

A guide for practitioners

Acknowledgements

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Abbreviations

CFS	Climate Field School
CRMFS	Climate Risk Management Farmer Field school
CSIRO	Commonwealth Scientific and Industrial Research Organization
ENSO	El Niño Southern Oscillation
ECMWF	European Centre for Medium-Range Weather Forecasting
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
GCM	global climate model
GDP	gross domestic product
ITCZ	Inter-tropical convergence zone
NHMS	National Meteorological and Hydrological Service
NIWA	New Zealand's National Institute of Water and Atmospheric Research
NOAH	National Oceanic and Atmospheric Administration
PCCSP	Pacific Climate Change Science Program
RCP	representative concentration pathways
RIMES	Regional Integrated Multi-Hazard Early Warning System for Africa and Asia
SESAME	Specialized Expert System for Agro-Meteorological Early Warning
SPC	Secretariat of the Pacific Community
SPCZ	South Pacific Convergence Zone
SPREP	Secretariat of the Pacific subregional Environment Programme
UNDP	United Nations Development Programme
WMO	World Meteorological Organization
WPM	West Pacific monsoon

BACKGROUND

The Pacific small island developing States (SIDS) is home to about ten million people.¹ In many of these countries, the majority of the population lives in rural areas (86 per cent in Papua New Guinea, 81 per cent in Samoa, 77 per cent in Solomon Islands and the Federated States of Micronesia, 76 per cent in Tonga and 73 per cent in Vanuatu).² The primary economic sectors in most of these countries are agriculture and fisheries. Agriculture remains the main source of livelihood for the majority of the population and is an important contributor to the economy of the Pacific SIDS. Agriculture supports, both directly and indirectly, about two-third of the population of Fiji, Papua New Guinea, Samoa, Solomon Islands and Vanuatu. The sector is responsible for about one quarter of the gross domestic product (GDP) in the Federated States of Micronesia, Kiribati, Papua New Guinea, Solomon Islands, Tuvalu and Vanuatu. The share of agriculture to total exports is around 30 per cent in Fiji, Papua New Guinea and Solomon Islands and more than 60 per cent in Samoa, Tonga and Vanuatu.³ Aside from being a major source of household and export income, agriculture in the subregion is also important in sustaining the domestic food supply to reduce dependence on food imports.

The Pacific SIDS face significant reductions in their agriculture potential, in part due to extreme climate variability as well as the frequency of El Niño events. As evidenced by the decrease in sugarcane production in Fiji (its main foreign export accounting for 12 per cent of its GDP), the decrease in tuber crops in Vanuatu and decreasing rice production in Papua New Guinea, maintaining or increasing agriculture production in the context of climate variability continues to be a challenge (SPC, 2016).

Building a resilient agriculture sector in the Pacific SIDS requires: (a) understanding the overall Climate Risk Management systems for agriculture, (b) assessing key sectoral issues and challenges in climate resilient agriculture, (c) application of climate information for agriculture production and (d) improving end-user capacity to implement strategies.

To promote these practices, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), in collaboration with the Secretariat of the Pacific Community jointly organized a workshop on building climate-resilient agriculture

1 ESCAP Statistical Database based on data from the UNSD National Accounts Main Aggregates database. Available from http://data.unescap.org/escap_stat/ (accessed 2 December 2016).

2 Ibid.

3 World Bank. Available from <http://data.worldbank.org/country> (accessed 15 December 2016).

in the Pacific SIDS in Nadi Fiji from 9–11 August 2016 that served as a South-South cooperation forum, bringing together stakeholders in climate-sensitive agriculture sectors of the Pacific SIDS and Asia. The deliberations of the workshop focused on mainstreaming disaster risk reduction (DRR) and climate change adaptation (CCA) in the agriculture sector in the Pacific as part of a larger regional project on Enhancing Knowledge and Capacity to Manage Climate and Disaster Risk for a Resilient Future in Asia and the Pacific. Examples of good practices in agriculture from Asia, based on an understanding of climate monitoring and disaster risks and customized to the agriculture sector, were shared to support decision-making and partnership with stakeholders in the Pacific.

As a response to the interest expressed by participating countries at the meeting to integrate DRR and CCA into their agriculture sector strategies, plans and budgetary process, ESCAP and the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia developed this guide to provide a practical tool for planners and practitioners. The guide highlights good practices on climate-resilient agriculture from Asia for potential implementation in the Pacific context, such as the Monsoon Forums and Climate Field School for farmers. This guide is intended to be a living document—it can be reviewed and updated as the agriculture sector in the Pacific SIDS gain more experience in mainstreaming DRR and CCA.

INTRODUCTION

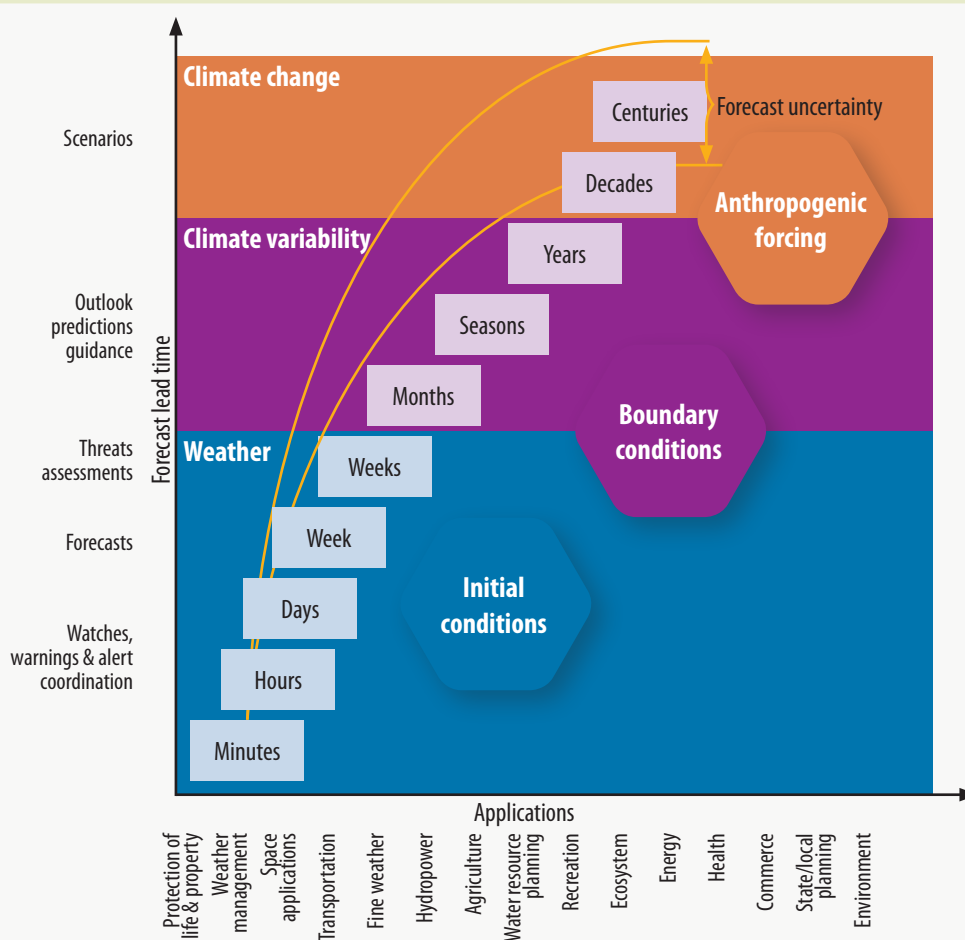
The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) developed this guide on mainstreaming disaster risk reduction and climate change adaptation for climate risk in the agriculture sector. Tailored to the Pacific context, these guidelines can be used by policymakers and practitioners in the agriculture sector to minimize risks and maximize potential gains associated with climate variability.

This guide adopts the climate risk management (CRM) approach for climate risks and optimal use of favourable climate situations in the agriculture sector in the Pacific islands. The CRM framework has three distinct but interconnected components to manage climate risks and opportunities:

- managing current climate variability
- managing observable climate trends
- managing climate change projections

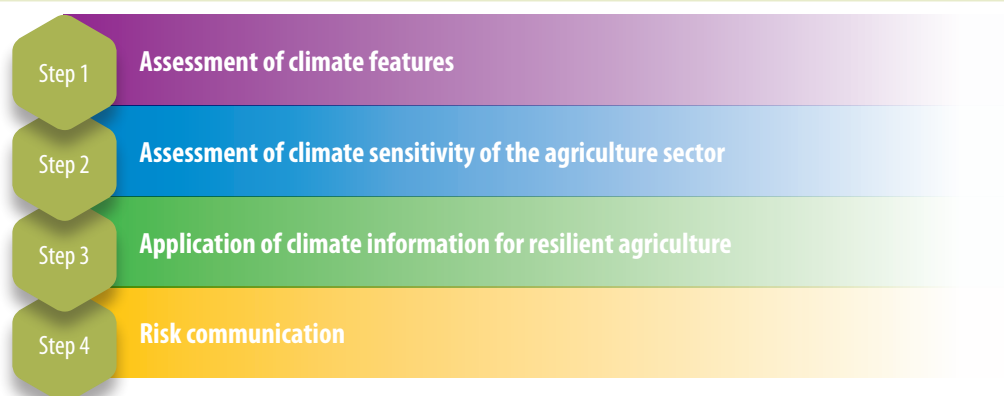
The CRM framework also entails application of climate information with seamless timescales (see figure 1) for decision-making purposes of different stakeholders.

Figure 1 Seamless integration of climate information



Source: World Meteorological Organization Strategic Plan 2012–2015.

Using climate and agriculture data from the Pacific subregion, the handbook adopts a step-wise process to guide climate risk assessments and management. There are four steps in the process and these are presented as modules, as shown in figure 2.

Figure 2 The step-wise process to guide climate risk assessment and management

The modules in this guide are structured as follows.

The first module in the assessment methodology deals with the assessment of climate features, which includes the following topics: climatology, climate drivers, observed climate trends over the recent 30-year period, projected climate change trends for the future and climate impacts on the agriculture sector.

The second module focuses on the assessment of climate sensitivity in the agriculture sector. The sensitivity of the agriculture sector is dealt with in three subsectors that are crops, livestock and fisheries.

The third module deals with the application of climate information for resilient agriculture, which covers the following topics: a general framework on the climate risk information system, agriculture risk management for observed climate variability and long-term climate changes and an in-depth description on application of climate forecast products in the agriculture sector.

Risk communication is featured in the fourth module, which is key to implementing the climate risk assessment to benefit end users. Climate risk management Farmer Field Schools, one of the good practices in communicating climate risk, are described using case studies. In addition, how the uncertainties in climate forecast products are dealt with in the risk communication process are also discussed.

Finally, the fifth module looks at the application of climate information in the planning process.



ASSESSMENT OF CLIMATE FEATURES

Climatology

Learning objective

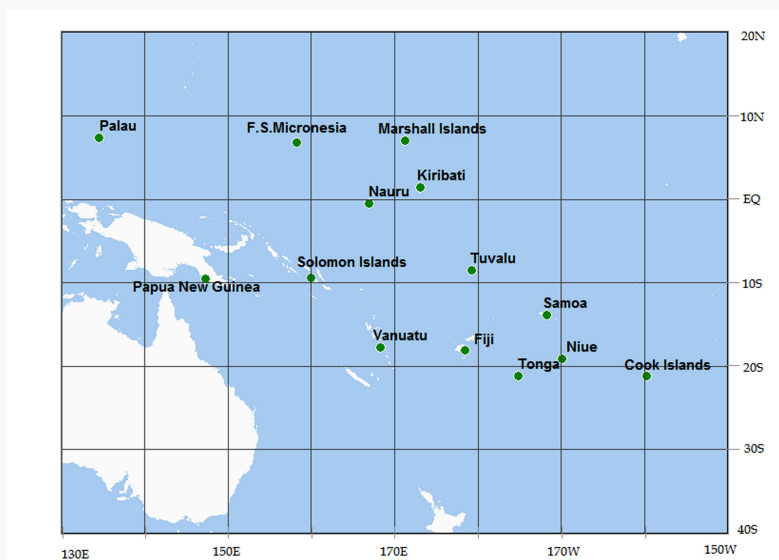
Familiarization with the weather and climate characteristics of Pacific small island countries

See
worksheet
on page
66

Geography

The small island developing States in the Pacific (SIDS) comprise thousands of islands in the Pacific Ocean, with a population of approximately 10 million, extending from 25°S to 15°N latitude and from 130°E to 150°W longitude (see figure 3). The Pacific SIDS include islands located at elevations as high as 13,000 feet above mean sea level and as low as a few feet above mean sea level (Finucane and others, 2012). The major source of income for the population comes from agriculture and fishing activities. Limited land availability and vast geographic locations leave no alternative for the population in the Pacific islands if agriculture and fisheries—their main sources of income generation—are damaged by climate hazards.

Figure 3 Map of selected Pacific island countries

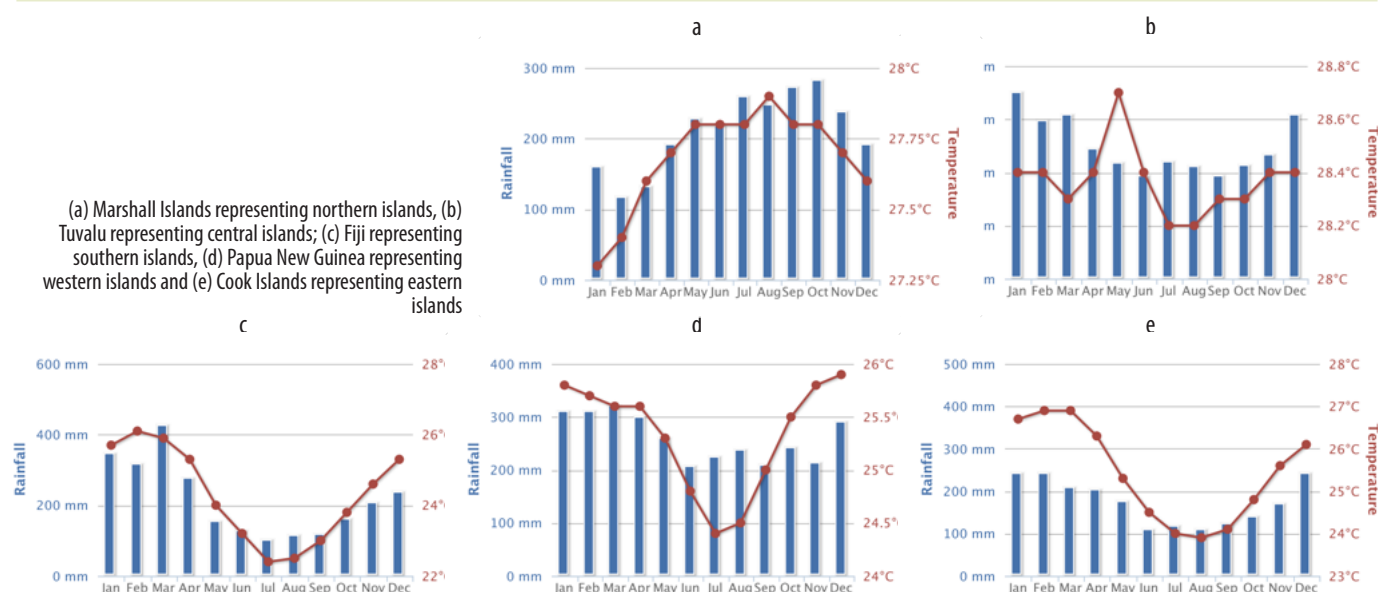


Temperature

The surface air temperature varies across the islands in the Pacific Ocean, from North to South as well as from West to East (see figures 4a–e). The surface air temperature in the islands closer to the equator has less fluctuation (1° – 2° °C) between the months in a year; for instance in Marshall Islands (see figure 4a). In addition, the variability increases (1° – 4° °C) as we go farther southward, for instance in Fiji (see figure 4c). Tonga in the South experiences a huge variation between months; for instance, the average summer to winter maximum and minimum air temperature ranges are more than 6° C (CSIRO, 2015).

Rainfall

Most of the Pacific SIDS have two major seasons: wet, from November to April and dry from May to October (see figures 4a–e). The central and southern islands have two major seasons: wet, from November to April and dry from May to October, with Papua New Guinea (see figure 4d) receiving much less rainfall, particularly during the dry season. The northern islands have a seasonal climate that is different from the central and southern islands, receiving higher rainfall during May to October. The western islands, covering Papua New Guinea, receive smaller amounts of rainfall, compared with islands in the eastern region (see figure 4d and 4e). The northern Marshall Islands, located in higher latitudes, have a seasonal climate that is different from the rest of the islands, receiving heavier rainfall from May to October.

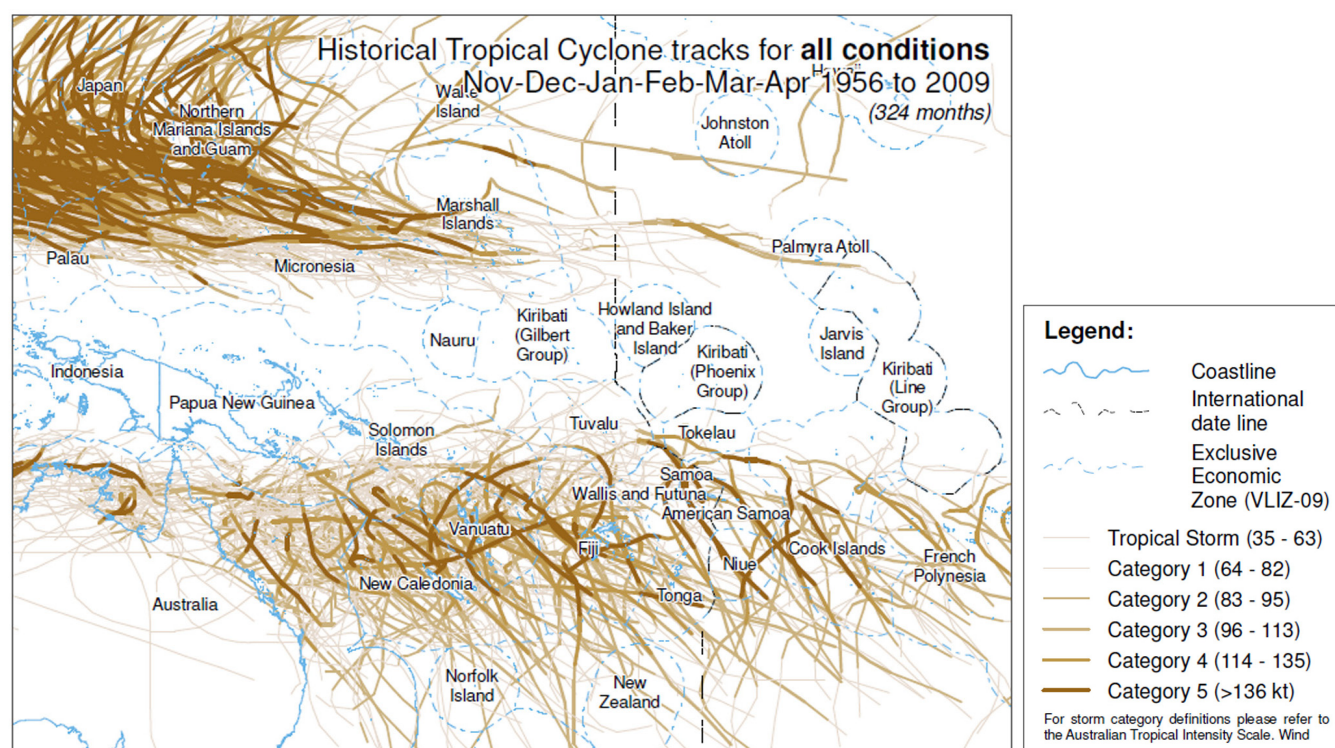
Figure 4 Monthly rainfall distribution for selected countries in the Pacific SIDS

Source: World Bank Climate Change Knowledge Portal. Available from <http://sdwebx.worldbank.org/climateportal/> (accessed 2 November 2016).

Tropical cyclones

Tropical cyclones pose a serious threat to the Pacific island countries (see figure 5), particularly during the months of November to April, when maximum wind speed reaches between 65 and 120 km per hour. The heavy winds, sudden downpours, flooding and storm surges associated with tropical cyclones cause large-scale damage to coastal infrastructure and the agriculture sector.

These tropical cyclones are the most common extreme weather events and result in the most damaging disasters in the Pacific subregion. They accounted for 76 per cent of reported disasters from 1950 to 2004, followed by earthquakes, droughts and floods. The average cyclone damage to economies of the Pacific SIDS during this period was US\$75.7 million in 2004 real value, as reported by the World Bank (2006). The spatial patterns of cyclone tracks and annual cyclone frequency (see table 1) indicate that Vanuatu, Fiji, Samoa, Solomon Islands and Tuvalu are the most affected by tropical cyclones.

Figure 5 Cyclone tracks in the South Pacific during November–April, 1956–2009

Source: OCHA, 2012.

Table 1 Climatology of tropical cyclones in selected Pacific islands, 1969–2014

Country	Average tropical cyclone occurrence in a year	Average severe tropical cyclone occurrence in a year
Kiribati	0.0	0.0
Solomon Islands	2.9	0.6
Vanuatu	1.7	0.9
Tuvalu	2.0	0.1
Fiji	2.1	0.8
Tokelau	1.1	0.2
Samoa	1.9	0.1
Tonga	0.5	0.5
Niue	0.3	0.1
Southern Cook Islands	0.3	0.4
Northern Cook Islands	0.5	0.2

Source: NIWA Outlook, 2015.

Sea-level rise

Many low-lying islands and coastal areas of the Pacific islands are vulnerable to sea-level rise, which can be short term, seasonal or long term. Short-term sea-level rise is mainly due to extreme events, such as storm surges, ocean waves and tsunamis. The seasonal fluctuations are often due to changing winds, pressure and ocean temperature patterns influenced by ENSO conditions. Sea-level rise brings coastal inundation in the Pacific islands and thereby poses huge threat to the populations and infrastructure in the region, as demonstrated by coastal flooding in 2008 (see box 1).

Box 1 The 2008 coastal flooding in the Pacific islands

In December 2008, the Federated States of Micronesia, Kiribati, the Marshall Islands, Papua New Guinea and Solomon Islands experienced severe sea-swell floods due to the following factors:

- High waves—Large swells ranging between 3 and 10 feet were generated due to low-pressure weather systems far to the North (near Wake Island). These waves coincided with higher-than-normal sea levels and caused damage.
- Seasonal high tides—During early to mid-December 2008, the tides were building to their spring stage. Though the first major storm hit a week prior to the spring peak, tide levels were still higher due to the twice-annual strengthening of local spring tides during November–February (as well as May–August).
- La Niña influenced higher sea levels—During La Niña conditions, the North-East trade winds are generally increased and bring higher sea levels in central and western Pacific, during the second half of the year. In December 2008, weak La Niña-like conditions existed, producing higher-than-normal sea levels.
- Long-term sea-level rise—Sea levels have risen about 7.87 inches (20 cm) in the western North Pacific subregion since the 1990s. This sea-level rise, the largest of any region in the world, is the result of a long-term increase in Pacific trade winds (Merrifield and Maltrud, 2011). It is similar to the effect of La Niña conditions but over a longer time frame.

These factors caused widespread damage on numerous low-lying islands, such as eroded beaches, damaged roads and flooded houses. A state of emergency was declared in Majuro, the capital of the Marshall Islands (Wannier, 2011) and in the Federated States of Micronesia (Fletcher and Richmond, 2010). Seawater contaminated aquifers, farms, wells and wetlands, damaging or destroying croplands and thus causing food shortages.

Over the years, as the countries were exposed to a rapidly globalizing economy and State enterprises and mechanisms faced challenges of efficiency, competition and corruption, both the controlled and mixed economic systems went through many changes. Economies were liberalized to permit private investments in a range of sectors and the governments became facilitators in promoting private investments and focusing more on basic issues of governance. Innovative mechanisms for public-private partnerships were developed, even for the delivery of public services.

Source: PIRCA, 2012; OCHA, 2008.

Climate drivers

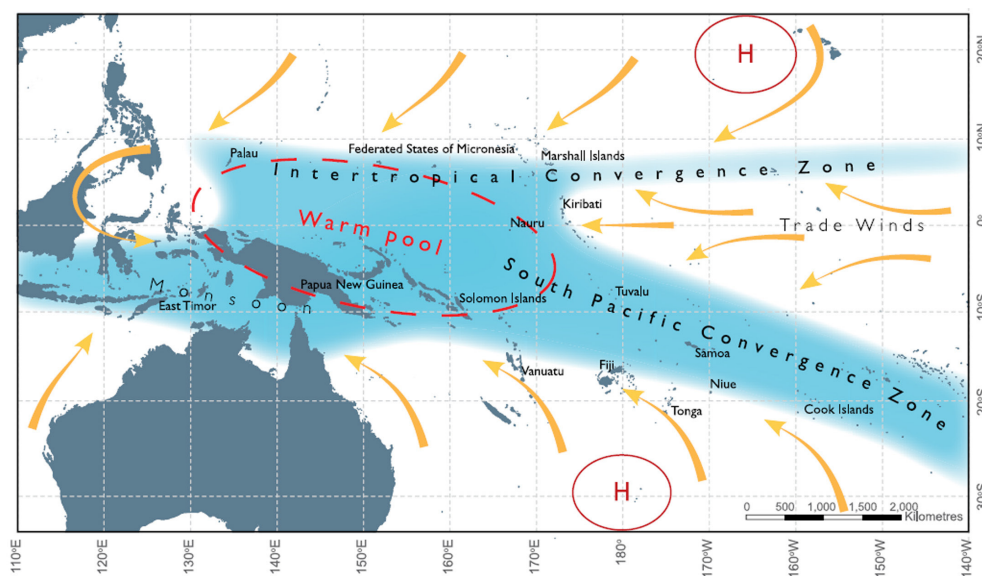
Learning objective

Understand the climate drivers of Pacific island countries, especially large-scale features that control the region's climate

See
worksheet
on page 67

The Pacific Ocean has a key role in controlling the regional and global climate because it occupies one third of the Earth's surface area. The presence of large-scale climate features and different-sized land masses leads to profound regional variations in climate. Understanding these large-scale climate features in the Pacific is essential to improve our understanding of local and global climate trends. Climate conditions are influenced by geographic location as well as the influence of one or more of the following climate drivers: El Niño Southern Oscillation (ENSO), the South Pacific Convergence Zone (SPCZ), the Inter-Tropical Convergence Zone (ITCZ), the West Pacific Monsoon (WPM), the Madden-Julian Oscillation and the Indian Ocean Dipole. The ITCZ, SPCZ and WPM features affect the regional pattern and seasonal cycle in rainfall, winds, tropical cyclone tracks and ocean currents (see figure 6 and table 2). ENSO is a major large-scale feature that causes year-to-year climate variations that result in profound impacts on the Pacific islands (CSIRO, 2015).

Figure 6 Map showing average positions of the SPCZ, ITCZ and WPM during November–April



Source: CSIRO, Australian Bureau of Meteorology and SPREP, 2015.

Note: The yellow arrows show near-surface winds and the red-dashed ovals indicate the West Pacific Warm Pool. H represents the typical positions of moving high-pressure systems.

Table 2 Climate drivers in selected Pacific SIDS

<i>Country</i>	<i>Major drivers</i>
Cook Islands	SPCZ, subtropical highs, trade winds, tropical cyclones, topography
Federated States of Micronesia	ITCZ, WPM, trade winds
Fiji	SPCZ, trade winds, subtropical highs, tropical cyclones, topography
Kiribati	ITCZ, SPCZ, trade winds
Marshall Islands	ITCZ, WPM (in some years), tropical cyclones
Nauru	ITCZ, SPCZ, trade winds
Niue	SPCZ, trade winds, subtropical highs, tropical cyclones
Palau	WPM, ITCZ, trade winds
Papua New Guinea	WPM, ITCZ, topography
Samoa	SPCZ, trade winds, subtropical highs, tropical cyclones, topography
Solomon Islands	SPCZ, WPM, tropical cyclones, topography
Tonga	SPCZ, trade winds, subtropical highs, tropical cyclones, topography
Tuvalu	WPM, SPCZ, trade winds, subtropical highs, tropical cyclones
Vanuatu	SPCZ, trade winds, subtropical highs, tropical cyclones, topography

Source: CSIRO, Australian Bureau of Meteorology and SPREP, 2015.

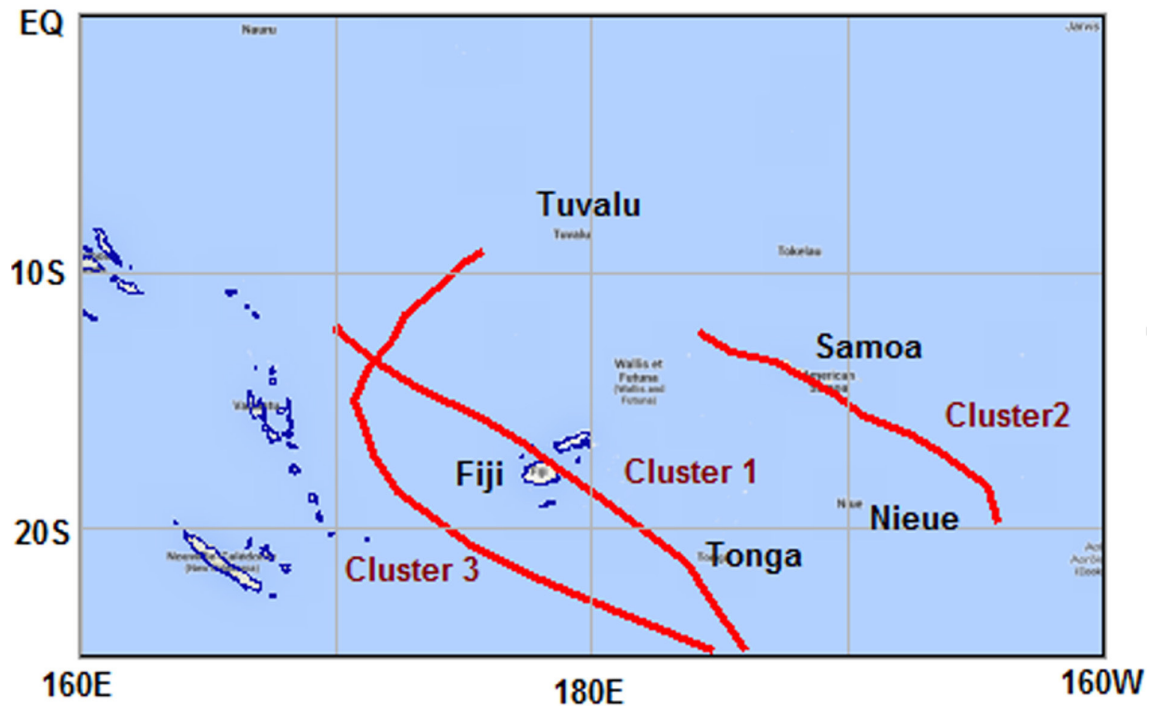
ENSO impacts on rainfall, cyclones and sea levels

El Niño is associated with suppressed rainfall in most of the Pacific SIDS, leading to droughts, increased tropical cyclone frequency and abnormal sea-level conditions. A strong El Niño causes dry conditions. La Niña brings the opposite weather patterns of El Niño in most of the Pacific islands—a wetter condition (see table 3). El Niño is a complex phenomenon and the impacts differ by region; for example, northern parts of these islands experience increased rainfall during an El Niño year, while southern parts experience decreased rainfall (Thomson, 2009).

Table 3 Summary of impacts of El Niño and La Niña, November–April in selected Pacific islands

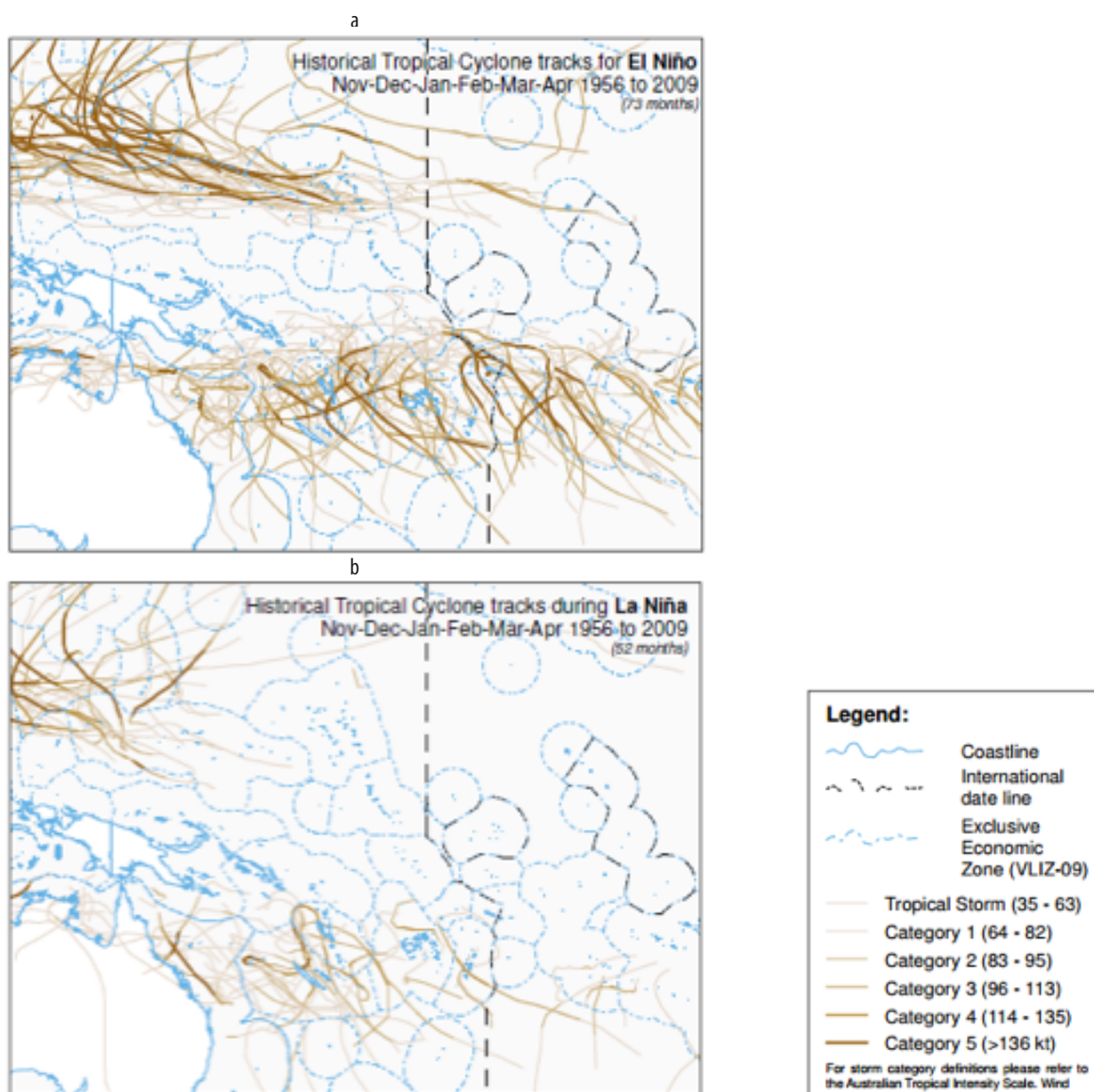
<i>Country</i>	<i>El Niño</i>	<i>La Niña</i>
Papua New Guinea	Dry	No consistent impact on rainfall
Fiji	Dry	Wet
Tonga	Dry	Wet
Vanuatu	Dry	Wet
Solomon Islands	Dry	Wet
Samoa	Dry	No consistent impact on rainfall

Source: CSIRO, Australian Bureau of Meteorology and SPREP, 2015.

Figure 7 Tropical cyclone clusters in the Fiji-Samoa-Tonga region

Source: Redrawn from Chand and Walsh, 2013.

Tropical cyclones in the region are grouped into three clusters, as shown in figure 7. About 75 per cent of Cluster 1 cyclones form at 10°S and 10°W of the dateline and move poleward to the East along a straight path, affecting Fiji and Tonga. Cluster 2 cyclones, which mainly affect Samoa, form at 8°S and 8°E of the dateline, also move poleward to the East along a straight path. Cluster 3 cyclones develop at 10°S, but closer to the equator and take a recurving path westward of Fiji, largely affecting areas west and south-west of Fiji. Cyclones in all three clusters are highly influenced by ENSO. El Niño displaces the genesis positions of Clusters 2 and 3 cyclones further north-east; La Niña displaces the genesis position of Cluster 1 cyclones towards west of 170°E (Chand and Walsh, 2013). In general, El Niño increases cyclone frequencies over the Pacific islands, compared with La Niña years (see figure 8).

Figure 8 Cyclone tracks in the South Pacific in November–April during (a) El Niño years and (b) La Niña years, 1956–2009

Source: World Bank Climate Change Knowledge Portal. Available from <http://sdwebx.worldbank.org/climateportal/> (accessed 2 November 2016).

The changes in trade wind patterns and temperature due to ENSO conditions in the Pacific cause sea-level changes of (more than 20 cm), depending on the time of year and location. ENSO-related changes in sea level generally occur over months to several years. As presented in table 4, El Niño causes a decrease in sea level in all countries—Fiji, Marshall Islands, Papua New Guinea, Samoa, Solomon Islands and Tuvalu. La Niña brings the opposite effect and causes an increase in sea level in all countries except the Solomon Islands.

Table 4 Summary of the impacts of El Niño and La Niña on sea level in selected Pacific islands

<i>Country</i>	<i>El Niño</i>	<i>Extreme El Niño</i>	<i>La Niña</i>
Papua New Guinea	▼	▼	▲
Fiji		▼	▲
Tuvalu	▼	▼	▲
Marshall Islands (North)	▼	▼	▲
Marshall Islands (South)	▼	▼	▲
Solomon Islands	▼	▼	▼
Samoa	▼	▼	▲

▼ - Decreased; ▲ - Increased

Source: CSIRO, Australian Bureau of Meteorology and SPREP, 2015.

Observed climate trends

Learning objective

Assess trends in climate variability on the parameters of rainfall, temperature, frequency of tropical cyclone and sea-level rise during the twentieth century



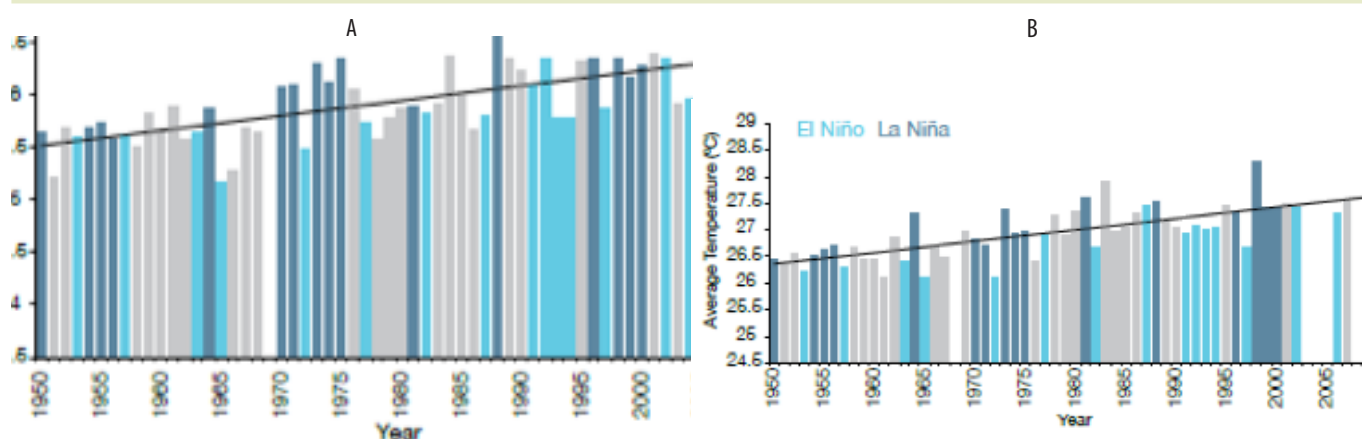
See worksheet on page 67

Climate-related hazards affecting large parts of populations and economies are evident in the past and are of growing concern. The variability in past climate provides baseline information to understand climate change. The trends in climate variability provide a signal of how climate is changing or fluctuating in a region for the instrumental period, which is during the past century. Depending on data availability, trends in variability can be assessed, which could be for 100 years or 50 years or at least a 30-year period. The long-term trends on climate variability in the Pacific islands discussed in this section are inferred from available literature and online tools, such as the World Bank Historical Climate Variability Tool.

Temperature

The long-term annual mean temperature trend across the Pacific subregion indicates an average increase in temperature of 0.9°C from 1961 to 2001. Among the stations, Fiji exhibited the lowest decadal change, at 0.25°C and French Polynesia exhibited the highest decadal change, at 1.7°C (CSIRO, 2015). The annual mean temperature variability between 1950 and 2010 for Fiji and Papua New Guinea (see figure 9) indicates an increasing trend of temperature. The extreme temperature is critical, because the sudden increase in temperature has the greatest impacts on societies and the natural and managed systems they rely on (SPC, 2016).

The sensitiveness of extreme temperature should be understood in order to incorporate it in a climate risk assessment. For example, the warming trends in overnight (minimum) temperatures and daytime (maximum) temperatures are higher in the western tropical Pacific than in the North-West Pacific and the subtropical South Pacific (CSIRO, 2015).

Figure 9 Trends in annual average temperature for (a) Fiji and (b) Papua New Guinea

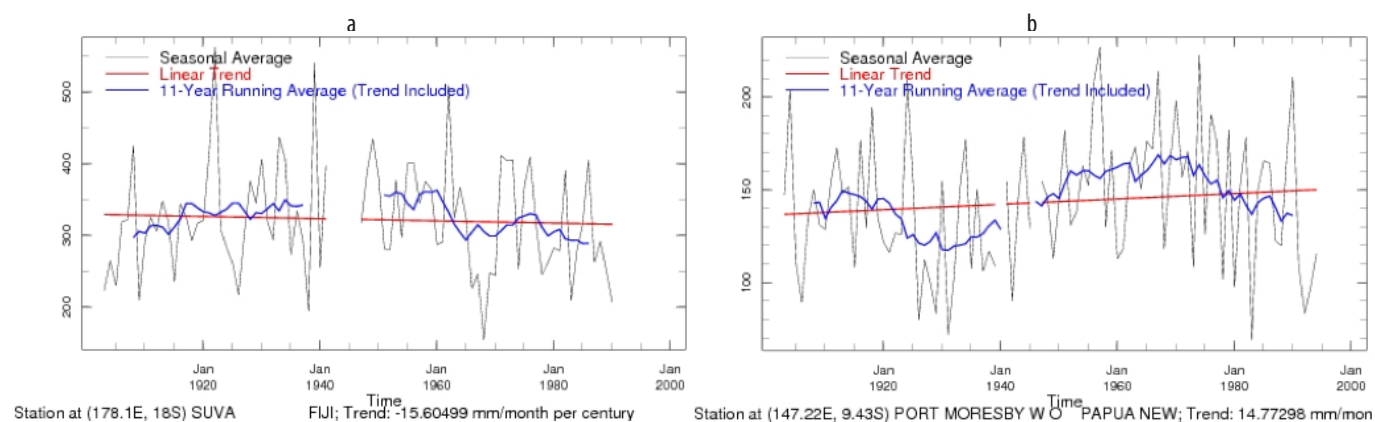
Light blue bars indicate El Niño years, dark blue bars indicate La Niña years and grey bars indicate neutral years.

Source: PCCSP, 2013a and b.

Note: Light blue bars indicate El Niño years, dark blue bars indicate La Niña years and grey bars indicate neutral years.

Rainfall

Detecting rainfall trends is not as straightforward as detecting temperature trends because of its distribution. The short-term trend analysis of rainfall for 1961–2011 does not reveal any trends, but the longer-term trends exhibit a pattern over the past three decades (1981–2011). An increased rainfall condition is evident over the South-West Pacific and decreased rainfall is evident in Central Pacific, which could be due to South Pacific Convergence Zone (CSIRO, 2015). The seasonal (November–April) rainfall over Fiji and Papua New Guinea for 1900–2000 (see figure 10) exhibits a decreased rainfall trend for Fiji but an increased rainfall trend for Papua New Guinea. These trends might vary between stations; a careful interpretation should be made because of the huge spatial and temporal variability existing in rainfall data across the globe.

Figure 10 Trends in seasonal (November–April) rainfall for (a) Fiji and (b) Papua New Guinea

Sea surface temperature

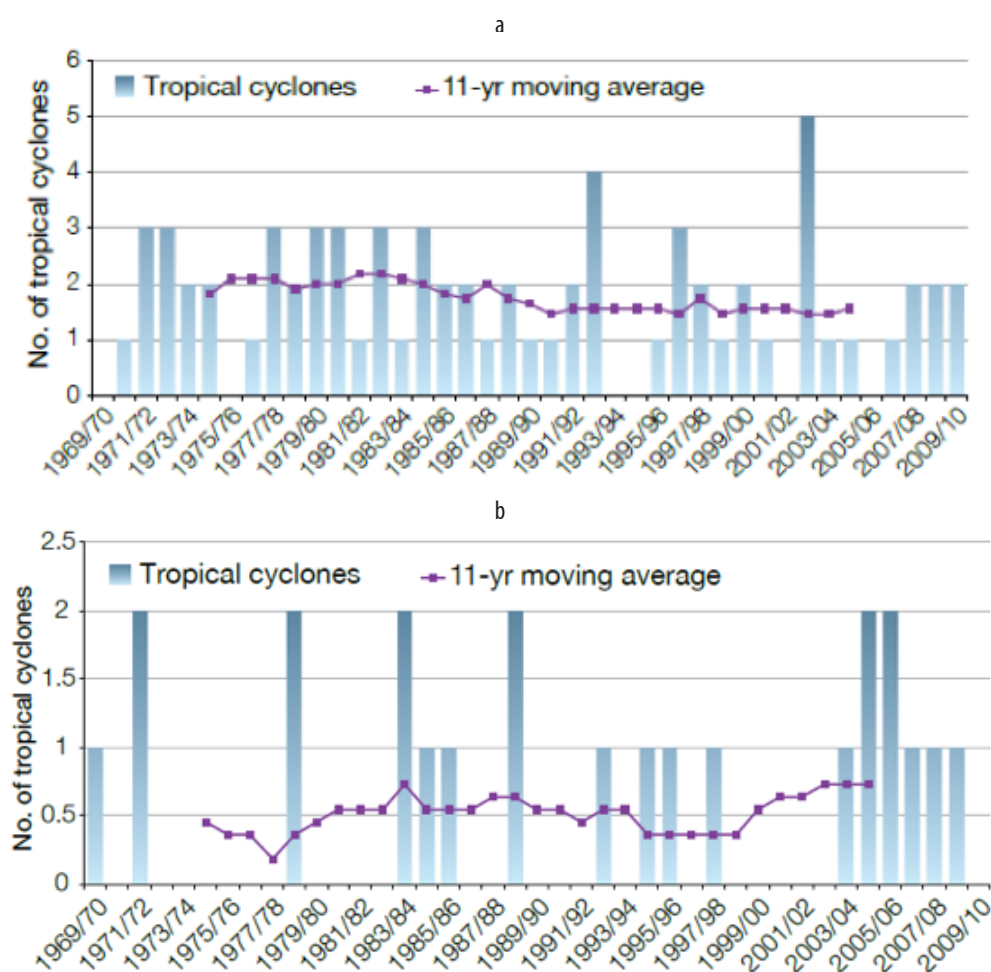
Source: World Bank Historical Climate Variability Tool, 2016.

Note: Sea surface temperature

The sea surface temperature is equally important as surface-air temperature in the Pacific, because of the region's unique geographical context. The inter-annual variability of the sea surface temperature is driven by ENSO conditions (L'Heureux and others, 2013), which is a large-scale oceanic phenomenon with a three- to seven-year cycle. Depending on the ENSO condition, the warm and cold pool of water movements between the eastern and western tropical Pacific causes variation in sea surface temperature over the ocean (CSIRO, 2015). Guan and Nigam (2008) reported that sea surface temperature cooling was found in the central equatorial Pacific amid widespread but non-uniform warming in all basins during the twentieth century.

Tropical cyclones

Although the trends in frequency of tropical cyclones across the Pacific during the cyclone season between 1970 and 2010 indicate that there is a reduction in the general number of cyclones, their intensity has been increasing in recent decades (CSIRO, 2015). The pattern is evident in Fiji and Papua New Guinea (see figure 11). At the same time, the record is too short to determine if this decrease in frequency is the result of a trend or if it is due to natural variability (PCCSP, 2013a and 2013b).

Figure 11 Trends in frequency of tropical cyclones for (a) Fiji and (b) Papua New Guinea

Source: PCCSP, 2013a and 2013b.

Sea-level rise

The observed trends in sea level from satellite records of the early 1990s to the present indicate that the global average has been rising at 3.2 ± 0.4 mm per year. The reconstructed sea-level data also indicate that global averaged sea-level data confirm the satellite record, and indicate that global averaged sea-level has been rising at about 1.7 ± 0.2 mm per year since 1900 (PCCSP, 2013a and 2013b).

The Marshall Islands has experienced sea-level rise of about 7 mm per year since 1993, which is much larger than the global average of 2.8–3.6 mm per year (PCCSP, 2013c). Similarly, Albert and others reported in 2016 that the Solomon Islands had experienced sea-level rise of 10 mm per year at certain locations. For instance, Nuatambu Island, home to 25 families, had lost 11 houses and half of its inhabitable area since 2011 and many uninhabited islands had washed away.

Climate change projection scenarios

Learning objective

Inter-region and country-specific climate change projection scenarios for the parameters of rainfall, temperature, frequency of tropical cyclones and sea-level rise

See
worksheet
on page 68

Climate change poses a huge risk for the Pacific islands, especially to the lives and livelihoods in the low-lying islands that are threatened due to likely changes in temperature, rainfall patterns, sea level and the frequency of cyclones. Global climate models, regional climate models and downscaled location-specific climate change products are important tools for studying climate change and making projections for future scenarios in the Pacific subregion.

Considering the geographical context, downscaled climate change projections give realistic representations for the Pacific islands. Based on available literature and online tools, this section discusses climate change projection scenarios. Table 5 presents projected climate change scenarios (for air temperature, rainfall and tropical cyclones) for Pacific SIDS under various representative concentration pathways scenarios. This is a generalized scenario for the Pacific islands; country-specific climate change projections should be derived from downscaled climate change products.

Table 5 Summary of future climate change scenarios in the Pacific islands countries

Parameter	RCP	2030	2050	2090
Air temperature (in degree Celsius)	RCP2.6	0.75	0.75	0.75
	RCP4.5	0.75	1.0	1.5
	RCP6.0	0.75	1.0	2.2
	RCP8.5	0.75	1.5	3.0
Temperature extremes	Becoming more frequent and intense through 21st century and higher emission scenarios.		One in 20-year extreme daily temperature will be 2°–4°C warmer than present extremes RCP8.5.	

Parameter	RCP	2030	2050	2090
Rainfall	RCP2.6	Becoming wetter across much of region, especially near-equatorial Kiribati and Nauru, with magnitude of change increasing through the 21st century and higher emissions scenarios.		
Drier French Polynesia and Pitcairn Islands	RCP4.5			
	RCP6.0			
	RCP8.5			
Rainfall extremes		Becoming more frequent and intense through the 21st century and higher emissions scenarios.		
Tropical cyclones		Similar number or fewer tropical cyclones but those that occur will be more intense.		
Sea -level rise (in cm)	RCP 2.6		24	40
	RCP 4.5		26	47
	RCP 6.0		25	48
	RCP 8.5		30	63

Source: SPC, 2016.

Note: The following islands are included in the climate change assessment: American Samoa, Cook Islands, Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Pitcairn Islands, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna.

RCP = representative concentration pathways.

The country-specific climate change scenarios are available from CSIRO, the Australian Bureau of Meteorology and SPREP. Scenarios are presented for five islands: Marshall Islands, Papua New Guinea, Cook Islands, Tuvalu and Fiji, representing the different geographical regions in the Pacific Ocean (see table 6). All the countries listed in the table are expected to experience an increase in annual mean temperatures as well as an increase in average rainfall. Sea level will continue to rise. The projections also show that tropical cyclones may become less frequent, although their intensity is expected to increase, with potentially severe impacts.

Table 6 Country-specific future climate change scenarios

<i>Country</i>	<i>Air temperature</i>	<i>Rainfall</i>	<i>Tropical cyclones</i>	<i>Sea-level rise</i>
Marshall Islands	Increase in annual mean temperatures and extremely high daily temperatures.	Average rainfall is projected to increase, along with more extreme rain events. Droughts are projected to decline in frequency.	Less frequent but more intense.	Sea level will continue to rise. Wave height is projected to decrease in the dry season, and wave direction may become more variable in the wet season.
Papua New Guinea	Increase in annual mean temperatures and extremely high daily temperatures.	Average rainfall is projected to increase in most areas, along with more extreme rain events. Droughts are projected to decline in frequency.	Less frequent but more intense.	Sea level will continue to rise. No changes in waves along the Coral Sea coast are projected, while on the northern coasts, December–March wave heights and periods are projected to decrease.
Fiji	Increase in annual mean temperatures and extremely high daily temperatures.	Little change in annual rainfall but an increase in the wet season, with more extreme rain events. The proportion of time in drought is projected to decrease slightly.	Less frequent but more intense.	Sea level will continue to rise. Wave height is projected to decrease across the area in the wet season, with a possible small increase in dry season wave heights.
Cook Islands	Increase in annual mean temperatures and extremely high daily temperatures.	Average annual rainfall is projected to stay similar to the current climate, except for a small decrease in the dry season in the northern Cook Islands under the high emissions scenario, with more extreme rain events. Drought frequency is projected to remain similar to the current climate in the southern Cook Islands, but increase slightly in the northern Cook Islands under the high emissions scenario.	Less frequent but more intense.	Sea level will continue to rise. Wave climate is not projected to change significantly.
Tuvalu	Increase in annual mean temperatures and extremely high daily temperatures.	Little change in annual rainfall with more extreme rain events. Incidence of drought is projected to decrease slightly.	Less frequent but more intense.	Sea level will continue to rise. December–March wave heights and periods are projected to decrease slightly.

Source: CSIRO, Australian Bureau of Meteorology and SPREP, 2015.

Climate impacts on the agriculture sector

Learning objective

Understand the agriculture sector impacts from: (a) climate hazards (such as extreme rainfall, drought and cyclones), (b) climate variability in the recent decades and (c) modelled future climate scenarios

See
worksheet
on page 69

The economies of the Pacific islands are highly vulnerable to cyclones, droughts and rising sea level in addition to external shocks in the world market (Malua, 2003). The risk to the agriculture sector is caused by two types of hazards (see table 7): (1) Sudden, unforeseen events (for example, windstorms or heavy rain) and (2) cumulative events that occur over an extended period (for example, drought). The impacts from either hazard vary widely according to crop type, variety and timing of occurrences (World Bank, n.d.).

Table 7 Climate hazards and impacts on the agriculture sector

Hazard	Impacts
Drought (rainfall deficit)	Extended dry conditions and poor availability of water affects cropping area and productivity.
Excess rainfall and flood	Excess rainfall and flooding cause direct damage to crops. For example, waterlogging makes root crops (sweet potato, yam) rot.
Wind storm	Strong winds from tropical cyclones cause huge permanent damage to export crops and uproot trees.
High temperatures	Increasing temperatures and in some areas reduced rainfall will stress native Pacific island plant and animal populations and species, especially in high-elevation ecosystems, with increased exposure to non-native biological invasions and fire. Extinctions may result.
Sea-level rise	Coastal inundation damaging infrastructure and crop lands, eroding the soil.
Saltwater intrusion	Saltwater affects crop lands and freshwater aquifers.

Source: PIRCA, 2012; SPC, 2016.

The impacts observed in the agriculture sector due to natural hazards are slowing down economic growth in the Pacific SIDS, which is setting back their level of development by as much as ten years (Malua, 2003). The Secretariat of the Pacific Community's 2016 report, *Vulnerability of Pacific Island Agriculture and Forestry to Climate Change*, classified the Pacific island countries and territories into three groups based on importance of the agriculture sector and its vulnerability towards climate risk (see table 8).

Table 8 The agriculture sector and its vulnerability to climate risk in Pacific island countries and territories

<i>Countries</i>	<i>Agriculture's role in livelihood, export market & economic growth</i>	<i>Vulnerability towards climate risk</i>
Group 1: Melanesia (Fiji, Papua New Guinea, Solomon Islands and Vanuatu)	Major importance	Major
Group 2: Polynesia (Samoa and Tonga)	Moderate importance	Moderate
Group 3: The States (Tuvalu, Kiribati and others)	Minor importance	Minor

Source: SPC, 2016.

The impacts observed in the agriculture sector can lead to serious socioeconomic implications because subsistence agriculture contributes towards a significant component of GDP in the following Pacific island countries: Papua New Guinea, Solomon Islands, Fiji, Vanuatu and Cook Islands. In the past, a reduced wet season had large-scale impacts on subsistence agriculture, causing a loss of cash income and reducing people's ability to support themselves (see table 9). Seawater inundation of agricultural lands from surge associated with tropical cyclones rendered these lands unproductive. Recovery often took several years (three years for Cook Islands, for instance) (FAO, 2008).

Table 9 Selected historical impacts of climate hazards on agriculture

<i>Country</i>	<i>Observed impacts</i>
Floods	During 2009, the western islands received more than 45 cm of rain in 24 hours that resulted in severe flooding of up to 3–5 mts and severely damaged agriculture and infrastructure worth FJ\$100 million (SPC, 2010)
Drought	<p>Fiji—Drought in 1997–1998 caused a 26 per cent decline in sugarcane production and led to a decline in GDP by at least 1.3 per cent (World Bank, n.d.); losses from livestock death amounted to around US\$7 million (McKenzie and others, 2005).</p> <p>Papua New Guinea—The 1997–1998 drought severely affected subsistence farming and significantly affected the production of coffee and cocoa. About one million people suffered from food insecurity due to failure of food crops. The Australian Government provided AU\$30 million in food aid to areas affected by drought (SPC, n.d.).</p>

Country	Observed impacts
	Samoa—Drought-associated forest fires during the dry seasons of 1982–1983, 1997–1998, 2001–2002 and 2002–2003 (Australian Bureau of Meteorology and CSIRO, 2011).
	Tonga—Severe droughts in 1983, 1998 and 2006 caused stunted growth in sweet potatoes and coconuts; the livestock sector, particularly swine, were badly affected (Tonga, 2012).
Tropical cyclones	<p>Cyclones in the southern Pacific Ocean heavily impacted the Pacific islands. During 1950 to 2004, about 207 extreme events were recorded in the Pacific subregion. The cost of climate-related disasters on agricultural crops was estimated to range from US\$13.8 million to US\$14.2 million.</p> <p>In 2004, Cyclone Ivy affected more than 80 per cent of food crops in Vanuatu while Cyclone Val hit Samoa in 1991 with maximum wind speeds of 140 knots causing massive damage; the damages were equivalent to 230 per cent of the country's real 2004 GDP (World Bank, 2006).</p> <p>In 2016, Cyclone Winston hit Fiji, where the damage to the agriculture sector was estimated at FJ\$208.3 million. The damage included crops, livestock and infrastructure. However, the estimates did not include the sugar sector due to a lack of information about economic damage in the sugarcane sector (PIFON, 2016).</p>
Saltwater intrusion	<p>In Marshall Islands, saltwater intrusion polluted the groundwater during the 1997–1998 El Niño.</p> <p>In Palau, the saltwater intrusion associated with high tides caused extensive damage to taro crops (losses from 75 up to 100 per cent) in 1998 (Berthe and others, 2014).</p>

Source: Cited in ESCAP and RIMES, 2014.

Impacts of observed climate variability on crops in Pacific island countries

Table 10 Historical impacts of climate change and climate variability on staple crops in Pacific islands countries

Crop	Impacts
Sweet potato	ENSO-induced droughts have decreased production, particularly in Papua New Guinea.
Mango	Climate variability adversely affected the fruit production in some locations but improved it in others. Rising temperatures are making some locations that were previously too cold for mango production more suitable.
Sugarcane	Severe impacts of cyclones, floods and droughts associated with ENSO cycles, although, it is unclear what the contribution of climate change has been.
Coconut	Main impact has been loss of palm trees growing close to the sea and cyclones breaking senile palms.

Source: SPC, 2016.

Potential climate change impacts on the agriculture sector in Pacific island countries

Table 11 Potential impact of future climate change scenarios on staple crops of Pacific islands

<i>Crop</i>	<i>The impact of climate change over the next two to three decades (2030–2050)</i>	<i>The impact of climate change beyond 2050</i>
Sweet potato	Impact on tuberization and yield will be greatest in those countries where rainfall is already high and where temperature is currently around 32°C. Impact on pests and diseases is unclear—possibly increased pressure from sweet potato scab. Overall production assessment impact: Moderate	Increasingly serious impact for those countries where there is currently high rainfall and temperature, especially with a high emissions scenario. The impact on pests and diseases is unclear. Overall production assessment impact: Moderate to high
Mango	Fruit sets will continue to be adversely affected by unpredictable rains and temperature fluctuations during winter months. Reduction of fruit quality could result from frequent rains. Increasing problems with anthracnose are possible. Overall production and economic impact assessment: Low to moderate	Mango production will be negatively impacted by increasing intensity of cyclones. Unpredictable rains could also have a significant impact. Possible increasing mango fly problems. High temperatures could affect flowering. Overall production and economic impact assessment: Moderate
Coconut	No major effect is expected until at least 2050. The main impact will be from the expected increased intensity of cyclones on the increasingly senile population of coconut palms. Overall production and economic impact assessment: Low	The likelihood of increasingly severe cyclones could have severe impact on coconut production. Rainfall could reduce production, especially in areas where rainfall and cloud cover are already relatively high. The impact of major pests and diseases is unclear; effectiveness of biocontrol agents for rhinoceros beetle could be reduced. Overall production and economic impact assessment: Low to moderate
Sugarcane	ENSO cycles will continue to have a significant impact on Fiji's sugar production. Increased interaction with climate change expected, but climate change is likely to be a minor factor contributing to the decline of the industry, compared with other factors. Overall production and economic impact assessment: Small production; insignificant economic impact	Unlikely that a 2°C increase in average temperature will have any major impact, but more severe cyclones, floods and droughts would have a significant impact. Overall production and economic impact assessment: Moderate production; small economic impact

Source: SPC, 2016.



ASSESSMENT OF CLIMATE SENSITIVITY OF THE AGRICULTURE SECTOR

Crops

Learning objective

Understand the climate sensitivity of various crops by analysing the cropping system, crop calendar and climate-related risks at various stages of cropping

See
worksheet
on page 70

The impacts of climate hazards on the agriculture sector depend on the combination of two factors: (1) the characteristics of the climate hazard and (2) the type and stage of crops.

Constructing the details of the cropping system, crop calendar and weather patterns can help characterize the historical climate sensitivity of crops. The selected crops grown in the Pacific islands and the climate sensitivities are discussed in this section. A case study from the Pacific islands demonstrates how the thresholds of climate sensitivity on stages of crops are characterized and used for decision-making purposes in agricultural operations.

The crops grown in Pacific island countries and territories are classified into three types: staple food crops, high-value horticulture crops and export commodities (see table 12).

Table 12 Crops grown in Pacific islands and territories

<i>Crop type</i>	<i>Crops</i>
Staple food crops	Banana, breadfruit, sweet potato, rice and taro
High-value horticulture crops	Citrus, pineapple, mango, tomato and papaya
Export commodities	Oil palm, coconut, sugar, cocoa and coffee

Source: SPC, 2016.

Agricultural activity is a primary source of income for households in the Pacific. Climate hazards (flood, drought, cyclones) that affect crop production have critical impact on the socioeconomic conditions of the Pacific island countries. Based on the 2016 Secretariat of the Pacific Community, table 13 explains the optimal climatic condition and climate sensitivity for selected crops.

The deviation of the optimal climatic condition and climate sensitivity helps practitioners interpret what the likely impact will be if the climate forecast is available. This will guide practitioners in preparing strategies that can be used to minimize the negative impacts.

Table 13 Optimal and vulnerable climatic conditions for selected crops in the Pacific islands

<i>Crop</i>	<i>Optimal growing condition</i>	<i>Climate sensitivity</i>
Sweet potato (STAPLE CROP)	<p>Good yield—High sunshine, an average temperature of 24°C or more and well distributed annual rainfall of 1,000 to 2,000 mm (Lebot, 2009).</p> <p>Greatest storage root weight—grown at a constant soil temperature of 30°C, combined with an air temperature of 25°C at night (Spence and Humphries, 1972).</p>	<p>Tuber formation is impaired when air temperature exceeds 34°C (Bourke, 2013).</p> <p>Temperature in major growing areas in the Papua New Guinea highlands can fall below the minimum threshold (10°C), particularly during drought periods and cause production loss and food insecurity.</p> <p>The low-growing habit of sweet potato helps the crop to withstand cyclones. Once established, it is also reasonably tolerant of drought but not to flooding or sea surge.</p>
Mango (HIGH-VALUE HORTICULTURE CROP)	<p>Optimum temperature range for mango production is 24°–27 °C (Bally, 2006), with flowering bud induction promoted by a period of cool weather (Nunez-Elisia and Davenport, 1994). The maximum temperature of the warmest month may be a limiting factor for mango cultivation and will vary between varieties.</p> <p>The mango originated in a monsoonal tropical environment and is well suited to many parts of the Pacific island countries and territories, particularly the leeward sides of islands with a distinct dry season.</p> <p>The mean annual rainfall range is 400–3,600 mm, with a dry period that lasts from one to two months (Bally, 2006). Low rainfall during fruit development and maturity is critical for achieving disease-free fruit.</p>	<p>The most likely impacts of climate change on mango production relates to the unpredictable rains and temperature fluctuations occurring during winter months when trees are flowering, which adversely affect fruit set.</p> <p>Similarly, frequent pre-wet season rains encourage anthracnose, which affects fruit quality and therefore its market value.</p> <p>Cool temperatures below 17°C produce abnormal and non-viable pollen grains in mangoes.</p>
Coconut (EXPORT COMMODITY)	<p>Mean temperature of 28°C, a maximum of not more than 34°C and minimum of not less than 22°C (Foale and Harries, 2011).</p> <p>A diurnal variation of 6°–7°C is ideal.</p> <p>Preferably the relative humidity should be more than 60 per cent, with no prolonged water deficit or excess soil salinity.</p> <p>Evenly distributed rainfall of 1,000–2,250 mm annually, but can tolerate higher rainfall if soils are well drained.</p>	<p>The gusts of 240 km per hour winds are sufficient to fell the normally cyclone-resistant tall coconut trees in Fiji.</p> <p>Nut setting is the most important yield-determining factor in coconut crop and reduced nut setting due to heat stress and long dry spells is often experienced in coconut plantations in the dry-intermediate and dry zones, even those under irrigation.</p> <p>High temperatures, low relative humidity and a high vapour pressure deficit at the stage of pollination may result in pollen drying, consequently resulting in reduced nut set. The degree of sensitivity to high temperature can vary with the variety, depending on their tolerance to stress.</p>

<i>Crop</i>	<i>Optimal growing condition</i>	<i>Climate sensitivity</i>
Sugarcane (EXPORT COMMODITY)	Long, warm growing season with a high incidence of solar radiation and adequate moisture (rainfall).	Vulnerable to severe droughts that occur during the growing period.
	Fairly dry, sunny and cool, but frost-free season for ripening and harvesting.	Flooding would adversely impact production during harvesting.
	Total rainfall between 1,100 and 1,500 mm is adequate, provided that rainfall is abundant in the months of vegetative growth, followed by a dry period for ripening. During the active growth period, rainfall encourages rapid cane growth, cane elongation and internode formation.	High temperatures (greater than 38°C) reduce the rate of photosynthesis and increase respiration.
	Cool night and early morning temperatures (14°C in winter and 20°C in summer) significantly inhibit photosynthesis the next day.	At higher temperatures, reversion of sucrose into fructose and glucose may occur.
	High humidity (80–85 per cent) favours rapid cane elongation during the main growth period; 45–65 per cent with limited water supply is favourable during the ripening phase.	Extreme rainfall leading to prolonged flooding has serious implications for sugar.
	The absence of cyclones.	During the ripening period, heavy rainfall is not desirable because it leads to poor juice quality, encourages vegetative growth, formation of water shoots and an increase in tissue moisture. It also hampers harvesting and transport operations.

Source: Cited in SPC, 2016.

The assessment of weather characteristics and the cropping pattern are critical to understand the climate sensitivity of a crop in an island. Table 14 presents an example of how to assess annual weather characteristics and related farming practices in Vanuatu.

Case studies on the crop-weather calendar as well as climate sensitivity for root crops in Emae Island of Vanuatu are discussed in box 2 and box 3, respectively.

Table 14 Annual weather characteristics and farming practices in Vanuatu

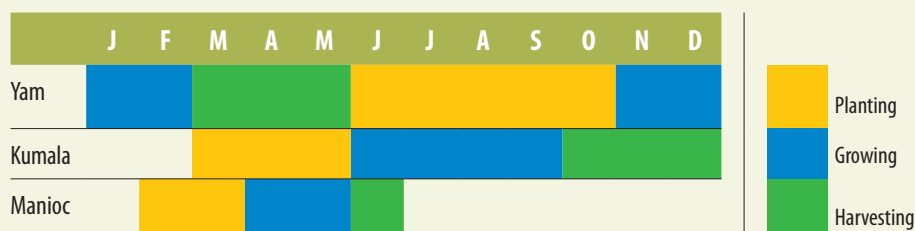
<i>Months</i>	<i>Crop-weather calendar</i>	<i>Potential impacts of extreme weather on crops</i>	<i>Potential adaptive practices to implement with climate forecast</i>
January	Little bird and animal activity. Rain and cyclone season. North-east trade winds bring cyclones.	No impacts.	No action required.
February	Little bird and animal activity. Rain and cyclone season. Fruits (nandau) ready for picking. North-east trade winds bring rough or calm seas.	Damage to nandau fruits due to cyclone.	Pluck fruits before cyclone damages them.
March	Vegetative regrowth. Reef covered with brown seaweed. Nakavika fruits ready for picking. North-east trade winds bring rough or calm sea. Rain and cyclone season still ongoing.	Damage to nakavika fruits due to cyclone.	Pluck fruits before cyclone damages them.

<i>Months</i>	<i>Crop-weather calendar</i>	<i>Potential impacts of extreme weather on calendar</i>	<i>Potential adaptive practices to implement with climate forecast</i>
April	Harvesting of new yam. Orange, mandarin, sugarcane and nakatambol ready for picking. North-east trade winds bring rough or calm sea. Last month of rainy season.	Harvest gets affected.	Early harvest is recommended.
May	Best yams and fruits selected for offerings to the gods. North-east trade winds brings rough or calm sea.	Harvest gets affected.	Early harvest is recommended.
June	Last harvest and selection of yams for subsistence and custom ceremonies. Mango begins fruiting season. West trade winds bring rough or calm seas. Start of dry season.	Harvest gets affected.	Early harvest is recommended.
July	Clearing of new garden sites. Beginning of dry season. Nights become cold.	Trees, including natavoa, banyan and blue water, begin losing leaves.	No action required.
August	Preparation of land for new garden (ploughing, etc.). Start of breeding season for birds. North-east trade winds bring cold nights.	No impacts.	Land preparation.
September	Beginning of yam-growing season. Emerging of yam vines. Yam staking. Trees begin growing new leaves. South-east trade winds. End of dry season.	Delay in yam growth if it is wet.	Avoid water logging in crop lands.
October	Yam at peak growth. Stakes, poles and beds are fully covered with yam vines. Trees begin growing new leaves. Start of rainy season. Small sporadic rains.	Growth gets affected due to excess dry or wet conditions.	Avoid dry condition or excess water logging in crop lands.
November	Nantau and nakavika starts flowering. Start of cyclone season.	Period of food shortage.	Increase reliance on banana and manioc.
December	Manioc and taro in Fiji. Mango and namambe begin flowering.	Period of food shortage.	Population revisits old garden sites for root crops.

Source: Willie Lau cited in FAO, 2013.

Box 2 Case study: Crop calendar in Emae Island, Vanuatu for selected crops

The crop calendar of selected root crops in Emae Island is presented in the table below and some of the crop details are given as bullet points.



Yam is planted between July and October. It can be planted as late as December. Planting between July and October gives the plant sufficient time to establish itself before the wet season. In addition, yam dominance is naturally broken during this period. Planting at this period also ensures that the plant is strong and able to withstand anthracnose disease during the wet season.

Kumala is grown throughout the year. However, tuber formation is poor during wet season. Hence, planting from November to February does not allow for good tuber formation because vegetative growth is high. Planting March to June allows the plant to establish itself before the onset of dry season in August. The plant needs the dry season for tuber formation. February to March is the optimum planting period. This is prior to the dry period. The end of the wet season provides sufficient time for Kumala to establish itself before the onset of the dry season. The plant needs the dry season for tuber formation.

Source: FAO, 2013.

Box 3 Case study: Climate sensitivity of Kumala in Emae Island, Vanuatu

In Vanuatu, Kumala is grown throughout the year, but the planting season is from July to October and the harvesting season is from May to June. Kumala grows best with an average ambient temperature of 24°C and requires sunlight and warm nights. The plant needs annual rainfall of 750–1,000 mm with 500 mm in the growing season. At the tuber initiation stage (50–60 days) after planting, the plant is sensitive to drought. It cannot tolerate waterlogging either. Excess water in the soil and poor aeration causes root rot. Tuber formation is poor during the wet season, hence planting it during November to February does not allow for good tuber formation. The plant needs the dry season for tuber formation. Vegetative growth is high and therefore planting March to June allows the plant to establish itself before the onset of the dry season in August.

Source: FAO, 2013.

Livestock

Learning objective

Characterize the climate sensitivity of the livestock sector by understanding the optimal and vulnerable climate conditions



See
worksheet
on page 71

The practice of livestock rearing exists in most countries in the Pacific. At the national level, livestock is a major source of food security and employment and also contributes to the foreign exchange earnings (SPC, 2016). The livestock production systems in the Pacific islands are categorized into three types: (1) traditional, extensive or subsistence, (2) semi-commercial or smallholder and (3) commercial production (SPC, 2016). The major livestock reared are chickens, pigs, cattle, goats, ducks and bees. Climate change is likely to present an additional challenge for the livestock sector. Higher temperature that affects maize and wheat production is likely to affect the livestock feed; similarly, dry conditions can potentially affect food for livestock (see box 4).

Box 4 Climate sensitivity of the livestock sector in Pacific island countries

- Higher temperature and climate change affecting maize and wheat production is likely to affect availability of livestock feed.
- Dry conditions affecting pastures are likely to affect food for livestock.
- *Bos Taurus* dairy breeds and chickens are sensitive to higher temperature and heat stress, especially those raised in a traditional production system.

Source: SPC, 2016.

Fisheries

Learning objective

Understanding fish species and their sensitivity to sea surface temperature and the salinity condition

See
worksheet
on page 71

The populations of Pacific island countries are greatly supported by fisheries for both their own consumption and income generation. Fisheries account for huge economic value in the Pacific islands. For example, the fishing industry accounts for US\$14 million in direct domestic commerce in Papua New Guinea (Nicol and others, 2014). The most commonly available marine fish in the Pacific subregion are the varieties of tuna: skipjack, yellowfin, bigeye and albacore. Freshwater fish, such as Nile tilapia, are reared in freshwater sources in the Pacific (Bell and others, 2016).

Fish are sensitive to warm water during El Niño years. The sensitivities are not clear; the documented climate sensitivity of the fisheries sector is presented in box 5. The potential reduction in fish catch due to El Niño is discussed in box 6.

Box 5 Climate sensitivity of the fisheries sector in Pacific island countries

Fishing is a way of life in the Pacific islands. Subsistence fisherfolk ply the waters of every inhabited shore as well as many uninhabited ones; seafood consumption is high, providing a primary protein source; and fishing is prominent in cultural traditions. The Western Pacific subregional Fisheries Management Council estimates the annual catch of skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), bigeye tuna (*T. obesus*) and South Pacific albacore tuna (*T. alalunga*) is at about 2.7 million metric tonnes. These tuna species are highly migratory and range throughout the Pacific and adults tolerate a relatively wide range of conditions (Brill, 1994). Yet, climatic conditions greatly influence the productivity and geographic range of Pacific tuna populations (Miller, 2007). Tuna have been shown to respond to El Niño Southern Oscillation (ENSO) events. Sea surface temperature influences tuna productivity and their optimal development through different life stages (Lehodey and others, 1997; Lehodey, 2001; Lu and others, 2001). ENSO-related shifts create a disadvantage for local fisherfolk who, unlike large-scale commercial fleets, cannot follow the tuna to more productive waters thousands of miles away.

The sensitivities of the fisheries:

- Small fish catch is noticed during cyclone periods in Vanuatu.
- Abnormal warm water in the tropical Pacific causes fish migration eastwards.
- Increased ocean temperature causing coral bleaching might also affect the distribution of fish species in the Pacific subregion.
- Higher air temperatures and increased rainfall conditions could increase the growth of freshwater fish, such as the Nile tilapia, because higher temperature could favour faster rates of growth and increased rainfall conditions are likely to support enough water in the rainfed ponds for fish rearing.

Source: FAO, 2008; Bell and others, 2016; PIRCA, 2012.

Box 6 Analysing risk of El Niño on fisheries using thermal sensing around the Pacific islands

The concentration of chlorophyll pigments (the photosynthetic pigments of phytoplankton) is often considered as an index of biological productivity in an oceanic environment. A lack or abundance of phytoplankton can be an indication of the amount of fish production and fish catch. Chlorophyll content of about 0.2 mg per cubic metre is indicative of the presence of sufficient phytoplankton to sustain a viable commercial fishery.

Chlorophyll pigments have a specific and distinctive spectral signature because they absorb blue and red light and strongly reflect the green—thus affecting ocean colour. Therefore, multispectral observations from spaceborne sensors allow the detection of phytoplankton content from the chlorophyll pigmentation.

In figure 12, tracks 1–9 indicate fish activity. The fish tend to aggregate along areas that have higher chlorophyll content, indicating higher phytoplankton bloom and biological productivity.

Using calibrated data from Ocean Colour Monitor sensors of NASA-SeaWiFS and Aqua-MODIS, an analysis was done to examine the impact of warming of waters from El Niño on chlorophyll content around the Pacific islands. Aqua-MODIS provides global variations in chlorophyll content. To examine impacts of El Niño-induced warming on potential fish populations, the georeferenced global data were downscaled to the Pacific islands. Figure 13 shows chlorophyll content around the Pacific islands during normal non-El Niño years, indicating normal phytoplankton bloom.

Figure 12 Fishing tracks along chlorophyll content

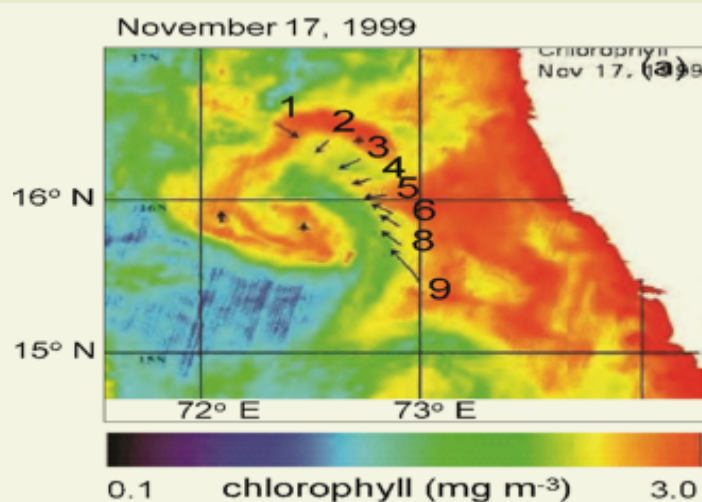


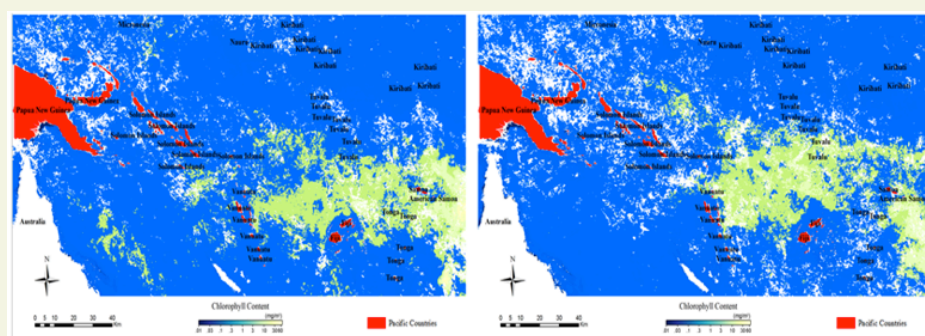
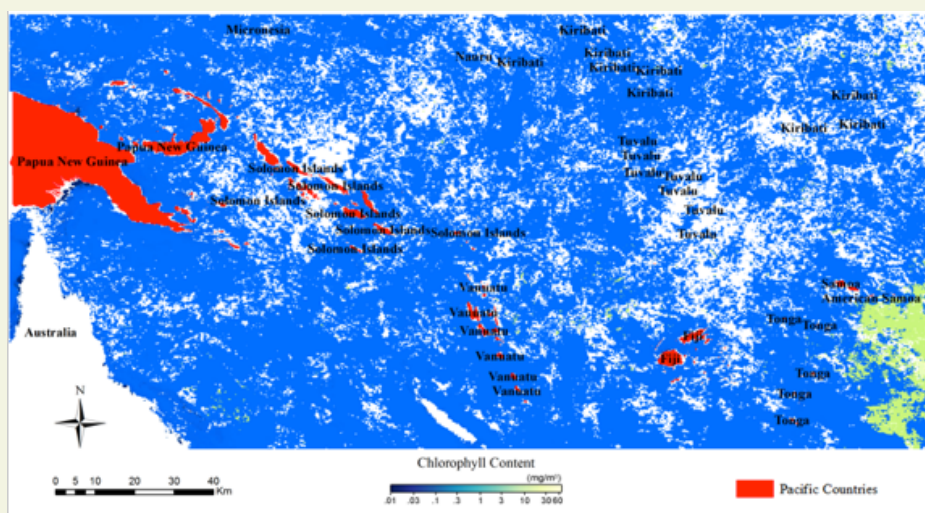
Figure 13 Chlorophyll content around Pacific islands, 2005 and 2013**Figure 14** Chlorophyll content around Pacific islands, 2015

Figure 14 shows chlorophyll content around Pacific islands in 2015, a strong El Niño year. As can be seen from the comparison of 2005, 2013 and 2015, there was a substantial decrease in chlorophyll content in 2015 due to the warming waters. This can have potentially devastating impacts on fisheries as well as subsistence fisherfolk, whose livelihoods depend on the volume of fish catch.

Source: Saitoh and others, 2009.



APPLICATION OF CLIMATE INFORMATION FOR RESILIENT AGRICULTURE

Climate risk information system

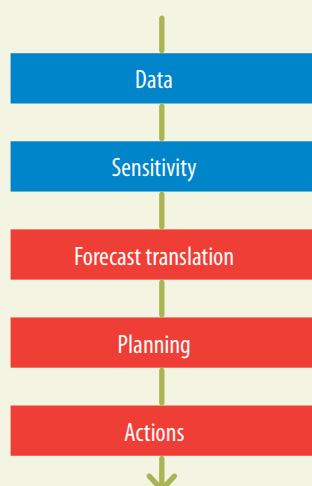
Learning objective

Understand the holistic framework of the climate risk information system for effective risk management in the agriculture sector

See
worksheet
on page 72

A full-fledged climate risk information system incorporates not just past data but also integrates weather and climate forecasts, observable climate change trends and climate change projection information in a dynamic manner. This allows climate risk to be managed holistically on all timescales. A full-fledged climate risk information system that integrates climate data on all timescales could be used to derive information and knowledge on risk patterns to take decisions and actions (see box 7).

Box 7 Climate informatics: Human experts and the end-to-end system



Climate knowledge is used in tandem with knowledge from many other sources for developing responses to climate change. Climate informatics focuses on how people and computers interact to smoothly convert data into information and knowledge. Current climate data systems provide a range of useful data, but that kind of data is often not usable. This system can be improved by addressing the chain from data to actions as an end-to-end process of human computer design.

Source: Rood and Edwards, 2014.

The establishment and institutionalization of a user-relevant climate risk information system should incorporate the following steps.

- **Assessment of users' information requirements**

Different users have different climate information requirements. Within the same group of users, information requirements are guided by the planning horizon, which could vary from 20 to 25 years at the organizational or ministerial level (strategic) to five years or less at the department or directorate level (tactical) and hours, days and months at the sector and local levels (operational).

- **Assessment of data and information availability**

Decisions on adaptation planning need to be guided by data and information, encompassing a range of stakeholders, including meteorological services, the planning ministry and ministries from the environment, tourism, agriculture, health, etc. It is vital to assess the availability of various data and their interoperability.

- **Tailoring climate information to users' needs**

Climate information lead time varies with user type; for example, climate projections of a 20- to 25-year lead time at a specific spatial scale is required for adaptation, while seasonal prediction of information at the island level is required for water resource planning. Weather forecast information up to 10 days could be used for the management of risks associated with severe weather events.

- **Characterizing and understanding uncertainties associated with climate information of different timescales**

Uncertainties inherent in longer-lead climate information need to be characterized and communicated clearly to facilitate application in a risk management framework. This would also prevent untrained and non-technical users from immediately perceiving and attributing climate variability-related phenomena to global warming.

- **Interpretation and translation of climate information**

Climate information should be interpreted in terms of agriculture sector-specific thresholds that are jointly determined by institutional users and communities.

- **Application in a risk management framework**

Climate information is to be applied in planning and decision-making, with awareness of the risks and opportunities due to uncertainties in the information.

- **Demonstration of the socioeconomic benefits in using climate information and adopting the climate risk information framework**

Highlighting the economic and social benefits derived from using climate risk information, in terms of time, human resources and finances, can lead to the adoption of the climate risk information system framework and its institutionalization.

Agriculture risk management for observed climate variability

Learning objective

Building awareness about the tools and methods that can help devise strategies for managing risks in the agriculture sector due to observed climate variability



See worksheet on page 73

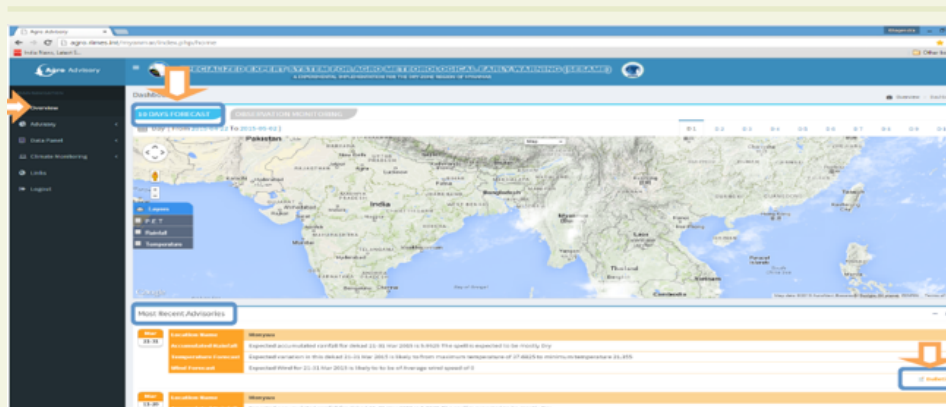
The impacts of climate variability on the agriculture sector during recent decades are evident and require strategic planning to minimize risks. The climate risk information system (explained in chapter 3) can help characterize the risk patterns that can further strengthen capacities in early warning for preparing a contingency plan in agriculture based on the seasonal and sub-seasonal climate forecast and outlook. The climate forecast essentially helps analyse the risks and vulnerability based on the climate profile so that action plans can be prepared and implemented.

The case study in box 8 highlights a good practice to manage agricultural risks. It focuses on how farming decisions can be better guided with a longer lead time weather forecast using an expert system called SESAME for generating agricultural advisories. The system is being tested in Myanmar.

Box 8 Specialized Expert System for Agro-Meteorological Early Warning

The Specialized Expert System for Agro-Meteorological Early Warning (SESAME) is a decision-support system for generating forecast-based agricultural advisories to guide farm-level decision-making in Myanmar. This expert system was developed by RIMES in collaboration with the Department of Meteorology and Hydrology and Department of Agriculture and was funded by the ESCAP Multi-Donor Trust Fund for Tsunami, Disaster and Climate Preparedness in Indian Ocean and South-East Asian Countries.

Figure 15 Screenshot of the SESAME website



The system generates 10-day agro-meteorological bulletins and advisories for pilot sites in Myanmar and receives feedback on the products. It is expected that the system will be improved through a feedback mechanism process. The tool also possesses a web interface that provides a platform for visualization and analysis of weather and climate data to generate and disseminate forecasts, bulletins and advisories to end users in the agriculture sector.

Source: RIMES, 2015a.

Application of climate forecast products in the agriculture sector

Learning objective

Gain experience on climate forecast applications, how to use climate forecast products with various timescales to prepare impact outlooks and risk management plans

See worksheet on page 74

Review of the climate forecast and outlook products

There are several climate forecast products available from global, regional and national centres that are relevant for the Pacific islands. The seasonal forecast products give an outlook of rainfall, air temperature, sea surface temperature and mean sea-level pressure for a period ranging from three to six months. Tropical cyclone outlook products indicating the frequency and intensity of cyclones are also available. Sub-seasonal products are also available from regional and national meteorological agencies (see table 15).

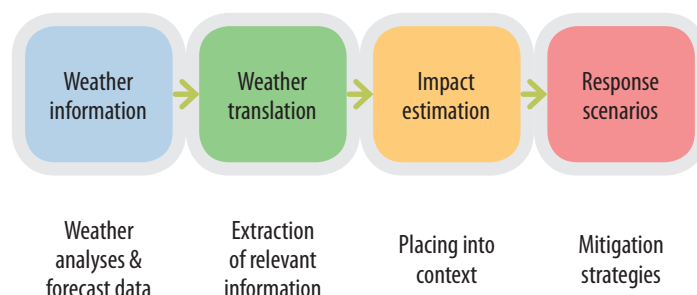
Table 15 Climate forecast products

Forecast	Description
Seasonal-annual climate outlook (3–6 months to a year)	<p>Seasonal climate outlook:</p> <ul style="list-style-type: none"> Climate and Oceans Support Program in the Pacific (COSPPac) Bulletin—The bulletin takes account of the global products SCOPIC, UKMO, ECMWF and POAMA models to give a summary of the seasonal outlook in the Pacific islands. See http://cosppac.bom.gov.au/products-and-services/climate-bulletin/ Seasonal outlook products relevant for Pacific islands are also available from: <ul style="list-style-type: none"> APEC Climate Center, www.apcc21.org/eng/service/6mon/ps/japcc030703.jsp NASA GMAO GEOS-5, gmao.gsfc.nasa.gov/research/ocean/ NOAA CFSv2, www.cpc.ncep.noaa.gov/products/CFSv2/CFSv2seasonal.shtml IRI for Climate and Society, iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/ POAMA Pacific Seasonal Prediction Portal, poama.bom.gov.au/experimental/pasap/index.shtml UKMO global long-range model probability maps, www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/glob-seas-prob ECMWF Rain (public charts) for long-range forecasts, www.ecmwf.int/en/forecasts/charts/seasonal/rain-public-charts-long-range-forecast COSPPac, cosppac.bom.gov.au/products-and-services/seasonal-climate-outlooks-in-pacific-island-countries/ Pacific Seasonal Prediction Global Producing Centre for long-range forecasts, highlighting the prediction of accumulated rainfall, average surface air temperature, average sea surface temperature and average mean sea-level pressure for the selected Pacific islands for a 3-month period and are updated every month. See poama.bom.gov.au/experimental/pasap/ New Zealand's National Institute of Water and Atmospheric Research rainfall outlook, www.niwa.co.nz/island-climate-update-190-july-2016

Forecast	Description
	<ul style="list-style-type: none"> National meteorological agencies also provide seasonal rainfall and temperature outlook. For example: <ul style="list-style-type: none"> Solomon Islands climate outlook and drought watch by Meteorological Services Division, www.met.gov.sb/3-months-rainfall-outlook Fiji Climate Outlook, www.met.gov.fj/Outlook1.pdf <p>Seasonal cyclone outlook: Outlook highlighting the frequency of cyclones and its intensity during the cyclone season (November–April), affecting various Pacific islands.</p> <ul style="list-style-type: none"> South Pacific tropical cyclone season outlook Bureau of Meteorology, www.bom.gov.au/climate/ahead/south-pacific/tc.shtml National Oceanic and Atmospheric Administration Eastern Pacific Hurricane Season Outlook for eastern Pacific hurricane region covers the eastern North Pacific Ocean east of 140°W of the equator, www.cpc.ncep.noaa.gov/products/Epac_hurr/Epac_hurricane.html New Zealand's National Institute of Water & Atmospheric Research Tropical Cyclone Outlook for Pacific islands, www.niwa.co.nz/news/el-ni%C3%B1o-expected-to-produce-severe-tropical-storms-in-the-southwest-pacific
Sub-seasonal climate forecast (daily, weekly, 10–15 days and up to a month) Weekly and 10–15-day outlook	<p>Long-range forecasting</p> <ul style="list-style-type: none"> Fiji Meteorological Service issues a 7-day weather outlook (rainfall, temperature and winds) for various regions in its island territory, www.met.gov.fj/aifs_prods/outlook.pdf Vanuatu Meteorological Services issues a 7-day weather outlook for selected centres, www.meteo.gov.vu/ <p>Short-term weather forecasting for a 1–5-day period is available through national agencies for the parameters of rainfall, air and ocean temperature, sea conditions, winds, mean sea-level pressure and clouds.</p> <p>Selected examples:</p> <ul style="list-style-type: none"> Fiji Meteorological Service—National Weather Forecasting Centre issues public weather bulletins (issued at 03:30, 07:30, 11:00, 17:30, 22:45, and 00:00), highlighting weather forecasting for various regions in Fiji. Fiji Meteorological Service issues special weather bulletins, especially during tropical cyclones, every three hours. It also issues regional weather bulletins for the following Island nations: Niue, Tokelau, Tonga, Tuvalu, Kiribati, Cook Islands and Nauru. Vanuatu Meteorological Services issues a 3-day weather summary for selected locations, www.meteo.gov.vu/ Solomon Islands Meteorological Service Divisions issues a weather bulletin for 18 hours, www.met.gov.sb/public-weather-forecast Tonga Meteorological & Coast Radio Services issues weather forecasting for 5 days, www.met.gov.to/

Application of climate forecast information

Climate risk information is useful for decision-making purposes only if there is a clear understanding about how to respond and use the information effectively. However, there is a huge gap between generating the forecast risks and the sharing of these risks to provide early warning to end users. The translation of weather impacts into sector impacts helps end users understand and judge climate risk at an operational level and thereby implement better response actions to minimize the risks. Figure 16 illustrates the process of translation of weather information into impact estimation and then into response scenarios.

Figure 16 Framework for translating weather information into response actions

Source: Baode Chen and Xu Tang, 2014.

A case of El Niño impact outlook prepared for Pacific islands is presented in box 9, and a case of climate forecast application in Vanuatu is presented in box 10.

Box 9 Climate Forecast Applications Network

Weather forecasts support operational decision-making on the timing of cultivating, irrigating, spraying and harvesting. Seasonal forecasts support strategic decisions regarding crop cultivar selection and intended acreage for planting. Viable forecast information beyond the traditional 10-day window can extend the time horizon for agricultural commodity price analysis and forecasting. This will support farmers' decisions about production, storage and marketing, as well as logistical decisions to deal with regional shortfalls and excess product availability.

The Climate Forecast Applications Network (CFAN) is a pioneer in applying the latest weather and climate research towards decision-oriented solutions. CFAN uses sub-seasonal weather forecasts (three to six weeks) to support hedging strategies for commodities with futures markets. CFAN's sub-seasonal decision-support system helps users better navigate a volatile agricultural commodity marketplace and reign in risk exposure faced by agricultural producers and suppliers.

Source: See www.cfandclimate.net/agriculture.

Box 10 A case of potential climate forecast application for growing root crops in Vanuatu

In Vanuatu, root crops are sensitive to dry and wet conditions at different stages of crop cultivation. For example, the kumala, a root crop grown in Vanuatu is sensitive to drought at the tuber initiation stage (50–60 days) after planting and does not tolerate waterlogging. If the short-term forecast is available, then hydrological operations could be planned to avoid damage to the roots. Seasonal products could be useful to take decisions on the cropping strategy. For example, vegetation growth requires wet conditions during the rainy season because it helps to establish the roots before the dry season. In such cases, likely rainfall characteristics are forecasted. Given this, we can estimate potential impacts, such as likely production fall and also prepare a cropping strategy to overcome the climate risks posed on the agriculture sector.

Seasonal flood forecasts can help in:

- developing a cropping strategy,
- national planning for the budget dedicated to relief and rehabilitation,
- government planning on response activities and
- estimating the likely crop production.

The medium- to short-range flood forecast products are useful for taking the following decisions:

- draining out the logged water during the excess rainy period,
- irrigation during the dry period,
- planning of planting and
- carrying out pest management activities.

Source: FAO, n.d.

Long-term agriculture risk management

Learning objective

Understanding strategies and action plans for long-term agriculture risk management



See
worksheet
on page 75

Long-term agriculture risk management requires reliable climate change scenarios to implement better-designed adaptation strategies. Downscaled climate change scenarios are useful to interpret impacts, which could be valuable information for national and local planning.

The review of literature for this report indicates that the likely climate change conditions and their impacts on the agriculture sector are documented for Pacific island countries. However, a finer resolution (in spatial terms) analysis should be carried out for each island because the risk profile varies from island to island. The interpretation of climate change scenarios into climate change impact outlooks and disaster risk profiles and the communication of results are key in planning and preparing for long-term risks.

Long-term agriculture risk management requires strategic planning for action plans to be implemented in the Pacific islands (see box 11).

Box 11 Considerations for long-term agriculture risk management

- Complex technical information on climate change can be processed into one integrated information system and presented in a user-friendly way. This can inform development planning, both by policymakers and farmers.
- A multi-stakeholder approach is needed to deal with disaster risks, food insecurity, climate change and natural resource degradation and food in an integrated and long-term manner.
- To understand local climate change impacts, innovative approaches may be required to obtain site-specific data.
- A sound framework should be developed for strengthening capacities at all levels (national, atoll and island).
- There is no one-size-fits-all solution because adaptation to climate change is location specific. Climate change adaptation technologies should be need driven because they have proven to be more acceptable to beneficiaries.
- An effective monitoring and evaluation system helps implementation and targeting and generates a better understanding of climate change adaptation technologies.
- National climate change scenarios should be translated for local application in the agriculture sector and linked to the local observed impacts.
- Indigenous practices, such as farming practices, early warning systems and coping mechanisms used by farmers and fisherfolk should be scientifically documented and evaluated so that they can be considered for replication.
- Risk management and early warning systems are essential service mechanisms to reduce disaster impacts.
- Downscaled climate data can be combined with a household-level analysis of vulnerability to food insecurity to profile the vulnerable populations.

Source: FAO, 2010.

Managing the impacts of likely climate change is critical for long-term risk management in the agriculture sector. With the help of projected climate change scenarios and impacts, responses can be devised. For example, some of the documented responses in Vanuatu are presented in table 16.

Table 16 A long-term agriculture risk management strategy for Vanuatu

<i>Climate change impact</i>	<i>Mitigation</i>	<i>Adaptation strategy</i>
Declining crop production because of changing climatic conditions.	Promote adaptive management approaches.	Diversify root crops.
	Increase public awareness about potential impacts of climate change on agriculture and food security.	Select crops and cultivars that are tolerant to abiotic stresses.
	Review breeding strategies and regulations concerning release of varieties and seed distribution.	Increase support for plant breeding programmes.
	Support agricultural research, especially on traditional food crops.	Broaden the genetic base of traditional food crops.
	Encourage and support local processing of food crops (cassava chips and flour, coconut oil, etc.).	Develop locally adapted crops.
		Adopt agro-forestry practices.
		Promote low tillage and permanent soil cover on agricultural lands.
Shifts in weather patterns affecting planting and harvesting regimes.	Put in place early warning and risk management systems.	Construct safe food storage facilities.
	Apply adaptive management and risk-coping production systems.	Identify alternative food sources, including imports.
		Research farming systems, including soil and land husbandry.
		Adjust planting and harvesting timetables to the prevailing conditions of the past three to four years.
		Revive traditional food preservation techniques.
		Undertake assessment of impacts of shifting weather patterns on traditional food crops.
		Establish crop improvement programmes focusing on climate change adaptation.

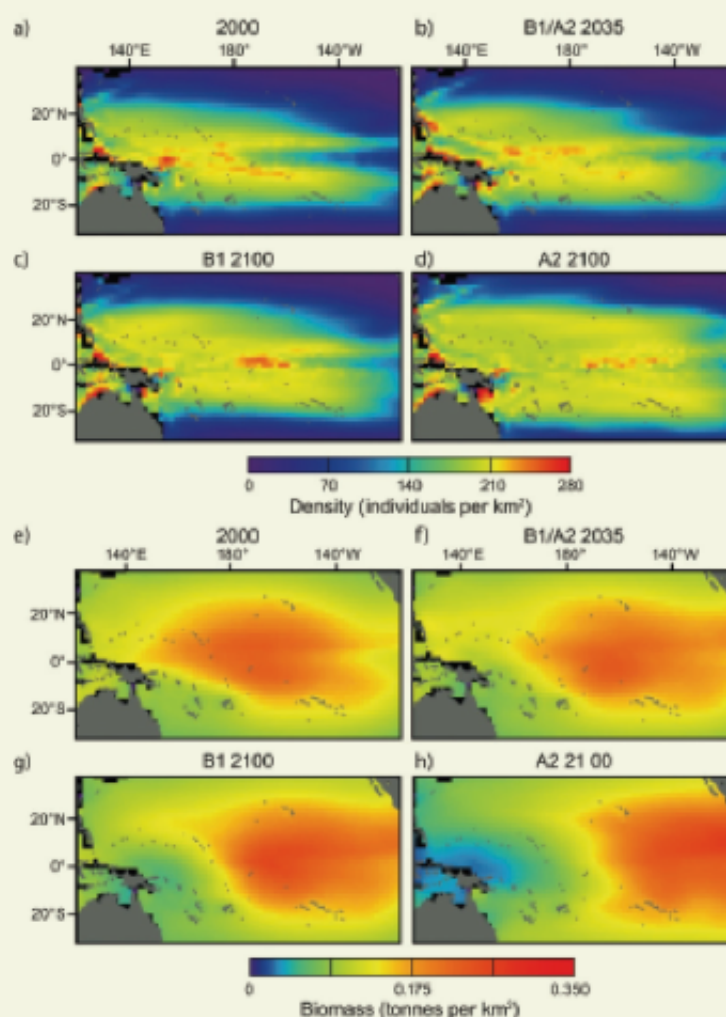
Source: FAO, n.d.

Contextualizing the sector-based impacts is critical for long-term risk management. For example, links between sea surface temperature and fish population were evaluated to interpret impacts for future climate projections (see box 12). Such translations are helpful for planning purposes.

Box 12 Understanding future vulnerability of the fisheries sector with projected climate information

The climatic conditions greatly influence the productivity and geographic range of Pacific tuna populations (Miller, 2007). From projected ocean warming and other climate-associated changes in marine ecosystem productivity, tuna distributions over the twenty-first century “are likely to shift progressively towards the central and eastern Pacific” (see figure 17) (Bell and others, 2016). Currently in the western North Pacific, the domestic tuna fisheries of the Federated States of Micronesia and Marshall Islands are valued at US\$2.67 million and US\$2.44 million annually, respectively (Bell and others, 2011). The contribution of tuna fisheries to these economies may decline as the projected shift in population takes place. The planning of adaptation activities in the fisheries sector could make use of this projected scenario while new programmes and projects are developed.

Figure 17 Projected distribution (density) for skipjack tuna larvae recruits from the Spatial Ecosystem and Population Dynamics model



(a) in 2000; (b) under the B1/A2 emissions scenario for 2035; (c) under B1 for 2100; and (d) under A2 for 2100. Also shown are estimates of total biomass (tonnes per sq km) of skipjack tuna populations based on average (1980–2000) fishing effort in (e) 2000; (f) under B1/A2 in 2035; (g) under B1 in 2100; and (h) under A2 in 2100. (Lehodey and others, 2011).

Source: PIRCA, 2012.

A useful tool, the Google Globe Vanuatu (see box 13) proved efficient in terms of understanding the threat of sea-level rise and to prepare adaptation strategies for the future. Such tools have great impact with the help of satellite and observed data records in communicating the risk of long-term climate change.

Box 13 Vanuatu Google Globe

The Pacific islands are among the most vulnerable countries to sea-level rise globally. Vanuatu Globe was a project that was developed out of the Pacific Australia Climate Change Science and Adaption Planning Program, funded by the Government of Australia to help Pacific island countries better understand and prepare for the potential impacts of climate change. Vanuatu Globe was established using the Google Maps Engine Cloud technology. The result provided consolidated access to a wealth of high-resolution elevation data and aerial photography, including inundation layers, to illustrate the predicted impact of sea-level rise for Vanuatu. The capacity-building component of the project aimed to provide governments and communities within each Pacific island country with the capacity and tools to effectively plan for sea-level rise. As part of capacity building, the programme needed to provide the people of Vanuatu with access to the acquired data so they could increase their awareness about sea-level rise and coastal flooding, which would enable effective planning and decision-making.

Figure 18 Screenshot of Google Globe



Source: See www.crcsi.com.au/research/commissioned-research/vanuatu-google-globe/.



RISK COMMUNICATION

Climate Risk Management Farmer Field Schools

Learning objective

Getting introduced to Climate Risk Management Farmer Field Schools, which is a capacity-building activity for farmers to enhance their understanding about climate risk management in the agriculture sector



See worksheet on page 75

The Climate Risk Management Farmer Field Schools (CRMFFS), which is a capacity-building activity conducted by the Centre for Ecological Research and Regional Integrated Multi-Hazard Early Warning System for Farmers in Tamil Nadu, India, is a good practice could be adapted for the Pacific subregion. The CRMFFS aims to educate farmers on weather parameters. The increased incidence of climate-related disaster, such as droughts and floods, high incidences of pests and diseases, coupled with increased demand for water and the need to increase agricultural production necessitate effective utilization of available climate information and its forecasts for informed decision-making purposes (CER and RIMES, 2012).

The CRMFFS is similar to the Climate Field School (see box 14) and Farmer Field School, with a focus on educating farmers to manage agricultural risks by understanding climate aspects.

Box 14 Objectives of the Climate Field School

The Climate Field Schools have discovered innovative approaches to manage disasters side by side with climate change adaptation with the following objectives:

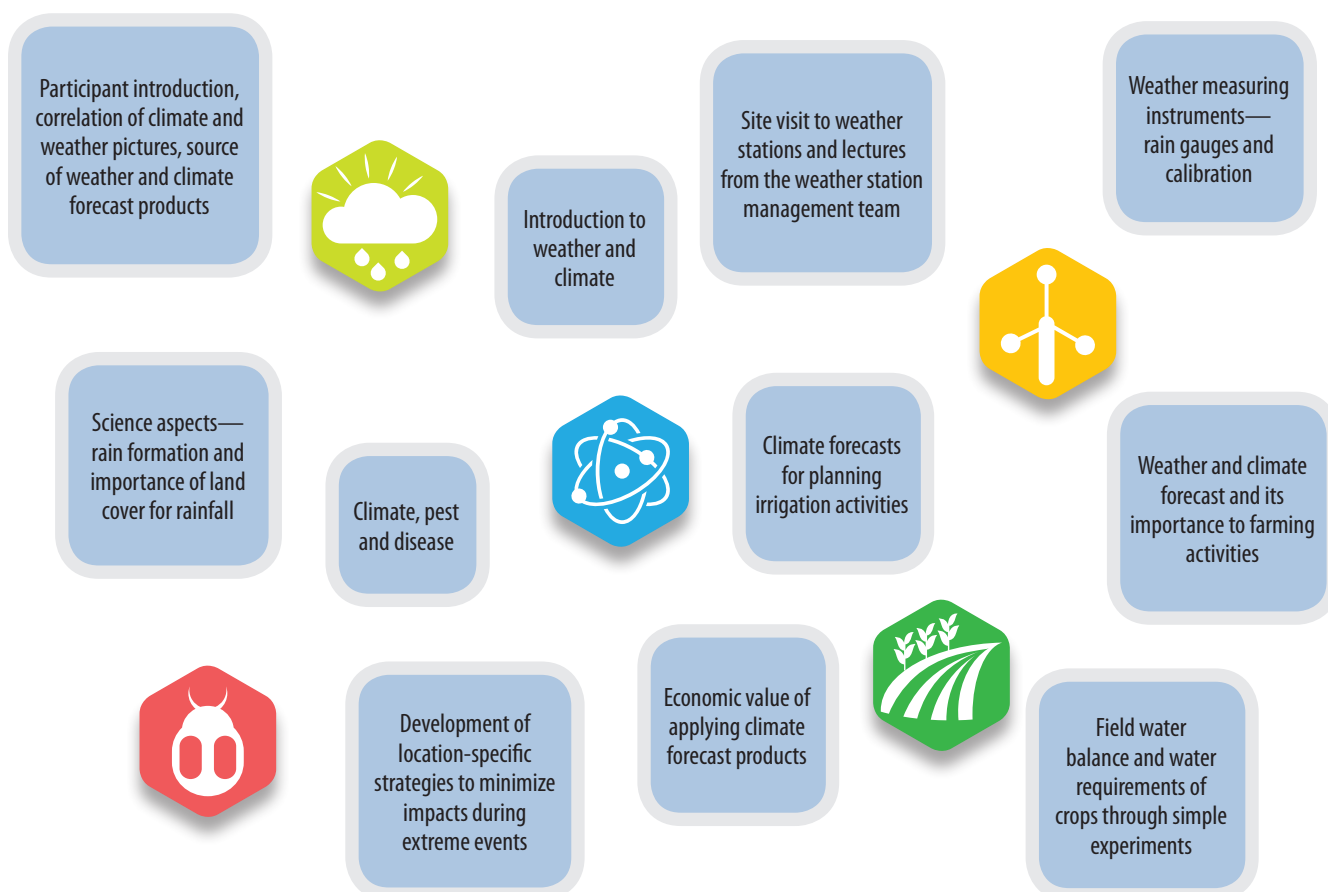
- enable farmers to understand climate-related risks in agriculture and the rice crop management system;
- show the importance of climate in plant growth and development as well as its relationship with plant pests and diseases;
- familiarize participants on forecast implementation, climate parameters and instruments;
- help farmers learn to integrate weather and climate information with disaster management and agricultural planning; and
- create awareness of participants on DRR and CCA.

Source: See www.climatechange.searca.org/index.php/climate-change-adaptation-knowledge-showcases/1244-climate-field-school-an-innovative-approach-to-agricultural-adaptation.

Lack of climate knowledge among farmers leads them to make risk-averse decisions as opposed to perceiving and managing risk with tactical and strategically made decisions. The CRMFFS is designed to improve the livelihoods of farmers and the village community by augmenting their understanding on crop-weather interaction, ex ante and ex post analyses on climate events, weather forecast information and their translation into farm actions. Understanding their domain climate, water resources, pests and diseases related to weather are the major outcomes targeted by the CRMFFS

through non-formal education as well as discovery and experiential learning processes (CER and RIMES, 2012).

The CRMFFS is a 12-week training programme, covering the following topics (but customized for the region or pilot site, where the training takes place).



Building farmers' capacity to prepare themselves to better understand climate risks and forecasts and thus make informed decisions would greatly help in minimizing the risks they face. For example, the Climate Field School conducted in Indonesia and the Philippines have achieved great benefits for farmers. The Climate Field School helps the farmers to be more aware of how to use climate information in managing their soil, water and crop resources for best effects. Box 15 highlights the success story of the Climate Field School in Indonesia and the Philippines.

Box 15 Success of the Climate Field School in Indonesia and the Philippines

In Indonesia, Indramayu was the first place where the Climate Field School was implemented. Since 2010, the Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) has reached more than 3,600 extension workers throughout Indonesia and has expanded from 11 provinces in 2011 to 25 provinces in 2014. The farmers from the village of Gempolsari in Banten Province who participated in a three-month session of the Climate Field School organized in 2014 by the BMKG with the Agriculture Agency reported a 25 per cent increase in corn harvest.^a

In the Philippines, the first Climate Field School was implemented in 2007 in Dumangas municipality of Iloilo Province in 2007. In 2008, Dumangas had a significant increase in rice production. It even surpassed the municipality of Pototan, Iloilo—the biggest rice producer in the Western Visayas. In 2011, Dumangas continued to be one of the dominant rice producers. The municipality and the farmers achieved this success because of the programme. Climate Field School enabled them to monitor the changing weather and adjust their farming practices. Hence, they could maintain good-quality agricultural products, despite exposure to weather and climate hazards.^b

a. See <http://climate-l.iisd.org/news/climate-field-school-increases-agricultural-productivity-food-security/>.

b. See www.climatechange.searca.org/index.php/climate-change-adaptation-knowledge-showcases/1244-climate-field-school-an-innovative-approach-to-agricultural-adaptation.

Such initiatives have also taken place in the Pacific islands. Box 16 highlights the Climate Field School conducted in 2013 on Pele Island, Vanuatu to strengthen the climate change adaptation capacity of farmers.

Box 16 Initiatives of the Climate Field School in Vanuatu

In Vanuatu, the Climate Field School was organized to include both hands-on exercises and practical information on natural hazards and disasters in the Pacific. It covers the causes and effects of climate change, climate change vulnerabilities and impacts in Shefa Province and improving delivery of services in adaptation, emission mitigation and disaster risk reduction. The local experts acted as resource persons to train the farmers. Fifty farmers were trained in the technologies of weather observation and recording, livestock husbandry, forest nursery management, food preservation and storage, banana multiplication, citrus grafting, vulnerability assessment, compost toilet construction, sea wall construction, management of marine conservation areas and honey bee husbandry. It was planned to expand to other pilot sites in Vanuatu.

The training was first given to a range of local experts from the Department of Meteorology, the National Disaster Management Office, the Department of Agriculture, Secretariat of the Pacific Community/GIZ Coping with Climate Change in the Pacific Island Region, the Nguna-Pele Marine and Land Protected Area Network, the US Peace Corps, the University of the South Pacific and the environmental NGO. Live and Learn by SPC's Community Education Training Centre with the technical support of Secretariat of the Pacific Community/GIZ, the USP-EU Global Climate Change Alliance Project, the Australian Agency for International Development, the Secretariat of the Pacific subregional Environment Programme and the United Nations Educational, Scientific and Cultural Organization.

Source: SPC Land Resource Division, 2013.

Uncertainties in climate forecast products

Learning objective

Familiarity with uncertainties and limitations in climate forecast products while making probabilistic agriculture operational decisions based on the risk communication



See worksheet on page 75

Climate forecast products only become usable when end users use them for informed decision-making. Often people expect the forecast to be accurate and deterministic and ignore the probabilistic forecast products because they are not ready to perceive the risk.

Meteorological agencies, such as the Met Office in the United Kingdom, have developed a technique called “ensemble forecast” to understand the uncertainties. Rather than forecasting a single outcome, ensemble forecasts provide an indication of all possible scenarios. This information can help users prepare a range of actions or take a range of decisions to match the various possibilities (UK MET, 2012).

The predictability of the atmosphere is often a complex task because of the complicated interaction between the land, ocean and atmospheric conditions. The uncertainty is an integral part of the forecasting process and weather prediction models are very sensitive to initial conditions. Hence, uncertainty and limitations in the climate forecast have to be well understood and also communicated to end users. Because the Pacific islands are dominated by subsistence farming, educating subsistence farmers on the uncertainties of forecasts becomes vital for agriculture risk management.

Even if there are reliable climate forecast products available, many users are not ready to prepare action plans to minimize the risks involved. There is a huge gap existing in terms of communicating risk to decision-makers in the various sectors for taking informed decisions based on forecast products. Therefore, these gaps should be addressed through a well-established risk communication mechanism among the agencies.

The UK Monsoon Forum (see box 17) is another good practice that can be used to communicate the uncertainties and limitations of climate forecast products to end users. During the Monsoon Forum, various stakeholders and the Hydrometeorological Department are brought together to discuss the seasonal climate characteristics and its implication on various sectors. This facilitates the dialogue between agencies and thereby generates a better understanding of forecast products.

Box 17 Monsoon Forum—Connecting science, institutions and society

Impacts of climate variability, extremes and changes on societies may be exacerbated by development decisions that are not adequately guided by climate information. Application of climate information to anticipate events and guide decision-making is not optimum due to gaps that exist in the end-to-end information generation and application system. These gaps include limited user understanding of forecast products and mismatch between users' needs and available climate products and services. In addition, the institutional mechanism to facilitate effective translation and communication of information to users and receive feedback from them is limited.

The UK Monsoon Forum is a platform for regular dialogue between the National Meteorological and Hydrological Service and multi-sector forecast users, aimed to address the gaps. The Forum is a cyclical process of forecast provision by the National Meteorological and Hydrological Service; forecast users' analysis of potential impacts on their sectors based on the forecast information, identification of impact management options, providing feedback at the end of the season on actions taken during the course of the season and identification of recommendations for improving forecast product generation and provision, as well as application; and National Meteorological and Hydrological Service improvement of products and provision of services to meet user demands.

The main objectives of this forum are to:

- ensure that forecast products, including their limitations and uncertainties, are communicated to and understood by users;
- encourage forecast applications for optimizing resource management and mitigating risks in climate-sensitive sectors;
- receive user feedback for improving usability of forecast products;
- provide a platform for inter-agency coordination of policies, sector plans and programmes for managing potential impacts; and
- provide a platform for the long-term process of understanding climate opportunities and risks.

An ongoing project being implemented by RIMES, with support from the ESCAP Multi-Donor Trust Fund, will establish Monsoon Forums in Fiji, Papua New Guinea and Samoa.

Source: RIMES, 2015b.



CLIMATE INFORMATION IN POLICY AND PLANNING

In general, many countries in the region lack usage of climate information in their planning process, which is evident in their long-term planning documents. We present two cases that reflect how well climate information can be used in planning documents.

The Fiji 2020 Agriculture Sector Policy Agenda: Modernizing Agriculture highlights that the declined contribution of the sugar industry to their agriculture GDP in the past decade (2001–2011) was due to many reasons, which include natural disasters and pest and disease outbreaks related to climate hazards (Fiji Ministry of Agriculture, 2014). Such disaster risks should be accounted for, quantified and considered in policy documents. In the Agriculture Development Objective Formulation Process, water resources are considered as one of the most important elements and it is greatly influenced by the climate in the region. Farmer Field Schools were encouraged and planned in the policy document. Such outreach activities, such as the Climate Field School, could help farmers to minimize climate risk and maximize opportunities.

A section on climate change in the policy document highlights the importance of climate information: “Other climate change agriculture activities focus on the management of natural resources. In areas where soils are prone to water-logging, new drainage techniques can get rid of flood waters more rapidly; while in dryer villages particularly the outer island rainwater harvesting is important. More effective management of soil carbon, precision application of fertilizers on nutrient, the use of energy-efficient machinery all play a part in the community.” And “Fiji must focus also on trainer’s training. The trainers then must be equipped with knowledge on soil, land and water conservation technologies, efficient and effective use of fertilizer, agroforestry and other climate change cropping systems” (Bacolod, 2014, p. 36). Microclimate thresholds for characterizing climate risks to the agriculture sector must be understood. Such knowledge on climate sensitivity of crops would enable management of productivity of the agriculture sector.

Similarly, Vanuatu’s Agriculture Sectoral Policy document 2015–2030 highlights the importance of mainstreaming climate variability (see box 18). The projections of agriculture growth and future investments have to carefully consider the climate information at various timescales for better outcomes.

Box 18 Agricultural Planning in Vanuatu

When mainstreaming climate variability, climate change and DRR using adaptation and mitigation strategies in all agricultural initiatives and developments:

- All stakeholders should consider climate variability, climate change and disaster risk reduction in all agricultural development initiatives (farmers, industries, National Advisory Board on Climate Change, Vanuatu Meteorology and Geo-hazards Department, National Disaster Management Office, Department of Agriculture and Rural Development, NGOs, civil society organizations, development partners, international institutions and Government ministries).
- Consider climate variability, climate change and disaster risk reduction in all farming practices (farmers, Department of Agriculture and Rural Development, Vanuatu Agricultural Research and Technical Center, NGOs, civil society organizations, development partners and international institutions).
- Build risk reduction capacities of farming communities through training and awareness to adapt and mitigate effects of climate variability, climate change and natural disasters (Vanuatu Meteorology and Geo-hazards Department, National Disaster Management Office, Department of Agriculture and Rural Development, NGOs, civil society organizations, development partners and international institutions).
- Provide adequate funding for activities to address climate variability, climate change and disaster risk reduction (Government, development partners, NGOs, civil society organizations, and international institutions).
- Promote adaptive strategies in all agricultural development initiatives (farmers, industries, Vanuatu Meteorology and Geo-hazards Department, National Disaster Management Office, Department of Agriculture and Rural Development, NGOs, civil society organizations, development partners, international Institutions and Government Ministries).
- Promote adaptive strategies in all farming practices (farmers, Department of Agriculture and Rural Development, Vanuatu Agricultural Research and Technical Center, NGOs, civil society organizations, development partners and international institutions).
- Promote mitigation strategies in all development initiatives (farmers, Industries, Vanuatu Meteorology and Geo-hazards Department, National Disaster Management Office, Department of Agriculture and Rural Development, (Vanuatu Meteorology and Geo-hazards Department, NGOs, civil society organizations, development partners, international institutions and Government Ministries).
- Promote mitigation strategies in all farming practices (farmers, Department of Agriculture and Rural Development, Vanuatu Agricultural Research and Technical Center, NGOs, civil society organizations, development partners and international institutions).
- Develop collaborative networks with national and international agencies to address climate change, climate variability and disaster risks (all stakeholders).
- Develop collaborative networks with national and international agencies regarding REDD+ initiatives and implement REDD+ activities and projects (all stakeholders).
- Strengthen traditional and self-reliant agricultural systems through development and implementation of programmes with components that encourage growing traditional climate-resilient staple crops, such as sweet potato, taro, banana, yam, cassava, trees and animals (all stakeholders).
- Prioritize micro and meso-scale (broad) land-use planning to reduce land and water degradation and reduce climate-related losses and vulnerability and maximize local production.
- Facilitate and coordinate research to develop stress-tolerant crop varieties, introduce new crops, and manage pests for climate change adaptation (Government, Vanuatu Agricultural Research and Technical Center and international agencies).
- Trial novel community extension models that enhance climate adaptation adoption at the same time as decentralizing technological development and enabling service delivery by NGOs and civil society organizations stakeholders (Government and civil society).
- Design and maintain a climate risk-informed decision-support system using geographic information system (GIS) to optimize the planning and design of crucial agricultural adaptation investment project (Government, Vanuatu Meteorology and Geo-hazards Department and international agencies).
- Direct diversification efforts towards reducing reliance on climate-sensitive farming practices and crops in high-risk areas and towards fast-yielding high-value crops to give farmers more tangible assets for adaptation .

Source: Vanuatu Department of Agriculture and Rural Development 2015.

Final note

This guidebook is based on interest from the participants of the capacity-building workshop on climate resilient agriculture in the Pacific SIDS that was jointly organized by ESCAP and Secretariat of the Pacific Community. It was developed to provide policymakers and decision-makers in the Pacific countries a practical tool to mainstream disaster risk reduction and climate change adaptation into their agricultural policies, plans and programmes. This guide is a living document and can be updated as the agriculture sector in Pacific SIDS gain more experience in mainstreaming DRR and CCA.

Ongoing initiatives by the Economic and Social Commission for Asia and the Pacific and partners in the Pacific are expected to further strengthen DRR and CCA in agriculture. Supported by the ESCAP Multi-Donor Trust Fund on Tsunami, Disaster and Climate Preparedness, work is underway to establish Monsoon Forums in some countries in the Pacific to capture good practices and lessons learned on using and communicating weather and climate information in Asia, where the Monsoon Forums are institutionalized. The Monsoon Forums will also serve as a platform for tailoring the regional climate information received by Pacific SIDS from the Pacific Island Climate Outlook Forum for national and community-level application.

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Glossary

Sources

The glossary was compiled from the following sources

- <http://ggweather.com/enso/glossary.htm>
 - www.esrl.noaa.gov/psd/enso
 - www.ipcc.ch/pdf/special-reports/srex/SREX-Annex_Glossary.pdf
 - www3.epa.gov/climatechange/glossary.html#GCM
 - http://unfccc.int/essential_background/glossary/items/3666.php
 - www.climate-science.org.au/content/379-new-scenarios-spm1-representative-concentration-pathways-rcps
-

Adaptation - Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Climate - Climate in a narrow sense is usually defined as the “average weather,” or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands of years. The classical period is three decades, as defined by the World Meteorological Organization. These quantities are most often surface variables, such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

Climate change - A change in the state of the climate that can be identified (by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climate extreme (also known as extreme weather or extreme climate event) - The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as “climate extremes.”

Climate modelling - A representation of climate processes using a theoretical mode, statistical model or numerical model. Climate models can be simple or complex.

Climate projection-A projection of the response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols, or radiative-forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions to emphasize that climate projections depend upon the emission concentrations and radiative-forcing scenario used, which are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized and are therefore subject to substantial uncertainty.

Climate scenario-A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that have been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections are often serve the raw material for constructing climate scenarios, but climate scenarios usually require additional information ,such as the observed current climate.

Climate variability-How climate deviates from normal or “mean” conditions. The variability is with respect to a particular time period (say, 1950 to 1979) and with respect to a particular timescale (such as weekly).

Climatological normal-Climate is usually defined by what is expected, or “normal”, which climatologists traditionally interpret as the 30-year average. By itself, “normal” can be misleading unless we also understand the concept of variability. For example, many people consider sunny, idyllic days as “normal” for southern California. History and climatology tell us that this is not the full story. Although sunny weather is frequently associated with southern California, severe floods have had a significant impact there, including major floods in 1862 and 1868, shortly after California became a state. When you also factor in severe droughts, most recently those of 1987–1994, a more correct statement would be that precipitation in southern California is highly variable and that rain is most likely between October and April.

Climatology-A quantitative description of climate, showing the characteristic values of climate variables over a region. Climate refers to the statistical collection of weather conditions over a specified period of time. Note that the climate taken over different periods of time (30 years, 1000 years) may be different.

Concentration pathways scenarios-Provides spatially resolved datasets of land-use change and sector-based emissions of air pollutants and it specifies annual greenhouse gas concentrations and anthropogenic emissions up to 2100.

Coping capacity-The ability of people, organizations and systems, using available skills, resources and opportunities, to address, manage and overcome adverse conditions.

El Niño – It comes from the Spanish term for “the Christ Child” because of the occurrence of warmer-than-normal waters that disrupted fishing along the coast of Ecuador and Peru around Christmas. Common use of the term has expanded to refer to the large-scale warming of the tropical Pacific Ocean at irregular intervals of between about two and seven years and lasting for one to three years.

Emission scenario – It refers to a plausible representation of the future development of emissions of substances that are potentially radiatively active (such as greenhouse gases and aerosols), based on a coherent and internally consistent set of assumptions about driving forces (such as technological change, demographic and socioeconomic development) and their key relationships. Concentration scenarios, derived from emissions scenarios, are used as input to a climate model to compute climate projections. In the IPCC 1992 supplementary Report, a set of emissions scenarios was presented, which were used as a basis for the climate projections in the IPCC Second Assessment Report. These emissions scenarios are referred to as the IS92 scenarios. In the IPCC Special Report on Emissions Scenarios, new emissions scenarios, the so-called SRES scenarios, were published. SRES scenarios (A1B, A1FI, A2, B1 and B2) are used as a basis for some climate projections.

ENSO - Acronym for El Niño Southern Oscillation. ENSO is a general term used to describe warm (El Niño) and cool (La Niña) ocean-atmosphere events in the tropical Pacific as well as the southern oscillation, which is the atmospheric component of these phenomena.

General circulation model- A global, three-dimensional computer model of the climate system, which can be used to simulate human-induced climate change. GCMs are highly complex and represent the effects of such factors as reflective and absorptive properties of atmospheric water vapour, greenhouse gas concentrations, clouds, annual and daily solar heating, ocean temperatures and ice boundaries. The most recent GCMs include global representations of the atmosphere, oceans and land surface.

Hazard - The potential occurrence of a natural or human-induced physical event that may cause loss of life, injury or other health impacts as well as damage and loss to property, infrastructure, livelihoods, service provision and environmental resources.

La Niña - Means “infant girl” in Spanish and is so named because in many ways it is the opposite of El Niño. La Niña is characterized by large-scale cooling of the tropical Pacific Ocean and often begins during the summer at irregular intervals of between about two and seven years and lasting for one to three years.

Resilience - A capability to anticipate, prepare for, respond to and recover from significant multi-hazard threats with minimum damage to social well-being, the economy and the environment.

Sea Surface Temperature-A characteristic of El Niño and La Niña events. Sea surface temperatures are monitored from ship reports, buoys and satellite imagery.

Sensitivity-The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (such as, a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (damages caused by an increase in the frequency of coastal flooding due to sea-level rise).

Southern oscillation-Is the periodic change of sea-level pressure differences across the tropical Pacific that have been found to correlate with El Niño and La Niña events. It was first recognized by British scientist Sir Gilbert Walker in the 1920s by observing pressure differences between Darwin, Australia and Tahiti while stationed in India studying the monsoon. The Southern Oscillation is a see-saw of atmospheric mass (pressure) between the Pacific and Indo-Australian areas. The pressure difference results in circulation changes.

Tropical cyclone-The general term for a strong, cyclonic-scale disturbance that originates over tropical oceans. Distinguished from weaker systems (often named tropical disturbances or depressions) by exceeding a threshold wind speed. A tropical storm is a tropical cyclone with one-minute average surface winds between 18 and 32 m s⁻¹. Beyond 32 m s⁻¹, a tropical cyclone is called a hurricane, typhoon or cyclone, depending on geographic location.

Vulnerability-The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed; its sensitivity; and its adaptive capacity.

B. Worksheet for climate drivers and observed climate trends

Practice exercise

What are the observed rainfall and temperature trends during the past century in your island?

Notes

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Practice exercise

Discuss the future climate change on Pacific islands.

Notes



D. Worksheet for climate impacts on the agriculture sector

Practice exercise

What are the weather- and climate-related hazards that affect the agriculture sector in the Pacific islands?

Why are Pacific islands more vulnerable to climate hazards?

Describe a climate hazard and its major impacts on the agriculture sector.

What are the impacts of observed climate variability on the agriculture sector?

Notes

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This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.



F. Worksheet for climate sensitivity of livestock and fisheries

Practice exercise

Notes

This image shows a full page of blank, lined paper. It features approximately 20 evenly spaced horizontal grey lines across its entire width, providing a template for handwriting practice or general note-taking. The margins are consistent on all sides.

Notes



H. Worksheet for agriculture risk management for observed climate variability

Practice exercise

Notes

[illegible]

J. Worksheet for risk communication

Practice exercise

- What are the advantages of the Climate Risk Management Farmer Field Schools? Do you think the farmers at Pacific Island Countries and Territories would benefit by such type of training in building their capacity? Discuss.
- What are the challenges you face while using the climate forecast products? What are the uncertainties in the climate forecast products from your experience?
- Do you think a probabilistic approach is better than the deterministic forecast for decision-making? If so, why?

Notes

This image shows a full page of blank, lined paper. It features approximately 20 horizontal blue or grey lines spaced evenly apart, typical of notebook paper. The lines extend across the entire width of the page, leaving small margins at the top and bottom. There are no vertical lines, text, or other markings on the page.

FROM **RISK**^{TO} **RESILIENCE** SERIES



This series—a product under the **Enhancing Knowledge and Capacity to Manage Disaster Risk for a Resilient Future in Asia and the Pacific Project**—is part of a larger effort within ESCAP to support its member States in building up their resilience to changes in climate conditions and to help foster sustainable development. ESCAP and partners initiated the project with support from the United Nations Development Account.