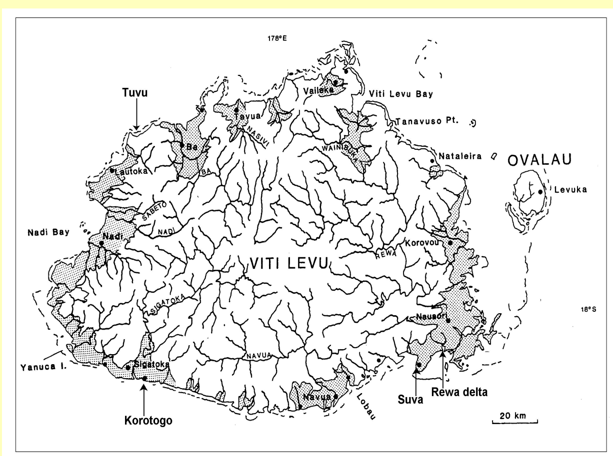
# Chapter 3
# Impact of Climate Change on a High Island
# Viti Levu, Fiji

With an area of 10,389 square kilometers, Viti Levu is the largest island in Fiji. Seventy-seven percent of Fiji's population—595,000 people in 1996—reside there. It is also in Viti Levu that Fiji's major cities, industries, and tourism facilities are located (box 3).

By 2050, under the climate change scenarios used by the study, Viti Levu could experience annual economic losses of US$23–$52 million (table 3). Because the losses are annual averages, they dampen the potential impact of extreme weather events, which could be

### Box 3. Viti Levu (Fiji) at a Glance




***Climate:*** Oceanic tropical

- Average temperature: 23° –27° C.
- Average rainfall: East Viti Levu 3,000–5,000 milimeters. West V. Levu 2,000–3,000 milimeters.

***Major Influences***

- Southeast trade winds.
- El Niño Southern Oscillation (ENSO).
- South Pacific Convergence Zone.

***Extreme Events***

- Tropical cyclones.
- Droughts (often associated with ENSO).

***Population***

- Population: 772,655 in 1996 (595,000 or 77% in Viti Levu).
- Average annual growth rate: 0.8%.
- 60% rural, but growing urbanization.

***Economy***

- GDP (1998): US$1,383 million.
- Narrow base, with sugar and tourism dominating.
- Average annual growth: 2.7% (1993–96).
- Growth affected by tropical cyclones and drought.
- Main exports: sugar, gold, garments.

***Future Population Trends***

- Increasing population density, especially in urban areas, coastal areas, flood plains, and marginal hill lands.

***Implications:***

- Denser urban structures.
- Spread of urban areas to coastal margins and inland.
- Increase in proportion of squatter housing.
- Increase in coastal infrastructure (related to tourism).

***Future Economic Trends***

- Continued dependence on natural resources.
- Tourism sector likely to grow.
- Agriculture will continue to be important in subsistence production and as export earner. Role of sugar uncertain due to future removal of subsidies and land tenure. Possible increase in traditional crops, such as kava.
- Growing importance of cash economy.
- Continued dependence on foreign aid.

***Future Environmental Trends***

- Environmental degradation in densely populated areas (especially coastal and lowland) and in marginal farmland.
- Increase in deforestation.
- Increase in problems of waste disposal (sewage, solid waste, and chemical pollution).

***Future Sociocultural Trends***

- Reduction in importance of traditional kinship systems.
- Increase in preference for imported foods.
- Increase in noncommunicable diseases associated with nutritional and lifestyle changes.
- Increase in poverty and social problems in urban areas.

**Table 3. Estimated Annual Economic Impact of Climate Change on Viti Levu, Fiji, 2050 (millions of 1998 US$)**

| *Impact* | *Annual damage*[a] | *Level of Certainty* | *Likely cost of an extreme event*[b] | *Extreme event* |
|---|---|---|---|---|
| *Impact on coastal areas* | | | | |
| Loss of coastal land and infrastructure to erosion | 3-6 | Moderate | — | — |
| Loss of coastal land and infrastructure to inundation and storm surge | 0.3-0.5 | Moderate | 75-90 | Large Storm Surge |
| Loss of coral reefs and related services | 5-14 | Very low | — | — |
| Loss of nonmonetized services from coral reefs, mangroves and seagrasses | + | Very low | — | — |
| *Impact on water resources* | | | | |
| Increase in cyclone severity | 0–11 | Moderate | 40 | Cyclone |
| Increase in intensity of droughts (related to El Niño) | + | Moderate | 50-70 | Drought |
| Changes in annual rainfall (other than impacts on agriculture) | + | Low | — | — |
| *Impact on agriculture* | | | | |
| Loss of sugarcane, yams, taro, and cassava due to temperature or rainfall changes and ENSO | 14 | Moderate | 70 | Drought |
| Loss of other crops | + | Very Low | — | — |
| *Impact on public health* | | | | |
| Increased incidence of dengue fever | 1-6 | Moderate | 30 | Large epidemic |
| Increase in fatal dengue fever cases | + | Very Low | — | — |
| Increased incidence of diarrhea | 0-1 | Low | — | — |
| Infant mortality due to diarrhea | + | Very Low | — | — |
| Impact of cyclones and droughts on public safety | + | Very Low | — | — |
| **Total estimated damages** | **>23-52+** | | | |

+ Likely to have economic costs, but impact not quantified. — Not available.
[a] Reflects the incremental average annual costs of climate change. [b] Reflects the absolute (non-incremental) cost of a future extreme event. Numbers are rounded.
*Note:* For assumptions, see annex A.
*Source*: Background studies to this report.

substantially higher in a particular year: an average cyclone could cause damages of more than US$40 million, while a drought comparable to the 1997/98 event could cost Viti Levu some US$70 million in lost crops.

Among the most significant incremental impacts of climate change would be damages to infrastructure and ecosystems of coastal areas (averaging about US$8–$20 million a year by 2050). But a higher intensity of cyclones could also result in substantial damages, up to US$11 million a year. Changes in rainfall could lead to agricultural losses of US$14 million per year, and the combined effect of higher temperatures and stronger climate variability could result in public health costs of more than US$1–$6 million a year. These estimates assume no adaptation and are subject to large margins of uncertainty. But they probably underestimate the costs of actual damages, as many impacts (such as nutrition and loss of lives) could only be assessed qualitatively.

## A. Impact on Coastal Areas

Viti Levu's coastal areas are naturally exposed to weather events. About 86 percent of the 750-kilometer coast lies at elevations that are less than 5 meters from sea level. Intensive urban development, growing poverty, deforestation of watersheds, pollution, and increased exploitation of coastal resources have exposed large areas of the coast to erosion and inundation. Some villages have reported shoreline retreats of 15–

20 meters over the past few decades due to loss of mangroves (Mimura and Nunn 1994).

Climate change is expected to affect the coast of Viti Levu through a rise in sea level (23—43 centimeters by 2050), higher temperatures (0.9—1.3° C by 2050), and more intense cyclones, resulting in further coastal erosion and inundation as well as a decline in coral reefs (figure 4.1). The resulting economic losses are conservatively estimated at US$8—$20 million a year by 2050.

To assess the potential impact of sea level rise on coastal erosion and inundation, four sections of Viti Levu were surveyed (see map, box 3):

- *Suva Peninsula*, representing major towns or about 5 percent of Viti Levu's coast.
- *Korotogo* on the southern coast, representing areas with major tourism settlements and coastal villages (28 percent of the coast).
- *Tuvu*, on the northwest coast, with intensive sugarcane fields and mangroves (about 47 percent of the coast).
- *Western Rewa River Delta*, representing low-lying mangrove and delta areas (10 percent of the coast).

The erosion analysis did not include Suva because the city is already heavily protected by seawalls.

***Coastal Erosion.*** The first-order estimates of potential erosion indicate that, by 2050, Viti Levu's shoreline could retreat by 1—3 meters at Korotogo, 9—12 meters at Tuvu, and 112—251 meters at the Rewa river delta (table 4). Extrapolating these results to other areas of Viti Levu is difficult due to the variations in topography. Nevertheless, using estimates from the three sites surveyed, 1,150—2,300 hectares of coastline (2 to 4 percent of the land below 10 meters altitude) could be lost by 2050. By 2100, the proportion of

**Figure 1. Likely Impact of Climate Change on Coastal Areas in Viti Levu, Fiji**

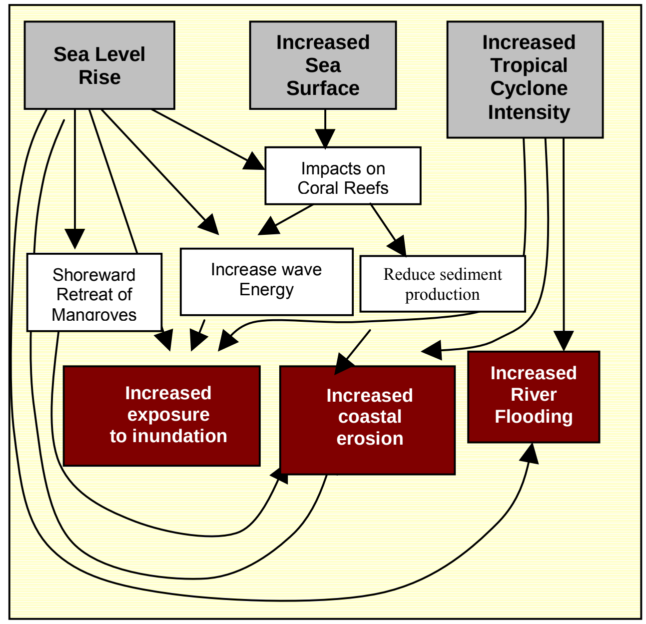



**Table 4. Potential Shoreline Retreat in Viti Levu, Fiji Resulting from Sea Level Rise, 2025, 2050, and 2100**

| *Impact* | *2025* | *2050* | *2100* |
|---|---|---|---|
| *Potential shoreline retreat (in meters)* | | | |
| Korotogo (South coast) | 1 | 1-3 | 4-9 |
| Tuvu (Northwest coast) | 7-9 | 9-12 | 13-29 |
| Western Rewa river delta | 50-112 | 112-251 | 319-646 |
| *Total land eroded (in hectares)* | | | |
| Tourism areas (like Korotogo) | 10-22 | 22-53 | 63-145 |
| Sugarcane areas (like Tuvu) | 188-253 | 253-323 | 362-818 |
| Low-lying mangrove and delta (like Rewa) | 390-875 | 875-1,955 | 2,485-5,036 |
| Percentage coastal strip eroded (< 10 meters) | 1-2 | 2-4 | 5-10 |
| Total land eroded (in hectares) | 588-1,150 | 1,150-2,331 | 2,910-6,000 |
| ***Value of land lost to erosion (US$ million)*** | | | |
| Tourism areas (like Korotogo) | 0.2-0.4 | 0.4-1.0 | 1.2-2.8 |
| Sugarcane areas (like Tuvu) | 4.3-5.8 | 5.8-7.3 | 8.2-18.6 |
| Low-lying mangrove and delta (like Rewa) | 8.9-19.9 | 19.9-44.5 | 56.5-114.5 |
| **Total capital value of land lost** | **13.3-26.1** | **26.1-52.8** | **66.0-136.0** |
| **Annualized losses[a]** | **1.5-2.9** | **2.9-5.8** | **7.3-15.0** |

*Notes:* Ranges reflect best guess (lower value) and worst case scenarios (higher value).
Land eroded and value of land lost are extrapolated from the sites surveyed, and cover about 85 percent of the Viti Levu coast.
a. Reflects the annual value of the losses, or the capital recovery factor.
*Source:* Background studies to this report. For assumptions, see annex A.

**Table 5. Potential Inundation of the Coast of Viti Levu, Fiji, as a Result of Sea Level Rise**

| | | *Potential Inundation* | | | |
|---|---|---|---|---|---|
| | | *Physical Impact* | | *Inundation costs (in US$ million)* | |
| *Sea Level Rise (m)* | *Scenario equivalent to* | *Land inundated (ha)* | *Percentage of total land below 10 meters altitude* | *Annualized losses*[a] | *Incremental capital value of lost assets during an extreme event* [b] |
| 0.2 | 2025 worst-case<br>2050 best-guess | 370 | 0.6 | 0.3 | 14.6 |
| 0.4–0.5 | 2050 worst-case<br>2100 best-guess | 3,530 | 5.9 | 0.5 | 30.1 |

[a] - Reflects the incremental annual value of the losses due to climate change, or the capital recovery factor. The costs take into consideration the impact of a 1 in 50 year storm event.
[b] - Reflects the incremental cost of capital losses during a 1 in 50 year storm event.
*Note:* For assumptions, see annex A.
*Source:* Background studies to this report

land eroded could be as high as 10 percent. Based on current values of land, the annualized economic damages due to climate change would be in the order of US$2.9 to US$5.8 million a year by 2050 (table 4). This is likely to be an underestimate, as the sites surveyed were representative of just about 85 percent of Viti Levu's coast, and the Tuvu site under-represents low-lying sugarcane fields on the north shore.

***Coastal Inundation.*** The analysis conducted in Viti Levu indicates that sea level rise would result in relatively modest levels of inundation ─ affecting about 0.6 to 5.9 percent of coastal land below 10 meters altitude by 2050. However, in years of strong storm surge ─ such as the 1 in 50 year event shown on table 5 ─ Viti Levu could experience losses in capital assets of US$75-$90 million, some US$15-$30 million higher than what is experienced today (table 5).

Past research also suggests the following likely impacts of climate change (Solomon and Kruger 1996):

- Overtopping of shore protection in downtown Suva during extreme wave impacts (if sea level rises 25 centimeters).
- Serious flooding in large parts of Suva Point and downtown Suva even during moderate tropical cyclones (if sea level rises 100 centimeters).
- Raised water tables in low-lying areas.
- Reduced efficacy of in-ground septic and sewer pumping systems.
- Increased sedimentation of channels, shoreward retreat of mangroves, and increased susceptibility to floods in the Rewa Delta.

***Mangroves and Coral Reefs****.* Viti Levu is estimated to have 23,500 hectares of mangroves (Watling 1995) and about 150,000 hectares of coral reefs.[3] Mangroves play key roles in trapping sediments and protecting coastal areas against erosion. They are also vital nursery grounds for coastal fisheries. The impact of sea level rise and storm surges on mangroves is expected to be mixed: some expansion might be observed due to the increased sedimentation of the coastal zone; the net impact of erosion, however, is expected to be negative.

Coral reefs are likely to be particularly affected by climate change. A rise in sea surface temperature of more than 1$^{o}$C could lead to extensive coral bleaching and, if conditions persist, to coral mortality. Such bleaching events were observed during the 1997–98 El Niño episode (Wilkinson and others 1999) and more recently in Fiji, Tonga and the Solomon Islands

[3] This estimate is derived based on the total area of coral reefs in Fiji (an estimated 1 million hectares, according to WRI 1999), and Viti Levu's share of the total coastal area of Fiji (15 percent).

in April 2000. The deeper water resulting from an increase in sea level could stimulate the vertical growth of corals, but reef response is likely to lag the rise in the sea level by at least 40 years (Hopley and Kinsey 1988; Harmelin-Vivien 1994). As a result, many coral species may not be able to adapt sufficiently rapidly to a succession of bleaching events triggered by higher sea surface temperatures.

The climate change impact on coral reefs in Viti Levu is projected to cost an estimated US$5—$14 million a year by 2050 in lost fisheries, habitat and tourism value (see annex A for detailed assumptions).

## B. Impact on Water Resources

Average rainfall could either increase or decrease by 2050 (see table 2). The impact will depend to a large extent on the South Pacific Convergence Zone (SPCZ). If the SPCZ moves away from Fiji and the region shifts to a more El Niño–like state, Viti Levu could experience more pronounced droughts. If the SPCZ intensifies near Fiji, average rainfall could increase.

It is also possible that Viti Levu would experience greater climate variability, with alternating floods and droughts brought on by more intense cyclones and ENSO fluctuations. The sequence of four cyclones and two droughts experienced in 1992–99 could reflect the future pattern of climate variability.

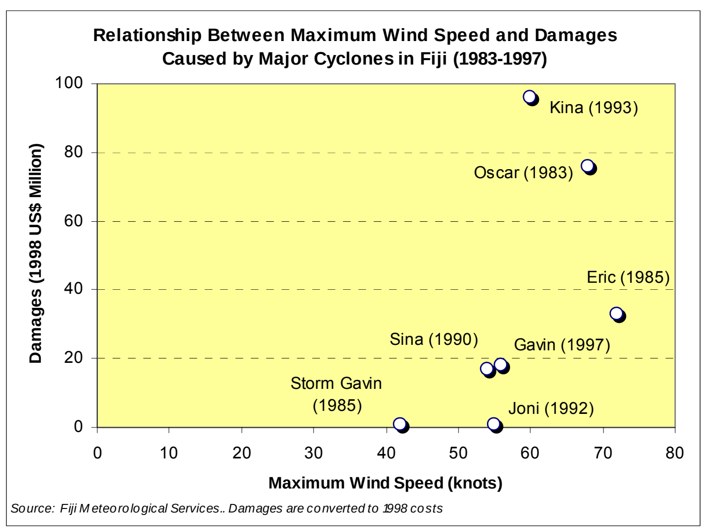
***Cyclones.*** With an average of 1.1 cyclones a year (Pahalad and Gawander 1999), Fiji has the highest incidence of cyclones in the South Pacific. The four tropical cyclones that hit Fiji between 1992 and 1999 killed 26 people and caused damages estimated at US$115 million (Fiji Meteorological Services undated). Most of the damage occurred on Viti Levu.

**Table 6. Summary of Estimated Annual Economic Impact of Climate Change on the Coast of Viti Levu, Fiji, 2050 (millions of 1998 US$)**

| *Category* | *Annual damages* |
|---|---|
| *Impact on coastal assets:* | |
| Loss of land to erosion | 2.9—5.8 |
| Inundation of land and infrastructure | 0.3—0.5 |
| *Impact on coral reefs — Loss of:* | |
| Subsistence fisheries | 0.1–2.0 |
| Commercial coastal fisheries | 0.0.5—0.8 |
| Tourism | 4.8—10.8 |
| Habitat | 0.2—0.5 |
| Biodiversity | + |
| Nonuse values | + |
| *Impact on mangroves*[a] | |
| *Impact on seagrasses* | + |
| **Total estimated damages** | **>8.4—20.4** |

+ Likely to have economic costs, but impact not quantified.
[a] Accounted for in the erosion analysis.
*Note:* For detailed assumptions, see annex A.
*Source*: Background reports to this study.

**Figure 2. Cyclone Wind Speed and Impact in Fiji**




Regional studies indicate that cyclone intensity may increase by 0–20 percent in the Pacific Island region as a result of climate change (Jones and others 1999). Based on historical records of cyclone damage in Fiji and scientific theory, a 20 percent increase in maximum wind speed could result in a 44–100 percent increase in cyclone damage (figure 2).[4] Taking Fiji's average annual cyclone damage for the 1992–99 period (US$14.4 million) as a baseline and adjusting the figure to reflect the relative share

[4] See Annex A, pages 32-34 for detailed assumptions.

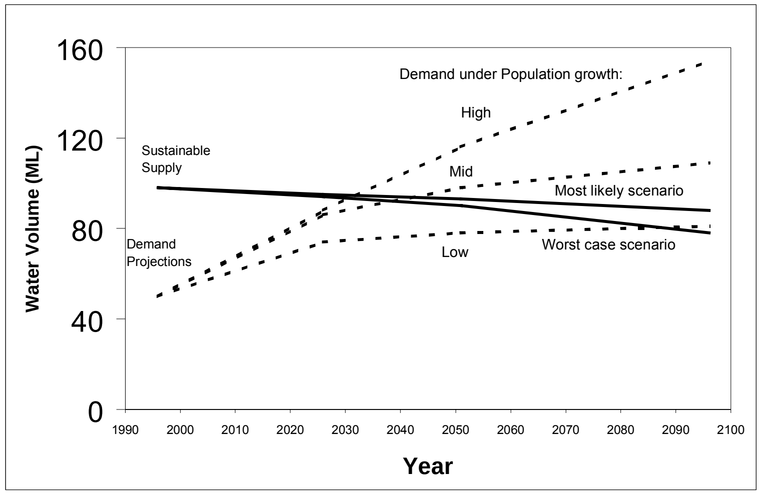
of Viti Levu in Fiji's population, the likely change in cyclone intensity could cost Viti Levu as much as US$11 million a year by 2050.

***Droughts.*** Fiji experienced four El Niño–related droughts between 1983 and 1998. The 1997/98 event—one of the worst on record—caused damages of US$140–$165 million, equivalent to about 10 percent of Fiji's GDP. The drought affected food supplies, commercial crops, livestock, and the water supply of schools and communities. Droughts of this severity could well become the norm in the future. However, due to the scarcity of economic data on past droughts in Fiji, it is not possible to separate the effects of climate variability from those of climate change. The incremental impact of climate change on drought intensity could only be computed for crop losses (see section C). Non-agricultural impacts related to water shortages and nutrition are believed to be substantial, but could not be quantified.

***Water Supply.*** Among the most important effects of climate change are the impacts of changes in rainfall on water supply. Models of two streams in Viti Levu—the Teidamu and Nakauvadra creeks—indicate that rainfall variations could cause a 10 percent change in water flow by 2050 and a 20 percent change by 2100. The direction of the change would depend on whether rainfall increases or decreases. For larger rivers, an increase in rainfall could lead to extensive flood damage.

Figure 3 shows the projected supply and demand for water in Nadi-Lautoka, a prime tourism and urban area of Viti Levu which serves 123,000 people. Provided the distribution system is fully efficient, the impact of a decreasing rainfall scenario would not become substantial until the second part of the century. Under a worst-case scenario and moderate population growth, demand would exceed supply by 38 percent by 2100—as compared to an 18 percent shortfall in the absence of climate change. The deficit caused by climate change is smaller than the amount currently lost to leakage and water losses (29 percent), suggesting that more aggressive leak repair would be a logical adaptation strategy.

**Figure 3. Estimated Supply and Demand of Water in Western Viti Levu, under a Decreasing Rainfall Scenario**




*Note:* Assumes future demand to be 300 l/capita/day, 25% loss, yield 98 million l/day.
*Sources:* JICA 1998 and background studies to this report.

**Table 7. Estimated Annual Economic Impact of Climate Change on Water Resources in Viti Levu, Fiji, 2050**

| *Category* | *Annual damage (millions of 1998 US$)* |
|---|---|
| Changes in average rainfall | + |
| Increased cyclone intensity | 0–11.1 |
| Increased severity or frequency of El Niño related drought | ++ |
| **Total** | **0–11.1** |

+ Likely to have significant economic costs, but impact could not be quantified.
*Source*: Background studies to this report.

Table 7 summarizes the quantifiable economic impacts of climate change on the water resources of Viti Levu. The estimate of US$0-$11 million reflects only the average incremental annual costs of more intense cyclones; absolute costs in disaster years could be much higher, up to US$44 million for an average cyclone. Given the uncertainties surrounding extreme events—and the difficulty associated with quantifying certain types of damages—these estimates should be viewed primarily as illustrations of what may happen.

## C. Impact on Agriculture

Changes in rainfall, temperature, and climate variability will affect agricultural production in Viti Levu. An 8 percent increase in rainfall (as expected in 2050) would benefit most crops except yams, while a drier climate (an 8 percent decrease in rainfall) would hurt most crops, particularly sugarcane (figure 4).

The impact of climate change on agriculture in Viti Levu is estimated to cost about US$14 million a year by 2050 (table 8). This estimate reflects annual average costs; damages in an El Niño year could be much greater as indicated by the 1997/98 drought, which cost Viti Levu some US$70 million in lost crops (UNDAC 1998).

The most significant economic damage would be on sugarcane, which accounts for 45 percent of Fiji's exports and is cultivated primarily in Viti Levu. But losses of traditional crops, such as yams and taro, could have a substantial effect on subsistence economies in Viti Levu.

**Figure 4. Likely Impacts of Climate Change on Agriculture in Viti Levu, Fiji**

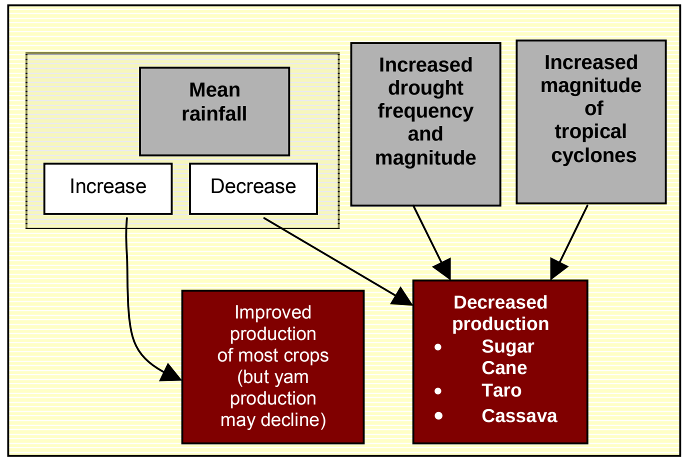
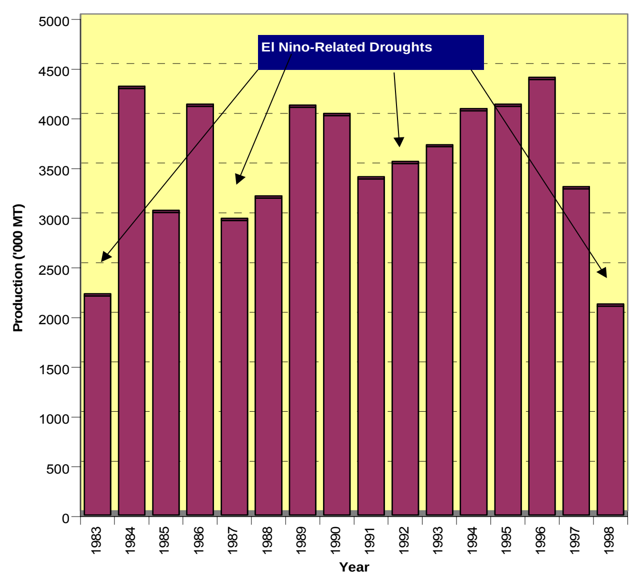



**Figure 5. Sugarcane Production in Fiji, 1983–1998**




*Source:* Official Fiji Statistics.

***Sugarcane.*** Sugarcane is particularly sensitive to droughts: the 1983 and 1997/98 events, for example, resulted in a 50 percent loss in production (figure 5).[5] In the future, increases in rainfall during good years may offset the impacts of warmer temperatures, with little change in sugarcane production. However, a warmer—and possibly drier—climate could lead to more intense droughts during El Niño years. Using the impact of the 1997/98 drought as representative of the intensity of future events and assuming a drought frequency similar to that observed in 1983–98 (one drought every four years), the following projections can be made for the next 25–50 years:

- Sugarcane production is likely to total 2 million metric tons—just half of output in a normal year—every four years, or 25 percent of the time (4 out of 16 years).
- Sugarcane production is likely to total 3 million metric tons—three-quarters of output in a normal year—31 percent of the time (5 out of 16 years) as a result of the residual effects of cyclones and droughts.
- Sugarcane production might total 4 million metric tons—the normal level of output—44 percent of the time (7 out of 16 years).

Under this scenario, the future production of sugarcane could average 3.2 million metric tons a year, a drop of 9 percent from the 1983–98 average level of 3.5 million metric tons. The resulting economic losses would be about US$14 million a year by 2025–50, assuming constant sugar prices.

[5] The agricultural climate change model used by the study (Plantgro) did not provide reliable scenarios for sugarcane. The impacts were thus estimated based on historical data.

**Table 8. Estimated Economic Impact of Climate on Change on Agriculture in Viti Levu, Fiji, 2050**

| | | *Impact of change in average rainfall and temperature* | | *Impact of change in rainfall, temperature, and climate variability (ENSO)* | |
|---|---|---|---|---|---|
| *Crop* | *Current production (US$ thousands)* | *Economic Impact (US$ thousands)* | *Change in average yield (percent)* | *Economic Impact (US$ thousands)* | *Change in average yield (percent)* |
| Sugarcane | 147,200 | — | — | -13,700 | -9 |
| Dalo (Taro) | 800 | -40 – +9 | -5 – +1 | -111 – +6 | -15 – +1 |
| Yam | 1,600 | -76 – +63 | -5 – +4 | -164 – +54 | -11 – +4 |
| Cassava | 2,100 | -189 – -105 | -9 – -5 | -242 – -128 | -12 – -6 |
| **Total** | | | | **-13,800─14,200** | |

— Not available. Minus signs indicate an economic cost. Plus signs indicate an economic benefit (from rainfall increases).
*Note*: Ranges reflect best-guess and worst–case scenarios under two different climate change models. See annex A for assumptions used.
*Source*: Background studies to this report.

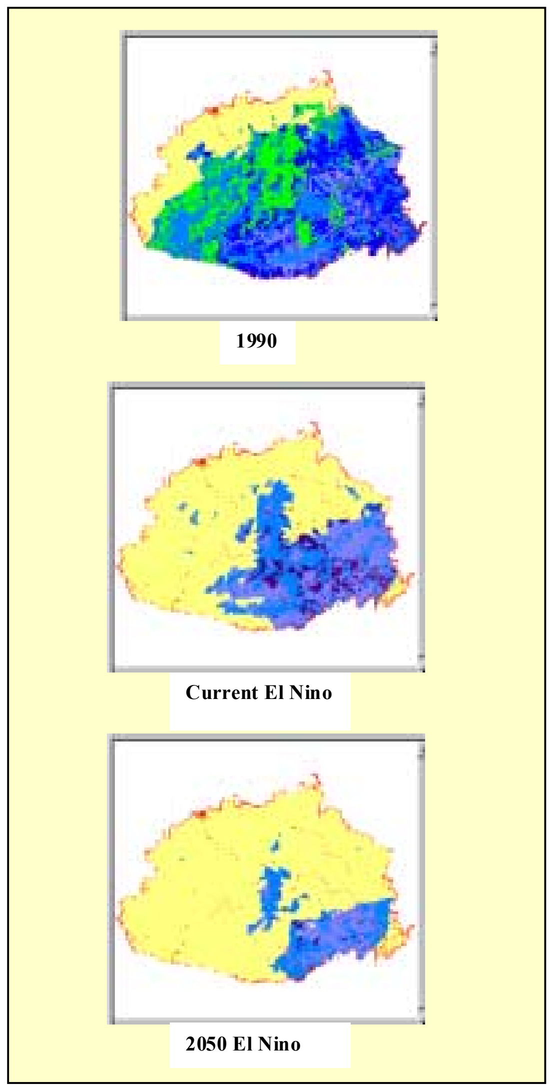
The impact on the Fijian economy is expected to be substantial, but localized. In 1997/98, for example, a 26 percent decline in sugarcane production value led to a decline in GDP of at least 1.3 percent (Ministry of Finance 1999). More importantly, Viti Levu could suffer a 50 percent drop in sugarcane production every fourth year due to stronger El Niños. These periodic droughts could well prove to be the most disruptive to the Fijian economy once preferential trade agreements are phased out.

***Food Crops***. By 2050 climate change may cost Viti Levu some US$70─520,000 in lost food crop production (table 8). Projected changes in average climate conditions (temperature and rainfall) would have little effect on dalo production. In El Niño years, however, the dalo yield could be reduced by 30–40 percent of current levels (figure 6).

Yam production would also remain relatively unaffected by changes in average conditions. The response to climate variability is the opposite of dalo. During El Niño events, production might be expected to remain the same or even increase. Production could decline by nearly 50 percent, however, as a result of wetter or La Niña–type conditions. This response is consistent with the traditional use of yam and *dalo* as dry and wet season crops.

Cassava output is expected to decline as a result of changes in average climate conditions, with yields falling 5─9 percent by 2050 (table 8). Productivity could also worsen with future

**Figure 6. Effect of El Niño─induced Droughts on Taro Cultivation Area and Yields in Viti Levu**




*Note:* Shaded areas show land suitable for cultivation.
*Source:* Background studies to this report.

climate variability, particularly under an intensified La Niña.

*Yaqona* (kava) showed little response to climate change or El Niño/La Niña anomalies. *Yaqona* harvests were affected by the 1997/98 drought, however. The crop is best suited to upland areas in central and southwestern Viti Levu, which are least affected by drought. This suggests that if production expands into nontraditional areas, *yaqona* could become increasingly susceptible to climate variation.

## D. Impact on Public Health

Climate change could have significant impacts on public health as a result of higher temperatures (0.9–1.3° C by 2050), changes in water supply, and decline in agriculture production. The impacts could include:

- *Direct impacts on public safety*, including injuries, illness, and loss of lives due to cyclones or droughts.
- *Indirect effects*, such as increased incidence of vectorborne diseases (dengue fever and malaria), waterborne diseases (diarrhea), and toxic algae (ciguatera).
- *Nutrition-related diseases*, particularly malnutrition and food shortages during extreme events.

Public health impacts are likely to be particularly severe for the 12-20 percent of households in Fiji that live below the poverty line (UNDP and Government of Fiji 1997). Poor households are more vulnerable to the impacts of climate change because of their greater propensity for infectious diseases, limited access to medical services, substandard housing, and exposure to poor environmental conditions. Many of the poor are also landless and (particularly in urban areas) may lack access to traditional safety nets that assisted them in times of disaster. Poverty is thus both a contributor to vulnerability as well as an outcome of climate-related events.

Quantifying these impacts is difficult, yet it is also vital for the development of appropriate public health policies. Based solely on the likely increase in dengue fever and diarrheal disease, the public health impacts of climate change in Viti Levu are estimated at US$1–$6 million a year by 2050. This figure is almost certainly an underestimate, as it does not take into account the costs of fatalities, injuries, or illnesses from cyclones or droughts; the costs of nutrition-related diseases; or the indirect impact of climate change on the poor and the most vulnerable, including infants.

***Public Safety.*** Fiji has lost more than 77 people to cyclones over the past 20 years (table 9). Injuries and illnesses caused by extreme events are also believed to be significant. Cyclone Kina alone caused 23 deaths in 1992/93, in addition to US$96 million in damages (Fiji Meteorological Services undated). An increase in cyclone intensity, as envisaged, could increase the impact on public safety by as much as 100 percent relative to what is observed today. An average cyclone in the future might come to resemble the impacts of cyclone Oscar (1983) or Eric (1985).

***Dengue Fever.*** Dengue fever is a growing public health problem in Fiji. The most recent epidemic—which coincided with the 1997/98 drought—affected 24,000 people and left 13

**Table 9. Loss of Lives and Damages from Recent Cyclones in Fiji, 1983–97**

| *Cyclone* | *Number of lives lost* | *Number of people missing* | *Damages (1998 US$ million)* |
|---|---|---|---|
| Oscar | 9 | — | 76 |
| Eric | 25 | — | 33 |
| Storm Gavin | 7 | 3 | 1 |
| Sina | — | — | 17 |
| Joni | 1 | — | 1 |
| Kina | 23 | — | 96 |
| Gavin | 12 | 6 | 18 |
| **Total** | **77** | **9** | **242** |

*Source:* Fiji Meteorological Services.

dead, at a cost of US$3–$6 million (Koroivueta, personal communication; Basu and others 1999).

Climate change is expected to cause significant increases in the frequency, severity and spatial distribution of dengue fever epidemics. Higher temperatures would increase the biting rate of mosquitoes and decrease the incubation period of the dengue virus.

In 1990, 53 percent of Viti Levu was at low risk of a dengue epidemic. By 2100 less than 21 percent of the island, all in the interior highlands, may remain at low risk. Under the worst-case scenario, up to 45 percent of the island could be at high or extreme risk of a dengue fever epidemic (table 10). The economic impact would average about US$1-$6 million a year by 2050 (table 11).

Climate change could also result in:

- A 20–30 percent increase in the number of cases of dengue fever by 2050 and as much as a 100 percent increase by 2100 (under a worst-case scenario).
- Dengue fever becoming endemic (that is, occurring all the time rather than in epidemics).
- A change in seasonality, so that dengue fever outbreaks could occur in any month.
- The emergence of more severe forms of the disease, such as dengue hemorrhagic fever and dengue shock syndrome, resulting in higher fatality rates.

***Diarrheal Disease.*** Diarrheal disease is likely to become more common in a warmer and wetter world. More intense droughts and cyclones could also increase the incidence of diarrhea by disrupting water supplies and sanitation systems.

Quantitative analysis indicates that a 1$^{o}$C increase in temperature could result in at least 100 additional reports of infant diarrhea a month. Since the actual incidence of diarrhea is at least 10 times the incidence of reported cases, a 1$^{o}$C rise in temperature, as expected by 2050, could lead to 1,000 additional cases of infant diarrhea a month. These results can be used, with lower levels of confidence, to estimate the potential impacts of diarrhea in children and adults. The economic costs of climate change on diarrheal disease are estimated to average US$300,000–$600,000 a year by 2050 (table

**Table 10. Potential Impact of Climate Change on Dengue Fever in Viti Levu, Fiji**

| *Likely changes* | *Baseline (1990)* | *2025* | *2050* | *2100* |
|---|---|---|---|---|
| *Estimated change in number of cases (percentage change)* | 0% | 10% | 20–30% | 40–100% |
| *Epidemic potential in Viti Levu (in percentage of land area)* [a] | | | | |
| Low risk | 53% | 38–39% | 25–31% | 7–21% |
| Medium risk | 47% | 61–62% | 69–72% | 48–72% |
| High risk | — | — | 0–3% | 7–41% |
| Extreme risk | — | — | — | 0–4% |
| *Seasonality* | | | | |
| Nadi | Seasonal | Seasonal | Seasonal to all year | All year |
| Suva | Seasonal | Seasonal | Seasonal to extended season | Prolonged season to all year |
| *Frequency of epidemics* | 1 in 10 years | ——— | Likely increase | ——— |
| *Severity of strains* | ——— | ——— | Likely increase | ——— |

[a] - Epidemic potential is an index that reflects the efficiency of transmission in a particular area.
*Note:* Ranges represent the most likely and worst-case scenarios in the CSIRO9M2 General Circulation Model.
*Source:* Background studies to this report. For assumptions, see annex A.

11).

***Other Public Health Impacts.*** Fiji is presently malaria-free: the strict border controls and quarantine requirements have so far been successful in keeping the malaria vector *(Anopheles)* away. Climate change could increase the risk of malaria, though modeling results indicate that the epidemic risks in Fiji due to climate change are small.

Climate change could also increase the risk of filariasis. However, Fiji has started an intensive program to control filariasis and is expected to eradicate the disease in 5—10 years (Koroivueta, personal communication).

***Nutrition-Related Diseases***. More intense cyclones and droughts are likely to increase the incidence of nutrition-related diseases, as subsistence crops and fisheries are affected. The impacts may be similar to those experienced during the 1987 and 1997/98 droughts, when milk production fell 50 percent and some US$18 million in food and water rations had to be distributed (UNDAC 1998). Up to 90 percent of the population in western Viti Levu required emergency food and water rations. Loss of agriculture income and failure of household gardens also caused protein, vitamin, and micro-nutrient deficiency, particularly among young children and the poor.

**Table 11. Estimated Annual Economic Impact of Climate Change on Public Health in Viti Levu, Fiji, 2025–2100 (millions of 1998 US$)**

| *Event* | *2025* | *2050* | *2100* |
|---|---|---|---|
| Cyclones and droughts[a] | ——— | Likely to be substantial | ——— |
| Dengue fever | 0.3—2.3 | 0.5—5.5 | 0.7—15.9 |
| Diarrheal diseases | 0.2 | 0.3—0.6 | 0.6—2.2 |
| Nutriton-related illnesses | + | + | + |
| **Total estimated costs** | **0.5—2.5** | **0.8—6.1** | **1.3—18.1** |

— Not available.
\+ No quantifiable data available, but damages are likely to be substantial.
a. The effect of cyclones and droughts on health could not be calculated, though the overall impact of cyclones was taken into account in section B.
*Note*: For assumptions, see annex A.
*Source*: Background studies to this report.