PACC TECHNICAL REPORT 17

APRIL 2015

PACC Demonstration Guide: Building resilience to climate change in lowland farming communities in Fiji

SPREP
Secretariat of the Pacific Regional Environment Programme

UNDP
Empowered lives.
Resilient nations.

Australian Aid

gef

unitar
United Nations Institute for Training and Research

SPREP LIBRARY/IRC CATALOGUING-IN-PUBLICATION DATA

PACC Demonstration Guide: Building resilience to climate change in lowland farming communities in Fiji. Apia, Samoa : SPREP, 2015.

36 p. 29 cm. (PACC Technical Report No.17)

ISSN 2312-8224

SPREP, PO Box 240, Apia, Samoa
T: +685 21929
F: +685 20231
E: sprep@sprep.org
W: www.sprep.org

This publication is also available electronically from SPREP's website: www.sprep.org

SPREP
Secretariat of the Pacific Regional Environment Programme

SPREP Vision: The Pacific environment, sustaining our livelihoods and natural heritage in harmony with our cultures.

www.sprep.org

PACC
Building Resilience to Climate Change in Pacific Communities

UNDP
Empowered lives.
Resilient nations.

gef

Australian Aid

unitar
United Nations Institute for Training and Research

PACC Demonstration Guide: Building resilience to climate change in lowland farming communities in Fiji

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This report is an output of the Fiji PACC project. It was written by Mary Taylor, with input from Doug Ramsay (Manager, Pacific Rim, NIWA) and Kyaw Win and Jone Waqanidrola (Fiji PACC project team). It was reviewed by Peniamina Leavai (SPREP), Herman Timmermans (SPREP), Netatua Pelesikoti (SPREP) and Damien Sweeney (Pacific Research and Evaluation Associates).

EXECUTIVE SUMMARY

In Fiji, the Pacific Adaptation to Climate Change (PACC) project focused on food security, with a goal 'to contribute to reducing vulnerability and increasing adaptive capacity to adverse effects of climate change in the food sector of Fiji'. More specifically, the project aimed to enhance and, where necessary, to develop new drainage design features for drainage networks and infrastructure at two pilot sites in lowland farming areas of Fiji. Baseline information and expert opinion collected during the consultation stage indicated that the current infrastructure of drainage networks was unlikely to cope with increased water flow as a result of projected changes in rainfall regimes and sea level (both through sea level rise and storm surge). As a result there would be an increase in the damage caused by prolonged flooding of cropland as well as adverse effects on the livelihoods of lowland farmers. The project also evaluated the use of climate-resilient crop varieties as a tool with which to manage conditions caused by climate change, such as waterlogging.

The project was implemented in the provinces of Tailevu/Rewa (on the Rewa river delta) and Serua/Namosi (on the Navua river delta). These areas have land elevations of the order of 1 m above mean sea level and are already prone to both river flooding and tidal influx of salt water. Project activities began in 2011, with most studies and modelling work being carried out in the period 2012–2014. Initial activities included compilation of a vast amount of data required for the modelling and tool development.

Several tools were developed to assess the impact of the changes expected under climate change scenarios (namely increased rainfall intensity under more frequently occurring extreme rainfall intensity conditions) and sea level rise on the performance of the drainage network: (a) Extreme Rainfall and Sea Level Calculator, a tool to assess the impacts of climate change on rainfall and sea level; (b) Conveyance Estimation System (CES), a tool to understand the impact of vegetation in drains and channels; (c) HEC-HMS , a rainfall runoff tool which uses the output from the Rainfall Calculator to estimate runoff from each sub-catchment; and (d) HEC-RAS , a tool which takes the runoff from each of the catchments and models the flows out through the main channels and tide gates. Training was provided in the use of these tools.

The tools highlighted the importance of an effective maintenance regime for both the catchment land drains and the main discharge arteries, such as Qaraniki Creek, to improve the performance of the drainage system. A suite of drain maintenance approaches combining manual, mechanical and environmental measures has been recommended. Design changes to any new tide gates and flaps were also recommended. As a result a new tide gate structure has been constructed in Waikete Village, which is located in a very low lying area. The design generally used for tide gates was modified, removing a central pillar, which will increase the discharge coefficient of the tide gate, resulting in more discharge capacity during heavy rain events.

Trials of varieties of three major crops, cassava, taro and sweetpotato, were conducted in the two pilot sites to assess their resilience to waterlogging and salinity, and also farmer acceptability. Based on the results from these trials demonstration farms were established to provide farmers with planting material of the selected crops and varieties. Training was given in farming practices best suited to managing waterlogged conditions.

In parallel, the project team has been addressing food security and climate change at the strategic level, through involvement in the development of the National Climate Change Policy, and also at the community level through the development of Community Development Plans.

ABBREVIATIONS

ARI	Annual recurrence interval
CDP	Community Development Plan
CES	Conveyance Estimation System
EEZ	Exclusive economic zone
ENSO	El Niño Southern Oscillation
GDP	Gross domestic product
KRS	Koronivia Research Station
LWRM	Land and Water Resources Management Division (of the MASLR)
M&E	Monitoring and evaluation
MASLR	Ministry of Agriculture, Sugar and Land Resettlement
MTR	Mid-term review
NCCP	National Climate Change Policy
NIWA	National Institute of Water and Atmospheric Research (New Zealand)
PACC	Pacific Adaptation to Climate Change (programme/project)
PACCSAP	Pacific–Australia Climate Change Science and Adaptation Planning Program
PCCSP	Pacific Climate Change Science Program
PMU	Project Management Unit
SPCZ	South Pacific Convergence Zone
SPREP	Secretariat of the Pacific Regional Environment Programme

1. INTRODUCTION

The Pacific Adaptation to Climate Change (PACC) programme is the largest climate change adaptation initiative in the Pacific region, with projects in 14 countries and territories. PACC has three main areas of activity: practical demonstrations of adaptation measures; driving the mainstreaming of climate risks into national development planning and activities; and sharing knowledge in order to build adaptive capacity. The goal of the programme is to reduce vulnerability and to increase adaptive capacity to the adverse effects of climate change in three key climate-sensitive development sectors: coastal zone management, food security and water resources management. The programme began in 2009 and officially ended in December 2014, with some activities carrying over to 2015.

In Fiji, the PACC project focused on food security, with a goal 'to contribute to reducing vulnerability and increasing adaptive capacity to adverse effects of climate change in the food sector of Fiji'. The project focused on low-lying coastal farming areas at two pilot sites on the island of Viti Levu. The main activities of the project involved enhancing drainage networks and infrastructure to withstand increased water flows, and trialling crop varieties with tolerance to climate-related conditions such as waterlogging. The implementing agency for the PACC Fiji project was the Ministry of Agriculture, Sugar and Land Resettlement (MASLR; now the Ministry of Agriculture, Rural and Maritime Development and Disaster Management), with the Drainage and Irrigation Section of the Land and Water Resources Management (LWRM) Division responsible for on-the-ground project management.

This demonstration guide provides a comprehensive description of the Fiji PACC project, from inception and early planning stages, through design and implementation, to monitoring and evaluation. Aimed primarily at climate change practitioners across the Pacific region, it gives details of the planning and execution of this food security project, with a focus on lessons learned along the way and best practices identified. As with the demonstration guides from the other PACC projects, the hope is that future projects can build on the experiences of PACC, contributing to a more resilient Pacific region.

2. BACKGROUND AND CONTEXT

2.1. The Fiji Islands

The Republic of Fiji lies in the southwest Pacific Ocean, between longitudes 175° east and 178° west and latitudes 15° and 22° south. Fiji has two major islands – Viti Levu and Vanua Levu, with land areas of 10,429 and 5,556 km^2 respectively. Fiji's exclusive economic zone (EEZ), which covers about 1.3 million km^2, contains approximately 332 islands of which one-third are inhabited. The islands include large mountainous islands (mainly of volcanic origin) such as Viti Levu and Vanua Levu, and numerous small volcanic islands, low-lying atolls and elevated reefs.

Fiji has a low overall population growth due to out-migration, and the majority of the population lives in urban and peri-urban areas. In 2007 (at the last census), the total population was 837,271, with 51% living in urban areas. With current trends, the urban population is projected to reach 61% by 2030[1].

The agriculture sector was once a major stronghold of Fiji's economy but is now the third largest, contributing 9% annually to the nation's GDP. Sugarcane which used to dominate the sector now contributes only 0.9% and has been surpassed by other crops, horticulture, livestock production and the subsistence sector[2], although it still directly employs about 13% of the labour force. About 17,000 people are directly or indirectly dependent on the export of taro for their livelihood[3].

In recent years, economic growth in Fiji has been largely driven by a strong tourism industry. Tourism has expanded since the early 1980s and is the leading economic activity in the islands. Fiji's gross earnings from tourism in 2011 totalled F$1.051 billion, more than the combined revenues of the country's top five exports (fish, water, garments, timber and gold).[4]

2.2. Policy and institutional context

Key national policies of relevance to agriculture, food security and climate change include the following:

- 'People's Charter for Change, Peace and Progress';
- Roadmap for Democracy and Sustainable Socio-economic Development;
- National Climate Change Policy;
- National Disaster Management Act;
- Fiji 2020 Agriculture Policy.

The People's Charter for Change, Peace and Progress (December, 2008) serves as an umbrella framework for national development. The Roadmap for Democracy and Sustainable Socio-economic Development (2009–2014) provides the implementation framework for the charter, for achieving sustainable democracy, good and just governance, socio-economic development and national unity based on the eleven pillars articulated in the People's Charter. Pillars 4, 5, 6, 7 and 8 of the People's Charter are relevant to the agriculture sector:

- Pillar 4: Enhancing public sector efficiency, performance effectiveness and service delivery;
- Pillar 5: Achieving higher economic growth while ensuring sustainability;
- Pillar 6: Making more land available for productive and social purposes;
- Pillar 7: Developing an integrated development structure at the Provincial level;
- Pillar 8: Reducing poverty to a negligible level by 2015.

1 http://www.spc.int/prism/fjtest/cens&surveys/cens&surveystats_index.htm

2 http://www.investmentfiji.org.fj/pages.cfm/for-investors/sector-industry-profiles/agriculture-industry.html

3 Koka Siga Pacific 2012

4 http://www.fijihighcommission.org.uk/about_3.html

The Fiji 2020 Agriculture Policy complements the National Green Growth Framework and addresses 'climate smart agriculture' that generates both adaptation and mitigation benefits. The policy also focuses on 'sustainable intensification' for increasing production.

The National Climate Change Policy (NCCP; Government of the Republic of Fiji, 2012), based on the Climate Change Policy Framework (2007), is aligned to the Roadmap for Democracy and Sustainable Socio-economic Development 2009–2014. The NCCP provides guidelines for sectors to ensure that current and expected impacts of climate change are considered in their planning and implementation programmes, and recognises the need for constructive cooperation amongst all relevant sectors.

Reduction of the vulnerability of rural communities to disasters is undertaken through the Disaster Management Office under the National Disaster Management Act of 1998. The focus is on the promotion of rapid, effective response to emergencies; investment in safe, cost-effective and strategic infrastructure to mitigate the impact of disasters; and capacity building for disaster management.

2.3. Climate

Climate information is taken from the Pacific–Australia Climate Change Science and Adaptation Planning Program (PACCSAP) (Australian Bureau of Meteorology and CSIRO, 2011, 2014).

2.3.1. Current climate

Fiji has a warm, wet season from November to April and a cooler dry season from May to October (Figure 1). The seasonal cycle is strongly affected by the South Pacific Convergence Zone (SPCZ), which is most intense during the wet season. The El Niño Southern Oscillation (ENSO) is the most important influence on year-to-year climate variations. Annual and half-year maximum and minimum temperatures have been increasing at both Suva and Nadi Airport since 1942. Annual, half-year and extreme daily rainfall trends show little change at Suva and Nadi Airport since 1942.

Tropical cyclones affect Fiji mainly between November and April, and occasionally in October and May during El Niño years. Over the period 1969–2010, the centre of 70 tropical cyclones passed within 400 km of Suva. An average of 28 cyclones per decade developed within or crossed Fiji's EEZ between the 1969/70 and 2010/11 seasons. Twenty-five out of 78 (32%) tropical cyclones between the 1981/82 and 2010/11 seasons became severe events (category 3 or stronger) in Fiji's EEZ.

The sea level rise near Fiji, measured by satellite altimeters since 1993, is about 6 mm per year.

Wind-waves around Fiji are typically not large, with wave heights around 1.3 m year-round. Seasonally, waves are influenced by the trade winds, location of the SPCZ, southern storms and cyclones. Little variability on inter-annual time scales is displayed with ENSO and the Southern Annular Mode.

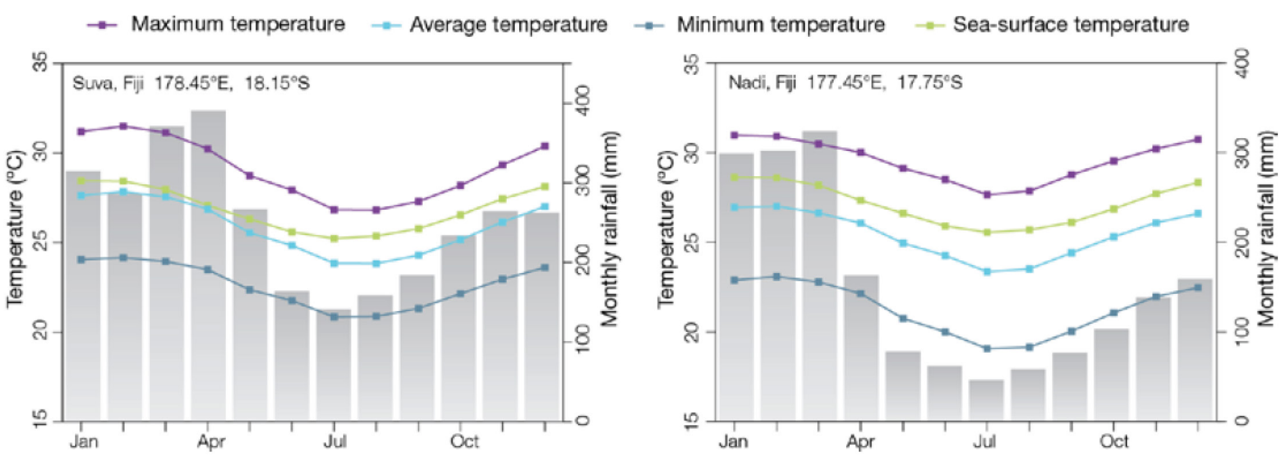


Figure 1. Monthly temperature and rainfall for Fiji. (Source: Australian BoM and CSIRO (2011), with permission.)

2.3.2. Climate projections

According to PACCSAP (Australian Bureau of Meteorology and CSIRO, 2011, 2014), over the course of the 21st century:

- El Niño and La Niña events will continue to occur in the future (very high confidence), 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 (very high confidence).
- Little change is expected in annual rainfall, but an increase is anticipated in the November–April season (low confidence) with more extreme rain events (high confidence).
- The proportion of time in drought is projected to decrease slightly (low confidence).
- Tropical cyclone numbers are projected to decline in the southeast Pacific Ocean basin (0–40°S, 170°E–130°W) (moderate confidence).
- Ocean acidification is expected to continue (very high confidence).
- Mean sea level rise will continue to rise (very high confidence).

2.4. Risks and vulnerabilities of the lowland farming sector

2.4.1. Climate-related risks and vulnerabilities

Flooding is a regular occurrence in the low-lying areas of the Fiji Islands. Floods bring some benefits such as increased soil fertility, but can also result in significant damage to crops, livestock and infrastructure and depending on the duration of the floods, can affect planting schedules and future agriculture-related activities. Lowland farming in Fiji is vulnerable to both flooding and saltwater intrusion.

Flooding in the Central Division is an increasing concern. In 2014 the total cost of damage and loss in the Central Division from flooding was estimated to be F$11.5 million – with the total crop loss for the Central Division estimated at F$1,072,931, and livestock loss estimated at F$1,244,925[5]. With the projected climate change conditions, in particular the increase in frequency and intensity of extreme rain events, such losses are likely to increase.

2.4.2. Non-climate drivers of vulnerability

Non-climate factors contributing to vulnerability of lowland farming areas in Fiji include the following:

- Old drainage infrastructure: the construction of drainage facilities, seawater protection dykes, tidal gates, culverts, road access and other infrastructure allowed low-lying and deltaic areas to be used for agriculture. Proper land drainage helped in lowering the high groundwater table and protective barriers prevented saltwater and tidal intrusion into suitable land areas. These drainage schemes were constructed between 1980 and 1992 under the 'Agricultural Development Programme'. Over 50% of these drainage schemes are now over 20 years old and many have reached the end of their design life span.
- Increasing need for maintenance: Maintenance is carried out by the Central Division Drainage Board on a yearly basis and focuses mainly on desilting of the main and outlet drains; as the drainage system gets older, more maintenance is required. Weeding along the drains is also required to control the deposition of silt. There is an increasing number of invasive weed species that are reducing the water capacity of the drains. Further, financial constraints within the Central Division Drainage Board (budget allocation decreased from F$450,000 in 1998 to F$200,000 in 2006) have affected maintenance programmes with a resulting negative impact on the effectiveness of the drainage system. A drainage levy system was in operation where a landowner paid a

5 http://www.fijitimes.com/story.aspx?id=262422

small contribution to help with the maintenance of the drains. This levy has been scrapped in recent years, and replaced with central government funding of drainage maintenance.

- Lack of technical knowledge on resilient lowland farming practices: although Pacific farmers have significant experience of climate variability, projected climate conditions, especially extreme events, are likely to be beyond their farming experience. More information and understanding is required regarding the use of resilient crop diversity and farming practices.

3. THE DEMONSTRATION PROJECT

3.1. Objectives, outcomes and outputs

The overall goal of the PACC project is 'to contribute to reduced vulnerability and increased adaptive capacity to adverse effects of climate change in the food sector of Fiji'.

With food security as its priority focus, the objective is improved crop resilience and drainage systems in the lowland areas of Tailevu-Rewa and Serua-Namosi Provinces.

To achieve this objective, the three outcomes sought by the project are:

- Outcome 1: Policy/plans mainstreamed to build resilience in the context of emerging climate risks;
- Outcome 2: Demonstration measures delivered to reduce vulnerability in crop production;
- Outcome 3: Increased understanding of climate change impacts and awareness of how to adapt and build resilience (at the community level).

The following outputs all relate to the above three outcomes and are numbered to reflect the relevant outcome:

- Output 1.1: National Climate Change Policy for Fiji endorsed;
- Output 1.2: Consultation on the National Climate Change Policy carried out;
- Output 2.1: Drainage guidelines developed incorporating new engineering standards for drainage networks;
- Output 2.2: Demonstration project delivered – drainage infrastructure improved to adapt to high precipitation levels and sea level rise;
- Output 2.3: Resilient crops are trialled and distributed to farmers;
- Output 3.1: National communications plan developed and implemented;
- Output 3.2: Knowledge management products produced;
- Output 3.3: Sharing of best practices nationally and regionally.

This report focuses on activities under Outcome 2, with a brief summary of activities under mainstreaming of climate change (Outcome 1) and awareness and knowledge-building activities (Outcome 3).

3.2. Preparatory phase

3.2.1. Selection of project and site

The early stages of the PACC project involved stakeholder consultations, workshops and focus group meetings with representatives of relevant ministries, government agencies and non-government organisations in Fiji. Eight stakeholder consultations and workshops and several focus group meetings were held. Seven government ministries (Ministry of Agriculture, Sugar and Land Resettlement; Ministry of Fijian Affairs, Lands and Provincial Development; Ministry of Finance and National Planning; Ministry of Foreign Affairs; Ministry of Environment; Ministry of Multi-Ethnic Affairs; and Ministry of Works) were involved in the consultations and one international non-government organisation (the World Wildlife Fund – South Pacific). The purpose of the consultations was to first select a priority area from the three PACC focus areas of food production and food security, water resources management and coastal zone management; and then to identify a demonstration project within that priority area.

Recognising the huge importance of food production and food security for the country, and the threat posed by climate change, this was selected as the sector for adaptation intervention under the PACC project. As well as a demonstration project, PACC would assist in integrating climate change concerns into the planning and budgetary processes relating to food production and food security – at the time of the project there was limited integration of climate change adaptation into these aspects (PACC, 2009).

The 2006 stakeholder consultations also selected the demonstration project and pilot sites. Criteria for identifying the demonstration project were:

- A strong alignment with the Government's existing programmes;
- All necessary baseline assessments have been carried out, and additional activities are ready for implementation; and
- Ability to co-finance and ability to deliver.

Extreme rainfall events, flooding after cyclones and storm surges can have a significant negative impact on agriculture. The stakeholder consultations reviewed the data on damage from flooding from cyclones and severe rainfall events in the 1990s. A number of studies that have focused on the impacts of climate change on the agriculture sector were also considered (World Bank, 2000; ADB, 2005).

Poor drainage contributes to the flooding problem. Effective land drainage can lower the groundwater table, supporting the cultivation of potentially swampy and boggy land. Protective barriers, such as tide gates, are also very useful to prevent saltwater intrusion.

The consultations examined the capacity of the drainage system to manage the increased flow of water resulting from changes in rainfall and sea level. The existing drainage network is over 20 years old and its design did not take into account projected climate conditions. The stakeholder consultations therefore agreed that the PACC project would focus on enhancing and, where necessary, developing new drainage design features for drainage networks and infrastructure in lowland farming areas of Fiji.

The pilot areas identified were the provinces of Tailevu/Rewa (on the Rewa river delta) and Serua/Namosi (on the Navua River delta) (Figure 2). These areas have land elevations of the order of 1 m above mean sea level, and are already prone to both river flooding and tidal influx of salt water. The project focused on five drainage catchments in Tailevu/Rewa, namely Qaranaki, Naitalasese, Dravatu, Nakelo and Waikete, and on the Waikalou drainage catchment and the coastal area along the Naitonitoni frontage in Navua (Serua/Namosi), and covered nine communities (PACC, 2009).

The Ministry of Agriculture, Sugar and Land Resettlement (MASLR), and in particular the Land and Water Resources Management (LWRM) Division, are responsible for the land drainage work which supports agricultural activity in the low-lying and deltaic areas, especially in the Central Division of Fiji. The stakeholder consultations agreed that the MASLR would act as implementing agency for the PACC Fiji project, with the Drainage and Irrigation Section of the LWRM Division responsible for day-to-day management of activities.

Drainage infrastructure alone will not ensure that crop production is viable in lowland areas prone to waterlogging and saltwater intrusion. The type of crop grown and the variety is also an important consideration; for example, sweetpotato (kumala) generally does not grow well in waterlogged soil but there are some varieties that are more tolerant of these conditions. The project stakeholders decided that the project would also evaluate the resilience of selected crops to the impact of climate-related extremes such as flooding, waterlogging and saltwater intrusion, and would provide awareness on how farming practices can improve crop tolerance to waterlogging. The crop trials were established at two sites within the two provinces, namely Visama, Nakelo (Tailevu/Rewa) and Rovadrau, Deuba (Serua/Namosi)

The populations of the two pilot areas are estimated at 149,763 (Tailevu/Rewa) and 21,203 (Serua/Namosi). The total land areas are 121,701 ha and 139, 201 ha, of which 10,122 ha and 3,643 ha are considered arable land. In the Tailevu/Rewa province, there are 10,195 farmers of whom 944 are full-time, and in Serua/Namosi Province, there are a total of 3,370 farmers of whom 459 are full-time (according to the 1996 census). Major crops grown in the two pilot sites include taro, kava, cassava, ginger, sweetpotato, yams, banana, pineapple and assorted vegetables. Two of Fiji's largest producers of taro, ginger and cassava are in Navua (Serua/Namosi province). In 2005, the gross value of crops was estimated at FJ$34 million for Tailevu/Rewa and FJ$16.4 million for Serua/Namosi provinces.

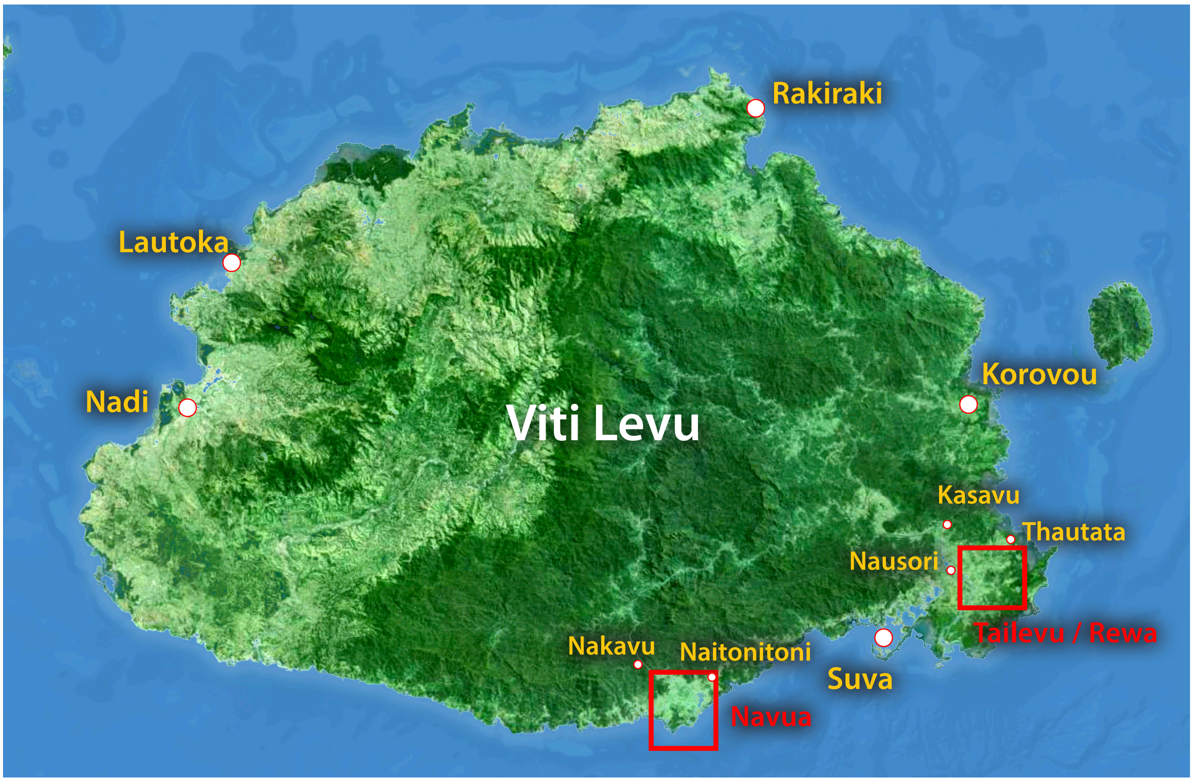


Figure 2. Location of pilot sites on Viti Levu, Fiji.

3.2.2. Linkages with strategic plans and processes

The PACC Project is directly contributing to Pillars 6 and 8 of the 'Roadmap for Democracy and Sustainable Socio-Economic Development'. Pillar 6 specifically focuses on 'Making more land available for productive and social service' and Pillar 8 targets 'Reduction in poverty'. The project is also in line with the Ministry of Agriculture Annual Corporate Plan 2014, in particular, endorsing sustainable management of natural resources (flood protection programmes and sustainable land management practices), and capacity building for farmers to increase food production.

The project is aligned with Objective 5 (Adaptation) of the National Climate Change Policy which aims to 'reduce the vulnerability and enhance the resilience of Fiji's communities to the impacts of climate change and disasters'. The project addresses four of the strategies under Objective 5, namely:

- Include vulnerability assessments and climate change impact projections into resource management planning, such as integrated coastal and watershed management plans (Strategy 2);
- Incorporate climate change impact projections into infrastructure and urban and rural planning (Strategy 3);
- Use appropriate consultation mechanisms for the participation of all members of the community in the planning, management and implementation of adaptation measures (Strategy 10); and
- Undertake national research to identify effective adaptation measures to support sector-specific adaptation and disaster risk reduction responses (Strategy 14).

3.2.3. Community engagement

Engaging the communities was central to the successful implementation of the project. A communication plan was developed following the inception phase, which provided a framework for community engagement as the project progressed. Target audiences identified in the plan included the communities in the two pilot provinces, decision makers at the national level, development partners and the media.

Some of the community-level activities that were successfully carried out included:

- Production and distribution of 100 PACC tee shirts;
- Production and distribution of 100 USB wristbands;
- Production and distribution of 200 posters;
- Production and distribution of 500 easy-to-read pamphlets providing general information on the Fiji PACC project;
- A cabinet briefing paper that highlighted the aims, objectives and benefits of the Fiji PACC project;
- A video about the project (Vital Food);
- A local TV programme about the project (Close-Up).

The socio-economic component of the project (see Section 3.3.3 below) conducted community meetings in July 2012 which focussed on seven indigenous Fijian (or iTaukei) villages in the Nakelo District and one iTaukei and two Indo-Fijian settlements in the Navua District. Meetings took three to four hours and focussed around how the current drainage system affected their quality of life, what crops they could grow, the resources they had, and any problems they faced with respect to waterlogging or coastal inundation. The meetings also provided the communities with the opportunity to discuss how they managed any waterlogging and coastal inundation issues, how they would like to see the drainage system managed, and how they might cope with the changes projected as a result of climate change (NIWA, 2012a).

During March/April 2013 PACC Fiji had a major focus on raising awareness and, together with government partners, carried out presentations and workshops in ten schools and eight communities, reaching more than 3,300 students, 150 teachers and 168 community members. Posters, videos and the iTaukei (Fijian) glossary, which explains climate change terms in the Fijian language, were used to aid the discussions.

COMMUNITY FACILITATORS

A mid-term review (MTR) of the project was carried out in mid-2012, and one of the recommendations was to strengthen community engagement and ownership of the project. The MTR suggested identifying and training climate change 'champions' within the community. In October and November 2012, three community leaders' training workshops were conducted in the Nakelo/Nuku district, Deuba district and at Nakaulevu for the communities of Rovadrau. A total of 32 men and 22 women participated in these workshops, which highlighted the importance of the community leader's role in integrating climate change in the community/village development programme.

This was followed in November 2012 by a one week community facilitator training workshop for 20 participants in the Nakelo/Nuku and Deuba districts. The objectives of the training were to build capacity in pilot communities for individuals to champion climate change adaptation and act as community facilitators who would focus on improving the skills and understanding of men and women of the communities; and to train and empower these individuals in leadership and good governance.

This process resulted in the establishment of community facilitators for each of the nine target communities in the two pilot sites. The community facilitators had responsibility for facilitating engagement between the project and communities. They contributed to the planning of annual work programmes and activities for 2013 and 2014, and played a key role in the generation of Community Development Plans (CDPs). They also arranged awareness and training sessions and facilitated the filming of the 'Vital Food' video. Two district facilitators were also appointed to coordinate the work at the district level.

Engaging community facilitators as a link between the project team and communities was seen to have significant benefits for the project, enhancing community ownership as well as contributing to the sustainability of the project. With the establishment of the community facilitators, four of whom were women, engagement with all members of the community improved. The community facilitators highlighted the need for more involvement of women in the project, which led to the food processing and value adding workshop in 2013.

PACC Fiji supported four communities in developing CDPs as a direct response to climate change and disaster risks such as flooding. These four communities had experienced serious flooding in 2009, 2010 and 2012, so had a good understanding of their vulnerability and had considered adaptation approaches. This understanding was further strengthened through the PACC awareness sessions with the communities.

3.2.4. Addressing gender

Climate change is affecting all members of the community, however the impacts felt by each member are likely to be different depending on their role in the community. Women and men have different roles and responsibilities which determine their knowledge and skills as well as their vulnerabilities. These differences need to be recognised by climate change projects because of their influence on the vulnerability of the community and also the adoption and success of any adaptation approach. Gender is very relevant for food production and food security projects, where women may have roles in farming as well as responsibility for the family food.

Ideally, a gender perspective would have been included from the very beginning of the project, and carried through all stages to final M&E. In fact, gender issues were mostly overlooked until midway through the project. At this point, efforts were made by the Regional Programme Management Unit to increase gender awareness within the PACC project teams, and to build capacity for integrating gender into project activities. A Gender Action Plan was developed for the PACC programme (PACC, 2014), with objectives including:

- Adaptation measures in selected pilot communities, and all replication and up-scaling activities, address gender-specific vulnerabilities and result in gender-specific benefits for both women and men;
- Women and men at local and national levels acquire technical knowledge and skills to be able to plan for and respond to climate change risks.

The PACC Fiji team pursued these gender objectives. For example, they ensured that women and men had equal opportunities to build capacity through the training provided.

In collaboration with the Ministry of Agriculture, PACC Fiji also held a workshop for women on food processing and value adding in 2013, to demonstrate how to produce, for example, flour from cassava and to use it in recipes for bread and cakes. These workshops recognised that utilisation of the crops being introduced as part of the adaptation strategy was an important component of the strategy, and that it was also important to provide new opportunities for livelihoods as part of reducing vulnerability to climate change. Workshops were conducted over seven days, with an average of 12 women per day attending from nine villages.

Over 90 women from the pilot sites took part in the different workshops (farming practices and food processing/value adding), and 11 women farmers received planting material (out of a total of 65 farmers).

3.3. Situation and problem analysis

3.3.1. Drainage assessment

The drainage catchments and coastal area included in the two pilot sites are shown in Figure 3. The drainage systems in the catchments were constructed in 1980, and have reached the end of their design lifespan. Moreover, the systems were designed for maximum rainfall of 100 mm in 24 hours. With increasing rainfall intensity, this is no longer adequate.

Evidence collected by LWRM in their regular monitoring of the drainage systems in the two pilot areas clearly indicated the need to improve the discharge capacity of Qaranaki Creek, a vital artery draining much of the Tailevu/Rewa area. Consultations prior to and at the start of the project with the communities located near Qaranaki Creek reinforced the problems that existed with this creek. It was found that the installation of tide gates on the creek to prevent seawater intrusion had reduced the flow along the main channel. As a result, sedimentation had increased along with dense aquatic plants. People in the villages adjacent to the creek (Vunivaivai, Muana, Nakulevu and Visama) suffered from skin irritation problems if they came into contact with the water, and there was a strong, pervasive odour from the creek. In addition, the overall reduced flow of the creek was increasing inundation problems in the villages.

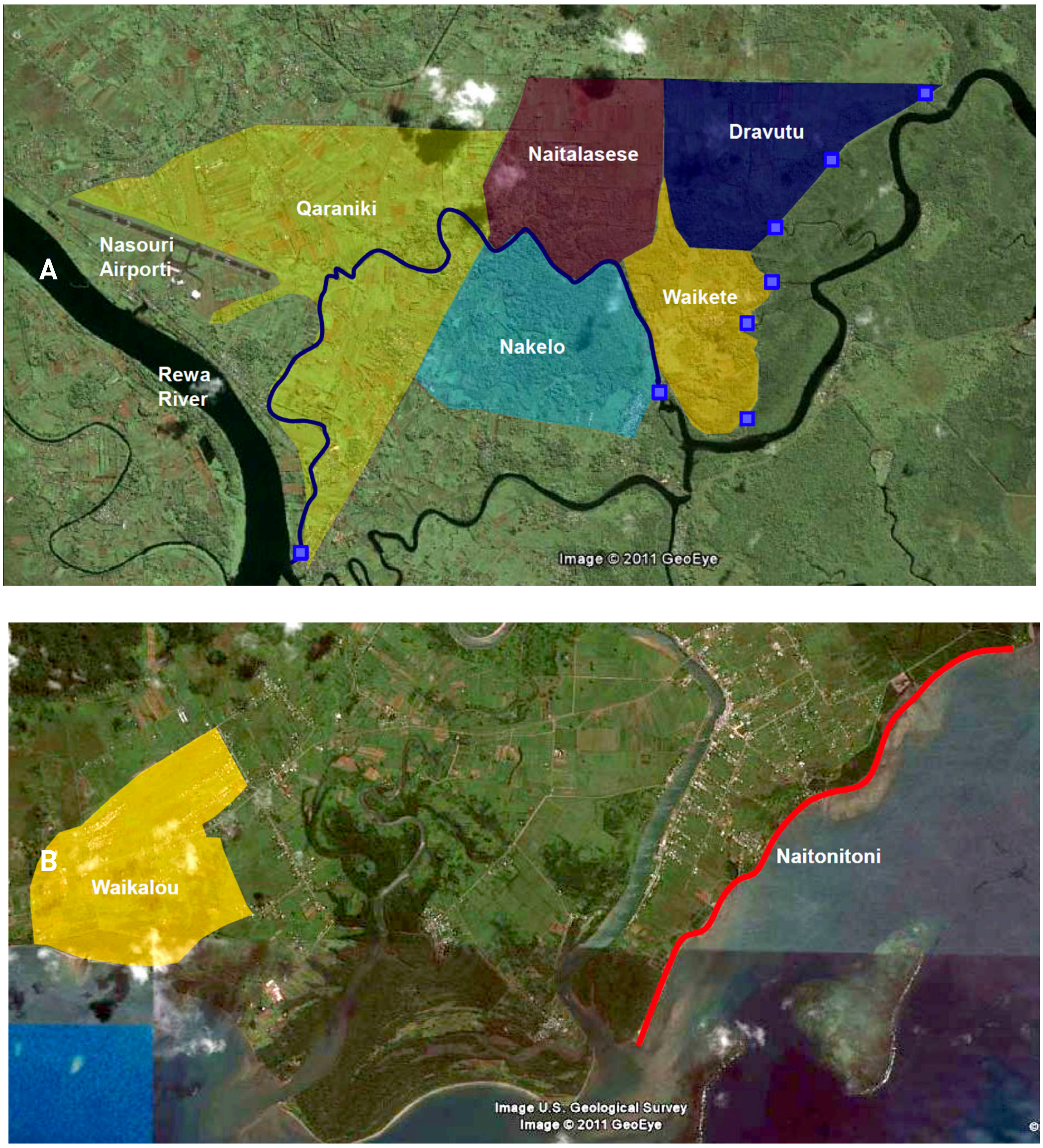


Figure 3. (A) Tailevu/Rewa pilot site showing the five drainage catchments.
(B) Drainage catchment and coastal area in the Navua demonstration area (Serua/Namosi).

A tender was awarded to the New Zealand National Institute of Water and Atmospheric Research (NIWA) to undertake drainage and coastal flood protection re-design and to develop drainage guidelines for future use. In collaboration with LWRM, NIWA identified that several assessments and analyses were needed to fully understand the situation and problem, and develop solutions; these included hydrology and climatology, hydraulic engineering, storm and wave run-up modelling, cost–benefit analysis, and vulnerability and adaptation assessment including socio-economics (NIWA, 2011).

DATA COLLECTION

The following data were compiled for these assessments.

- Recorded rainfall datasets of sufficient duration to derive extreme rainfall projections (20–30 years), obtained from the Fiji Meteorological Service;
- Global and regional climate model temperature and rainfall data;
- Sea level data (from the Suva tide gauge);

- Sea levels recorded at tide gate outlets at Waikalou and Qaranaki over 32 days[6];
- Topographical data (derived from 1978 Fiji topographical map spot heights and new GPS data);
- Satellite imagery;
- Drainage network and infrastructure information (cross-sections, tide gates, tide flaps, culverts etc.);
- Soil types in the drainage catchments;
- Village and LWRM staff knowledge.

Some drainage systems are situated on the seashore and seawalls (levees) have been constructed to prevent seawater from intruding into the system. This is the case with the pilot site in Navua, and therefore further data were needed to assess the status of the seawalls, namely:

- Shore normal profiles extending from the existing offshore multibeam bathymetry areas to the shoreline, over the immediate beach and berm/embankment seawall (eight along the Naitonitoni frontage and five along the Waikolou frontage);
- Indicative spot heights or transects over the offshore reefs (Vatusolo, Bauwa, Naitata and Cakaurakawa reefs).

MODELLING TOOLS

The following tools were developed and used to analyse the situation and problem.

- The Extreme Rainfall and Sea Level Calculator, a Microsoft Excel Spreadsheet, was developed to aid the incorporation of climate change considerations into technical aspects of drainage decision making. The Calculator is used to assess: (a) how the changes projected for precipitation would affect rainfall intensity and frequency; (b) how sea level rise projections would impact on tide level exceedences (the % of time sea levels are above certain levels (relative to land) due to the effects of astronomical tide and mean sea level fluctuation) by providing a description of how much more frequently a defined level will be exceeded by tide/sea levels under a selected climate change emission scenario/timeframe (NIWA, 2012b). The tide gate page in the calculator spreadsheet tool was developed by NIWA to provide a more accessible way of looking at any tide gate system. The dimensions and features of tide gates can be changed to assess the impact that sea level rise would have on tide gate discharge based on an upstream water level or to look at the impacts of slight changes to the tide gate design (e.g. removal of the central pillar).
- The Conveyance Estimation System (CES) is a tool that helps to understand how vegetation impacts on the performance of drains and channels. The CES software can be used to develop stage–discharge relationships for a range of drains and channels and assess the influence of vegetation on drain/channel discharge performance. This tool was used to analyse the negative impact of vegetation on the discharge capacity of the existing drainage system.

3.3.2. Agriculture assessment

Consultations with farmers in the communities at both sites identified that waterlogging was the main constraint to agricultural production. Farmers had abandoned areas due to frequent waterlogging and clogging of old drains by weeds and silt. In the Serua/Namosi area, saltwater intrusion and therefore salinity was an added constraint.

The water table at both sites was monitored using a piezometer in special monitoring bores to assess groundwater levels. Salinity measurements were taken using a conductivity meter.

6 32 days is the minimum length of data required to carry out an analysis of the tidal constituents at the two locations and relate it back to the longer term Suva gauge, which can be used to incorporate longer term sea level fluctuations, such as those due to ENSO effects. This was then used to derive the tide exceedance curves for each location. Storm surge (associated with cyclones) is not of direct concern when considering the performance of the drainage system – what is important is the particular tide level conditions over periods of heavy rainfall, hence the use of tide exceedance curves.

3.3.3. Socio-economic assessment

A socio-economic assessment was carried out by Fiji National University and NIWA (NIWA, 2012a). The aim of the assessment was to provide the present-day context upon which to develop options and approaches to disaster risk reduction and climate change adaptation planning and implementation within the communities at the two pilot sites. The villages/settlements were selected by the LWRM–PACC project team and meetings organised through the regional Provincial Offices. Seven iTaukei villages in the Nakelo District and one iTaukei village and two Indo-Fijian settlements in the Navua District were visited.

The key issues discussed, and main findings from the socio-economic assessment, were as follows.

1. Awareness of climate change – many of the people involved in the discussions had observed changes in the weather, mainly that it rained more often, that it was no longer reliably dry during the dry season, and rain fell for most of the year. These changes were causing problems for both planting and harvesting crops. The concept of climate change is difficult to explain because there is no Fijian word for future climate or climate change. (The iTaukei Affairs Board have however recently prepared a Glossary of Fijian Climate Change Terms.)

2. Local economy – discussions focused on the resources needed and how these were obtained. Sources of income were divided into groups, namely wages, salary and pensions; self-employment; exchange and bartering; tourism; and leasing land. The larger villages have the most diverse sources of income, with the settlements more focused on producing crops for sale. It was clear from these discussions that subsistence activities mainly associated with root crop vegetables, fruit and mangrove species make up a considerable proportion of the local economy.

3. Impacts of the drainage scheme – discussions focused around: (a) how drainage provided more dry land available for farming; (b) the reduction of waterlogging and inundation within the villages and settlements as a result of the drainage systems; (c) the land still unusable due to waterlogging; (d) the stagnation of Qaranaki Creek; and (e) drainage maintenance. Most villages and settlements agreed that drainage maintenance was a concern, and also that there was land that was too wet for cultivation.

4. Living with the current level of waterlogging, inundation and flood risk – the ways in which the villages and settlements have adapted to the current levels of impacts can be divided into physical or structural adaptations and social or behavioural adaptations. Physical risk reduction options include: raised homes, second storey rooms, raised footpaths, raised plantations and additional drainage or contouring. These options were not very popular. Social or behavioural risk reduction options include: regular drain clearance, refuge areas, avoiding being outside until problem is passed, maintaining stocks of subsistence crops, maintaining stocks of rapidly maturing crops such as sweetpotato, and buying in or receiving supplies. The latter was the least popular of these options.

5. Coping with future climate change – as a result of the discussions with the communities and an analysis of the data collected, the socio-economic assessment determined that adaptation activities need to assist communities over the next one to two generations to manage the impacts of climate change, in particular heavy rainfall and waterlogging, but at the same time support and accommodate long-term change. Drainage schemes alone should not be seen as a long-term option, but their effectiveness can be improved by addressing current operational limitations, namely constraints to maintenance and increased discharge capacity (through increasing the number of tide gates and replacing tide flaps). Options to address maintenance constraints could consider partnerships with the communities and other infrastructure-related projects (for example, incorporating the clearing of the remainder of Qaranaki Creek into the airport extension). More effort should also go into farming practices that will improve resilience of the food production systems, such as development of flexible crop planting strategies, on-farm trials to assess the effectiveness of hump and hollowing technique (generation of ridges), and food production diversification.

6. Effective partnerships – research and extension must work more closely with the communities in analysing the various adaptations. Government departments and other organisations should support village development and learning, for example, the delivery of weather and climate information through the Fiji Meteorological Service.

3.4. Solution analysis

3.4.1. Options for drainage maintenance

Both hydraulic modelling of the drainage system and subsequent investigations of vegetation effects of drain hydraulic performance using the CES software identified vegetation growth in the drainage channels as a major factor influencing the hydraulic effectiveness of the drainage system. Submerged vegetation within the channel (such as water hyacinth) can reduce discharge potential by three to four times that of a channel cleared of subsurface vegetation.

The lack of drainage maintenance was identified as the primary cause of the current waterlogging and inundation problems in the low-lying catchments. The limited and decreasing maintenance budget suggests the need to reconsider the contribution that farmers and communities play in drainage maintenance.

Best-practice and effective drain maintenance generally requires a suite of approaches combining manual, mechanical and environmental measures. The following approaches were suggested by NIWA for consideration (NIWA, 2013):

- A community-led routine preventative and minor maintenance programme. This would involve small maintenance work with labour provided on a regular basis by farmers or labourers in each community or sub-catchment with the aim of reducing planned maintenance requirements. It would include activities such as:
  - Monitoring the need for preventative maintenance measures;
  - Frequent weeding to control weeds before flowering or seeding in drains;
  - Clearing in and around drain culverts and other structures.
- Community-led vegetation control following LWRM maintenance in secondary/lower level drains. This would involve labour provided by the community to hand cut vegetation on the drain banks and clear vegetation from the base of the drain (either by hand and/or by spraying). Cutting vegetation on the drain banks (rather than spraying) is preferable as it will reduce sediment being washed into the drain during heavy rainfall.
- More efficient mechanical approaches to clearing vegetation. Potential options, which would likely require a capital purchase of equipment by LWRM for use by the contractors, include:
  - Using a hydraulic excavator with a weed cutting bucket rather than a desilting bucket. Between 600 and 1000 m of drain could be cleared per day using such an approach, depending on the size of the excavator and bucket, which is approximately double the rate of using an excavator and desilting bucket.
  - Using a tractor or hydraulic excavator with a rotary cutter capable of working above and in shallow water for cutting emergent weeds and grass on the drain banks. This has potential for 1000 to 2000 m of drain to be cut per hour. However, it would require the cut vegetation to be removed from the drain.
- In the longer term, the planting of trees to provide shade to inhibit vegetation growth in certain drains. This could offer livelihood potential if fruit trees were used – they could be planted along the drain margin where shading of the drain is most effective whilst minimising any impact on crops. Care should be taken to plant away from locations where wind could result in leaf accumulation in the drain or where they would prevent access for mechanical clearing activities. However, certain species of aquatic plants, such as water hyacinth, are not influenced to any great extent by shading.

Figure 4 provides a summary of the range of maintenance activities, lead responsibility and frequency of activities.

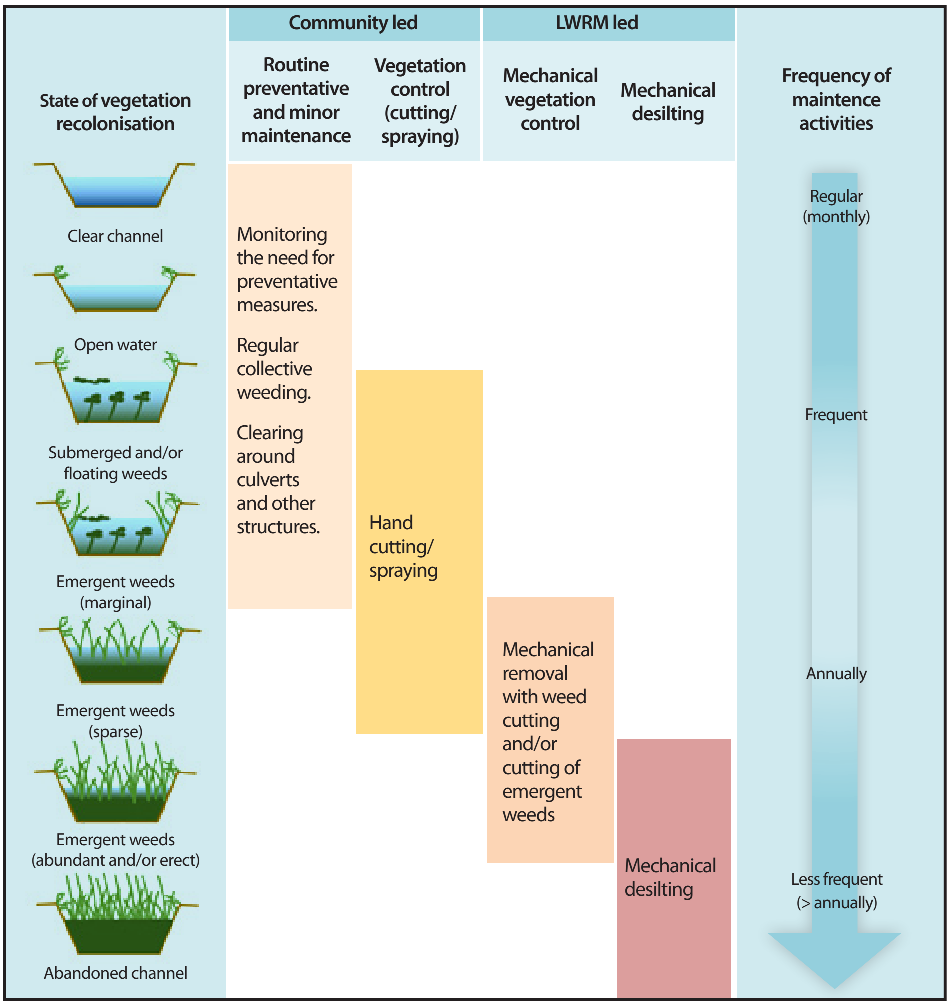


Figure 4. Summary of the range of drainage maintenance activities and lead responsibilities for different stages of vegetation recolonisation.

3.4.2. Cost–benefit assessment

The following options, identified by NIWA in discussion with LWRM, were subjected to a cost–benefit assessment (NIWA, 2013):

- Continued rehabilitation of Qaraniki Creek to include Naselai and Visama sub-catchments;
- Options to reduce drainage flowpaths in the Waikalou and Qaraniki catchments;
- Upgrading of current drainage infrastructure;
- Redesigning the drainage system at Natogadravu to support the airport runway extension.

The assessment determined there was little economic justification for any substantial changes to the drainage system or its operation, such as introducing pump systems, and reached the following conclusions:

- Given the fundamental role Qaraniki Creek plays in draining of the Qaraniki, Naitalese, Nakelo and Waikete catchments, ensuring vegetation growth in the creek is controlled and continuing the rehabilitation of Qaraniki Creek to include the Naselai and Visama sub-catchments should take priority for any new capital expenditure.
- There are likely to be only minor or localised improvements from the following options:
  - Design changes to the various tide gates and flaps to increase their efficiency. These can be incorporated as these structures are replaced over the coming decade as the existing structures reach the end of their operational life. The improvements in hydraulic efficiency are not likely to be significant enough to warrant earlier replacement of these structures.

– There are limited options to reduce drainage flowpaths in both the Waikalou and Qaraniki catchments, with the locations identified likely to lead to only localised and relatively short-term benefits, i.e. they tend to be in the lowest lying land areas.
– Assessment and, if feasible, redesigning the drainage system to discharge via Natogadravu to the Rewa River at Wainibokasi Landing should only be considered if it is to be part of the airport runway extension.

3.4.3. Drainage design modifications

Using the data described in Section 3.3.1, rainfall runoff and hydraulic models were developed for the drainage catchment systems at Waikalou, Navua, and Qaranaki, Tailevu, by drainage consultants MWH (Wellington, New Zealand). The overall aim of the modelling was to assess the impact of the relative changes in the performance of the drainage scheme network expected under climate change scenarios, namely increased rainfall intensity under more frequently occurring extreme rainfall events (1 to 10 year return period conditions) and sea level rise (which influences the discharge of water via the tide gates at the outlets of the drainage catchments). The focus on the drainage areas primarily concerns adapting to increased waterlogging issues due to more frequently occurring rainfall events rather than extensive delta-wide flooding from river flows in the wider Rewa/Navua delta regions caused by very severe but infrequent cyclone events.

The hydrologic modelling system (HEC-HMS) is a generalised GIS-based modelling system capable of representing many different watersheds. The hydraulic model was developed using a combination of spreadsheets, GIS programmes and HEC-HMS/HEC-River Analysis System (HEC-RAS) hydraulics software freely available from the US Army Corps of Engineers. Version 3.5 was used in this project.

The catchment basin, stream and drainage channels and rainfall are represented in the model. Rainfall losses to infiltration into the ground are applied and the remaining rainfall (rainfall excess) is routed through the channels to the catchment outlet. This modelling assessed both the impact of having well-maintained drains and drains with vegetation.

Discussions with each of the communities in the drainage catchment areas indicated that significant impacts on crops due to waterlogging typically began to occur during rainfall durations of three days and over. Seven day durations had a significant impact on village life. Therefore for the modelling, rainfall events of three day and seven day durations were selected. Higher frequency events, such as those with an annual recurrence interval (ARI) of 1 year, were also considered, as an ARI of one year was seen as the critical threshold for the sustainability of subsistence agriculture in these villages, with 10 years being the design ARI in the current drainage guidelines.

The modelling package HEC-RAS was used to convert the hydrographs generated by HEC-HMS into water levels and to calculate the relative duration of time that surplus water from the rainfall events takes to drain from each drainage catchment, that is, to convey the discharge from the drains in each of the drainage catchments along the main channels/Qaraniki Creek to the outlet. HEC-RAS is a one-dimensional hydraulic model. It can be used in steady flow computations of water surfaces and unsteady flow simulation, and allows for the incorporation of structures such as bridges, culverts and gates.

The hydraulic models were used to investigate the effects of two potential adaptation options identified and discussed during the community consultations to improve the performance of the drainage scheme (MWH, 2013):

- An additional tide gate at the outlet of each catchment – hence for the Waikalou catchment, four tide gates were simulated, and for the Namuka outlet of Qaraniki Creek, five tide gates. Where necessary the channel was widened to account for the additional outlet width. Given the very low lying nature and low gradient of the land, the tide gate outlets are a significant constraint on the discharge of heavy rainfall from the catchments via the gates to the sea.
- Improving the performance of the drainage channels through regular maintenance – for the investigation of channel effects the Manning's n roughness value was decreased from 0.08 to 0.035 for the channels and from 0.1 to 0.07 for the floodplain.

The following considerations were included in the modelling:

- The five Qaraniki catchments were treated as independent drainage catchments as there are no drains that inflow to these catchments.

- For the Waikalou drainage catchment, drainage areas and rivers/streams to the west and east are expected to not influence the Waikalou Creek area for the rainfall magnitudes and scale of events under consideration in the project, but input from the catchment to the north was assessed. Discharge from the entire Waikalou catchment was simulated as input to the Waikalou drainage catchment via the Waikalou Creek. The outlet channel capacity from Waikalou Creek seaward of the tide gate is not expected to influence the capacity of upstream drainage schemes for the scale of events considered in the project. Tidal levels at the main tide gate were assessed with minimal hydraulic grade from Rovodrau Bay for all scenarios.

The results from the modelling suggested that the tidal gates, if operating correctly, already have sufficient capacity and that the addition of an extra gate would provide a relatively small benefit especially in 2030 and 2050. However, improving the discharge capacity of tide gates through design modifications could have some benefit in specific areas. Overall, however, controlling flooding depends on the efficiency of flow through the channels, and keeping the channels maintained and free of vegetation is the most efficient way to ensure that the catchment drainage is effective, especially in the Waikalou drainage catchment area. Regular maintenance (removing vegetation/desilting) had the most influence on the discharge of Qaraniki Creek drains.

The approach used in the project was to develop the models using the minimum of data required, as this is likely to be the situation when the models are applied in other situations. Scheme plans of the drainage network in many cases did not reflect the actual drainage system, therefore satellite images and LWRM staff knowledge were used to create the correct network. All details of drain levels were not available, hence standard design cross-sections were used based on the level of drain and based on the surrounding ground levels (a basic digital elevation model had already been created). Spot heights at the start and end of each drain would have been useful information but were impossible to obtain because of the difficulties in getting the GPS to work given the vegetation coverage (and lack of budget). Despite the data limitations, the information gathered was sufficient to make an assessment of the effect of climate change on the drainage scheme and key approaches to improving the performance of the scheme. The approach (limited data and budget) used in developing the models helps in transferring this tool to other similar low-lying drainage catchments. Major assumptions around levels within drainage areas will have to be made, and the variability in profile or grade in drainage and river channels will either be neglected or where appropriate will be explored through determining the sensitivity of the assumptions. Guidance from local people may assist in identifying 'high' or 'low' areas.

3.4.4. Crop trials to identify resilient varieties

The agriculture component of the project had to identify which crops and varieties were best suited to the conditions at the pilot sites. The main crops currently grown in the project area were taro, cassava and sweetpotato, which were grown for household consumption and for sale.

Two sites were selected for trials in 2012 to identify varieties of these crops which may have some level of resilience to waterlogging and/or saltwater. One trial was established in Visama, Nakelo (Tailevu), and another trial was established in Rovadrau, Deuba (Navua). The selected varieties were known to have some tolerance of waterlogging and salinity based on the experience of the Ministry of Agriculture staff from the Koronivia Research Station (KRS), and importantly the varieties were also acceptable to the farmers. For taro, the varieties Hawaii, Uro ni Vonu and Wararasa were selected; for cassava, Merelisita, Nadelei and New Guinea; and for sweetpotato, Honiara, Papua and Vulatolu were chosen.

Taro varieties Uro ni Vonu and Hawaii had previously been tested at KRS in the period 2005–2010 in wetland conditions, and the results indicated that these two varieties could tolerate waterlogging up to 9 months with minimum crop loss. Yields were 11–15 t/ha with an average of 4–6% corm rot sustained due to waterlogging. Wararasa variety was tolerant of waterlogging up to 5 months. It was used in the trials as a control variety on both sites because it is a popular variety with the farmers.

Cassava varieties Nadelei and New Guinea are commonly cultivated cassava varieties in the area and are also preferred varieties in the market. Sweetpotato is less commonly grown in this area. This crop has early maturity (3–5 months depending on the varieties) and is therefore often used as the first rehabilitation crop after natural disasters such as cyclone and flooding.

Figure 5. Installation of piezometers for measurement of water table.

Soil samples were taken from both of the trial sites to determine the fertility and salinity of the soil. The two project areas have very different soil profiles. The site at Rovadrau is a sandy loam with a pH of 5.5 to 5.7, whereas in Nakelo the soil is heavy clay, and the pH is less than 5.5. Nine piezometers were used at the trial sites to monitor the water table during the trials (Figure 5). Readings were taken every 3 days and the water table monitored during heavy rainfall. Samples of water were also taken from the piezometer pipe to test for saltwater intrusion.

Data collected from the trials included yield, percentage of rot and time to maturity. In the Visama trial, where the soil was heavily waterlogged, the taro varieties Hawaii and Uro ni Vonu performed well with only 5% corm rot after 9 months in the ground, whereas the variety Wararasa had 35% corm rot after 6 months in the ground. Of the three cassava varieties only New Guinea gave a reasonable yield, tolerating waterlogging for up to 7 months but with 40% tuber rot. Sweetpotato did not perform well in the waterlogged soil in Nakelo, with 95% rot in all varieties by 4 months. In the Rovadrua trial, where the soil is less waterlogged, two varieties of cassava performed well, namely New Guinea and Noumea. Sweetpotato varieties produced good tubers up until 4 months but after 5 months tubers started to rot. The taro variety Hawaii gave a low yield but produced a higher number of suckers than in the Visama trial. Uro ni Vonu and Wararasa adapted well to the growing conditions and produced good quality corms – only 10% corm rot was recorded.

Based on these results, demonstration trials were established as described in Section 3.6.

3.5. Implementation: improving drainage

3.5.1. Qaranaki Creek

Qaranaki Creek is a vital artery draining much of the Qaranaki, Naitalasese, Nakelo and some of the Waikete catchments. As discussed in Section 3.3.1, dredging Qaranaki Creek was identified as a priority activity for the project. The dredging activities in Qaraniki Creek carried out under the PACC project was the first time the creek had been dredged since the drainage system and tide gates were installed in the 1980s. The dredging removed a large amount of aquatic vegetation from the western end of the Creek from the Nakelo tide gates to just west of the bridge at Vunivaivai.

The dredging of the Creek was carried out in two stages. In the first stage, in 2011, 550 m downstream of the tide gate structure was dredged using a mini-dredger. The contractor was Rewa Sand Supplier Ltd and the contract period was 120 days. In the second stage, in May 2012, 3000 m from tide gate to upstream near Vunivaivai was cleaned and dredged. This work was carried out by 'The K's' and the contract period was 150 days. The Naitalasese, QumQum, Qaraniki-Naselai and Qaraniki-Visama drainage schemes were all improved with seven villages, namely Namuka, part of Waikete, Vutuvo, Naluna, Nakaulevu, Muana and Visama, benefitting (Figure 6).

Figure 6. Qaraniki Creek at Vunivaivai bridge before (top) and after dredging (bottom). The images on the left hand side are looking downstream (east) from the bridge, and on the right upstream (west).

3.5.2. Waikete tide gate

Waikete village is located in a very low-lying area. A part of the village is regularly inundated during high tides, and the communities reported that over time more of the village is being affected and the water levels are creeping higher. The most significant impacts occur when high tide coincides with extended periods of heavy rain.

Installing a new tide gate would address the inundation problem, as doors will be closed by the hydraulic pressure when the tide is coming in, thereby protecting Waikete village and the surrounding farming areas. During heavy downpour, the rainwater will flow out easily from the village and farmland side pushing the floodgate doors open during the low tide. Further, as recommended by NIWA, a modification to the usual tide gate design, the absence of a central pillar, was made, which will increase the discharge capacity during heavy rain events.

The installation of the gate has been carried out by 'The K's' contracting company and was completed in December 2014 (Figure 7).

The seven villages which benefitted from the dredging of Qaranaki Creek are also benefitting from the tide gate.

Figure 7. Installing the tide gate at Waikete.

3.5.3. Capacity building in use of tools

Staff of the LWRM (17 in total, two of whom were women) were trained in the use of the tools developed by NIWA as part of the PACC project. The training was designed to develop the capacity of the technical staff to use and apply the local datasets that had been collated during the project to assess the impact of climate change on low-lying agriculture areas in Fiji and inform drainage-related decision making.

The course had two components. The first component focused on an introduction to climate variability and change, and the basic tools. Participants were trained in the use of the Extreme Rainfall and Sea Level Calculator to derive present and future extreme rainfall intensity information and sea level exceedences; loading and manipulating GIS data and creating basic maps in GIS using data from the Qaraniki and Waikalou drainage catchments; developing a map of Waikalou showing the areas of low-lying land below mean high water spring level now and by the 2050s (using both the calculator and GIS); and altering the drainage network GIS data to add in new drains and drainage infrastructure.

The second component aimed to give participants an appreciation of drainage modelling tools and how they can be applied in assessments of low-lying drainage systems. The training covered some straightforward tools which could be used in any situation, to more complex modelling software where the focus was on using and applying the models set up for the Waikalou and Qaraniki catchments. The course covered:

- Introduction to modelling;
- Hydrological processes;
- Rainfall runoff modelling;
- Using and applying the HEC-HMS rainfall runoff model;
- Assessing drain and channel discharge using the conveyance estimation software;
- Hydraulic modelling using HEC-RAS;
- Assessing stage and discharge from the drainage network using HEC-RAS;
- Using and applying the rainfall runoff and hydraulic models set up for the Waikalou and Qaranaki demonstration areas.

3.6. Implementation: climate-resilient crops

Based on the results of the pilot trials (Section 3.4.4) and in consultation with the farmers, demonstration plots were established at Naitalasese (about 2.5 km from the trial site at Visama, Nakelo) and at Rovadrau (about 1 km from the trial site in Navua), so that farmers could observe the different varieties and their performance under farm conditions. Koronivia Research Station (KRS) was responsible for establishing the demonstration farms, but other than the initial establishment the demonstration plots were managed by the farmers. The plots demonstrated a number of crops: those varieties that had performed well in the pilot trials, and also other varieties known by KRS to have potential for good productivity in those conditions. Farmers were also interested in cultivating some of the old varieties that were no longer available but were being maintained by KRS in their collection, for example the taro variety Vavai Dina.

Farmer training was conducted at both demonstration sites. All farmers from the community were invited and a total of 65 farmers were trained, nine of whom were women. The purpose of the training was to raise awareness on the importance of crop diversity and good farming practices as an adaptation option. The training covered:

- Good farming using planning and management as tools, and seasonal calendars;
- Farming practices that are appropriate to low-lying flood-prone sites;
- Crops and vegetables that are resilient to flooding and saltwater inundation;
- Water management, focusing on flood water, drainage and saltwater inundation;
- Using monitoring and evaluation to measure performance.

Sessions were very practical, hands-on training sessions. Farmers went on to practice what they had seen on the demonstration farms. They obtained planting material either directly from the demonstration plots, or went to KRS to collect the desired varieties. Through the project training and awareness sessions the farmers learned that diversifying cultivation (growing different crops and varieties) can spread the risk of crop loss. They also learned that selecting varieties that perform well under waterlogged conditions means that yields can, to some extent, be protected. Access to planting material of quick-maturing crops, such as sweetpotato, can also help in the provision of food after a climate disaster such as flooding. The farmers identified easy access to planting material as an important requirement for managing climate variability and made plans to establish a farmer-managed nursery for providing planting material.

3.7. Adaptive management

There were delays to the assessment phase of the project due to difficulties in accessing data, such as rainfall data, needed by NIWA to develop the assessments. This was eventually resolved through discussions with the relevant bodies and the data made available.

The project had a change of manager midway, which affected project implementation. The mid-term review (MTR) highlighted a number of issues which were likely due to the change in project management, and importantly the lack of any crossover period between the two managers. A project management unit which included technical staff familiar with the project would have helped with continuity.

The main recommendations from the MTR and the responses from the PACC project team are presented in Table 1.

Table 1. Recommendations for improvements to the PACC project made by the Mid-Term Review team, and PACC Fiji team responses.

MTR recommendation	PACC response
The project should carry out no further work on drainage maintenance, such as dredging	The project stopped the dredging work in Qaranaki Creek, but as highlighted by the different drainage assessment tools used in this project and the positive community response, clearing the creek was well justified. The dredging also appears to have provided the nearby villages with another source of food, as tilapia are now available in the creek, and women and youth from the villages are also farming prawns in the creek, thus enhancing food security
The project needs to fast-track the availability of planting material of resilient crops to farmers	Previous work carried out by KRS, consultations with farmers, and the pilot trials enabled speedy identification of varieties of taro, sweetpotato and cassava for use on the demonstration farms. KRS made planting material of these varieties available from the research station itself, as well as from the demonstration farms
The project needs to strengthen community engagement	As discussed in Section 3.2.3, the project responded by identifying and building capacity of community facilitators for each of the nine target communities. These people had responsibility for facilitating engagement of the project with the communities
The project should strengthen relations and information sharing with other PACC projects	PACC Fiji exchanged information on farm trials and farming practices with PACC Solomon Islands. Information and updates were also sent to the PACC food security projects in Palau and PNG

3.8. Monitoring and evaluation

Monitoring and evaluation (M&E) is critical for continual improvement during implementation, and for assessing the project's effectiveness and lessons – what worked and what could be improved in the future. The project's logical framework (logframe) was used to guide the M&E process. The logframe went through a number of iterations, with the final logframe (Table 2) coming out of an M&E workshop in Samoa in early 2014.

It is important to have a robust logframe developed as a result of a participatory process at the project's inception. This is an important lesson from the PACC Fiji project. The logframe should lead to the development of a more detailed M&E plan that provides a clear understanding of what data need to be collected before (baseline), during implementation, and post-implementation. The M&E plan should also identify roles and responsibilities, and the skills and resources (staff, time, equipment etc.) required to fulfill the plan.

Monitoring included undertaking surveys of farmers and farming communities, collecting data from crop trials, and collecting photos of works (e.g. before and after drainage works).

Project coordinators (LWRM and Agriculture) met at least weekly and sometimes twice weekly to discuss the project, and they also made regular visits to the farmers in the project areas to gather feedback from them. Regular farmer feedback is important in keeping the target group engaged in the project, and it allows any problematic issues to be identified and measures put in place to rectify them.

Table 2. An extract from the Fiji PACC project's logframe.

Goal/outcome/output	**Indicator**	**Source/data collection method**	**Results**
GOAL: To contribute to reduction of vulnerability and increase adaptive capacity to adverse effects of climate change in the food sector of Fiji			
Outcome 1: Policy/plans mainstreamed to build resilience in the context of emerging climate risks	No. of Community Development Plans incorporating CC No. of sector plans (ministerial/department level) modified in line with revised policy	Community Development Plans	12 Community Development Plans created that incorporate climate change Ministry of Agriculture has aligned their Agriculture Development Plan to National CC Policy Climate Change Unit established within Foreign Affairs
Output 1.1: National Climate Change Policy for Fiji endorsed	Final plan completed (draft)	National Climate Policy	Completed and endorsed in 2011 and in use
Outcome 2: Demonstration measures delivered to reduce vulnerability in crop production	No. of farmers (men and women) receiving resilient planting material Total no. of people (men and women) and communities benefiting from project Community satisfaction with new crops	Technical reports Farmer surveys and interviews	65 (11 female) farmers have received nine different varieties of crops (taro, cassava, sweetpotato) in four villages High level of satisfaction with new crops 13 communities benefiting

Goal/outcome/output	Indicator	Source/data collection method	Results
Output 2.1: Demonstration project delivered – Drainage infrastructure improved to adapt to increased rainfall and sea level rise	Increase in cropping area reclaimed	Technical reports	10 acres of cropping area reclaimed 3 km of drainage network improved
Output 2.2: Resilient crop trialled and distributed to farmers	No. of trial sites No. of crops/varieties tested No. of nurseries/ seed banks	Technical reports	2 sites were selected in 2012 Site 1 – Visama, Nakelo Site 2 – Rovadrau, Deuba 2 trial sites established in Jan & Feb 2013 Crops tested: taro (3 varieties); cassava (3 varieties); sweetpotato (3 varieties) Plans for nursery and seed bank in place and purchasing of materials ongoing (March 2015)
Output 2.3: Drainage guidelines developed incorporating new engineering standards for drainage network	(Gender-sensitive) technical guidelines developed	Drainage guidelines and consultancy review documents	
Outcome 3: Increased understanding of CC impacts and awareness of how to adapt and build resilience (at community level)	No. of community CC facilitators working in communities	Socio-economic survey (baseline) and follow-up interviews	18 community members trained to be focal point for CC adaptation at the village level workshops held with communities to review and finalise CDP using PLA method
Output 3.1: National communications plan developed and actioned	No. of workshops and school visits Awareness products	Communication plan report	12 community and 9 school workshops completed and follow-up before completion by October Banners, media releases, newsletters completed
Output 3.2: Knowledge management products produced	PACC video Technical guideline	Materials from PACC partners and RPMU	Vital Food and Fiji PACC Documentary completed Photo series is to be finalised

3.9. Communications and knowledge management

The project addressed communications and knowledge management at different levels, and both formally and informally.

Community engagement was guided by a communications plan developed early in the project. Activities for community engagement are described in Section 3.2.3.

Other key target audiences were identified by the project, at both national and regional levels, and communications products were developed and disseminated. Examples include news stories published on the PACC webpages (www.sprep.org/pacc), and the video Vital Food produced in 2013 and broadcast at national, regional and international events.

For communications and knowledge management targeting audiences beyond Fiji, the PACC webpages (www.sprep.org/pacc), and in particular the Fiji project webpage (www.sprep.org/pacc/fiji), has been the main dissemination tool used to share information and knowledge generated by the project. Outputs are also being shared through the Pacific Climate Change Portal, and other sites such as UNDP's Adaptation Learning Mechanism, Climate & Development Knowledge Network (CDKN), Eldis and ReliefWeb.

3.10. Upscaling and replication

The Extreme Rainfall and Sea Level Calculator can be used across Fiji provided the data are available to input into the Calculator. At present the tool can be applied to limited areas in Fiji, however when extreme rainfall analysis is done for other sites it can be added to the Calculator.

Data in the Calculator at time of writing (December 2014) included (NIWA, 2012b):

- Rainfall: extreme rainfall amounts for periods between 1 and 14 days and average recurrence intervals from 0.25 to 50 years for the south-east of Viti Levu (based on analysis of rainfall datasets at Nausori Airport and Laucala Bay);
- Sea-level: all tide and high tide exceedence curves with and without mean sea level variability for Suva and Lautoka, with mean sea level adjustments relative to Suva for Waikalou (Navua) and Nakelo (Tailevu). The Calculator allows the user to choose any one of the IPCC AR4 scenarios and to specify additional sea level rise by 2090 due to additional ice melt, or to use a specific sea level rise scenario for any decade between 2030 and 2120. It adjusts the tide exceedance curves and not extreme sea levels as the former are important for the performance of the drainage system.

The hydraulic models (HEC-HMS and HEC-RAS) can be used to assess other engineering mitigation options or combinations of options. These include levees, channel alteration and alternative gate types. If further information on the grade, typical cross sections and in particular cross sections around the gate becomes available these could be incorporated into the model. HEC-HMS and HEC-RAS are a suitable combination to model catchments as they are both freely available and recognised for application in river engineering.

The identification of crop varieties with tolerance to waterlogged conditions under different soil profiles is very useful information for Fiji farmers, especially with the projected climate change conditions, in particular extreme rainfall events. Planting material for the crops and varieties that demonstrated resilience to waterlogged conditions was made available through the demonstration plots or direct from KRS. The farmers in the Nakelo area have plans to establish a nursery so they can produce their own planting material, rather than rely on KRS. The project supported this initiative with the provision of some nursery materials. Planting material of the crops and varieties identified as 'resilient' can be made available through the Ministry of Agriculture to farmers in other parts of the country. The tissue culture laboratory at KRS could be used to multiply this planting material to provide a reasonable quantity to the different research stations and to distribute to key farmers and farmers' groups.

3.11. Mainstreaming climate risk at the strategic level

Alongside the practical demonstration project, the Fiji PACC team also devoted efforts to the mainstreaming of climate change into policy at the national level and at the community level. The project contributed to two key outputs in this area: the National Climate Change Policy (NCCP) and Community Development Plans (CDPs).

In 2007, Cabinet endorsed Fiji's National Climate Change Policy Framework, which defined the position of government and other stakeholders on issues of climate change, climate variability and sea level rise. The framework underwent review in 2011 to reflect current and emerging climate change issues at the local, national and international level, and the PACC project team contributed to the consultation. The reviewing and updating of the framework led to the development of the National Climate Change Policy. The policy provides a platform for coordination among sectors, and direction on national positions and priorities regarding climate change mitigation and adaptation.

As discussed in previous sections, five of the communities participating in the project (Naimalavau, Nakelo and Nuku in Deuba District, and Ravodrau and Waikete) drew up 'Adaptation to Climate Change Action Plans'. These plans considered activities such as climate change awareness, cleaning and improving creeks and drainage, planting crops resilient to climate change, and planting more trees to help with soil fertility and erosion. For each activity, the community decided where the activity would be implemented, who would be responsible for its implementation, and how many times that activity would be implemented annually. Four communities (Muana, Vunivaivai, Visama and Vutuvo) produced Development Plans which addressed a wider range of issues such as sanitation, youth development, women development, education and land issues. Both types of plan were developed by the community, supported by the project.

4. PROJECT IMPACT

4.1. Sustainability

The project identified that lack of maintenance, combined with aggressive growth of invasive weeds, was the main reason the existing drainage system was not effective in the low-lying catchments, with resulting impacts on agricultural production. The budget constraints currently experienced by LWRM are likely to continue, and therefore relying on LWRM to effectively manage the drainage system is not realistic and is unsustainable. The recommendations provided by NIWA, which include a combination of different approaches to maintain the drainage systems to be implemented by the communities and LWRM, if implemented, will contribute to sustainability of the drainage system and the project results.

The project has been effective in demonstrating to the communities in the pilot sites the importance of drain maintenance. Farmers were quick to note the results after Qaranaki Creek was dredged. During the awareness sessions the project promoted the importance of drainage through good soil practices and also the importance of keeping the drains clear. The community in Rovadrau have accepted their role in drainage maintenance and are keeping the drains clear of weeds through manual clearing and spraying. The efforts spent by the project in involving the community and training community facilitators will also help in sustaining the drainage maintenance component of the project.

The capacity building in the use of the various tools developed by the project will support LWRM to take the risks from the projected climate change conditions into account in future drainage designs.

The establishment of a nursery by the farmers in Nakelo for the supply of planting material reduces the reliance on the Ministry of Agriculture for planting material, and enables farmers to be more self-sufficient, which will add to sustainability. In Visama, Nakelo and Rovadrau, Deuba farmer associations exist, which will strengthen the sustainability of the activities after the completion of the project. The Agriculture Extension Services have also been engaging with the project and working with researchers from KRS; they will continue to support the farmer associations.

4.2. Relevance

The PACC Fiji initiative addressed the needs of the farmers in two lowland areas affected by waterlogging and saltwater intrusion. The dredging of specific drainage channels carried out in the early stages of the project enabled the farmers to grow crops on land that previously was too wet to cultivate. The farmers with land on the western side of Waikete, Nakelo and Naitalasese observed that after the dredging water was able to drain more effectively and quickly from catchments where the land drains discharge into the cleared section of Qaranaki Creek.

At the same time the project raised awareness with the farmers on the importance of crop diversity. If farmers know which crops and varieties are better suited to different conditions, such as waterlogging, this knowledge can help with crop production when conditions are less than optimal. During the community consultations and farmer training, the use of different farming practices was also discussed as an adaptation strategy for managing conditions such as waterlogging.

The availability of tools (the Extreme Rainfall Calculator, CES and the hydraulic models) to assist LWRM in future drainage assessments and to determine the capacity of the existing infrastructure to manage an increased water flow is a valuable and relevant development, considering the projections for extreme rainfall events. Further training in the use of these tools is however essential to ensure they are used effectively.

The project appreciated the importance of demonstrating the different ways in which the crops being recommended by the project could be utilised, hence the workshop which provided training in food processing and value adding was a very relevant activity.

4.3. Effectiveness

The project was effective in that it helped the farmers in the project areas to farm land that previously could not be cultivated because of waterlogging – a total of 10 hectares was reclaimed for cultivation. Sixty-five farmers are using the crop varieties made available through the project and incorporating the farming practices learned in the training into their farming programme. In discussions at both sites, the farmers commended the project for its effectiveness and for highlighting how best to farm on land where productivity can be significantly constrained by climate variability. The project was also effective in bringing farmers together and strengthening existing farmer associations which will be invaluable in taking the lessons learned by the project forward and building on them to improve adaptive capacity. The Agriculture Extension Services have also been engaging with the project and working with researchers from KRS; they will continue to support the farmer associations.

The effectiveness of the tools can only be assessed at a later date when the tide gate constructed at Waikete is put to the test under challenging climate conditions, and also in the use of the Calculator and the hydraulic models. However, the new tide gate should address the tidal inundation problem, as the doors will be closed by the hydraulic pressure when the tide is coming in. During heavy rainfall, the rainwater will flow out easily from the village and farmland side pushing the tide gate doors open during the low tide. The absence of a central pillar will improve the discharge capacity of the tide gate.

4.4. Efficiency

The difficulty in accessing meteorological data delayed the progress of the project and was wasteful of resources. The project would have benefitted if easy access to the required data had been organised prior to NIWA's involvement. Training in the use of the Calculator and the hydraulic models was provided to a significant number of participants – a better use of resources would be more targeted training to a few select individuals. The hydraulic models are fairly complex and so require intensive training, preferably on a one-to-one basis in order to ensure that the trainee is competent in their use.

5. LESSONS LEARNED

The following are the main lessons derived from the Fiji PACC project, which may be used to inform similar projects in the Pacific region in the future.

- It is important to recognise and respect that both local knowledge and external technical expertise are valid sources of information that can be used to address problems and seek solutions. The local technical knowledge of the Ministry of Agriculture was very useful in identifying the most suitable crops and varieties for evaluation in the Fiji PACC climate resilience pilot trials, and allowed for a degree of fast-tracking in this component of the project.
- For any food security project, farmers and farmer associations should be involved as much as possible. On-farm research, such as was carried out by the project, is the best approach for transferring any new methodology or practice. Importantly, on-farm trials are relevant to that location, rather than the research station, which negates any genotype by environment effect. Working with the farmers right from the start of a project also provides the opportunity to address potential problems such as the non-marketability of any introduced crops and varieties.
- It is important to consider gender from the very beginning of a climate change project, and maintain a gender perspective throughout. Women and men have different roles, responsibilities and priorities, and therefore differing vulnerability to climate change, as well as different skills and experiences to contribute to finding solutions. Women have a significant role to play in ensuring household food security. Failure to consider women from the beginning could, for example, result in recommending a climate change adaptation that could make more work for the women. Gender was not considered as an issue at the design stage of the project, however gender awareness did improve as the project progressed, especially with the establishment of the community facilitators as they helped to engage all of the community.
- The 'community facilitator' approach proved to be highly successful for community engagement. At the start of the project community engagement was achieved through the formal Fijian system with the project working with the Divisional Commissioners, Provincial Council Office, District Councillors and the village headmen in the two pilot sites. Greater ownership of the project resulted when the community facilitators were in place. The community facilitators became the focal points for climate change activities in their villages.
- A good M&E framework is needed for project success. It is important to have a robust logframe developed as a result of a participatory process at the project's inception. The logframe should lead to the development of a more detailed M&E plan that provides a clear understanding of what data need to be collected before (baseline), during implementation, and post-implementation. The M&E plan should also identify roles and responsibilities, and the skills and resources (staff, time, equipment etc.) required to fulfill the plan.
- An effective project management team is vital, covering all aspects of the project – technical, coordination, administration and management. Some of the delays and issues affecting the project could have been addressed if such a team had been in place from the beginning. The PACC project did have a steering committee/advisory board, which consisted of about 20 persons from Ministry of Agriculture, Foreign Affairs, Department of Environment, Provincial Councils, WWF and the University of the South Pacific. It is unlikely that such a wide group would have participated regularly in meetings to discuss the project, therefore a smaller management team, who would be able to meet regularly, should have been formed to help guide the project.
- Hydraulic models are very valuable tools, but they are also very complex, with implications for training in their use and application. Future projects should consider a more focused approach to training, possibly through on-the-job attachments. This approach would have cost implications, especially with the engagement of an overseas company, therefore training needs must be given due attention in the design phase.
- The project design could have considered the wider environmental and social context of lowland drainage issues in Fiji, for example through an ecosystem-based approach. The design and inception stages of a project present an opportunity to consider the scope of the project and determine which approaches should be included for assessment.

REFERENCES

ADB (Asian Development Bank) (2005) Fiji Islands: Country Environmental Analysis.

Australian Bureau of Meteorology and CSIRO (2011) Climate change in the Pacific: Scientific Assessment and New Research. Volume 2: Country Reports – Fiji.

Australian Bureau of Meteorology and CSIRO (2014) Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports.

Government of the Republic of Fiji (2012) Republic of Fiji National Climate Change Policy, Secretariat of the Pacific Community, Noumea, New Caledonia http://www.gendercc.net/fileadmin/inhalte/Dokumente/Actions/fiji-national-climate-change-policy_Feb2012_en.pdf

MWH (2013) Waikalou and Qaraniki Creek Drainage Catchments Hydrology and Hydraulics Assessment Prepared for Land and Water Resource Management Division, Ministry of Primary Industries, Fiji.

NIWA (2011) Pacific Adaptation to Climate Change: Assessment of climate change impacts on the drainage network and infrastructure in Fiji: Inception Report. Prepared for Land and Water Resource Management Division, Ministry of Primary Industries by National Institute of Water and Atmospheric Research Ltd (NIWA), New Zealand.

NIWA (2012a) Climate-related socio-economic impacts and adaptation option potential (Pacific Adaptation to Climate Change: Assessment of climate change impacts on the drainage network and infrastructure in Fiji). Prepared for Land and Water Resource Management Division, Ministry of Primary Industries by National Institute of Water and Atmospheric Research Ltd (NIWA), New Zealand.

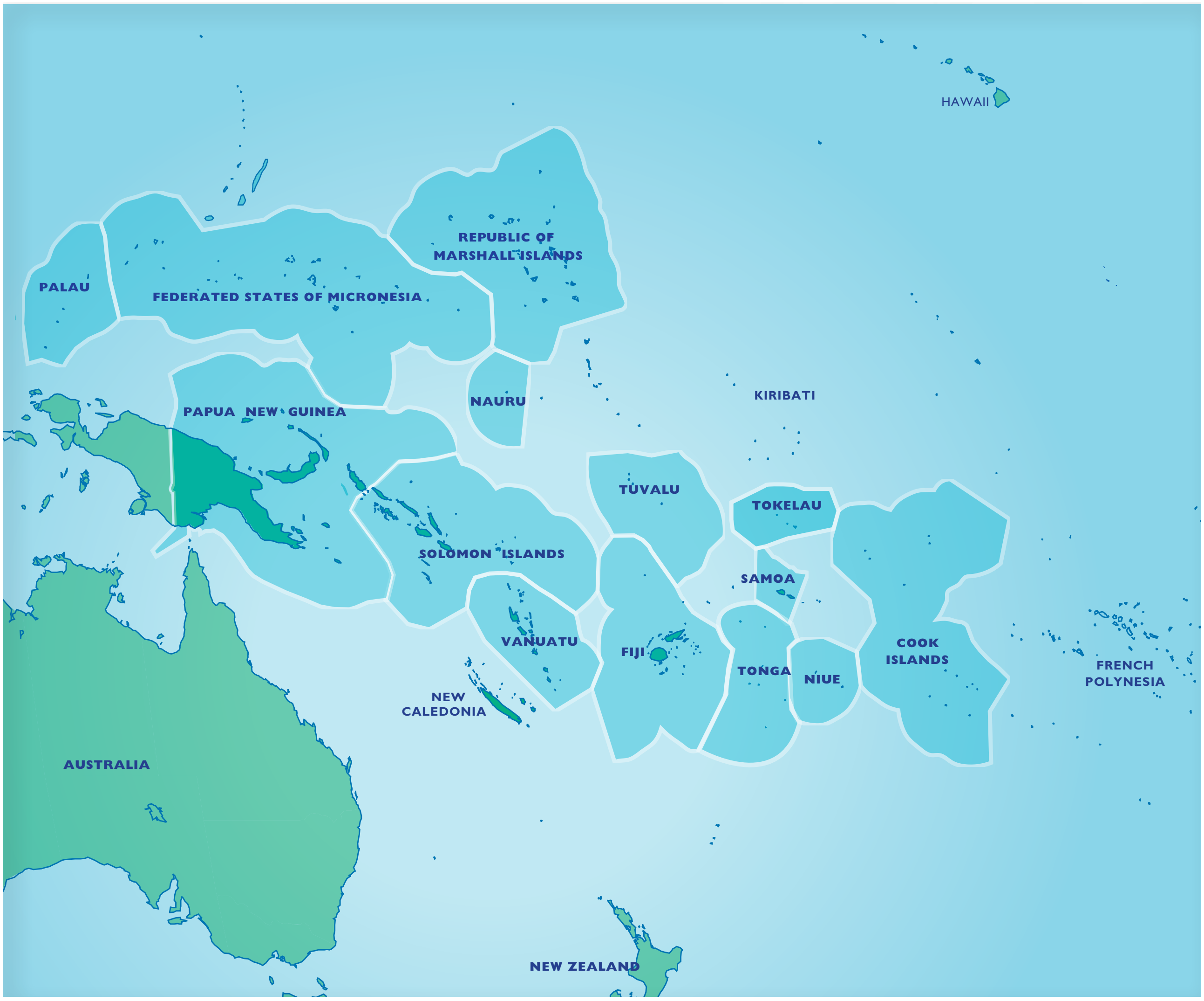
NIWA (2012b) Extreme rainfall and sea level exceedance calculator user manual. Prepared for Land and Water Resource Management Division, Ministry of Primary Industries by National Institute of Water and Atmospheric Research Ltd (NIWA), New Zealand.

NIWA (2013) Priority options for improving drainage scheme performance (Pacific Adaptation to Climate Change: Assessment of climate change impacts on the drainage network and infrastructure in Fiji). Prepared for Land and Water Resource Management Division, Ministry of Primary Industries by National Institute of Water and Atmospheric Research Ltd (NIWA), New Zealand.

Pacific Adaptation to Climate Change, Fiji Islands (2009) Report of In-country Consultations, GEF, UNDP, SPREP http://www.pacificdisaster.net/pdnadmin/data/original/FJI_SPREP_2009_cc_adaptation.pdf

PACC (2014) Gender and the Pacific Adaptation to Climate Change (PACC) programme: Assessment and Action Plan. PACC Technical Report 3. SPREP, Apia, Samoa.

World Bank (2000) Cities, Seas and Storms: Managing Change in Pacific Island Economies. Vol. IV, Adapting to Climate Change. World Bank, Washington, DC.



PACC – building adaptation capacity in 14 Pacific island countries and territories

PACIFIC ADAPTATION TO CLIMATE CHANGE (PACC) PROGRAMME

The PACC programme is the largest climate change adaptation initiative in the Pacific region, with activities in 14 countries and territories. PACC is building a coordinated and integrated approach to the climate change challenge through three main areas of activity: practical demonstrations of adaptation measures, driving the mainstreaming of climate risks into national development planning and activities, and sharing knowledge in order to build adaptive capacity. The goal of the programme is to reduce vulnerability and to increase adaptive capacity to the adverse effects of climate change in three key climate-sensitive development sectors: coastal zone management, food security and food production, and water resources management. PACC began in 2009 and is scheduled to end in December 2014.

The PACC programme is funded by the Global Environment Facility (GEF)'s Special Climate Change Fund (SCCF) and the Australian Government with support from the United Nations Institute for Training and Research (UNITAR) Climate Change Capacity Development (C3D+). The Secretariat of the Pacific Regional Environment Programme (SPREP) is the implementing agency, with technical and implementing support from the United Nations Development Programme (UNDP).

www.sprep.org/pacc

PACC TECHNICAL REPORTS

The PACC Technical Report series is a collection of the technical knowledge generated by the various PACC activities at both national and regional level. The reports are aimed at climate change adaptation practitioners in the Pacific region and beyond, with the intention of sharing experiences and lessons learned from the diverse components of the PACC programme. The technical knowledge is also feeding into and informing policy processes within the region.

The Reports are available electronically at the PACC website: www.sprep.org/pacc, and hard copies can be requested from SPREP.

ISSN 2312-8224