CHAPTER V

Climate-related Risks in the Case Study Countries

A. Background on the Case Study Countries

The Cook Islands

The Cook Islands comprises 15 small islands and atolls. The country has a total land area of 244 square kilometers (km^2) dispersed over an exclusive economic zone of 1.8 million km^2 of the South Pacific Ocean (Map V.1). The islands are predominantly coastal entities and because of their size and isolation, and the fragile nature of island ecosystems, their biological diversity is among the most threatened in the world.

The Cook Islands is divided into northern and southern groups, stretching over some 1,000 km of ocean. The southern islands are generally younger volcanic islands, while the northern group is made up of coral atolls. Islands in the southern group are generally larger and more heavily populated. The total population of the Cook Islands is 18,600, while that of the capital island (Rarotonga) is 13,200. This is the largest island, though only 6 km wide.

The climate of the Cook Islands is considered to be of a maritime tropical nature, dominated by the easterly trade winds. The rainfall regime exhibits a marked seasonality, with a dry season from May to October, during which only one third of the 2,000 millimeters (mm) annual rainfall occurs. The other two thirds falls during the wet season (November to April). The wet season is also the tropical cyclone season and is associated with the easterly shift of the South Pacific Convergence Zone (SPCZ) over the country.

BOX V.1

Key Points for Policy and Decision Makers

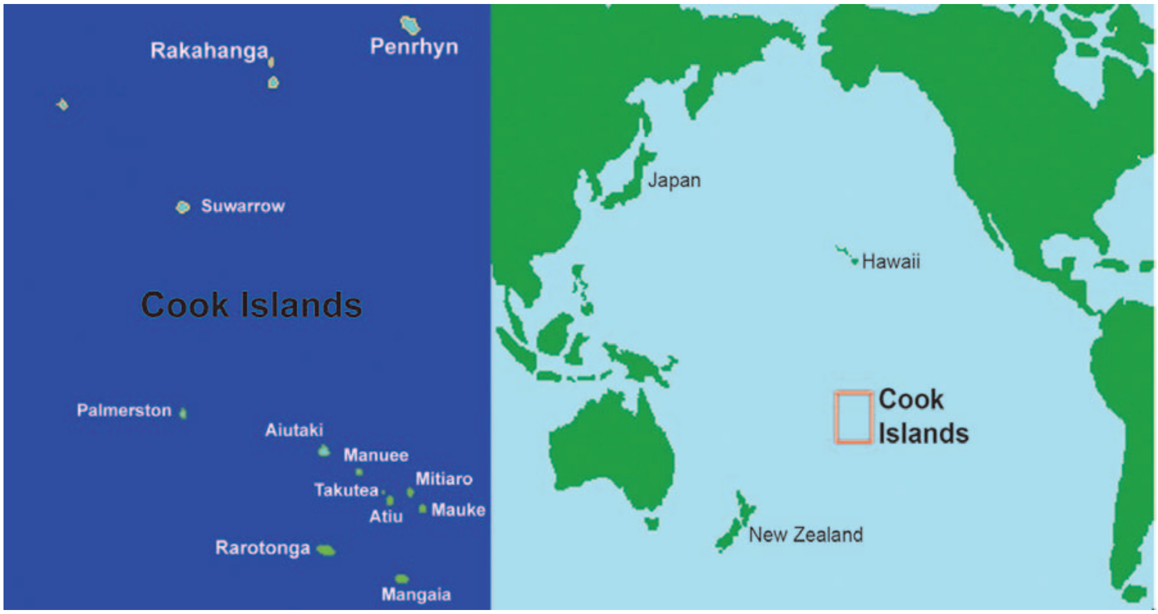
- Both the Cook Islands and the Federated States of Micronesia (FSM) comprise a mixture of relatively large and hilly islands, coral atolls, and raised coralline islands.
- While the climates of both countries are characterized as maritime tropical, FSM usually experiences warmer and wetter conditions. Both countries experience a marked seasonality in precipitation.
- The two countries also experience large interannual variations in rainfall, associated with the El Niño Southern Oscillation;
- Tropical cyclones (typhoons) are more common in the Cook Islands.
- The consequence component of climate risk is site or sector specific.
- The likelihood component of climate risk, however, is usually evaluated for a country, state, island, or similar geographical unit.
- For both countries, extreme climate events that are relatively rare at present (likelihood less than 0.05) are projected to become relatively common as a result of global warming. In many cases, likelihoods are projected to increase to over 0.20 by 2050.

Source: CCAIRR findings.

The monthly average temperatures range between 21°C and 28°C. Extreme temperatures have been recorded in the mid-30s and mid-teens. The climate of the Cook Islands experiences large interannual variability, especially during ENSO events.

The occurrence of tropical cyclones tends to be more frequent during an El Niño event, when

Map V.1. The Cook Islands



warmer than normal sea surface temperatures occur between latitudes 10° and 15° South and the SPCZ migrates eastward in the vicinity of the Cook Islands and French Polynesia. During an El Niño event, the southern Cook Islands experiences a reduction in rainfall, to as little as 60% of normal, while in the northern Cook Islands rainfall increases to as much as 300% *above* normal.

Tropical Cyclones Martin and Pam, during the 1997/98 ENSO, caused extensive damage to property and infrastructure and brought human suffering, including loss of lives. During the same period, the southern group of islands experienced prolonged drought. In the southern Cook Islands, cyclones are seldom associated with heavy rainfall.

The Federated States of Micronesia

The Federated States of Micronesia (FSM) comprises four states: Yap, Chuuk (formerly Truk), Pohnpei (formerly Ponape), and Kosrae (formerly Kusae), in the western Pacific Ocean between the equator and 14° North, and between 136° and 166° degrees East (Map V.2). The states stretch about 2,700 km in geographic sequence from west to east. The country has a total population of about 106,000.

The land area of the FSM comprises 607 islands, which have a combined area of only 701 km^2. Of these hundreds of islands, a number are relatively large and mountainous or hilly, while the rest are small, flat coral atolls or raised coralline islands. The latter are associated with 7,190 km^2 of lagoons. The marine area within the FSM's exclusive economic zone totals over 2.6 million km^2 and includes abundant and varied resources.

The climate of the FSM is typical of many tropical islands. Temperatures are relatively uniform, averaging in the mid to high 20°C range; humidity averages over 80%. Rainfall is high, varying from about 3,000 mm per year on drier islands to over 10,000 mm per year in the mountainous interior of Pohnpei. Most islands have a pronounced wet season (June to October) and dry season (November to May). For Pohnpei, the "dry" season contracts to January to March.

During an ENSO event, the FSM suffers drought conditions during the winter and spring months.

Map V.2. The Federated States of Micronesia

With a severe El Niño episode, drought can begin as early as late autumn and extend into the following summer. The stronger the El Niño, the longer-lasting the drought conditions are likely to be. Whether an El Niño event is "typical" or stronger than usual, Yap and western Chuuk, being in the western part of the FSM, tend to be affected somewhat earlier and, in most cases, more harshly than eastern Chuuk and the eastern states of Pohnpei and Kosrae.

The western region of the FSM is subject to the occasional (one in 20 years return period) tropical cyclone (typhoon). These can cause severe damage. A typhoon that struck Pohnpei on April 24, 1997 caused many landslides, damage to vegetation as well as infrastructure, and 19 deaths. When El Niño conditions prevail, typhoons tend to form farther to the east and northeast than usual. The typical directions of the storm tracks taken by these typhoons are to the north, northwest, or west. During an El Niño event the FSM is most vulnerable to typhoon activity during November and December, when typhoons have the greatest likelihood of forming directly east, then tracking west, and gathering strength before traveling across the FSM.

B. Characterizing Risk

Formally, risk is the combination of the consequence of an event and the likelihood (i.e., probability) of that same event. As illustrated by the examples in Table V.1, the full extent of a risk is evident only when both the likelihood and consequence components are considered together.

While the consequence component of a risk will be site or sector specific, the likelihood component generally will be applicable both over a larger area and to many sectors. This is due to the spatial scale and pervasive nature of weather and climate. Thus the likelihood of, say, an extreme event or climate anomaly is often evaluated for a country, state, small island, or similar geographical unit. While the likelihood may well vary within a given unit, information is often insufficient to assess this spatial variability, or the variations are judged to be of low practical significance. In such instances the main challenge is to determine the likelihoods using observed and other data, and to use climate change scenarios to develop projections of how the likelihoods might change in the future.

Table V.1 A Risk Register, Based on Hypothetical Examples

Risk Type	Risk Event	Consequence	Likelihood Probability	Risk	Rank
Natural	Typhoon/ Cyclone	Widespread damage and deaths	1 in 10 year	High	1
Human	Industrial Explosion	Several die	1 in >100 year	Low	3
Combined	Landslide	Damage to road and environment	1 in 50 year	Medium	2

Source: CCAIRR findings.

The remainder of Chapter V provides examples of such analyses, for both the FSM and Cook Islands. Since the case studies were located in the FSM states of Pohnpei and Kosrae, and on Rarotonga in the Cook Islands, the results are presented for those geographical units.

Chapter VI presents the results of characterizing the consequence components of the risks, as part of the detailed description of the case studies.

Summary Climate Risk Profile for Pohnpei and Kosrae

The likelihood (i.e., probability) components of climate-related risks in Pohnpei and Kosrae are evaluated, for both present-day and future conditions. Changes into the future reflect the influence of global warming. The risks evaluated in this way are extreme rainfall events (both hourly and daily), high sea levels, strong winds, extreme high air temperatures, and drought.

A summary of the climate risk profile (CRP) is presented here. The full CRP, including descriptions of the data sources and methods used, may be found in Appendix 1.

Table V.2 presents the average time between occurrences of specified extreme events, for both Pohnpei and Kosrae. These values, also known as return periods, are given for the present and for the projected future.

The information can also be presented as the likelihood that the specified event will occur within a given time period. In Table V.2, a time horizon of 1 year has been used. Graphs provided in Appendix 1 present the likelihoods for other time horizons.

While all the chosen events are relatively rare at the present time, global warming will cause marked increases in the frequency of all these extreme events except wind gusts.

Extreme high rainfall amounts are more common in Pohnpei than Kosrae, and this difference persists into the future, with global warming.

An analysis of observed rainfall for Pohnpei for 1953–2003 shows that most of the low rainfall months (below the fifth percentile, which is often used as an indicator of drought) are concentrated in the latter part of the period of observation, indicating that the frequency of drought has increased markedly since the 1950s. The years with a high number of months below the fifth percentile coincide with El Niño events. A similar analysis of projected daily rainfall amounts for Pohnpei reveals that the frequency of low rainfall months will generally remain at these higher levels for the 21st century.

Table V.2. Return Period and Likelihood of Occurrence in 1 Year[1], for Given Extreme Events in Pohnpei and Kosrae, for the Present and Projected Future

Event and Location	Present		2025		2050		2100	
	RP	LO	RP	LO	RP	LO	RP	LO
Rainfall—Daily Total at least 300 mm								
Pohnpei	21	0.05	9	0.11	4	0.23	2	0.65
Kosrae	38	0.03	21	0.05	12	0.08	4	0.22
Rainfall—Daily Total at least 200 mm								
Pohnpei	23	0.04	12	0.08	7	0.14	4	0.25
Kosrae	28	0.04	21	0.05	16	0.06	11	0.09
Sea Level—Hourly Average at least 120 mm above mean sea level								
Pohnpei	61	0.02	21	0.05	5	0.20	1	1.0
Wind Gust—Extreme at least 25 m/sec								
Pohnpei	8	0.13	10	0.10	9	0.10	0.9	0.11
Maximum Temperature—Daily at least 35°C								
Pohnpei	24	0.04	11	0.09	6	0.17	2	0.50

RP = return period in years; LO = likelihood of occurrence.

[1] A likelihood of 0 equals zero chance while a likelihood of 1 equates to a statistical certainty that the event will occur within a year.

Source: CCAIRR findings.

Summary Climate Risk Profile for Rarotonga

The likelihood components of climate-related risks in Rarotonga are evaluated, for both present-day and future conditions. Changes in the future reflect the influence of global warming. The risks evaluated in this way are extreme rainfall events (both hourly and daily), drought, high sea levels and wave heights, strong winds, and extremely high air temperatures.

A summary of the CRP is presented in Table V.3. The full CRP, including descriptions of the data sources and methods used, may be found in Appendix 2.

Table V.3 presents the return periods for Rarotonga of specified extreme events. The information is also presented in terms of the likelihood that the specified event will occur within a time horizon of 1 year. Graphs provided in Appendix 2 present the likelihoods for other time horizons.

While all the chosen extreme events are relatively rare at the present time, global warming will cause marked increases in the frequency of all of them.

An important point to consider is whether these likelihoods have changed during the recent past. Any such changes might signal the impact global warming has had on climate-related risks, although direct attribution of any changes to global warming would require detailed investigations that are beyond the scope of the present study.

The long rainfall record for Rarotonga provides an opportunity to investigate changes in likelihoods over time. Table V.4 shows that, between the periods 1929–1959 and 1970–2003, a substantial increase

Table V.3. Return Period and Likelihood of Occurrence in 1 Year[1], for Given Extreme Events in Rarotonga, for the Present and Projected Future

Event and Location	Present		2025		2050		2100	
	RP	LO	RP	LO	RP	LO	RP	LO
Rainfall—Daily Total at least 300 mm	38	0.03	26	0.04	19	0.05	11	0.09
Rainfall—Hourly Total at least 100 mm	91	0.01	57	0.02	25	0.04	13	0.08
Height of Sea Surge – Extreme at least 6 m above mean sea level	10	0.10	8	0.13	7	0.15	5	0.21
Wind Gust – Extreme at least 42m/sec	29	0.03	16	0.06	14	0.07		
Maximum Temperature – Daily at least 34ºC	29	0.03	14	0.07	9	0.12	3	0.29

RP = return period in years; LO = likelihood of occurrence.

[1] A likelihood of 0 = zero chance; a likelihood of 1 = a statistical certainty that the event will occur within a year.

Source: CCAIRR findings.

Table V.4. Probability Components for Daily Rainfall of at least 250 mm, Rarotonga

Time Period	Return Period (years)	Likelihood in Any One Year
1929–1959 (observed)	66	0.02
1970–2003 (observed)	17	0.06
2025 (projected)	13	0.08
2050 (projected)	10	0.10
2100 (projected)	6	0.17

Source: CCAIRR findings.

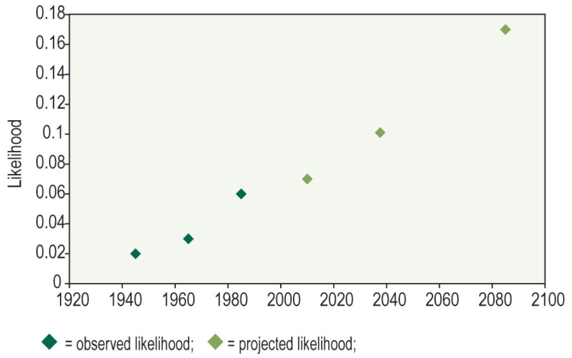
occurred in the likelihood of a daily rainfall of 250 mm or more. This finding is not surprising given that, of the six days since 1929 that had precipitation amounts over 200 mm, all but one was later than 1966.

An obvious question arises: are the past changes in the probability component consistent with the changes projected to occur in the future as a result of global warming?

Table V.4 also shows projected return periods and likelihoods. The trend of increasing likelihood that was apparent in the historical data for much of the last century is projected to continue, in a consistent manner, through the present century.

The likelihood results in Table V.4 are presented graphically in Figure V.1. A consistency between the

Figure V.1. Observed and Projected Likelihoods of a Daily Rainfall of at Least 250 mm Occurring in a Year, Rarotonga

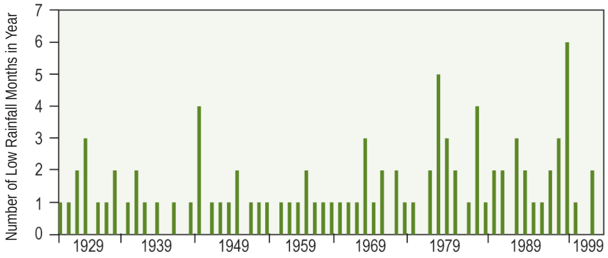


Source: CCAIRR findings.

observed and projected changes is readily apparent. This does not prove the existence of a global warming signal in the historical data, however. Once again, more detailed analyses are required before any such attributions might be made.

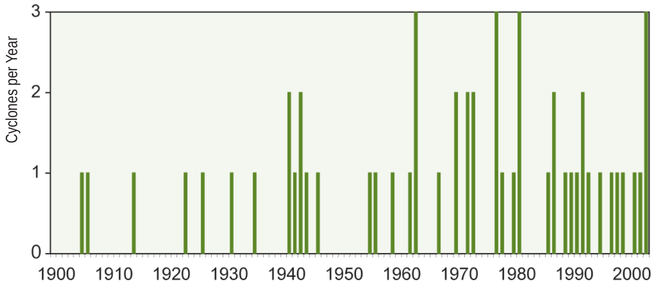
While the frequency of heavy rainfall events in Rarotonga is clearly increasing, so too is the frequency of low monthly rainfall totals. Figure V.2 shows the number of months in each year when the precipitation was below the 10th percentile. It is clear that in the latter part of the last century Rarotonga experienced unprecedentedly low rainfall conditions. In 1998 alone, 4 consecutive months had rainfall below the 10th percentile. In that same year, 6 months had rainfall below the 10th percentile, with 3 below the fifth percentile. All the low rainfall years, namely 1982/83, 1992/93 and 1997/98, coincided with El Niño events.

Figure V.2. Number of Months in each Year (1929–2003) when the Precipitation for Rarotonga was Below the 10th Percentile



Source: CCAIRR findings.

Figure V.3. Number of Tropical Cyclones per Year Passing Close to, and Affecting, Rarotonga



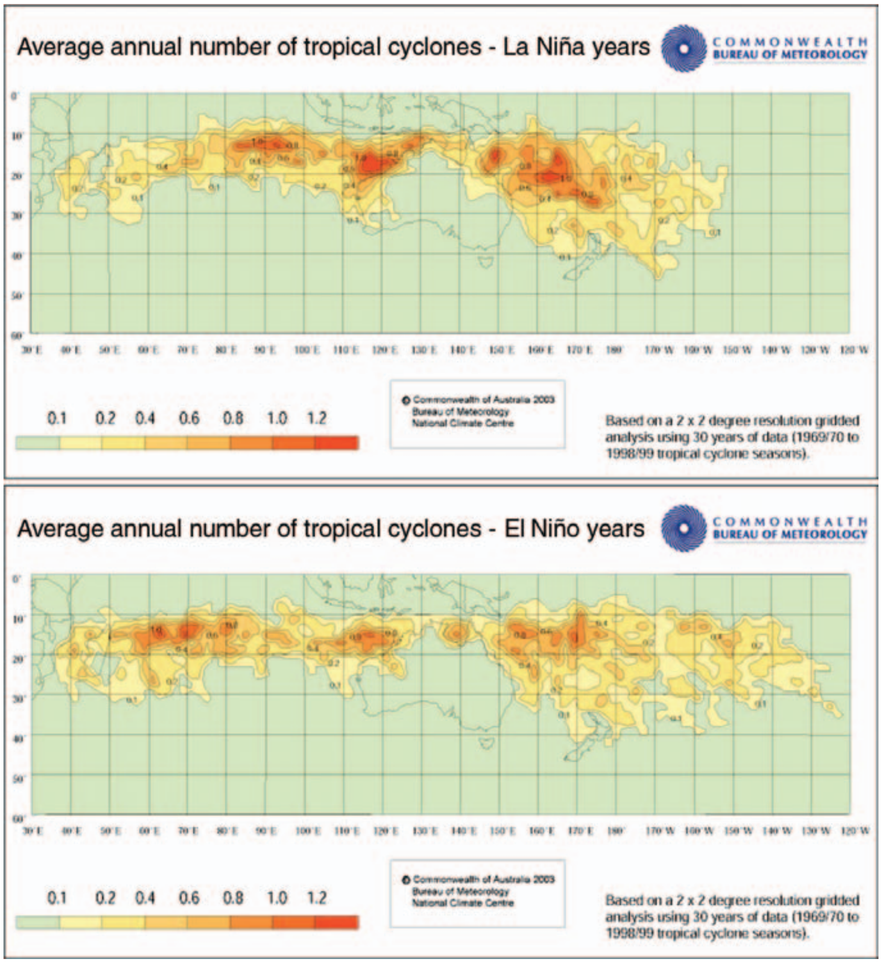
Sources: Kerr (1976), Revell (1981), Thompson et al. (1992), d'Aubert and Nunn (1994), Fiji Meteorological Service (2004) and Ready (pers. comm.).

The number of tropical cyclones passing close to, and affecting, Rarotonga, appears to have increased during the last century, as indicated in Figure V.3. However, since observing and reporting systems improved substantially over the time period, it is unwise to read too much into the marked contrast in frequency between the first and second halves of the 20th century. The record for the last few decades is much more reliable, and hence the doubling in decadal frequencies between the 1950s and 1990s may well be closer to the truth. It is certainly consistent with the fact that, since the 1970s, the tendency has been for more frequent El Niño episodes, without intervening "La Niña" events. The duration of the 1990–95 El Niño is unprecedented in the climate records of the past 124 years.

Studies by Australia's Bureau of Meteorology reveal the consequences of the weakened trade winds and eastward movement of the warm waters of the western tropical Pacific during El Niño events (Figure V.4). Because convective systems (e.g., thunderstorms and rainstorms) and tropical cyclones preferentially occur over warmer waters, changes in the pattern of sea surface temperatures is reflected in the distribution of rainfall and tropical cyclones.

A possible consequence of the increased persistence of El Niño conditions in recent decades is the apparent intensification of tropical cyclones. Table V.5 shows a systematic increase in upper 10th-percentile heights of open water waves associated with tropical cyclones occurring in the vicinity of Rarotonga.

Figure V.4. Average Annual Number of Tropical Cyclones for La Niña Years (Top Figure) and El Niño Years (Bottom Figure)



Source: Australian Bureau of Metereology n.d.

Table V.5. Open Water Wave Height (Average of Top 10%) Associated with Tropical Cyclones Recently Affecting Rarotonga

Cyclone (name and year)		Wave Height (m)
Charles	(1978)	11
Sally	(1987)	10
Val	(1991)	14
Pam	(1997)	14
Dovi	(2003)	17
Heta	(2004)	17
Meena	(2005)	17
Nancy	(2005)	22
Percy	(2005)	19
Olaf	(2005)	16

Source: Dorell (pers.comm.)