR policy This is especially relevant where required actions under the themes of Risk assessments, Early Warning Systems, Climate Change Adaptation and Disaster Risk Reduction is concerned.

Financial Requirements and Costs

A number of factors which are likely to contribute toward the cost of flood hazard mapping include:

- External expertise on numerical modelling of flood risk brought in from academic institutions or commercial organisations
- Topographic surveys (LiDAR or remote sensing) to provide information on land elevation which will feed back into the flood risk model
- Historic costs of collecting extreme event data such as water levels, wave heights, etc.
- Cost of employing a Geographic Information System (GIS)

The flood hazard mapping exercise for both Port Vila and Luganville towns amounted to approximately 70 million vatu (USD 632000) in capital costs.

Flood warnings Factsheet

Introduction

The purpose of a flood warning service is to detect and forecast threatening flood events so that the public can be alerted in advance and can undertake appropriate responses to minimise the impact of the event. This is a particularly important technology in developing countries, where flooding results in massive loss of life and property.

A flood warning process has two distinct stages: (1) flood warning and (2) response.

The flood warning stage requires constant monitoring of meteorological conditions. This allows detection and assessment of threatening events to take place before it hits a community. Forecasts may also be made to help decision-makers model how an event is likely to develop, how significant it will be upon arrival, and what sections of the population are likely to be at risk. This is necessary because simple detection of an event will not provide enough time to undertake appropriate responses. To achieve monitoring and forecasting, it is likely that a flood warning system will include meteorological and tidal detection systems and river and coastal flood forecasting models.

Once an event exceeds a given threshold, a warning will be issued. This message is likely to be disseminated to the 'at risk' population via a number of channels. The media, services such as the police and fire departments and basic signals such as sirens and flags all have important roles to play.

After the at risk population have been warned, the second stage of the flood warning service is initiated; the response. Communities in the hazard zone are required to take action to minimise their exposure to the hazard and to reduce the consequences of flooding. It is important that appropriate actions are communicated to the public through awareness raising campaigns, prior to an emergency. Doing so, will mean actions can be quickly taken, helping to mitigate the consequence of flooding to the greatest degree.

Technology characteristics

Country specific applicability and potential

- Capacity: the Department of Meteorology has existing technical capacity to determine, analysis and issue flood warnings.
- Scale of application: most suitable to be undertaken at national level. More community based flood warning systems can also be established to compliment national level flood warning systems
- Time horizon- medium to long term application of technology.

Status of technology in country

- Technology currently being implemented though more specific catchment or coastal flood warnings is required. A Green Climate Fund project on climate information systems is currently embarking on improving more specific flood warnings for select sites around Vanuatu.

Climate change adaptation benefits

Flood warning system is a way of detecting threatening events in advance. This enables the public to be warned en masse so that actions can be taken to reduce the adverse effects of the event. As such, the primary objective of a flood warning system is to reduce exposure to coastal flooding. Vanuatu is experiencing and will continue to experience coastal flooding given rising trends of sea level rise. Coastal flooding instances are also aggravated by the onset of storm surges especially during cyclones events.

Flood warnings are therefore a highly important adaptive measure where protection through large scale, hard defences, is not desirable or possible. This may be the case if defences would cause adverse environmental or social problems, or where the cost of defence construction would be prohibitive.

Benefits to economic / social and environmental development

Vanuatu's National Sustainable Development Plan (2016 – 2030) and the Vanuatu National Water Policy (2017 – 2030) emphasizes the strategic policy objectives of:

- ensuring safe water services for all
- protecting community water sources
- building community natural resource management capacity
- reducing communicable diseases
- strengthening local authorities to enable decentralised service delivery
- strengthening physical planning to meets the need of a growing population

Flood warnings seeks to achieve strategic objectives of the National Climate Change and DRR policy. This is especially relevant where required actions under the themes of Risk assessments, Early Warning Systems, Climate Change Adaptation and Disaster Risk Reduction is concerned.

Application of flood warning systems further aid to avoid or reduce loss of lives, property and livelihood activities particularly where vulnerable groups (i.e. women, children, elderly and people with disabilities) are concerned.

Financial Requirements and Costs

The costs of implementing flood warning systems are expected to differ widely, depending on the level of sophistication of monitoring and forecasting technologies.

In developing countries, meteorological observations are frequently made using basic methods, which may include ground-based methods and weather balloon observations, coupled with limited computing. In these cases, annual running costs are expected to be in the hundreds of thousands of dollars.

Household water treatment and safe storage (HWTS) Factsheet

Introduction

Household or point of use (POU), drinking water treatment and safe storage provides a means to improve the quality of their water by treating it in the home. Popular treatment technologies include chemical disinfectants, coagulants, ceramic filters, biological sand filters, solar disinfection (SODIS) or ultraviolet disinfection processes, and combined products with both coagulant and disinfectant. These technologies have been shown to improve the microbiological and, in some cases, the chemical quality of drinking water and to reduce diarrheal disease.

Technology characteristics

Country specific applicability and potential

- Capacity: Technology is amongst the several options that is being advocated by the Department of Water Resources and Department of Public Health.
- Scale of application: mainly at household level especially in areas outside of piped treated water supply coverage such as rural or peri-urban settings.
- Time horizon- short to long term application of technology.

Status of technology in country

- Technology not widely used in Vanuatu although pitcher water filters are sold in few water supply outlets.

Climate change adaptation benefits

Degradation of water quality is expected to be one of the key impacts of climate change on water resources and water supply. Projected increases in flooding, drought, decreasing water availability, algal blooms, coastal inundation, and sea level rise have both direct and indirect effects on drinking water quality. Direct effects occur through transport of fecal and other wastes into water supplies, growth of harmful algal blooms, for example. Indirect effects on drinking water quality occur when users are forced to switch to lower quality drinking water supplies, for example when groundwater tables decline and users must switch to contaminated surface water. HWTS increases resilience to water quality degradation by enabling users to improve water quality at the point of use.

Benefits to economic / social and environmental development

Vanuatu's National Sustainable Development Plan (2016 – 2030) and the Vanuatu National Water Policy (2017 – 2030) emphasizes the strategic policy objectives of:

- ensuring safe water services for all
- protecting community water sources
- building community natural resource management capacity
- reducing communicable diseases
- strengthening local authorities to enable decentralised service delivery
- strengthening physical planning to meets the need of a growing population

Diarrheal disease can contribute to the "poverty trap" that hinders development by decreasing economic productivity (Bonds et al., 2009). Preventing waterborne disease can lead to increased school attendance, more time spent in gainful activities and childcare, and less diversion of limited financial resources to pay for medical care. POU disinfection was the least expensive intervention reviewed in a World Health Organization (WHO) analysis of the costs and benefits of improved water and sanitation, resulting in a benefit-to-cost ratio of between $5-and-$60 per $1 invested.

POU systems further seek to achieve strategic objectives of the National Climate Change and DRR policy This is especially relevant where required actions Climate Change Adaptation and Disaster Risk Reduction is concerned.

Financial Requirements and Costs

Correct, sustained use of HWTS is necessary to achieve long-term impact on user health. Although HWTS devices are generally designed to be easy to operate and maintain, the complexity of design, and the durability, operation and maintenance requirements vary. Additionally, some HWTS technologies (e.g. chemical disinfectants) are consumable and need to be replaced frequently. Although research on the factors affecting use rates of HWTS is evolving, most evidence indicates that durable technologies (e.g. filters) that do not include consumable components achieve higher rates of sustained use following implementation.

Leakage management in piped systems Factsheet

Introduction

Technology characteristics

Country specific applicability and potential

- Capacity: Technical capacity rests namely with the private sector with the practical implementation experience of this technology.
- Scale of application: applicable to areas with reticulated water system or piped waste systems.
- Time horizon- short to long term application of technology.

Status of technology in country

- Technology mainly used in urban areas of Port Vila and Luganville. The private water supply firm, Unelco Ltd, employs such technology as part of its' operational activities. Whilst provincial centres do have some limited piped system, leakage management does not feature predominately in the respective water service provider operations. The Department of Public Works is responsible for managing piped systems on Luganville, Isangel and Lakatoro.

Climate change adaptation benefits

A warmer climate is highly likely to result in more frequent drought. Additionally, growing population will push many countries into water stress and water scarcity in the coming decades. Detection and repair of leaks in water systems is an important part of comprehensive strategies to reduce pressure on existing water resources.

Reducing water use in municipal systems also contributes to climate change mitigation by decreasing greenhouse gas emissions. Detecting and preventing leakage in piped water systems can lead to large savings in the energy used to transport, treat and distribute water.

Benefits to economic / social and environmental development

Increasing access to piped water at home leads to large gains in health and development. However, per capita demand for water increases rapidly during the development transition. As population expands and water resources are stressed, economic development can be hindered.

Leakage prevention can slow the onset of water stress and preserve limited water resources. Additionally, these programs often pay for themselves through water conservation, reduced costs for treatment and distribution, and reduced maintenance and pipe replacement costs.

Financial Requirements and Costs

The costs of leak management, detection and repair include staff training, management, labor, and equipment. However, leak management, detection and repair programs generally pay for themselves by enabling early repair of leaks and reducing water waste. Leaks often damage pipes through erosion; therefore, additional benefits of early detection include reduced maintenance costs and lower probability of catastrophic failures. Monitoring systems remotely also enables confirmation that pipes are in good condition, preventing premature replacement.

Post construction support for water supplies Factsheet

Introduction

Technology characteristics

There is a large and growing body of evidence demonstrating that post-construction support (PCS) increases the success and sustainability of community-managed water systems. This is even true for those systems that are implemented according to all the currently recognized the best practices of the "demand-driven, community-managed model.

PCS is typically carried out through government programs, municipalities, multilateral donors, and various NGOs. Types of PCS include, but are not limited to:

- Technical training for water system operators
- Technical and engineering support, including provision of technical manuals
- Financial and accounting assistance (e.g. setting tariffs)
- Help settling disputes (e.g. bill payment or water sources)
- Help with maintenance, repairs and finding spare parts
- Help finding external funding for O&M, expansion or repairs
- Help assessing the sufficiency of supply for expansion or in the case of drought
- Household visits to residents to discuss water system use, etc.

Country specific applicability and potential

- Capacity: Technical and institutional capacity present in Department of Water Resources and other NGO partners such as ADRA and Vanuatu Red Cross to roll out this technology
- Scale of application: applicable to areas with community owned or managed systems especially rural areas of Vanuatu.
- Time horizon- short to medium term application of technology.

Status of technology in country

- Approach is broadly implemented especially the provision of technical backstopping services or capacity building of rural water committees. It is now government policy as per the Water Resources Management (Amendment) Act 2016 that at least 40 percent of the rural water committee members must be women.

Climate change adaptation benefits

Piped water is the most popular form of access primarily due to an increase in water piped onto the premises (associated with a decline in access via public standposts) followed by access to rainwater. The proximity of access has improved with 86% of the population having access to drinking water on premises. Increasing the resilience of the growing number of rural, community-managed piped water supplies is one of the major challenges of climate change adaptation.

Community-managed water supplies are typically more vulnerable to extreme weather events and less able to assess water resource sustainability than utility-managed systems.

PCS can empower community water committees and operators to access the financial, management and technical resources that enable utility-managed supplies to prepare for and adapt to adverse precipitation conditions.

Benefits to economic / social and environmental development

Access to safe and sustainable water supply, particularly water in the home, is crucial to development. However, community managed systems frequently struggle to achieve safe and sustained supply. PCS can contribute to improving performance and sustainability of community managed water systems. Furthermore, PCS will be beneficial especially to women who now make up a substantial proportion (at least 40 percent) of rural water committee membership.

Financial Requirements and Costs

The effectiveness of PCS is well-documented, but not all stakeholders are aware of its importance.

Incorporation of PCS into the best practices of the rural water sector, as was accomplished with the demand-driven, community-managed model, requires education of key stakeholders.

Rainwater harvesting from rooftops Factsheet

Introduction

Collection of rainwater from rooftop catchments, although practiced since antiquity, is an increasingly promoted technical option for supplementing household and institutional water supply. The increased proportion of hard (e.g. metal or tile) roofs and the availability of metal and plastic for conveyance have decreased the cost of implementing household rainwater harvesting (RWH).

The salient features of rooftop RWH systems include: (1) a catchment surface where precipitation lands; (2) a conveyance system of gutters and pipes to transport and direct the water; and (3) containers to store the water for later use. Incorporating water quality protection adds one or more additional elements to system. Water quality can be protected by adding one or more of the following: filtration/screening, chemical disinfection, or a "first flush" system.

Technology characteristics

Country specific applicability and potential

- Capacity: Technical and institutional capacity present in Department of Water Resources and other NGO partners such as ADRA and Vanuatu Red Cross to roll out this technology.
- Scale of application: widely applicable from local to provincial levels in both urban and rural settings
- Time horizon- short to medium term application of technology.

Status of technology in country

- In Vanuatu, rainwater harvesting is the second most popular form of water access after piped water.

Climate change adaptation benefits

RWH contributes to climate change adaptation at the household level primarily through two mechanisms: (1) diversification of household water supply; and (2) increased resilience to water quality degradation.

It can also reduce the pressure on surface and groundwater resources (e.g. the reservoir or aquifer used for piped water supply) by decreasing household demand and has been used as a means to recharge groundwater aquifers. Another possible benefit of rooftop RWH is mitigation of flooding by capturing rooftop runoff during rainstorms.

Climate change is projected to increase intensity and variability in precipitation. These are of particular concern close to the equator, where developing countries like Vanuatu are concentrated. Changing climatic patterns associated with the El Niño events in 2015 - 2016 have also revealed that rainwater dependency and a lack of storage undermine the security of a sufficient quantity of water. Storage of rainwater thereforecan provide short-term security against periods of low rainfall and the failure or degradation of other water supplies.

Benefits to economic / social and environmental development

Incorporation of RWH into household water practices in developing countries can contribute significantly to development by saving money and time. Stored rainwater is a convenient, inexpensive water supply close to the home. This can greatly decrease the time spent fetching water or queuing at water points, especially for women and girls whom are heavily involved with water harvesting or collection duties.

It can also provide significant savings for households that are sometimes forced to purchase vended or bottled water. In many settings, RWH can reduce exposure to waterborne pathogens by providing improved potable water quality and high quality water for other household purposes including hygiene, bathing and washing.

Water scarcity can hinder economic development, human health and well-being. By reducing demand for high quality water supplies and capturing water that would otherwise evaporate, RWH effectively increases per capita water availability. This can increase the sustainability of water resources and reduce public and private expenditures associated with water infrastructure.

Financial Requirements and Costs

In low-density rural areas, RWH can often provide household water at lower expense than other available options. If a household already has a suitable hard roof for use as a catchment surface, storage containers are the major expense.

The cost of storage containers typically depends on construction quality, tank size, and other factors.

A large, high quality storage container can be a major investment for poor households. In the context of climate change, increased precipitation extremes could necessitate greater storage volume, thus enabling the capture of maximum volume during intense periods and providing for household water needs during extended dry periods.

<u>Solar groundwater extraction Factsheet</u>

Introduction

A solar water pump system is essentially an electrical pump system in which the electricity is provided by one or several PhotoVoltaic (PV) panels. A typical solar powered pumping system consists of a solar panel array that powers an electric motor, which in turn powers a bore or surface pump. The water is often pumped from the ground or stream into a storage tank that provides a gravity feed, so energy storage is not needed for these systems.

Technology characteristics

Country specific applicability and potential

- Capacity: Technical and institutional capacity spread over the Department of Water Resources, Department of Energy, private sector and other NGO partners such as ADRA and Vanuatu Red Cross to roll out this technology.
- Scale of application: widely applicable from local to provincial levels in both urban and rural settings
- Time horizon- short to long term application of technology.

Status of technology in country

- In Vanuatu, utilization of the technology is in its' early stages.

Climate change adaptation/mitigation benefits

Precipitation patterns are projected to become more variable under most climate change scenarios. The response of water resources to precipitation events varies widely. Groundwater systems typically show a much slower and more muted response to drought and heavy precipitation than surface water. Therefore, diversification of the resources used for water supply such as through groundwater utilization can reduce vulnerability to climate change.

When solar water pumps replace either diesel generated electricity or grid based electricity, there are certain climate related benefits. A diesel generator emits CO_2 during operation and grid based electricity is usually generated with either coal, oil or natural gas which also emits considerable quantities of CO_2. In contrast. a solar based water pump system does not result in greenhouse gas emissions. Extensive use of solar water pumps would therefore lead to substantial greenhouse gas emission reductions.

Benefits to economic / social and environmental development

Solar water pumps contribute to social development in several ways. Since other remote water supply systems are less reliable than solar water pumps. The use of solar water pumps therefore provides a reliable, safe and adequate water supply, which improves the community's health, an important aspect for vulnerable groups such as women, children and people with special needs.

Other benefits to social development are the improvement of social cohesion within the community, reduced migration out of the community, and increased community interaction in social events due to increased time availability.

In addition, in many developing countries there is a strong link between gender and water. In many developing countries, women are responsible for the water supply, spending a large portion of their time to gather the water. The use of solar water pumps can have considerable positive effects for women in these communities. The scope of these benefits is very broad. For instance, the adequate water supply improves the personal hygiene of women but also allows them to allocate more of their time to the other activities. After installation of solar water pumps women in these communities might allocate more time to activities such as education or food gathering.

Financial Requirements and Costs

Several aspects of a PV pump system are key in determining the system costs:

a) size of the system. The high initial capital costs of the PV array is the major barrier to high penetration rates of the use of solar water pumps. The PV array is the most expensive part of the system. The size and capacity of the PV array considerably influences the up-front costs of the system. Therefore, it is important to use the smallest system size possible that still meets all the criteria of that particular location. Government or aid agency subsidies which cover the high initial capital costs are required in many locations to realize PV water pump systems. The high reliability of solar water pumps might offset its higher initial costs compared to diesel powered pump systems.

b) insolation levels. This is directly related to the required size of the system. The intensity and number of hours of sunshine determine the capacity requirements and thus the PV array size requirements. The more sunshine, the smaller the system requirements.

c) pumping head. The pumping head is the distance over which the water needs to be moved. The costs of water volume unit are proportional to the pumping head. Odeh et al., outline that a shallow well of only 20 meters depth compared to a deep well of 100 meters depth reduces water volume unit cost by around five times.

While system size and insolation levels greatly influence the capital costs of a PV water pump the operational costs of the system are generally very low due to low labor and maintenance costs. In contrast, inexpensive diesel or gas generators have low initial capital costs but require constant maintenance and the parts have shorter lifetimes which increases operating costs. This long-term economic advantage makes solar water pumping more cost-effective to conventional pumping systems, such as diesel powered pumps.

<u>Water Safety Plans Factsheet</u>

Introduction

Water Safety Plans (WSPs) are described collectively as a systematic and integrated approach to water supply management based on assessment and control of various factors that pose a threat to the safety of drinking water. WSPs enable identification of threats to water safety during any and all steps in the catchment, transport, treatment and distribution of drinking water. This approach is fundamentally different from those traditionally adopted by water suppliers, which rely on treatment and end-product testing to ensure water safety. When implemented successfully, the WSP approach can ensure that water quality is maintained in almost any context.

A WSP consists of three separate activities: system assessment, monitoring and management.

Technology characteristics

Country specific applicability and potential

- Capacity: Technical and institutional capacity spread over the Department of Water Resources, UN agencies (UNICEF), private sector, donors and other NGO partners such as ADRA and Vanuatu Red Cross to roll out this technology.
- Scale of application: widely applicable from local to provincial levels especially in the rural setting.
- Time horizon- short to long term application of technology.

Status of technology in country

- In Vanuatu, WSPs or Drinking Water Safety and Security Plans (DWSSP) have become more prominent in its' application after the passage of Cyclone Pam in 2015. This is especially the case for numerous communities within the provinces of Shefa and Tafea.

Climate change adaptation/mitigation benefits

WSPs contribute to climate change adaptation at the catchment level primarily through increased resilience to water quality degradation. The WSP approach allows for water suppliers to be flexible and responsive to changing input parameters.

This means that the monitoring, management and feedback components of a successful WSP naturally absorb the acute impacts of climate change.

The WSP approach can also be modified to adapt to long-term climate change and slow-onset hazards by recognizing how the water supply system may be affected by specific climate change effects, by factoring these effects into the risk assessment, and by identifying appropriate control measures.

Benefits to economic / social and environmental development

The burden of disease attributable to poor water, sanitation and hygiene has been estimated to be over 200 times higher in developing than in developed regions. Waterborne illnesses diminish economic productivity and confine people to poverty. Since WSPs are developed to meet health-based targets that are specific to the disease burden of a particular region, the approach can significantly reduce the risk of exposure to health hazards that contribute the most to disease in developing countries. Therefore, WSPs can make a significant contribution to economic development by reducing the burden of waterborne illness in resource-limited settings. Women and people with special needs in particular will benefit from WSP outcomes given potential for reduced risk of disease exposure and burden.

Financial Requirements and Costs

The implementation of a WSP will potentially require water suppliers to increase sampling frequency and number of locations where process indicators (such as turbidity, chlorine, residuals, pH, etc.) are monitored. However, the amount of required microbiological tests will also decrease significantly. In fact, it is likely that the cost of providing and distributing safe water from a risk-based approach will actually be less than from a traditional end-product monitoring approach. This is especially true for Vanuatu, where consumables required for coliform and other microbiological testing are expensive and where a high percentage of monitoring funds are spent on field test kits or maintaining expensive certified laboratories. Even in cases where the equipment required for on-line monitoring must be purchased, the recurrent cost savings of using process indicators for monitoring instead of microbiological indicators is almost certain to outweigh the initial capital investment.

The WSP approach can also result in long-term decreased institutional costs. In general, the planning process identifies opportunities for low-cost improvements on operations and management practices.

However, WSPs also improve the efficiency of communication and collaboration between water providers, consumers, regulatory authorities and the commercial, environmental and health sectors. This creates an enabling environment where financial support can be leveraged and where capital improvement needs can be prioritized and sustained.

Annex II: List of stakeholders involved and their contacts

Water Sector stakeholders

Name and Sex	Institution/Agency	Position	Consultation Approach	Topic	Date and Time
Erie Sami (male)	Department of Water Resources	Hydrogeologist	Meeting	Pre-selection technology list	17 June 2019; 9.30am
			Workshop/focus group discussion	Category criteria, scores and weighting discussions	11 July 2019; 8.30am - 12.30pm
			Questionnaire	Technology scores	30 Aug 2019; 10am
Pauliane Basil (female)	Department of Climate Change	Adaptation/DRR officer	workshop/focus group discussion	Category criteria, scores and weighting discussions	11 July 2019; 8.30am - 12.30pm
			Questionnaire	Technology scores	12 Aug 2019; 10.30am
Thomas Belden (male)	ADRA	WASH Program coordinator	Meeting	Category criteria, scores and weighting discussions	19 Aug 2019; 9am
William Nasak (male)	Vanuatu Business Resilience Council	Project Coordinator	Workshop/focus group discussion	Category criteria, scores and weighting discussions	11 July 2019; 8.30am - 12.30pm
			Meeting	Technology scores	12 July 2019; 9am
Jenny Tuasu (female)	Department of Local Authorities	Planner	Workshop/focus group discussion	Category criteria, scores and weighting discussions	11 July 2019; 8.30am - 12.30pm
			Meeting	Technology scores	12 July 2019; 9am
John Botleng (male)	Vanuatu National Youth Council	Port Vila Municipal Youth Council President	Workshop/focus group discussion	Category criteria, scores and weighting discussions	11 July 2019; 8.30am - 12.30pm

Name and Sex	Institution/Agency	Position	Consultation Approach	Topic	Date and Time
Professor Krishna Kotra (male)	University of the South Pacific	Lecturer	Workshop/focus group discussion	Category criteria, scores and weighting discussions	11 July 2019; 8.30am - 12.30pm
			Meeting	Technology scores	13 Aug 2019; 10am
Michael Maniel (male)	University of the South Pacific	Lab technician	Meeting	Category criteria, scores and weighting discussions	13 Aug 2019; 10am
Nelly Wouloseje (female)	Department of Public Health	Manager, Environmental Health Unit	Meeting	Category criteria, scores and weighting discussions	21 Aug 2019; 2pm

Agriculture Sector Stakeholders

Name and Sex	Institution/Agency	Position	Consultation Approach	Topic	Date and Time
Gwenneth Natu Tari (female)	Department of Agriculture	Marketing officer	Meeting	Pre-selection technology list	11 July 2019; 1pm - 4pm
Fernarnd Massing (male)	Department of Agriculture	Farm Manager	Meeting	Pre-selection technology list	12 July 2019; 1pm - 4pm
Pakoa Leo (male)	Department of Agriculture	Van KIRAP Project Officer	Workshop/focus group discussion	Category criteria, scores and weighting discussions	1 Aug 2019; 10am - 12pm
			Questionnaire	Technology scores	8 Aug 2019; 5pm
Mathias Bule (male)	Department of Agriculture	Information officer	Workshop/focus group discussion	Category criteria, scores and weighting discussions	1 Aug 2019; 10am - 12pm
			Questionnaire	Technology scores	7 Aug 2019; 3.50pm
Heggar Molisa (female)	Department of Agriculture	Project officer	Workshop/focus group discussion	Category criteria, scores and weighting discussions	1 Aug 2019; 10am - 12pm
			Questionnaire	Technology scores	8 Aug 2019; 5.25pm

Name and Sex	Institution/Agency	Position	Consultation Approach	Topic	Date and Time
Pauliane Basil (female)	Department of Climate Change	Adaptation/DRR officer	Meeting	Pre-selection technology list	12 July 2019; 1pm - 4pm
			Questionnaire	Technology scores	12 Aug 2019; 10.30am
Peter Kaoh (male)	Farm Support Association	Coordinator	Meeting	Category criteria, scores and weighting discussions	9 Aug 2019; 2pm
			Questionnaire	Technology scores	16 Aug 2019; 4.30pm
Oniel Tabito (female)	Vanuatu Agriculture College	Lecturer	Email correspondence	Category criteria, scores, weighting and technology factsheets discussions	14 Aug 2019; 10am
			Questionnaire	Technology scores	30 Sep 2019; 4pm
Julia Marango (female)	Care International	Resilience Manager	Meeting	Category criteria, scores and weighting discussions	13 Aug 2019; 2.30pm
Isso Nimhei (male)	Futuna Area Council	Area Administrator/Youth rep	Meeting	Category criteria, scores and weighting discussions	14 Aug 2019: 3pm

Annex III: MCA Calculator

Agriculture Sector

Decision Matrix: Weighted Scores											
	Costs	Benefits					Other				
		Economic		Social	Environment	Climate related	Institutional/Implementation		Political		
Technology	Cost to set up and operate the technology per beneficiary /year	Improving farmer income and ability to re-invest	Trigger private investment	Poverty reduction potential, contribution to health outcomes	Contribution of the technology to protect and sustain ecosystem services	Improvement of Resilience to Climate Change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts or number of beneficiaries)	ease of implementation	replicability	Coherence with national development policies and priority	Total Score	Technology Rank
Agro-forestry	115	53	33	115	128	121	83	71	143	860	2
Community based agricultural extension agents	125	60	31	106	115	113	59	56	130	794	4
Crop diversification and new varieties	112	75	34	119	115	121	78	69	143	866	1
Ecological Pest Management	104	65	32	95	111	115	71	65	130	788	5
Farmer Field Schools	101	64	35	104	108	111	81	75	140	819	3
Slow-forming Terraces	93	45	27	93	115	108	57	65	123	727	11
Integrated Nutrient Management	88	67	31	95	113	102	63	56	135	749	9
Integrated Farming System / Mixed farming	64	76	33	111	111	113	63	55	135	760	6
Seed storage	53	65	36	108	98	121	69	65	138	754	7
Drip irrigation	56	75	39	100	108	121	68	49	135	751	8
Sprinkler Irrigation	53	75	39	102	111	117	66	39	135	736	10
Criterion weight	16	8	5	13	13	13	9	8	15		

Decision Matrix: Weighted Scores (sensitivity analysis)											
	Costs	Benefits					Other				
		Economic		Social		Climate related	Institutional/Implementation		Political		
Technology	Cost to set up and operate the technology per beneficiary /year	Improving farmer income and ability to re-invest	Trigger private investment	Poverty reduction potential, contribution to health outcomes	Contribution of the technology to protect and sustain ecosystem services	Improvement of Resilience to Climate Change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts or number of beneficiaries)	ease of implementation	replicability	Coherence with national development policies and priority	Total Score	Technology Rank
Agro-forestry	115	53	33	159	108	140	83	71	95	856	2
Community based agricultural extension agents	120	51	27	138	86	113	62	59	82	736	5
Crop diversification and new varieties	112	75	34	165	97	140	78	69	95	865	1
Ecological Pest Management	104	65	32	132	94	133	71	65	87	782	4
Farmer Field Schools	101	64	35	144	92	128	81	75	93	813	3
Slow-forming Terraces	93	45	27	129	97	125	57	65	82	721	11
Integrated Nutrient Management	83	67	29	130	92	111	63	56	94	725	10
Integrated Farming System / Mixed farming	64	76	33	153	94	130	63	55	90	758	6
Seed storage	53	65	36	150	83	140	69	65	92	753	7
Drip irrigation	56	75	39	138	92	140	68	49	90	746	8
Sprinkler Irrigation	53	75	39	141	94	135	66	39	90	731	9
Criterion weight, sensitivity	16	8	5	18	11	15	9	8	10		

Annex III(a): MCA Calculator

Decision Matrix: Weighted Scores

Technology	Costs	Benefits					Other			Total Score	Technology Rank
		Economic		Social		Climate related	Institutional/Implementation		Political		
	Cost to set up and operate the technology per beneficiary /year	Improving income to maintain water sys ability to reinvest	Trigger private investment	Poverty reduction potential, contribution to health outcomes	Contribution of the technology to protect and sustain ecosystem services	Improvement of Resilience to Climate Change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts)	ease of implementation	replicability	Coherence with national development policies and priority		
Desalination	43	22	17	108	115	71	26	20	179	599	10
Domestic water supply during drought	79	22	24	127	113	69	37	33	189	693	5
Flood hazard mapping	96	20	25	139	123	80	35	35	179	731	3
Flood warnings	96	18	21	124	118	72	36	36	168	688	6
Household water treatment and safe storage	82	26	27	124	103	62	46	51	168	688	6
Leakage management in piped systems	74	21	25	114	100	65	32	40	165	634	9
Post construction support for water supplies	77	28	28	127	113	66	33	41	165	676	8
Rainwater harvesting from roof tops	142	25	25	111	110	71	57	52	179	770	1
Solar groundwater extraction	71	26	30	130	110	72	35	41	179	694	4
Water Safety Plans	82	22	26	127	135	75	47	49	172	735	2
Criterion weight	17	3.5	3.5	19	15	9	6	6	21		

Decision Matrix: Weighted Scores (sensitivity)											
	Costs	Benefits					Other				
		Economic		Social	Environment	Climate related	Institutional/Implementation		Political		
Technology	Cost to set up and operate the technology per beneficiary /year	Improving income to maintain water sys ability to reinvest	Trigger private investment	Poverty reduction potential, contribution to health outcomes	Contribution of the technology to protect and sustain ecosystem services	Improvement of Resilience to Climate Change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts)	ease of implementation	replicability	Coherence with national development policies and priority	Total Score	Technology Rank
Desalination	43	22	17	136	77	110	26	20	136	585	10
Domestic water supply during drought	79	22	24	160	75	107	37	33	144	682	5
Flood hazard mapping	96	20	25	176	82	124	35	35	136	728	2
Flood warnings	96	18	21	156	78	112	36	36	128	682	5
Household water treatment and safe storage	82	26	27	156	68	96	46	51	128	680	7
Leakage management in piped systems	74	21	25	144	67	100	32	40	125	628	9
Post construction support for water supplies	77	28	28	160	75	103	33	41	125	670	8
Rainwater harvesting from roof tops	142	25	25	140	73	110	57	52	136	759	1
Solar groundwater extraction	71	26	30	164	73	112	35	41	136	689	4
Water Safety Plans	82	22	26	160	90	117	47	49	131	724	3
Criterion weight (sensitivity)	17	3.5	3.5	24	10	14	6	6	16		