CHAPTER FIVE

IMPACTS AND VULNERABILITY ASSESSMENT

Guyana, being a relatively large country with both a Tropical Coastal Marine Environment where most of the population and economic activity are located and an interior Continental Tropical/Equatorial Environment would be most vulnerable to climate change and impacts such as sea level rise, especially in the coastal zone, and in the water resources, agriculture, forestry, energy and health sectors.

A breach of the sea defence

5.1 INTRODUCTION

On account of human activities related to development practices, life style and population expansion, such as rapid industrialization and land-use changes, including forest utilization, the atmospheric concentration of certain gases – carbon dioxide (CO_2), carbon monoxide (CO), ozone (O_3), methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_x) and chlorofluorocarbons (CFC's) - have recently been increasing at an alarming rate. It is currently believed that, if present rates of emissions of these so-called greenhouse gases are maintained, a doubling of their combined and effective concentration could occur by around the year 2050. It is feared that an effective doubling of greenhouse gases could conceivably affect the earth's radiation and energy balances, which could eventually lead to climate change and as a consequence, sea level rise. Such a change in climate and sea level can have severe impacts on different ecosystems and on society both globally and regionally. Guyana, being a low lying state (according to Article 4.8 (b) of the Convention) and having a biodiversity consisting of numerous fragile ecosystems, can be deemed to be highly vulnerable although it is a net sink country in GHG's.

5.2 CLIMATE CHANGE AND SEA LEVEL SCENARIOS FOR GUYANA

5.2.1 Observed Climate

For this analysis, the climate record (temperature and rainfall) for the Botanical Gardens in the Capital city, Georgetown, is used. Georgetown is located at 6^0 47' North Latitude, 58^0 09' West Longitude, on the mouth of Demerara River in the Coastal Plain. Temperature data span close to 89 years (1909 to 1998) and rainfall data coverage exceeds 100 years (1884 to 1998).

5.2.1.1 Temperature

Figure 5.1 shows the yearly temperature variation with mean maximu m and minimum temperatures also included. Using linear extrapolation, the maximum temperature has shown an increase of 0.8^0C while the minimum temperature has shown an increase of 1.2 ^{0}C with a mean annual increase of 1.0 ^{0}C over the period of record. This supports the observed indication elsewhere in the Caribbean (Singh, 1997), that a greater increase in nighttime temperatures has been contributing to the observed global warming. This observed trend also corresponds to a decrease in the diurnal temperature range of about 0.5 ^{0}C - see Figure 5.2. Both the relatively greater increase in the night-time minimum temperature and the decreasing diurnal temperature range are symptomatic of global warming which is being demonstrated by increases in the night-time temperatures (Singh, 1997).

Seasonal temperatures are modulated by the rainfall amounts during the seasons. Hence, there is not expected to be significant fluctuations in the seasonal temperature records.

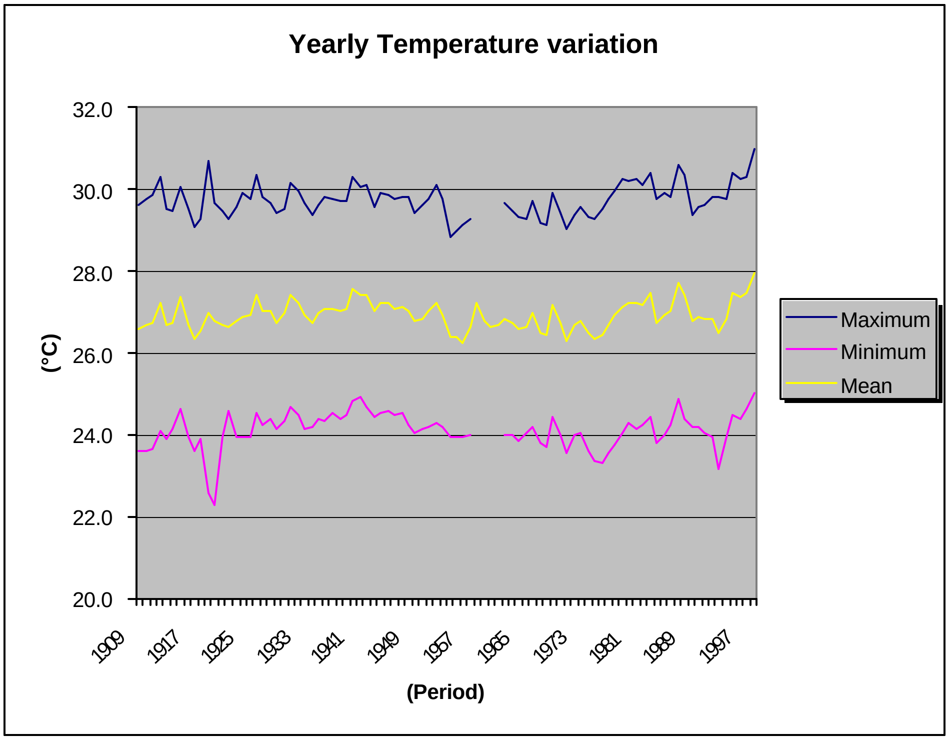


Figure 5.1: Yearly Temperature Variation at Botanical Gardens,

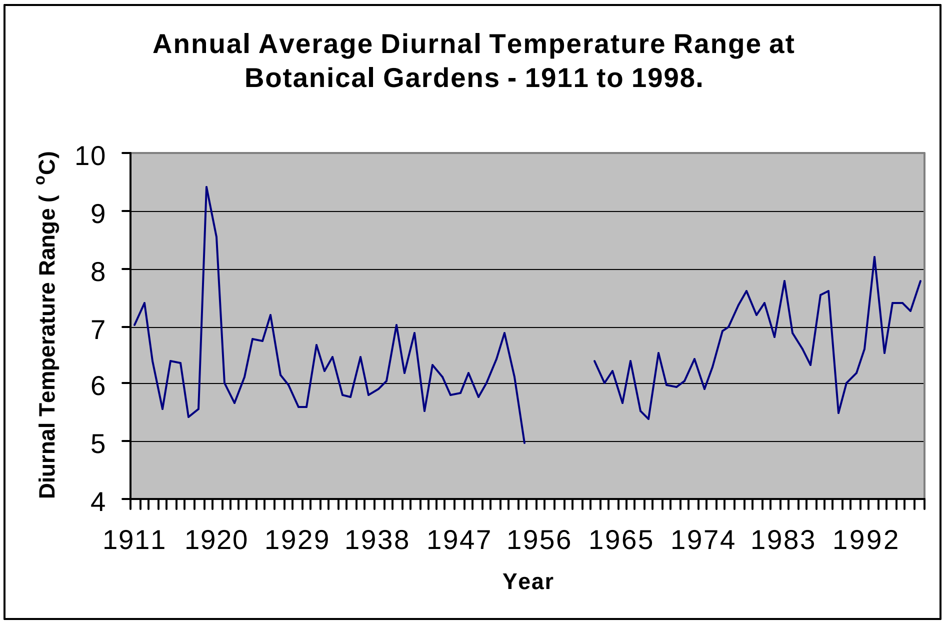


Figure 5.2: Annual Average Diurnal Temperature Range at Botanical Gardens – 1911 to 1998

When Georgetown Botanical Gardens mean air temperature (Figure 5.3) is compared to Global Average Temperatures (Figure 5.4), then there are some similarities:

- Temperatures have been rising from about 1890 up to about 1940,
- Then there was a decrease until the late 1970s, when temperatures increased again,
- The highest average temperatures were recorded in the 1980s and 1990s. However, there was a short period about 1940 when comparable high average temperatures were recorded.
- The highest average temperature was recorded in 1998.

The annual air temperatures at Georgetown Botanical Gardens also showed a pattern of responding to the cooling effect of major volcanic eruptions around the world - see Figure 5.3. The last cooling period during the early 1990s correlated with the Pinatubo eruption. It is therefore a consideration that the increase in air temperature in Guyana is being significantly masked by the cooling effect of the abundant aerosols introduced into the atmosphere during volcanic eruptions.

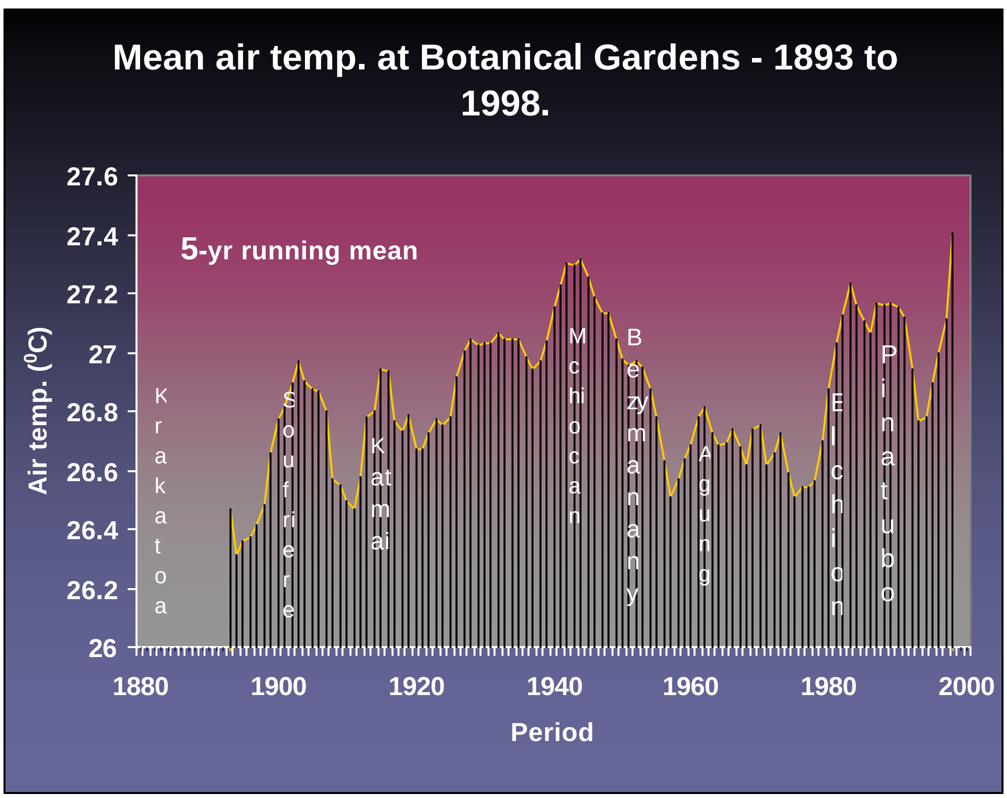


Figure 5.3: Annual Surface Temperature Variation, Botanical Gardens, Georgetown

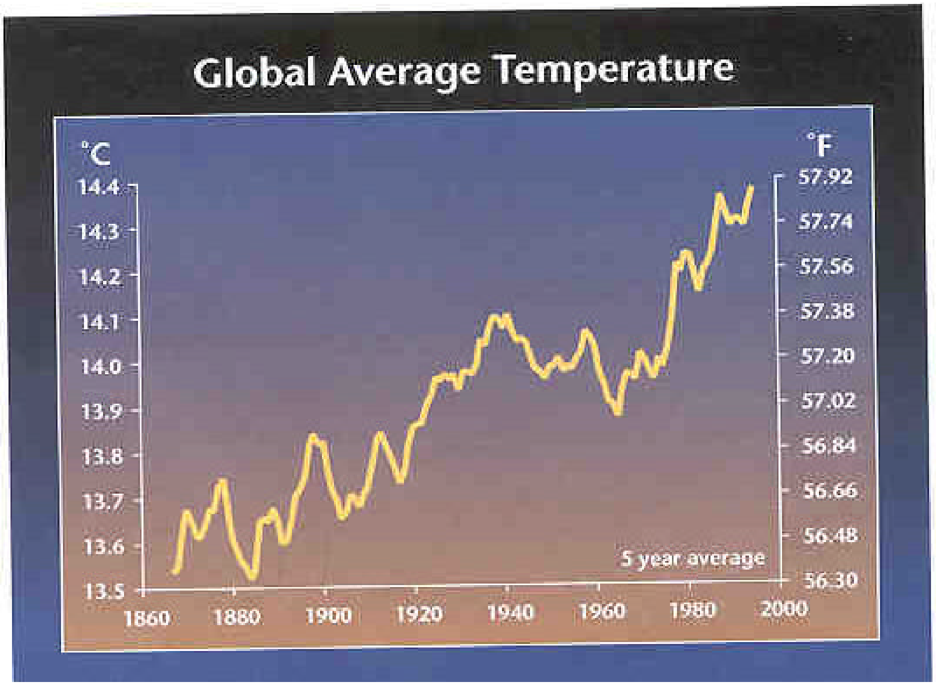


Figure 5.4: Average Global Surface Temperature Variation (reproduced from a WMO Publication)

5.2.1.2 Rainfall

Figure 5.5 shows the five-year running mean anomalies of annual rainfall amounts from the international normal (1961-1990) for Georgetown Botanical Gardens. Prior to 1960, annual rainfall amounts were generally above or about normal. However, from 1960 and onwards, there has been more below-normal periods than above-normal periods.

While ENSO events have been shown to be affecting Guyana (Simon, 1997) there seems to be a mechanism which is resulting in decreasing annual rainfall amounts during the last two decades (see Figure 5.5) when surface air temperature has been increasing. It appears that increased evaporation due to higher surface air temperatures did not result in higher rainfall. It could very well be that cloud cover has increased but this was due to more stratiform cloudiness rather than connective cloudiness. However, within the 1990s it has become apparent that convective storms have become more intense but fewer. The result was high intensity rainstorms leading to short-period flooding. The clusters in the Intertropical Convergence Zone off the Guianas are smaller and fewer but more intense. The monthly rainfall is therefore being accounted for by fewer days with higher rainfall.

With regards regional climate events, the ENSO has been very pronounced especially in the 1990s. While the EL NIÑO of 1982-3 did have an impact on Guyana's rainfall, the effect was not sufficiently intense to cause concerns for agriculture, etc.

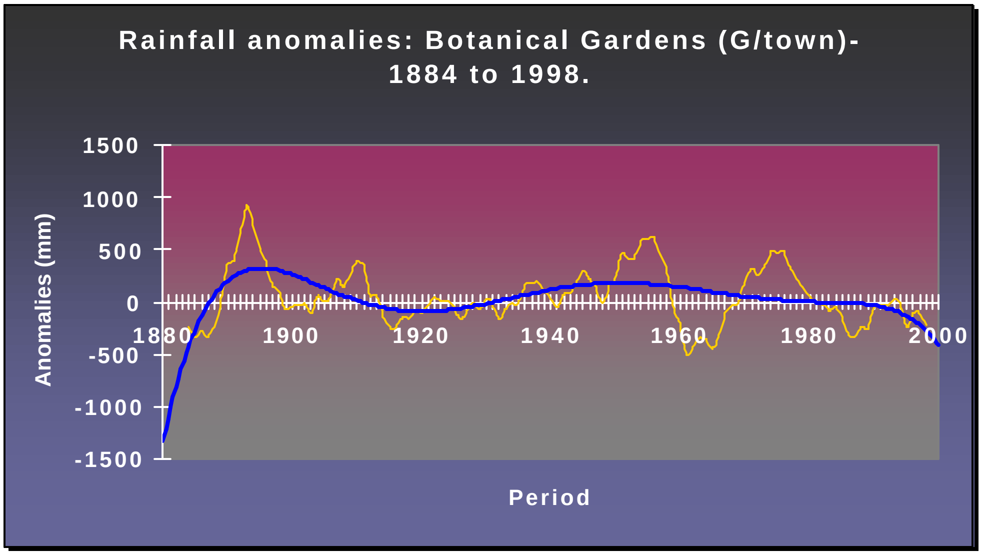


Figure 5.5: Anomalies of Annual Rainfall from the normal for 1961 – 1990 in mm, Botanical Gardens

However, the 1997/1998 El Niño event produced widespread drought with accompanying forest fires and a significant impact on the economy of the country. The La Niña of 1996 caused severe flooding to affect several parts of the country. In 1999 and 2000, La Niña's influence can be blamed for sporadic flooding especially of coastal regions.

The questions are:

- Will rainfall continue to have larger year to year variability as temperatures increase?
- Will rainstorms become more intense as global warming continues?
- Will ENSO events intensify as a consequence of global warming?
- Will doubling/tripling of the concentration of greenhouse gases in the atmosphere increase/decrease rainfall amounts in the rainy seasons?
- Will the rainy seasons shift, extend, or shorten as a consequence of global warming?

These questions may be answered but significant monitoring of climate and research will have to be done. These are needs which will have to be addressed in accordance with Article 5 of the Convention.

5.2.2 Scenarios of Future Climate Change

There are now discernable evidences that increases in atmospheric concentrations of greenhouse gases due to anthropogenic activities would warm the earth's atmospheric system (IPCC, 1996). In order to assess the effects of future climate change and to take appropriate adaptation measures against any adverse effects, estimates of how fast and to what extent global warming will occur are necessary. The most convenient and expeditious method has been the generation of future climate change and sea level rise scenarios using the A-O GCM (Atmosphere-Ocean General Circulation Model) approach.

Recent A-O GCMs adequately couple the atmospheric and oceanic circulations and in some cases emission scenarios of future greenhouse gases, tropospheric aerosols and, assumptions on population and economic growth, energy availability and fuel mix, are considered (IPCC, 1992). The climate simulations derived from these A-O GCM's have been extensively used in the development of scenarios of regional climate change for impacts assessment.

5.2.2.1 CGCM 1

In this chapter, we use the results generated by the most recent A-O GCM of the Canadian Climate Centre (CGCM 1) run in transient mode with CO_2 increasing by the observed values to the present and then by 1% per year into the future, to create regional climate change scenarios for the region in and around Guyana (see Figure 5.6). Cells 2, 3, 5, 6, 8, 9 and 11 include the major part of the territorial area of Guyana. For each of the grid cells, climatological data for 3 time slices: 1975 – 1995 (present), 2020 – 2040 (2 x CO_2) and 2080 – 2100 (3 x CO_2) are selected. For each of these time periods, changes in near-surface rainfall (Table 5.1), temperature (Table 5.2), evaporation (Table 5.3) and water deficit (Table 5.4), as simulated by CGCM 1 are extracted in monthly groupings corresponding to the First Dry Season (FDS: February to April), the First Wet Season (FWS : May to July), the Second Dry Season (SDS : August to October) and the Second Wet Season (SWS : November to January) of Guyana.

Figure 5.6: Selected Grid Cells in and around Guyana for CGCM 1

Table 5.1: THE CANADIAN A-O GCM (CGCM 1) PROJECTIONS OF RAINFALL (mm dy-^{1}) FOR GUYANA

	Doubling CO_2 (2020 to 2040) - (1975 to 1995)				**Tripling CO_2 (2080 to 2100) - (1975 to 1995)**			
CELL	FDS	FWS	SDS	SWS	FDS	FWS	SDS	SWS
2	-0.30	-0.69	-0.31	+0.30	-0.39	-0.16	-0.14	+0.25
3	-0.96	-0.93	-0.51	-0.15	-1.36	-0.92	-0.35	-0.07
5	+0.08	-0.65	-0.68	+0.30	+0.22	-0.34	-0.80	+0.29
6	-0.41	-1.44	-1.02	+0.07	-0.79	-2.49	-1.47	-0.12
8	-0.26	+0.09	-0.38	+0.11	+0.26	-0.80	-1.63	-0.09
9	-0.17	-0.04	-0.51	-0.71	+0.08	-1.83	-2.10	-1.48
11	-.0.23	-0.26	+0.52	-0.50	-0.19	-0.59	-1.02	-1.15
AVERAGE	-0.32	-0.56	-0.41	-0.08	-0.31	-1.02	-1.07	-0.34

Table 5.2: CGCM 1 PROJECTIONS OF AIR TEMPERATURE (°C) FOR GUYANA

	Doubling CO_2 (2020 to 2040) - (1975 to 1995)				**Tripling CO_2 (2080 to 2100) - (1975 to 1995)**			
CELL	FDS	FWS	SDS	SWS	FDS	FWS	SDS	SWS
2	+1.20	+1.04	+1.64	+1.73	+4.35	+3.99	+4.53	+4.79
3	+1.13	+1.06	+1.59	+1.77	+4.28	+3.99	+4.90	+5.08
5	+1.22	+1.17	+1.35	+1.62	+4.24	+4.06	+4.45	+4.76
6	+1.09	+1.01	+1.08	+1.20	+4.01	+3.93	+3.93	+4.00
8	+1.10	+1.12	+1.09	+1.16	+4.14	+3.99	+3.96	+4.07
9	+1.05	+1.01	+1.01	+1.02	+4.10	+3.95	+3.91	+3.88
11	+1.21	+1.05	+1.01	+1.07	+4.18	+3.84	+3.74	+3.87
AVERAGE	+1.14	+1.07	+1.25	+1.37	+4.19	+3.96	+4.20	+4.35

Table 5.3: CGCM 1 PROJECTIONS OF EVAPORATION RATE (mm dy^{-1}) FOR GUYANA

	Doubling CO_2 (2020 to 2040) - (1975 to 1995)				Tripling CO_2 (2080 to 2100) - (1975 to 1995)			
CELL	FDS	FWS	SDS	SWS	FDS	FWS	SDS	SWS
2	-0.17	-0.12	-0.37	-0.36	-0.22	+0.02	±0.00	-0.18
3	-0.13	± 0.00	-0.33	-0.65	-0.20	+0.11	-0.45	-0.66
5	-0.15	-0.11	-0.06	-0.38	-0.18	+0.05	+0.03	-0.37
6	+0.01	+0.02	+0.14	-0.05	+0.27	+0.28	+0.39	+0.14
8	+0.08	± 0.00	± 0.00	-0.06	+0.13	+0.16	+0.34	+0.13
9	+0.11	-0.12	+0.01	-0.04	+0.33	+0.22	+0.30	+0.28
11	+0.15	+0.10	+0.02	+0.16	+0.54	+0.55	+0.63	+0.41
AVERAGE	-0.01	-0.03	-0.08	-0.19	+0.10	+0.19	+0.18	-0.04

Table 5.4: CGCM 1 PROJECTIONS OF WATER DEFICITS (mm dy^{-1}) FOR GUYANA

	Doubling CO_2 (2020 to 2040) - (1975 to 1995)				Tripling CO_2 (2080 to 2100) - (1975 to 1995)			
CELL	FDS	FWS	SDS	SWS	FDS	FWS	SDS	SWS
2	-0.13	-0.58	+0.06	+0.66	-0.17	-0.18	-0.14	+0.43
3	-0.83	-0.93	-0.18	+0.49	-1.17	-1.03	+0.09	+0.59
5	+0.23	-0.54	-0.62	+0.68	+0.40	-0.39	-0.83	+0.66
6	-0.42	-1.46	-1.16	+0.12	-1.06	-2.77	-1.87	-0.26
8	-0.33	+0.09	-0.37	+0.17	+0.13	-0.96	-1.97	-0.22
9	-0.28	+0.07	-0.52	-0.68	-0.25	-2.05	-2.40	-1.76
11	-0.38	-0.36	+0.50	-0.66	-0.73	-1.14	-1.65	-1.56
AVERAGE	-0.31	-0.53	-0.33	+0.11	-0.41	-1.22	-1.25	-0.30

5.2.2.1.1 Temperature Change

For a doubling of CO_2 concentration in the atmosphere, the temperature of Guyana is expected to rise in the early part of the twenty-first century by 1.2°C on average but the Second Wet Season (SWS) is predicted to attain the highest increase of 1.4°C. Southern Guyana inclusive of the Rupununi Savannahs are expected to have the highest increase in excess of 1.5°C during the Second Dry Season (SDS) and the SWS.

For the latter part of the twenty-first century, with a tripling of the concentration of CO_2, temperature will rise by 4.2°C on average. Here again, Southern Guyana, including the Rupununi Savannahs, is expected to have the highest increases, in excess of 4.5°C during the SDS and the SWS.

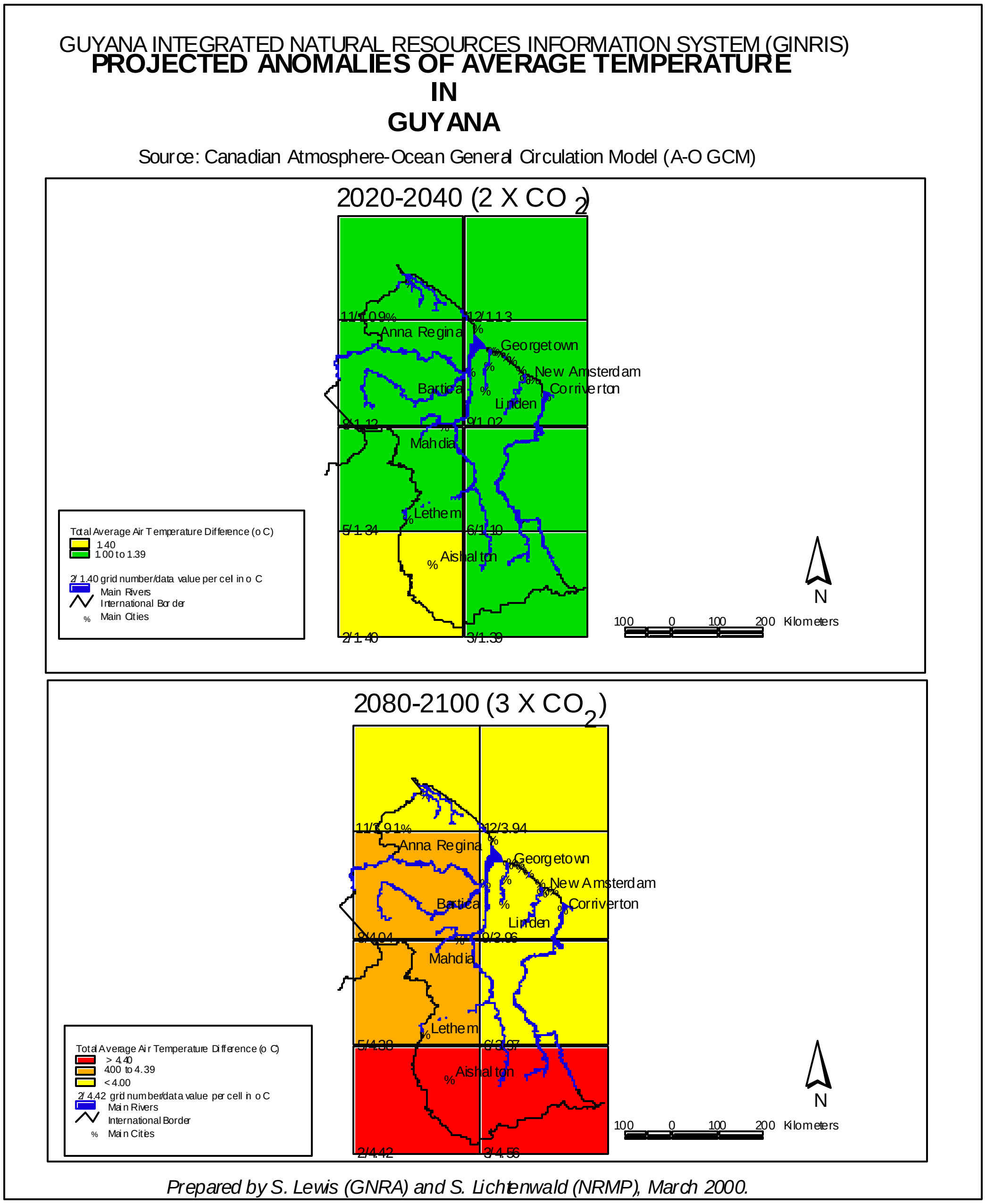


Figure 5.7: The regions of Guyana which will be affected by temperature changes due to increased CO_2 concentrations.

5.2.2.1.2 Rainfall Change

For a doubling of the concentration of CO_2, rainfall is expected to decrease by an average of 0.34 mm dy^{-1} or 10 mm per month. The decrease appears to be higher, 17 mm per month and 12 mm per month in the First Wet Season (FWS) and the SDS respectively.

For a tripling of the concentration of CO_2, the average decrease is expected to be 0.69 mm dy^{-1} or 21 mm per month. Here again, the FWS and the SDS will experience decreases higher than 1 mm dy^{-1} or 30 mm per month.

Again, Southern Guyana is targeted for the largest decreases in both the doubling CO_2 and tripling CO_2 scenarios of CO_2 concentration. However, with the tripling of CO_2 concentration, Northern Guyana (including the coast) is also expected to be affected by significant rainfall decreases.

Figure 5.8 shows the regions of Guyana which will be affected by rainfall decreases due to increased CO_2 concentrations.

5.2.2.1.3 Evaporation and Water Deficits

As for the change in evaporation rate, the slight (~ 1 ^{o}C) average increase in temperature, as a consequence of CO_2 doubling, does not translate into significant evaporation (less than 0.1 mm dy^{-1}). However, for a tripling of the CO_2 concentration, evaporation generally increases, in response to the higher temperature increase, to about 0.11mm dy^{-1}. The southern parts of Guyana will not be significantly affected but northern Guyana will, in general, experience increases of about 0.22 mm dy^{-1} or 7 mm per month. The northwest region will be subjected to evaporation rate increases in excess of 0.40mm dy^{-1} or 12 mm per month in all seasons.

Water deficit is defined as the difference between rainfall and evaporation. A positive value indicates that rainfall exceeds evaporation while a negative value indicates that rainfall is insufficient to meet the loss of water due to evaporation.

With a doubling CO_2 scenario, the average deficit is expected to be 0.27 mm dy^{-1} or about 8 mm per month. Southern Guyana will experience large water deficits especially in the FWS and SWS. With a tripling CO_2 scenario, the average deficit becomes 0.8 mm dy^{-1} or 24 mm per month. However, in this case it is northern Guyana which will encounter deficits in excess of 0.73 mm dy^{-1} or 22 mm per month with large deficits expected in the FWS and SDS.

A common observation, with both scenarios, is that southern Guyana is expected to have positive water deficit values in the SWS. That is, rainfall is expected to be higher than evaporation.

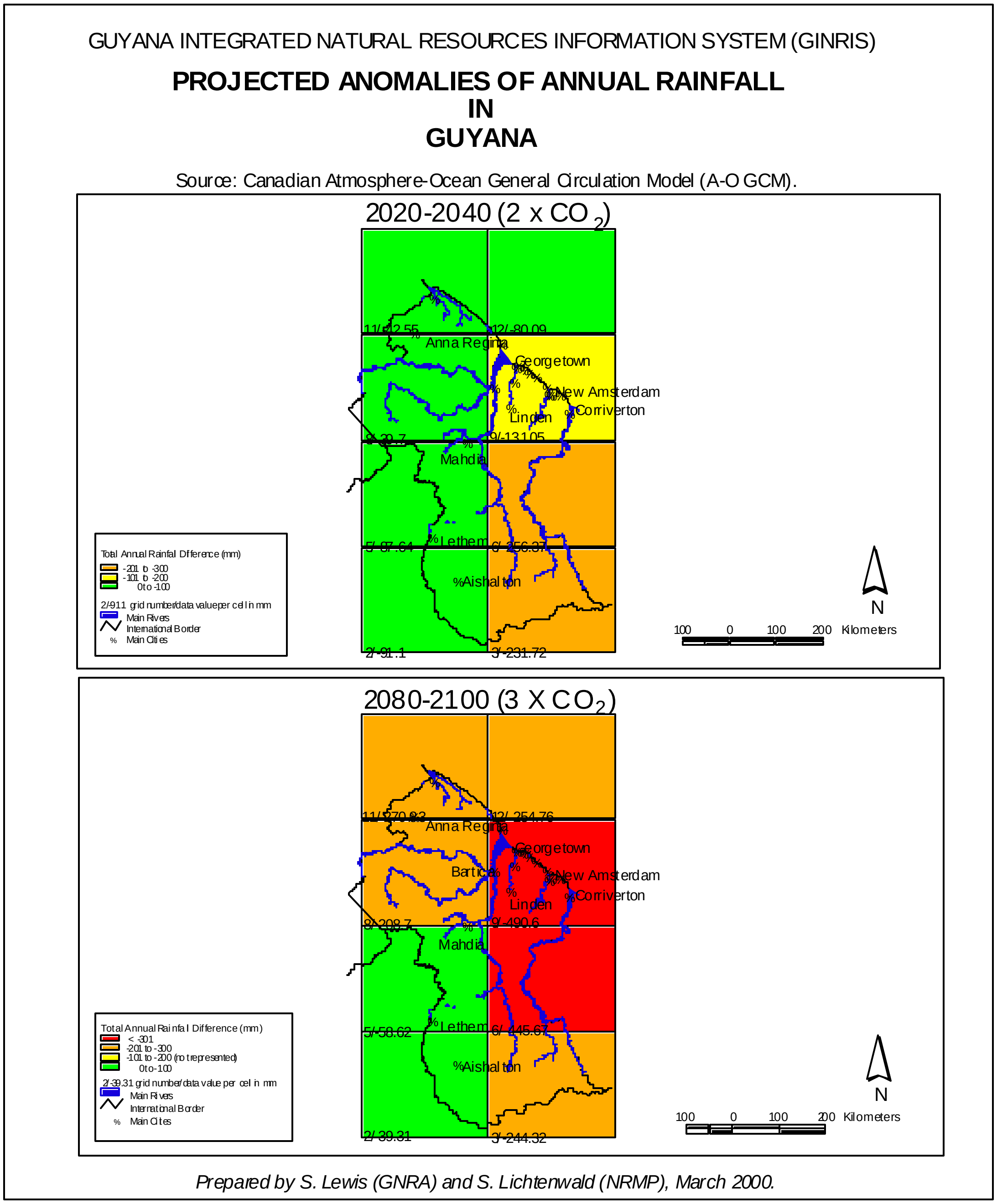


Figure 5.8: The regions of Guyana which will be affected by rainfall changes due to increased CO_2 concentrations.

5.2.2.2 Hadley Centre A-O GCM

For purposes of comparison and validation, we also use the results of the Hadley Centre A-O GCM (HadCM2Gsal) retrieved from the scenario generator SCENGEN within MAGICC (Model for the Assessment of Greenhouse gas induced Climate Change). Two future time periods centered around 2030s (2016-2045), corresponding to the 2 x CO_2 scenario and 2090s (2076-2105), corresponding to the 3 x CO_2 scenario, have been used, to generate scenarios of changes in surface air temperature and precipitation for Guyana. However, the grid spacings (5° x 5°) are slightly different (See Tables 5.5 and 5.6).

The SCENGEN version of the Hadley Centre A-O GCM projects similar changes as the Canadian Model increases in air temperature and rainfall with the increases in greenhouse gas concentration. In fact, the CGCM 1 and Had CM2 results are remarkably similar for the 2 x CO_2 scenario for air temperature and rainfall, although the latter gives the changes of rainfall as a percentage instead of mm/day.

For the 3 x CO_2 scenario however, Had CM2 gives lower temperature projections, of the order of 1.5 to 2.0°C lesser than the CGCM 1. This may be explained by the fact, that the Had CM2 projections are from MAGICC, based on patterns of change and by the fact that Had CM2 uses the IS95a sulphate scenario which is thought to be too high. However, the 3 x CO_2 rainfall scenarios are somewhat similar, although the Had CM2 projections of decreases in rainfall are more severe, especially for the FWS.

Table 5.5: The Hadley Centre A-O GCM (HadCM2) projected changes of screen air temperature (°C) for Guyana

DOUBLING CO_2 (2016/2045) - (1961/1990)						TRIPLING CO_2 (2076/2105) - (1961/1990)			
Lat.	**Lon.**	**FDS**	**FWS**	**SDS**	**SWS**	**FDS**	**FWS**	**SDS**	**SWS**
7.5	-62.5	+0.93	+1.33	+1.20	+1.23	+1.80	+1.33	+1.87	+1.90
7.5	-57.5	+0.77	+0.90	+0.97	+0.93	+3.07	+0.90	+3.37	+3.63
2.5	-62.5	+1.43	+1.63	+1.37	+1.48	+2.07	+1.63	+2.67	+2.53
2.5	-57.5	+1.37	+1.50	+1.23	+1.40	+1.90	+1.50	+2.30	+2.13
Average		1.13	1.34	1.19	1.26	2.21	1.34	2.55	2.55

Table 5.6: The Hadley Centre A-O GCM (HadCM2) projected changes of rainfall (%) for Guyana

		DOUBLING CO_2 (2016/2045) - (1961/1990)				TRIPLING CO_2 (2076/2105) - (1961/1990)			
Lat.	**Lon.**	**FDS**	**FWS**	**SDS**	**SWS**	**FDS**	**FWS**	**SDS**	**SWS**
7.5	-62.5	-1.27	-14.23	-6.10	-13.53	-12.80	-38.47	-16.07	-20.57
7.5	-57.5	+2.03	-13.57	-5.03	-11.53	-5.27	-36.60	-12.23	-14.90
2.5	-62.5	+1.83	-11.80	+3.00	-6.35	+0.17	-29.77	+4.20	-11.40
2.5	-57.5	-9.50	-12.87	-4.47	-11.98	-27.57	-32.97	-13.00	-15.67
Average		-1.73	-13.12	-3.15	-10.84	-11.37	-34.45	-9.28	-15.63

5.2.2.3 Extreme High Temperature & Precipitation Events

An analysis of model-simulated daily temperature and precipitation for the present-day atmosphere and two future time slices (2050s and 2080s) suggests that the frequency of extreme temperatures during Northern Hemisphere summer season, which more or less coincides with Guyana's First Wet Season, is likely to be enhanced thereby increasing the probability of thermal stress conditions during 2050s and more so during 2080s. Similarly, there is a possibility of a lesser number of rainy days in a year, although an increase in the daily intensity of precipitation is also expected (Lal et al., 1999). This suggests an increase in the probability of occurrence of more frequent droughts as well as floods for the future.

However, one important aspect of the observed temperature change over the globe during the past century relates to its asymmetry during the day and night. Observed warming in surface air temperatures over several regions of the globe has been reported to be associated with increases in minimum temperatures, accompanied by increasing cloudiness, and decrease in diurnal temperature range.

Any future changes in the diurnal temperature range (DTR) are important in respect of its crucial role in agriculture. GCM simulations, with increasing concentrations of GHGs in the atmosphere, suggest relatively more pronounced increases in minimum temperature than in maximum temperature over the North Atlantic and Caribbean regions on an annual mean basis as well as during Northern Hemisphere winter for both 2050s and 2080s, hence a marginal decrease of 0.3°C to 0.7°C in diurnal temperature range.

5.2.2.4 ENSO and Precipitation Variability

In general, Guyana suffers acute droughts during El Niño phase and oppositely, heavy rainfall accompanied by flooding during La Niña phase. In recent years, warm episodes (El Niño) have been relatively more frequent or persistent than the opposite phase (La Niña). The ENSO phenomenon is the primary mode of climate variability on the 2 -5 year time scale. At present the weight of evidence from both observations and A-O GCM projections is that it is uncertain whether there will be any significant change to the amplitude or frequency of ENSO in the future. Thus, the current large inter-annual variability in the rainfall associated with ENSO is likely to dominate over any effects attributable to global warming. However, the frequency and increased intensity of ENSO–related effects in Guyana will need to be examined.

5.2.2.5 Tropical Cyclones

Guyana, in close proximity to the equator, has not in the past suffered significant ill effects of hurricanes. On account of its equatorial location, climate change will very unlikely change this condition, except for the increased effects of sea swells and tidal surges, in the event of major shifts in hurricane numbers, patterns and intensities in the North Atlantic and Caribbean Sea to the north of Guyana.

There is no consensus regarding the behaviour of tropical cyclones in a warmer world. However, recent studies indicate a possible increase of about 10 to 20% in intensity of tropical cyclones under enhanced CO_2 conditions. Studies also suggest that, during ENSO events, tropical cyclones and hurricanes are likely to be more severe (Jones et al.,1999; Tonkin et al., 1997; Holland, 1997). However, another study found no significant change in hurricane frequency or geographical extent for the North Atlantic under a 2 x CO_2 Climate (Royer et al., 1998). The concern for Guyana is the possibility of spiral bands of the hurricanes that pass to the north, affecting Guyana with more frequency than in the past.

5.2.3 Sea Level Rise

5.2.3.1 Past Sea Level Rise

While the severity of the threat will vary regionally, sea level rise of the magnitude currently projected by A-O GCMs (i.e. 5 mm yr^{-1}), with a range of (2-9 mm yr^{-1}), is expected to have disproportionately great effects on the economic and social development of many small island states and coastal low-lying land masses such as Guyana.

Real or eustatic sea level rise as would be driven by climate change has to be combined with relative sea level rise as caused by land displacements in the vertical. In some locations, current sea-level change is dominated by land movement of various kinds: local tectonic movements, isostatic rebound or local anthropogenic effects. These processes are not related to current climate change. By selection and correction of tide gauges, these processes are excluded from the assessment of global average ecstatic sea-level change, which is estimated to lie in the range 1.0-2.5 mm^{yr-1} averaged over the last hundred years (Church and Gregory, 2000). The primary source of information on secular trends in global sea level during the past century is the tide gauge data set of the Permanent Service for Mean Sea Level (PSMSL). Estimates of global average sea level rise using this data set fluctuate over a wide range varying from 1.0 to 2.4 mm^{yr-1} (Douglas, 1995; Smith et al 1999).

The sum of these processes indicates that between a third and a half of the 20th century eustatic sea level rise is due to thermal expansion. Thermal expansion and changes in air/sea momentum, heat and freshwater fluxes associated with climate change will alter the ocean circulation and the pattern of sea-surface height. These processes are therefore expected to have a geographically non-uniform signal in sea level change (Church and Gregory, 2000). However, Singh (1997), reported rates of mean relative sea level of 8 to 10 mm yr^{-1} in Trinidad and Tobago, but this data set is limited by its short period (15 yrs) and lack of measurements on vertical land movements.

In the case of Guyana, based on available tide gauge data for the period 1951 to 1979 for Port Georgetown, mean relative sea level rise, using a linear extrapolation is 10.2 mm yr^{-1} – see Figure 5.9. High tide change has been calculated to be 9.7mm yr^{-1} with the low tide change being 11.1mm yr^{-1}. This rate of relative sea level rise is about 5 times the global average and close to that observed in Trinidad, albeit for a later time period. This is therefore suggestive of some mechanism other than eustatic sea level rise, such as subsidence due to water extraction, ocean floor sediment loading or plate tectonics. Plate tectonics, however, does not appear to be contributing to this problem - see Chapter 3 for a discussion on this matter. Subsidence and sediment loading may both be contributing to the high rises noted in Guyana. The high rises observed in Trinidad and in Guyana may suggest a generalized increase of sea level in the region.

This discussion did not examine the effects of the North Equatorial Counter Current, the Guyana Current and the eddies within the Guyana Current on the level of the sea off Guyana. These will definitely result in changes in water accumulation off the coast and may contribute to acute rises over short periods of time resulting in overtopping of defences and inundation of vulnerable areas, especially where weak earthen dams and mangrove defences exist. Studies will have to be done on these effects to guage the seriousness of the vulnerability.

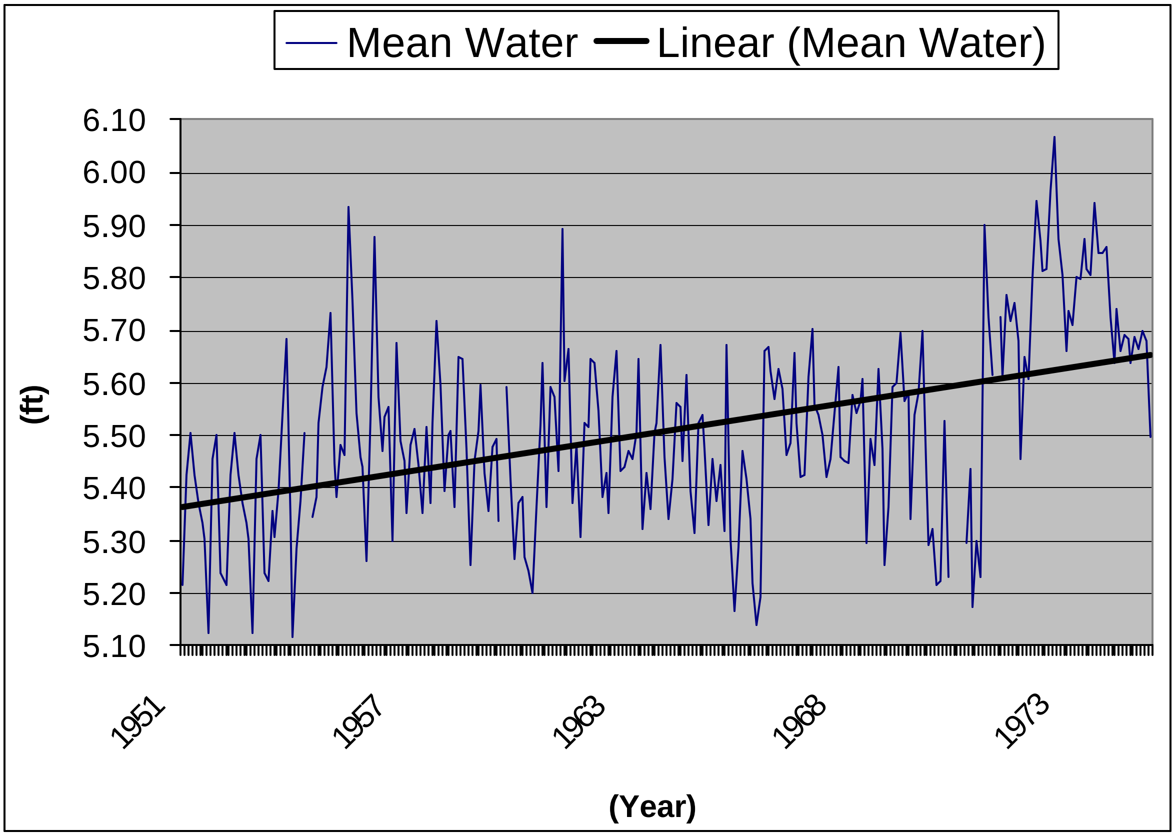


Figure 5.9: Observed Sea Level Changes at Port Georgetown, Guyana (1951 – 1979)

5.2.3.2 Future Sea Level Change

For the oceans, time-dependent experiments to simulate the evolution of the climate over the next century have been run with a number of AO-GCMs. Several of these have followed similar scenarios for climate forcing, starting from the beginning of this century or earlier with greenhouse gases increasing as they did historically up to 1990, then with the IS92a scenario, namely 1 % per year, for the future. Some experiments have also included the direct effect of sulphate aerosol emissions, which counteracts part of the positive greenhouse radiative forcing.

The experiments with only greenhouse gases show a range of about 0.1 to 0.2 m for the first half of the 21st century, corresponding to rates of rise of 2 to 4 mm yr^{-1}. In all the models, there is acceleration throughout the century; for the second half, the average rates are in the range 3 to 6 mm yr^{-1}.

Future sea level rise data was extracted from the CGCM 1in transient simulation, extending from 1901 to 2100, for grid cells 9 and 11 along the Atlantic coast of Guyana (see Figure 5.6 for the location of these cells).

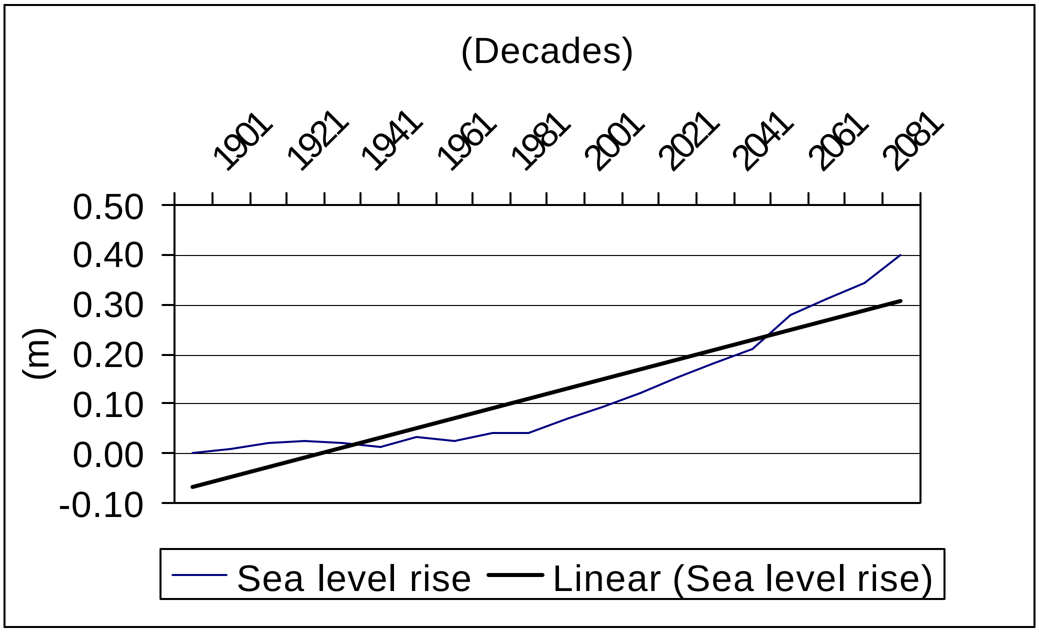


Figure 5.10: CGCM 11 Future Sea Level Projections

Figure 5.10 which is based on the steric component of mean sea level rise, that is, neglecting meltwater runoff from land areas, and on transient simulations of CGCM 1, shows that mean sea level along the Atlantic coast of Guyana is projected to rise by about 40 cm by the end of the twenty first century, that is, at a rate close to 4 mm yr^{-1}. If one were to add the contribution of meltwater from land ice, this rate of sea level rise would approach 60 cm by the end of the next century, the best guess estimate of the IPCC. Furthermore, it would appear that there is expected to be an acceleration of sea level rise at about the beginning of the 21st century. This was also a result of the other AO GCMs.

5.2.3.3 Extremes of Sea Level: Storm Surges and Waves

Changes in the highest sea levels at a given locality will result from the change in mean sea-level at that location and changes in storm-surge heights. If mean sea level rises, the present extreme levels will be attained more frequently, all else being equal. This effect can be estimated from a knowledge of the present-day frequency of occurrence of extremes of various levels (Flather and Khander, 1993; Lowe and Gregory, 2000). The increase in maximum heights will be equal to the change in the mean, and this may imply a significant increase in areas threatened with inundation (Hubbert and McInnes, 1999).

Changes in storm-surge heights would result from alterations to the occurrence of strong winds and low pressures. At low-latitude locations, such as the Tropical (North) Atlantic and the Caribbean Sea, tropical hurricanes are the major but not the only cause of storm surges. Changes in frequency and intensity of tropical storms could result from alterations to sea surface temperature, large-scale atmospheric circulation and the characteristics of ENSO (Pittock et al., 1996). Prediction of such changes is at present rather uncertain. Some recent climate model experiments have predicted a decline in tropical cyclone frequency, but no consensus has yet emerged (Royer et al., 1998; Jones et al., 1999).

Guyana's coast is presently subjected to seawater overtopping the sea defence when high tide prevails. Noting that it is water accumulation which results in higher water levels off Guyana's coast, it is necessary to understand how changes in the Northeast Counter Current, the eddies in the Guyana Current and the outflow of the Amazon and the other larger rivers along the Guianas affect the divergence of seawater off the Guianas and into the Caribbean Sea. It is also necessary to understand how climate change may affect the circulation of the Tropical Atlantic Ocean.

5.3 CLIMATE CHANGE IMPACTS

5.3.1 Impacts on Hydrology and Water Resources

According to most experts (IPCC, 1995), anthropogenic climate change is expected to accelerate the hydrological cycle. The resulting increase in average global precipitation and evaporation from a doubled CO_2 climate is estimated at between 7 and 15%. However, because climate models do not agree even on the direction of change in monthly or annual precipitation, for many regions, the potential impacts on regional hydrology and water resources is highly uncertain.

The impact of climate change on water supply is also uncertain. GCM's indicate possible changes in average annual precipitation for any given region on the order of plus or minus 20% of present rainfall, once the equilibrium change in climate for a CO_2 doubling is established.

For Guyana, the CGCM 1 and the Had CM2 both project lesser and more extreme rainfall conditions and increased water deficits, especially under the 3x CO_2 (2080-2100) scenario - see Tables 5.1 and 5.4.

Because runoff is essentially the difference between precipitation and evaporation/evapotranspiration the impact on runoff could even be greater. Due to expected warmer temperatures, evaporation and evapotranspiration would most likely increase (see Table 5.3). If however precipitation decreases or stays more or less the same, runoff and subsequently the level of the water table would very likely decrease. Furthermore, where runoff decreases, water quality in streams and rivers would decline unless pollutant loads also decrease. Also, extreme fluctuations in river levels may occur and will thereafter affect bank and slope stability and hence lead to flood conditions.

Sea-level rise, a consequence of global warming, can also affect water supplies through increased salt-water intrusions into aquifers that interface with the ocean. Ground water is the major source of domestic and industrial water in Guyana and this would increase the vulnerability to this type of impact.

The impact on water demand is also very uncertain. This will depend on population growth by the time of the 2 X CO_2 climate and the changes in the various competing sectors. Water use in urban and suburban areas would probably increase, with increasing temperature, for drinking, and other domestic and industrial uses.

In agriculture, irrigators would tend to use more water to compensate for higher evapotranspiration (ET) rates. However, the ET response of plants to increasing CO_2 levels is not clear. In addition, changes in other climatic parameters such as cloudiness, humidity and windiness could further affect ET rates.

The relative value of water for alternative uses would likely change. Drinking and domestic uses would remain top priorities, but changes in seasonal and annual supplies might result in changes in the allocation of water and consideration of changes in reservoir capacity to flood control demands, power generation, fish habitat or consumptive uses such as irrigation.

5.3.2 Energy Sector

There are two major economic sectors that are very likely to be affected by anthropogenic climate change in Guyana. These would include increased energy demand for interior space cooling on the one hand and possibly decreased hydro-generating potential supply from some river basins, depending on how the water balance and the Net Basin Supply (NBS) of these river basins are affected.

In the first case, the use of electric energy for air conditioners will most certainly rise under a warmer climate. Cooling degree days (°C/days) are evaluated for the city of Georgetown using the threshold temperature of 25°C, above which cooling is required. Then, based on the maximum daily temperature, cooling degree days are calculated for the current (1975 – 1995), 2 x CO_2 (2020 – 2040) and 3 x CO_2 (2080 – 2100) climate scenarios (see Table 5.7).

In Table 5.7, it is evident that energy demand for cooling requirements would increase substantially during all seasons under the two future climate change scenarios. For instance, under the 2 x CO_2 scenario (2020-2040), cooling degree days are projected to increase by 16.9 % in the SDS to 30.0 % in the SWS, with an annual average of 23.1 %. The situation gets worse under the 3 x CO_2 scenario (2080-2100), when cooling requirements are projected to increase by 65.0 % in the SDS to 102.5 % in the FDS, with an annual average of 85.9 %, relative to 1975 – 1995.

In both cases, especially for the 3 x CO_2 scenario, energy demands for interior space cooling (commercial, residential and vehicular) are expected to increase substantially, when the temperature impact of global warming becomes a reality.

Table 5.7: Changes in cooling degree days under climate change scenarios for Georgetown, Guyana

Season	1975-95 Min Temp (^oC)	1975-95 Max Temp (^oC)	1975-95 Cooling Degree Days (^oC/days)	2020-40 Max Temp (^oC)	2020-40 Cooling Degree Days (^oC/days)	Change Rel. to 1975-95 (%)	2080-2100 Max Temp (^oC)	2080-2100 Cooling Degree Days (^oC/days)	Change Rel. to 1975-95 (%)
FDS	24.5	29.0	360	30.05	455	**26.4**	33.1	729	**102.5**
FWS	24.0	29.5	405	30.51	496	**22.5**	33.5	765	**88.9**
SDS	24.5	31.0	540	32.01	631	**16.9**	34.9	891	**65.0**
SWS	24.0	29.0	360	30.2	468	**30.0**	32.9	711	**97.5**
The Year			**1665**		**2050**	**23.1**		**3096**	**85.9**

In the second runoff potential and hence the hydro-generating capacity of certain drainage basins may decrease, thereby decreasing Guyana's capacity to supply a widely available, cheaper and non-fossil fuel form of energy.

Two drainage basins that are already targeted for hydropower generation are examined. These are the relatively small Moco Moco drainage basin and the much larger Tumatumari basin, which are all to be found in grid cell 5 of figure 5.6.

Net Basin Supply (NBS: m^3/s), which represents the potential incremental seasonal or yearly discharge and hence hydro-generating potential is based on the difference between rainfall and evaporation and basin area, and can be calculated for each drainage basin for the time slices 1975-1995, 2020-2040 and 2080-2100 by using Tables 5.1 and 5.3. Figures 5.11 and 5.12 indicate the changing NBS with time for the two basins.

For the Moco Moco drainage basin, whose area is 115km2, current (1930-1975) average discharge is 0.60 m^3/s, with a range of 0.49 m^3/s for dry years and 0.73 m^3/s for wet years. However, 1975-1995 mean annual NBS is 0.027 m^3/s (Table 5.8), this being due to neglect of base flow, inter-basin flow and lag effects that are not taken into account in NBS.

Table 5.8: Changes in net Basin Supply for hydro-power generation: Moco Moco Basin

Season (months)	1975-1995			2020-2040				2080-2100			
	P mm dy-1	E mm dy-1	NBS m^3/s	P mm dy-1	E mm dy-1	NBS m^3/s	**Change %**	P mm dy-1	E mm dy-1	NBS m^3/s	**Change %**
FDS	4.26	4.03	0.31	3.96	3.86	0.13	**-138**	3.88	3.81	0.09	**-244**
FWS	4.56	3.61	1.26	3.86	3.49	0.49	**-157**	4.40	3.63	1.02	**-24**
SDS	3.42	4.19	-1.02	3.11	3.82	-0.94	**9**	3.28	4.19	-1.21	**-16**
SWS	3.50	3.88	-0.51	3.80	3.52	0.37	**238**	3.76	3.70	0.08	**538**
Mean	**3.94**	**3.92**	**0.027**	**3.68**	**3.67**	**0.013**	**-107**	**3.84**	**3.83**	**0.013**	**-108**

For the 2 x CO_2 climate scenario (2020-2040), mean annual NBS for the Moco Moco basin decreases to 0.013 m^3/s (- 107 %), with the greatest decreases in the First Dry Season (-138 %) and the First Wet Season (-157 %). However, NBS increases substantially during the Second Wet Season (238 %) (Table 5.8 and Figure 5.11).

Similarly, for the 3 x CO_2 scenario (2080-2100), mean annual NBS decreases to 0.013 m^3/s, with the greatest decrease during the First Dry Season (-244 %) (Table 5.9 and Figure 5.8). However, as in the case of the 2 x CO_2 scenario, NBS increase substantially during the Second Wet Season (538 %).

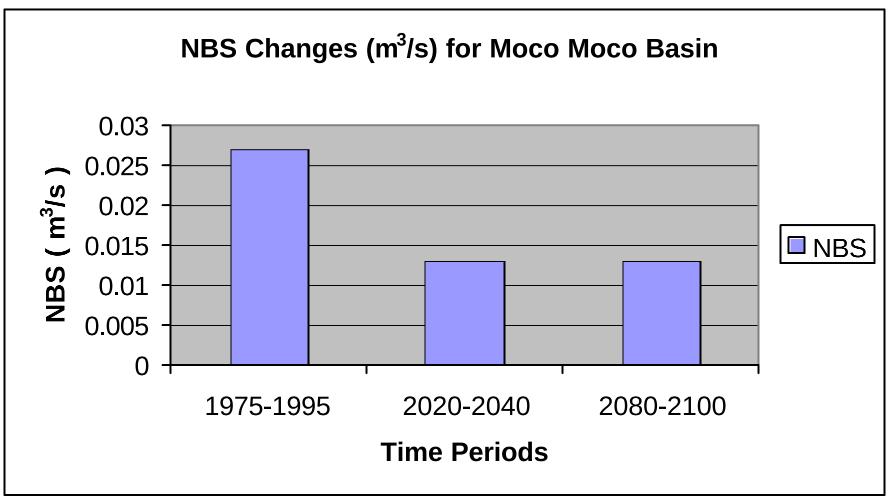


Figure 5.11: Changes in NBS for the Moco-Moco Basin for the three Climate Change Scenarios

In the case of the Tumatumari drainage basin, whose area is 3160 km^2, current (1950-1976) average discharge is 208 m^3/s. However, 1975-1995 mean annual NBS is 27.82 m^3/s (Table 5.9), this being due to the neglect of base flow, inter-basin flow and lag effects that are not taken into account in the calculation of NBS.

As for the 2 x CO_2 climate scenario (2020-2040), mean annual NBS for the Tumatumari basin decreases to 22.5 m^3/s (- 24 %), with the greatest decreases in the First Wet Season (-34 %) and the Second Dry Season (-67 %). However, NBS increases substantially during the Second Wet Season (324 %) (Table

5.9).

Similarly, for the 3 x CO_2 scenario (2080-2100), mean annual NBS decreases to 23.72 m^3/s, with the greatest decrease during the First Wet Season (-22.6 %) and the Second Dry Season (-72.8 %) - see Table 5.9 and Figure 5.12. However, as in the case of the 2 x CO_2 scenario, NBS increases substantially during the Second Wet Season (288 %) (Table 5.10).

Therefore, it would seem that NBS and hence hydro-generating potential of the Moco-Moco and Tumatumari drainage basins would generally decrease during the 2 x CO_2 (2020-2040) and 3 x CO_2 (2080-2100) climate change scenarios. Also, there are likely to be significant shifts in the seasonality of river discharge.

However, one must caution against relying totally on the data used in this analysis because the discharge data is not current and the model forecast values represent the average for a grid cell which includes rainforest and savannah types. A detailed country study will be required to assess the results of this analysis.

Table 5.9: Changes in Net Basin Supply (NBS) for hydro-power generation: Tumatumari Basin

Season	1975-1995			2020-2040				2080-2100			
	P mm dy^{-1}	E mm dy^{-1}	NBS m^3/s	P mm dy^{-1}	E mm dy^{-1}	NBS m^3/s	**Change %**	P mm dy^{-1}	E mm dy^{-1}	NBS m^3/s	**Change %**
FDS	3.44	4.00	-45.8	3.52	3.85	-27.0	**66**	3.66	3.82	-13.1	**250**
FWS	5.67	3.56	173.5	5.02	3.45	129.3	**-34**	5.33	3.61	141.5	**-22.6**
SDS	3.84	4.16	-25.4	3.17	4.10	-76.1	**-67**	3.05	4.19	-93.3	**-72.8**
SWS	2.89	3.77	-72.9	3.19	3.39	-17.2	**324**	3.17	3.40	-18.8	**288**
Mean	**4.21**	**3.87**	**27.82**	**3.97**	**3.70**	**22.5**	**-24**	**4.05**	**3.76**	**23.72**	**-17**

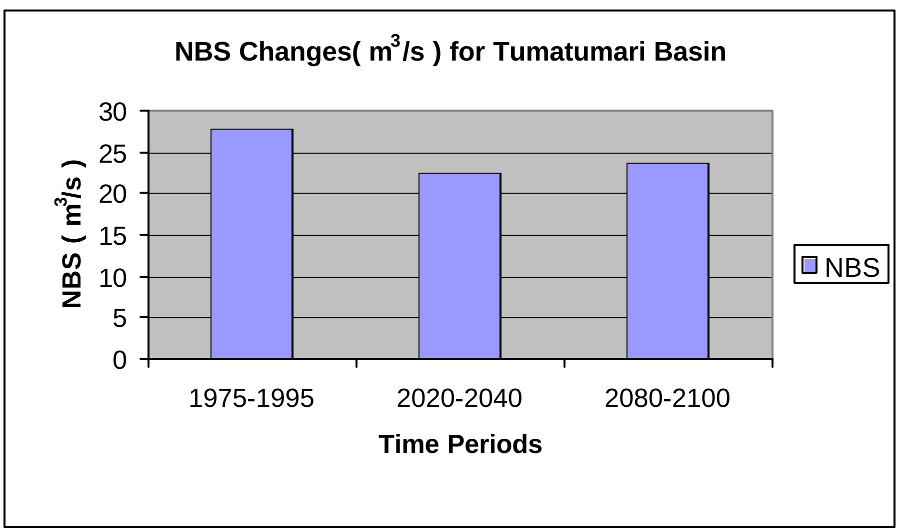


Figure 5.12: Changes in NBS for the Tumatumari Basin for the three Climate Change Scenarios.

5.3.3 Agriculture Sector

Anthropogenic Climate Change would very likely impact on agriculture, a key sector of the Guyanese economy. The agroclimatic, and possibly the soil conditions, for the growth of crops may be modified by, for example:

- Increase in drought periods and severity, and possibly wind erosion of soils, or

- More intense rainstorms leading to flooding and loss of crops, soil erosion and leaching of soil nutrients.

These would not only affect the physical constraints of crop growth and yields but also the cost of production especially when irrigation may be required to counter increased water deficits.

Two major implications of CO_2-induced temperature increase and changing climatic patterns for the growth of agricultural crops are: a lengthening of the potential growing season, and an increase in plant growth rates and thus a shortening of the required growing period. The problem of growing season length will not affect tropical countries such as Guyana. However, shortening of the growing season, through a more rapid accumulation of growing degree days, has been shown to lead to acceleration of maturation and reduced yields, especially for C3 cereal crops such as rice. In fact, in Guyana, it is rather the changes in soil moisture conditions as controlled by rainfall, rather than temperature, that may influence crop yields through excessive moisture that may cause flooding or soil moisture deficit that may restrict crop growth and yields. Should ENSO events intensify and occur more frequently, then soil moisture changes may be important.

5.3.3.1 Changes in Mean Crop Yield

In order to evaluate the vulnerability of Guyanese agriculture to anthropogenic climate change, the focus is placed on the yield changes of sugarcane and rice, two commercial crops, which significantly influence the economy of the country.

Yearly yield changes for sugarcane and rice are calculated for the 3 climate change scenarios, namely 1975-1995 (current), 2020-2040 (2 x CO_2) and 2080-2100 (3 x CO_2). Yields are calculated by coupling the most recent version (3.5) of the crop yield simulation model DSSAT (Decision Support System for Agro-technology Transfer) with climate data (daily solar radiation, maximum and minimum temperature and rainfall) from the CGCM 1 for the eastern coastal area of Guyana, namely grid cell number 9. Yield simulations are done for sugarcane over 365 days from January to December and for rice over 120 days from December to March, corresponding to the first rice crop of Guyana. In both cases, a minimum of management (fertilization, tillage) is used and no irrigation is assumed.

Sugarcane and rice yields for current climate conditions (1 x CO_2) are compared with yields under the perturbed (2 x CO_2 and 3 x CO_2) climate scenarios to evaluate the potential impacts of anthropogenic climate change on yields (Tables 5.10 and 5.11 and Figures 5.13 and 5.14).

Table 5.10: Changes in Sugarcane yields according to Climate Change Scenarios

Mean Observed Yields (kg/ha) (1979-1996)	Range of Observed Yields (kg/ha) (1979-1996)	Mean Simulated yields (kg/ha) (1975-1995)	Difference (%) Observed Simulated (1975-1995)	Mean Simulated yields (kg/ha) (2020-2040)	Range of Simulated Yields (kg/ha) (2020-2040)	**Difference (%) 2020/2040 - 1975/1995**	Mean Simulated yields (kg/ha) (2080-2100)	Range of Simulate Yields (kg/ha) (2080-2100)	**Difference (%) 2080/2100 - 1975/1995**
72,300	65,600-81,200	70,203	2.9	54,086	52,200-55,092	**-29.8**	50,739	48,764-52,753	**-38.4**

Table 5.11: Changes in Rice Yields according to Climate Change Scenarios

Mean Observed Yields (kg/ha) (1968-1997)	Range of Observed Yields (kg/ha) (1968-1997)	Mean Simulated Yields (kg/ha) (1975-1995)	Difference (%) Observed-Simulated (1975-1995)	Mean Simulated yields (kg/ha) (2020-2040)	Range of Simulated Yields (kg/ha) (2020-2040)	**Difference (%) 2020/2040 - 1975/1995**	Mean Simulated yields (kg/ha) (2080-2100)	Range of Simulate Yields (kg/ha) (2080-2100)	**Difference (%) 2080/2100 - 1975/1995**
2,920	1,530-4,000	3,180	-8.9	3,087	2,959-3,175	**-3.0**	2,744	2,639-2,840	**-15.9**

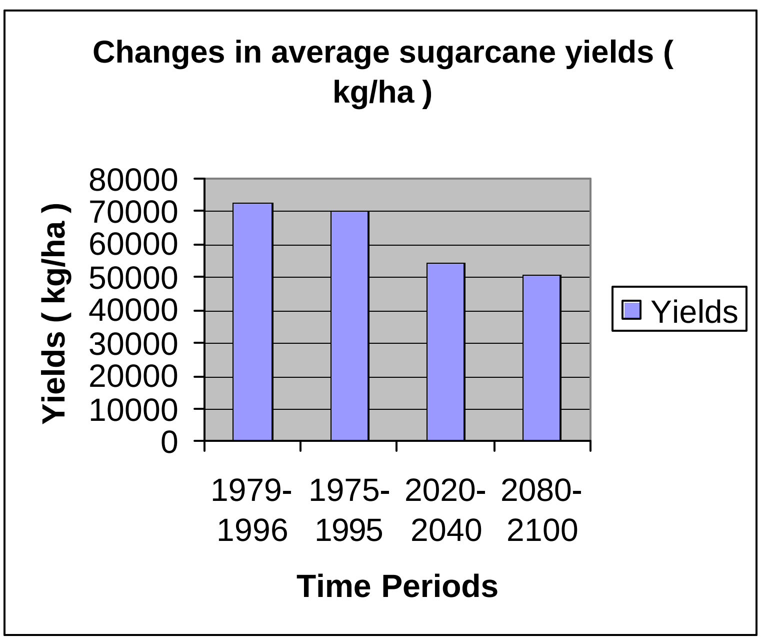


Figure 5.13: Changes in Sugarcane Yields for Guyana according to Climate Change Scenarios

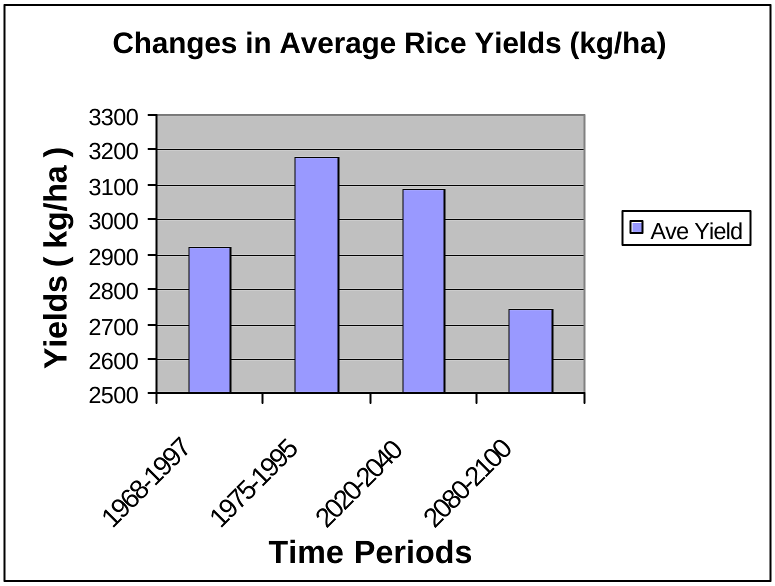


Figure 5.14: Changes in Rice Yields for Guyana according to Climate Change Scenarios

In the case of sugarcane mean observed (1979-1996) and mean simulated (1975-1995) yields for the current climate are very similar, the difference being 2.9 % (Table 5.10). Substantial yield losses are however observed for the 2 x CO_2 (2020-2040) (-29.8%) and the 3 x CO_2 (2080-2100) (-38.4 %) climate scenarios.

For rice the mean observed (1968-1997) and mean simulated (1975-1995) yields for current conditions vary by 8.9 %. However, the yield loss of 3.0 % is relatively small for the 2 x CO_2 (2020-2040) and for the 3 x CO_2 (2080-2100) climate change scenario where it rises by a factor of 5 or 15.9 %.

The yield losses for both rice and sugarcane reported above are only based on changes in climate variables, including solar radiation, maximum and minimum temperatures, rainfall and evapotranspiration rate. Decreases in yields may therefore be attributed to the increased water demand from crop transpiration and to greater respiration losses caused by markedly higher temperatures. The plant stress due to the extreme climate indicated above is not very clear and will require to be studied.

Little is currently known about changes in the inter-annual variability of temperature and precipitation, which might accompany global warming. However, in spite of the limited range of year-to-year yield fluctuations under the climate change scenarios, it is expected that future changes in climate would be accompanied by significant changes in year-to-year variability and hence by wide fluctuations in crop yields.

Furthermore, given the strongly non-linear relationship between variations in average climate and the frequency of extreme events, it is clear that climatic variations can be especially important in marginal farming areas where the risk of failure is already significant.

Changes in yield quality may also occur under a warmer climate. For instance, the decrease in the diurnal temperature range discussed earlier may decrease the sucrose content and hence the price of sugar.

One of the difficulties of estimating effects of climatic change on agriculture is that the sensitivity of yield to input such as fertilizers and pesticides also varies with climate. Also, under a warmer and possibly more humid climate projected for Guyana, the incidence of pests and disease may increase. It is evident that crop yield would be more responsive to altered fertilizer inputs during anomalous climatic periods if the mean level of nitrogen fertilization was lower than at present. This means that the adjusting of levels of fertilization can be an effective stabilizing response in extreme years. The gains in productivity however, can be eroded by significant increases in input costs and/or environmental impact (such as continued deterioration in water quality) emanating from use of agrochemicals.

Spatial shifts in comparative advantage, both regionally and globally, may occur in agriculture following anthropogenic climate change. Different crops growing in the same region often respond differently to a given change of climate. In order to optimize agricultural output in Guyana, then there might therefore be a need for a substantial switch of crops or species of crops. Likewise, the same crop grown in different regions may respond differently to a similar change of climate. The combination of these two complexities of response (by different crops or varieties in the same region and by the same crops or varieties in different regions) would bring about substantial shifts in the comparative advantage which one crop or mix of crops would have over another.

A consequence of the factors described above, together with many other sources of spatial complexity, is that climatic change can be expected to bring about a spatial shift of crop potential. Areas which are, under present climatic conditions, judged to be most suited to a given crop or combination of crops or to a specified level of management will change location. In this simplest form, this kind of shift can be seen as a shift in limits of the cultivable area.

There are also higher order impacts of climate change on agriculture, including farm profitability, farm level adjustments in terms of inputs and technology and economic and social government policy, including food security.

Assuming for the present that there is no change in costs of inputs, we can estimate the effect of yield changes on farm profitability by analyzing the effect on net returns per km^2. Changes in government agricultural support and subsidies, within the constraints of the World Trade Organization, as an appropriate response mechanism, are also to be considered.

Changes in farm profitability can be expected to affect non-agricultural sectors of the Guyanese economy. Changes in agricultural production and profitability and the effects of these on the wider Guyanese economy are likely, and in addition, may affect the level of employment.

The focus of this section is on the responses to anthropogenic climatic change of a single economic sector, agriculture. The mainly biophysical and economic effects that have been discussed above assumed no changes in technology, management or in background economic conditions (product prices, labour supply, etc.). This assumption is unrealistic, at least with respect to long-term changes in climate, because experience tells us that these factors are likely to change substantially over the kind of time-scale estimated for atmospheric $C0_2$, doubling or tripling.

The estimates are not, therefore, a prediction of future effects but a sensitivity analysis of present-day agriculture, enabling identification of those aspects and areas which may be especially vulnerable to climatic variations. This form of analysis also provides a basis for the next step: the evaluation, firstly, of potential adjustments at the farm level and, secondly, of potential policy responses at the regional and national level.

5.3.4 Forestry Sector

In the Forestry sector, non-climate change anthropogenic activities can lead to a vulnerable situation. Guyana's forests can be vulnerable to deforestation by these activities. Many different factors can be involved and their combination, relative importance, and interactions will vary not only from region to region, but also over the course of time, influenced by economic, political and social development. Frequently these activities are treated as causes that directly and obviously contribute to degrading or destroying the forestland and which strictly speaking should therefore be regarded as types or manifestations of forest destruction. These include:

- Small-scale shifting cultivation for food production, predominantly to meet the farmers' own needs (subsistence farming).
- Agroindustrial land use for production for certain cash crops for export and products from plantation crops (coffee, sugarcane, rice and palm oil).
- Extensive livestock production (cattle ranching).
- Fuelwood collection.
- Felling of trees for timber (logging).
- Clearing of forestland to exploit energy and mineral resources (mining, construction of dams and reservoirs) with installation of the required infracstructure.

The potential impacts of a CO_2-induced climate change on forestry, will be very similar to those for agriculture.

Depending upon changes in the thermal (temperature) and moisture (rainfall, evapotranspiration) regimes, forest growth rates can be expected to change. Of course, one would also have to consider how the increased CO_2 fertilization will impact upon forest growth.

Changes in the eco-climate may also trigger shifts in forest species. For instance if warmer, wetter and more humid conditions are projected, species that are currently abundant in Central Amazonia, say, may move into regions like Guyana. However, climate variability and change in seasonality will also have to be considered. For instance, if droughtier conditions occur in the dry season, this may impose severe constraints on forest growth and may be critical in determining species response.

Other factors such as soil suitability, wind changes (fertilisation) and the presence of insects and pathogens will also play a major role in forest response to climate change.

Finally the economics of the lumber industry may also change depending upon species selection, growth rates, workability (depending upon climate), government land use policies (afforestation or deforestation) and world markets.

In order to evaluate the response and vulnerability of the forest sector to climate change, the Holdridge forest classification system is used. The Holdridge system, which has been tested and applied worldwide, essentially determines the spatial distributions of the broad eco-zones, based on Mean Annual Air Temperature (MAAT: ^{o}C), adjusted for elevation where necessary, Mean Total Annual Precipitation (MTAP: mm) and the Potential Evapotranspiration Ratio (PER).

In Table 5.12, the spatial distribution of the major Holdridge eco-zones and the corresponding predominant Guyanese forest types are presented for the various grid cells shown in Figure 5.6 for the current (1975-1995) climate scenario. The present forest distribution is reflected in Figure 5.15.

It is evident that apart from differences in nomenclature, for instance Moist Tropical Forest (Holdridge) as opposed to Tall Evergreen Forest (Guyanese), the Holdridge system crudely captures the spatial distribution of the major forest species of Guyana.

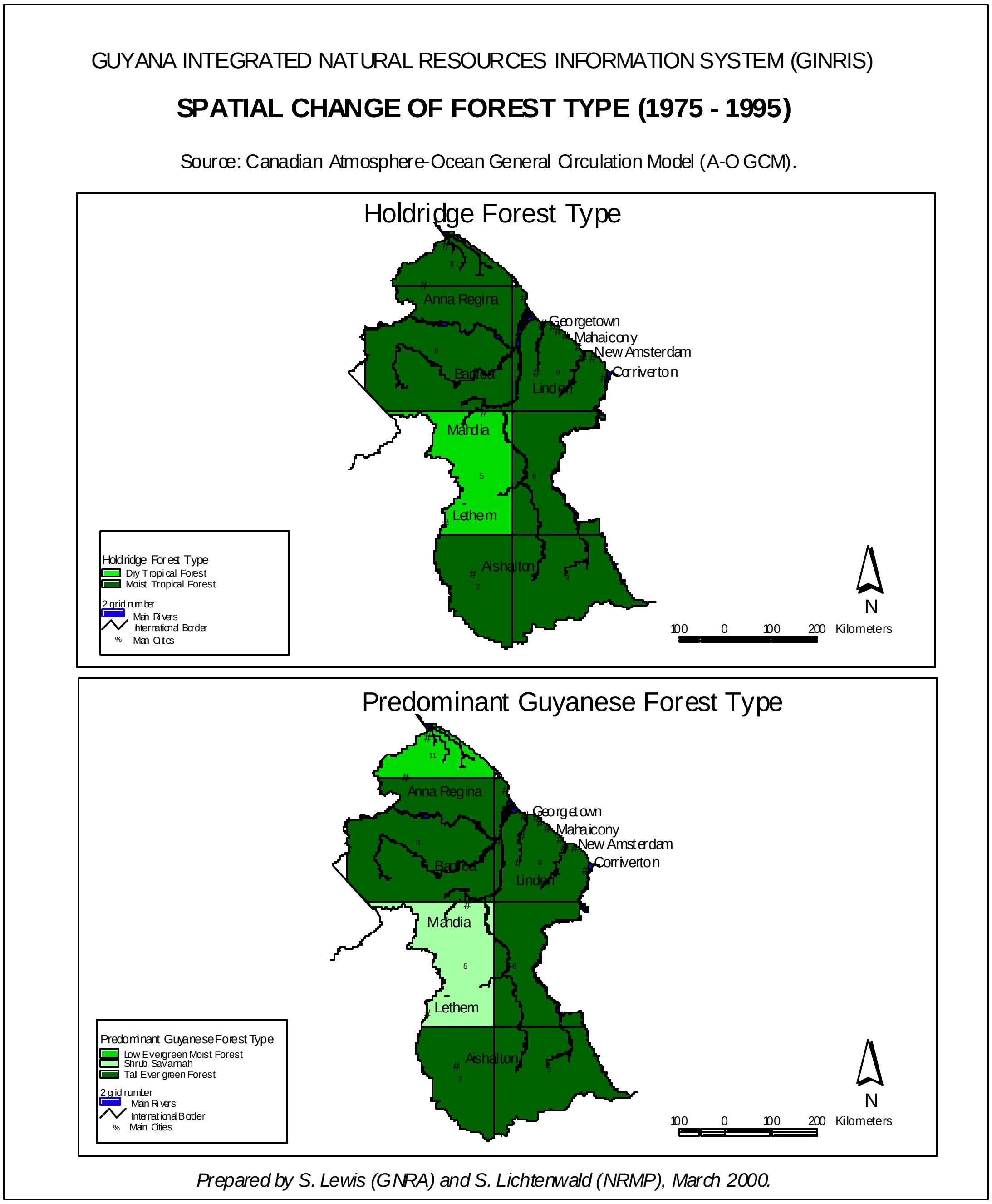


Figure 5.15: Present Forest Distribution (Holdridge and Predominant Guyanese Forest Types)

Under the 2 x CO_2 climate scenario (2020-2040), it would appear that the area of Dry Tropical Forest (Shrub Savannah) would extend at the expense of Moist Tropical Forest (Tall Evergreen Forest) in grid cells 3 and 4 (Table 13).

Furthermore, under the 3 x CO_2 (2080-2100) climate scenario, the area of Dry Tropical Forest (Shrub Savannah) would spread further, replacing Moist Tropical Forest (Tall Evergreen Forest) in grid cells 2 and 15, in addition to grid cells 3 and 4 (Table 14).

It would appear then that climate change, as shown in Tables 13 and 14, may affect the spatial distribution of the major forest zones of Guyana, with Dry tropical Forest (Shrub Savannah) replacing Moist Tropical Forest (Tall Evergreen Forest) in the southernmost (grid cells 2,3and 4) and northernmost (grid cell 15) parts of Guyana. This may have important economic consequences on the Guyanese forest industry.

Table 5.12: Holdridge Classification of Guyanese Forests for the 1975 – 1995 Climate Scenario.

	HOLDRIDGE FOREST CLASSIFICATION 1975 - 1995				
Grid cell	**MAAT (^{o}C)**	**MTAP (mm)**	**PER**	**HOLDRIDGE FOREST TYPE**	**Predominant Guyanese Forest Type**
2	23.42	1436	0.96	Moist Tropical	Tall Evergreen
3	25.12	1592	0.92	Moist Tropical	Tall Evergreen
5	24.43	1445	0.99	Dry Tropical	Shrub Savannah
6	24.85	2395	0.61	Moist Tropical	Tall Evergreen
7	23.67	1831	0.76	Moist Tropical	Tall/Medium Evergreen
8	23.97	2190	0.65	Moist Tropical	Tall Evergreen
9	24.22	2417	0.59	Moist Tropical	Tall Evergreen
11	27.09	1900	0.84	Moist Tropical	Low Evergreen Moist

MAAT: Mean Annual Air Temperature (°C)

MTAP: Mean Total Annual Precipitation (mm)

PER: Potential Evapotranspiration Ratio

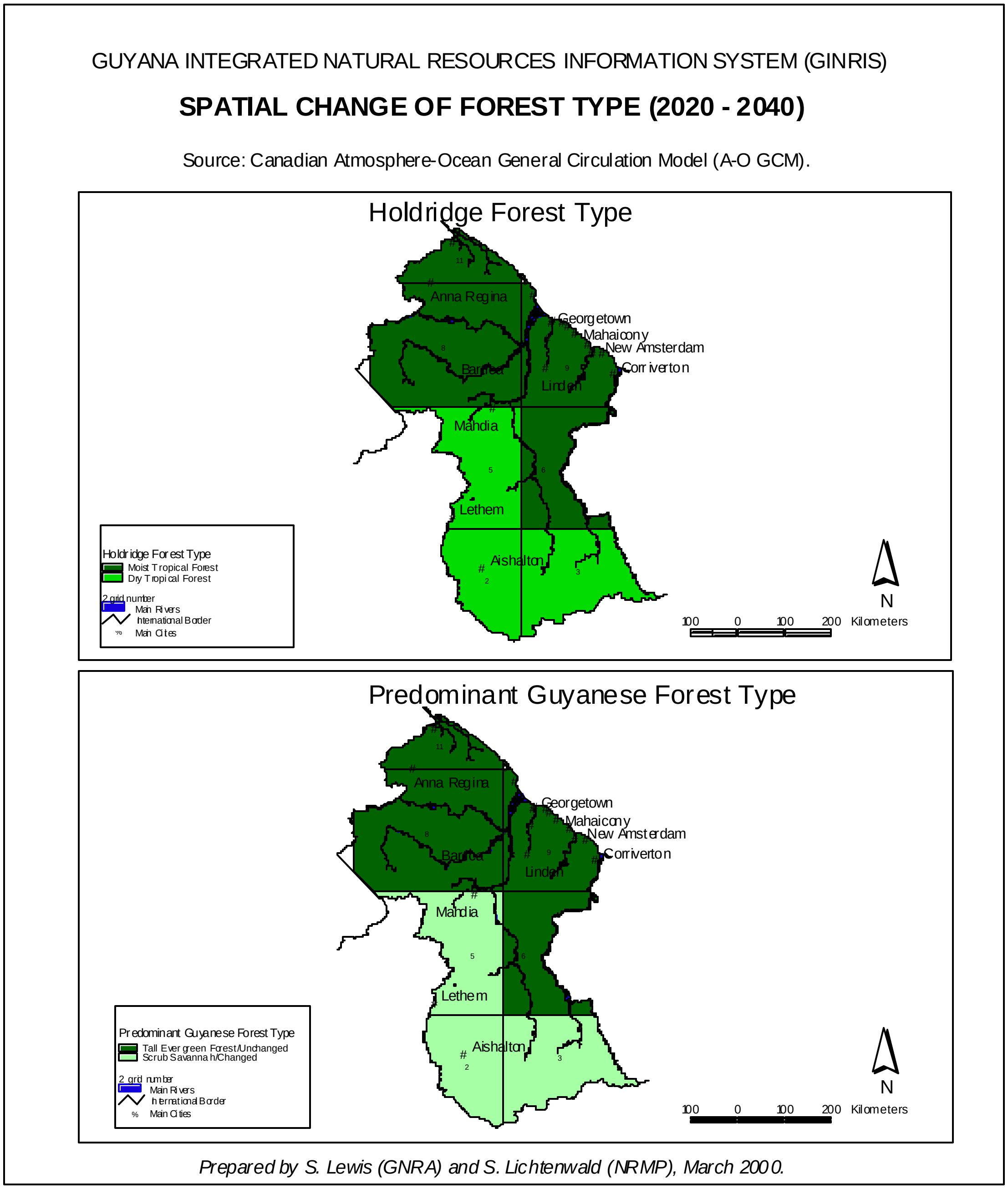


Figure 5.16: Projected change in Forest Distribution under the 2 x CO_2 Climate Scenario.

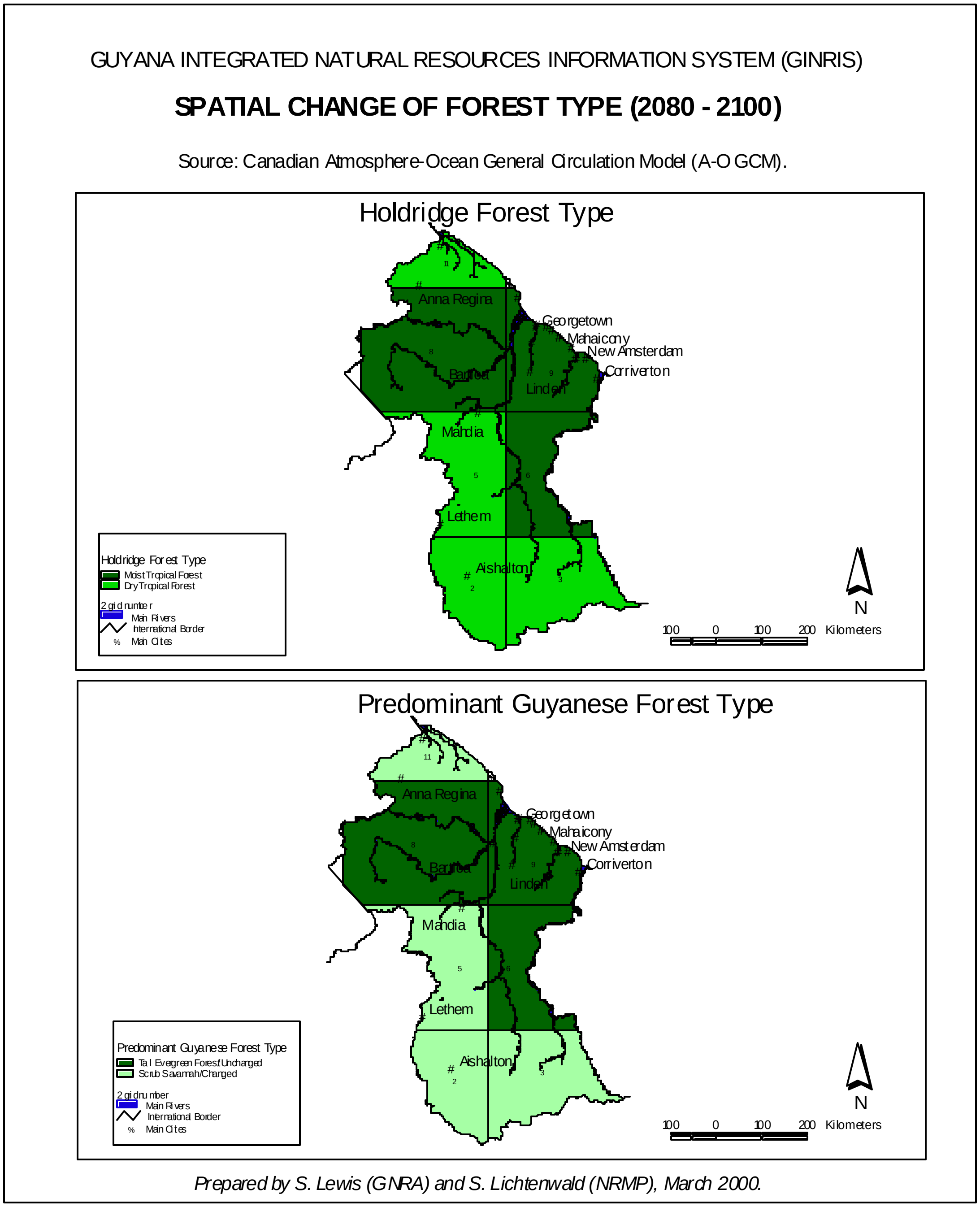


Figure 5.17: Projected Change in Forest Distribution under the 3 x CO_2 Climate Scenario

5.3.5 Vulnerability of the Coastal Zone

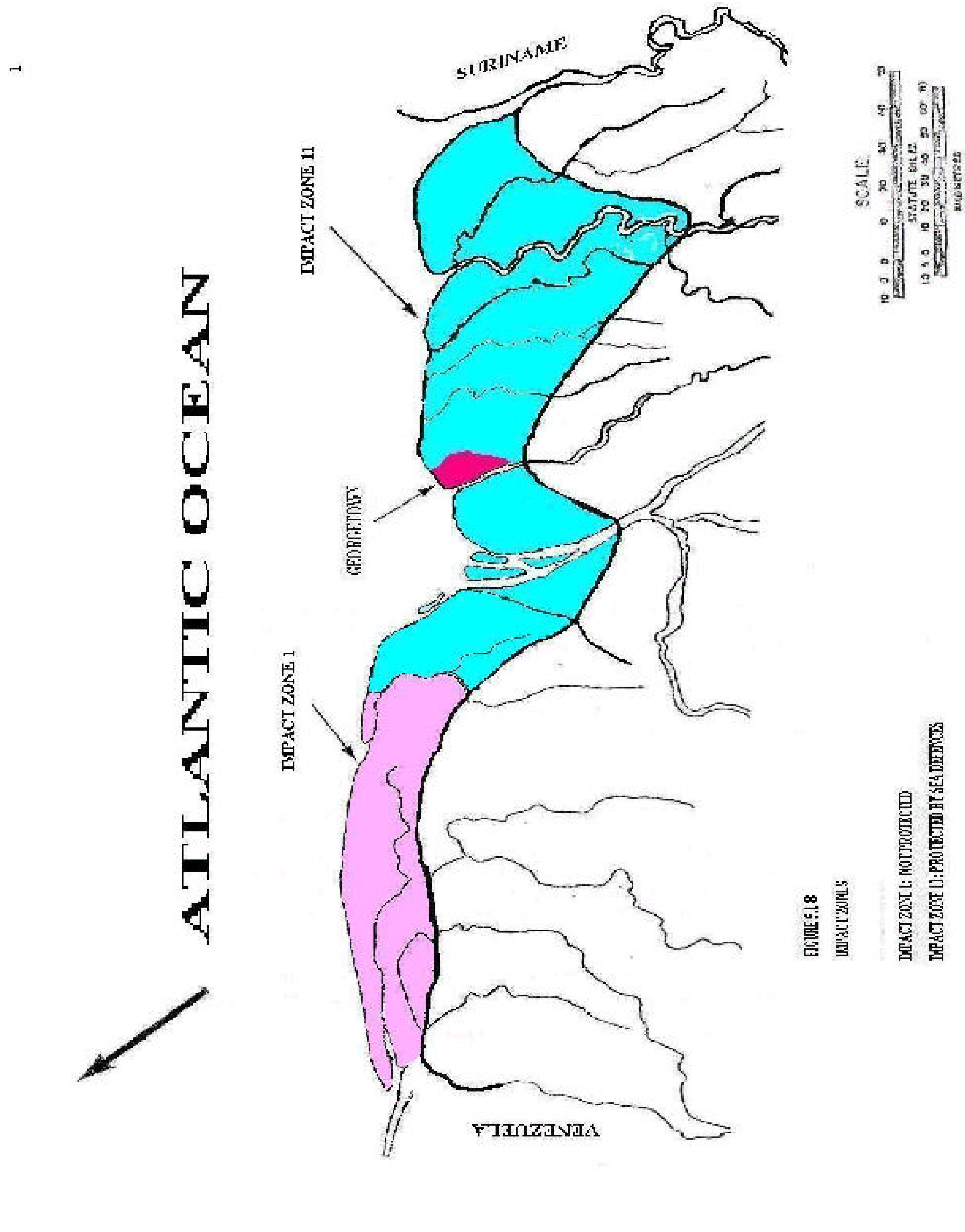
5.3.5.1 The Coastal Plain (Extracted from Khan and Sturm, 1994)

The coastal plain extends from Punta Playa at the Venezuelan border in the northwestern part of the country to the Corentyne River, which is its eastern boundary. The length of the coast is approximately 430 km, of which 360 km are maintained, including the islands of Leguan and Wakenaam – see Figure 5.18.

In their natural state, the coastal lands comprised swamps caused by the overflowing of the many rivers passing through or by flooding from the sea. To reclaim the coastal lands, lying at a level of 0.5-1 m below the level of spring tides, a system of dykes was constructed to form polders. The empoldered land was thus protected from flooding by the sea and segregated from the remaining swamps.

At the boundaries of each polder or estate, dams were built at right angles to the shoreline extending backwards to the dam closing off the polder from the remaining swamps. For irrigation purposes this backdam was provided with water inlets. At the seaward side the polders were protected by a dam situated on the shore ridge. The foreshore in front of this dam in general consisted of a mangrove belt a few hundred meters wide. In the sea dam sluice gates were built to obtain gravity drainage at low tide.

As the foreshore, mangrove belt, shore ridges and sea dams eroded from time to time and as the cost to maintain the defences under adverse conditions became greater, the proprietors would retreat inland and build a new sea dam and sluice gates. This policy still continues today where there is land available for retreat. In built-up areas however, a general policy of maintaining the sea defences in their existing position, by the construction of rigid defences consisting of concrete seawalls, has been followed over the last decades.


ATLANTIC OCEAN
SURINAME
IMPACT ZONE 11
GEORGETOWN
IMPACT ZONE 1
VENEZUELA
SCALE
IMPACT ZONES
IMPACT ZONE 1: NOT PROTECTED
IMPACT ZONE 11: PROTECTED BY SEA DEFENCES

At present about 110 km of coastline is protected by these concrete defences, 250 km by a mangrove belt backed up by an earth embankment and 70 km by natural sand banks. Addressing coastal vulnerability is important for Guyana because the coastal zone is vital since over 90 % of the population reside there and the important economic activities are located there – see Figure 5.19.

5.3.5.2 Coastal Morphology (Extracted from Khan and Sturm 1994)

The coastline of Guyana is dominated by the occurrence of large mud-banks travelling along the coast at fairly regular intervals. The banks are composed of very fine sediments originating from the Amazon River some 1000 km away. The coastal plain itself is composed of similar clays but derived from the Pre-Cambrian Guyana Shield. Its great age ensures that erosion products are low, in spite of the presence of many large rivers. It has been estimated that 5-10 million tonnes/year of silt is carried by the rivers into the coastal system compared with 100 million tonnes/year moving along the shore.

The banks move along the coast in a series of waves or macro-ripples at an average rate of some 1.3 km/year. The macro-ripples have an average length of about 40 km. Thus, a trough or crest will pass a given point on the coast about once in 30 years. The deeper water in the troughs between two banks will provide passage in the direction of the coast for higher waves from the wave trains of the Atlantic Ocean generated by the Northeast Trade Winds. This effect will be strengthened due to refraction and concentration of wave energy through the trough. The increased wave attack often causes erosion of the foreshore (DHV 1992).

The highest waves breaking on the sea defences rarely attain a height of more than 1.5 m. As such the wave attack occurring along the coastline of Guyana can be described as minor. These circumstances combined with the regular, relatively small tidal variations and the absence of storms, storm surges and tsunamis constitute a mild marine environment.

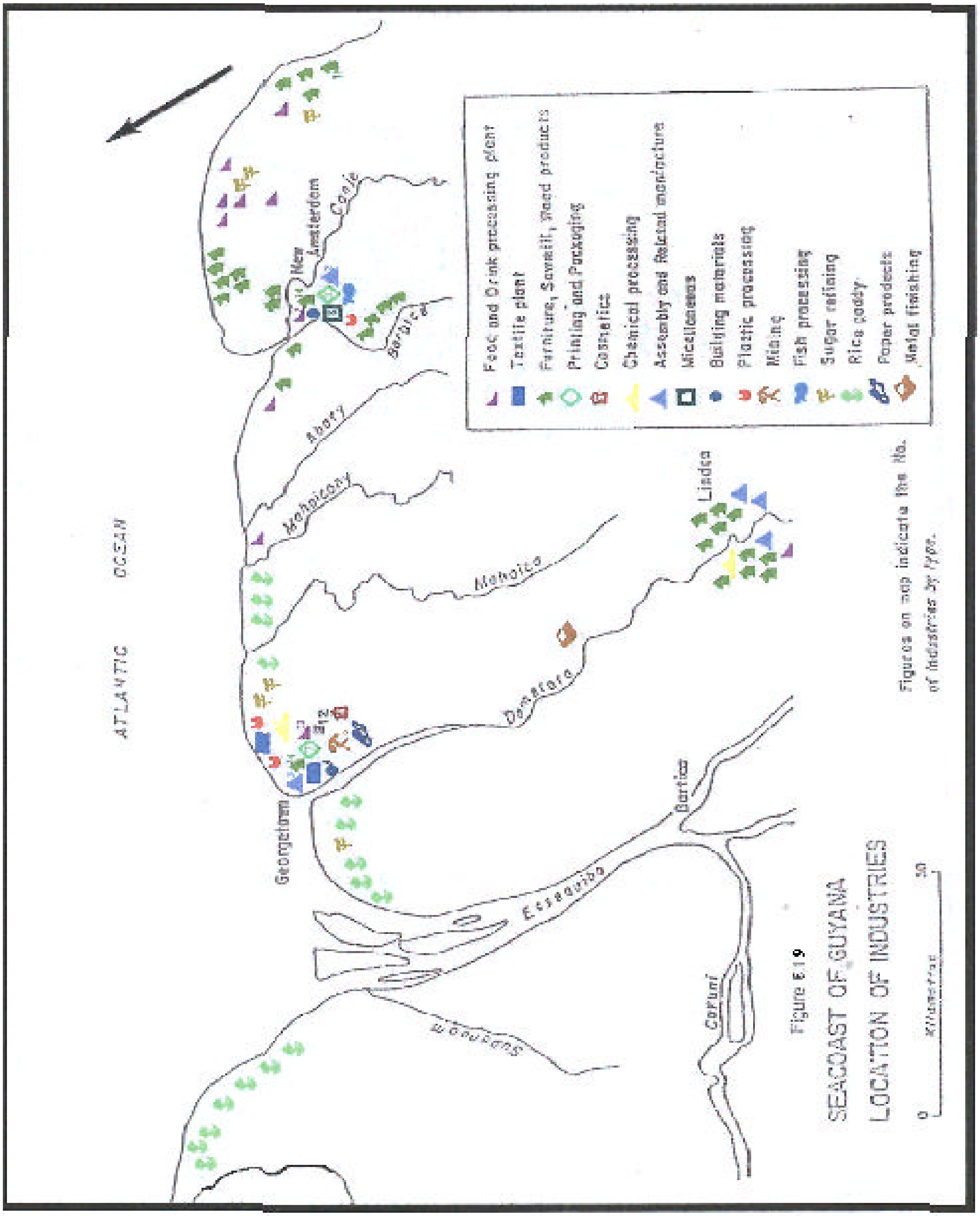


Figure 5.1 9
SEACOAST OF GUYANA
LOCATION OF INDUSTRIES

Serious erosion does not always take place in front of the trough. Local circumstances such as the occurrence of "sling mud", a highly viscous mud in suspension dampening the waves, the width of foreshore at mean high tide, the type of beach material and variations in the level of the foreshore prevent severe erosion in many cases.

Accretion and growth of the mangrove belt might occur when, due to the passage of the higher part of the mud-bank, the level of the foreshore rises. As in the case of erosion, accretion of the mangroves does not always take place. Actually, the regular pattern of travelling mud-banks and a 30year cycle of erosion can be observed only along the coasts of East Demerara and East Berbice. In the other areas, the influence of the Corentyne and the Essequibo rivers distorts this pattern to a great extent.

Erosion, comprising essentially a lowering of the near-shore zone and higher waves, affects the coast in different ways dependent on the nature of the foreshore. Where the shore is overgrown the roots of the mangrove trees become exposed and the mangrove area will start to suffer from increasing wave attack for which it is not designed. Strengthening of the seaward side of the dam by providing a slope protection is required if it is decided to maintain the existing line of defence. Due to this process, the length of permanently defended coastline is continuously increasing.

It has been attempted in the past to predict in the medium to long term where areas of erosion are likely to occur in order to reserve the necessary funds and make the preparations required. As indicated above serious erosion is generally co-incident with the passage of a trough. Consequently, such forecasting would only be possible along stretches of coastline where mud-banks can be clearly identified although the randomness of the erosion phenomenon reduces the usefulness of this activity.

There are indications that over the last decades accretion does not balance erosion along the Guyanese coast and that there has been a general retreat of the coastline. At locations where permanent sea defences are present the regression of the coastline will be halted.

5.3.5.3 Condition of Sea Defences

The existing sea defences are generally in a bad condition. Rehabilitation and reconstruction programmes for the medium term have been developed by consultants funded by international donor agencies, such as European Economic Community, Inter American Development Bank and World Bank. The Sea and River Defence Division of the Guyanese Ministry of Public Works and Communication is being supported in managing of the new capital construction works through technical assistance programmes funded by the international agencies.

5.3.5.4 Drainage System

Generally drainage of the polders is carried out by gravity flow during periods when sea or river levels experience low tides. The period of discharge is conditioned by the level of the land to be drained relative to the mean sea level at the outfall and by the tidal amplitude. Gravity drainage sluices typically discharge for 7 to 14 hours in every 24 hours due to the various hydraulic and morphological conditions. A rise of the sea level will reduce the discharge period.

Presently pumped drainage is required in some areas, especially at the sugar estates of the East Coast Demerara and the Corentyne Coast. In future conditions, demands for pumped drainage will increase and this will impact heavily on the economic development of the country. Drainage and irrigation problems constitute one of the main reasons for low agricultural productivity, particularly in rice production, (Hunting 1997).

5.3.5.5 Climate and Hydrology Factors

The most important climate factor is global warming. As previously indicated, the GCMs are indicating that temperature will rise in Guyana. The record has also shown that temperature has already risen on Guyana's coast. There has also been an indication that sea level has risen and is expected to show an accelerated rise.

Because of the interactions among the components of the climate system, coastal agriculture and fishery may be affected by the expected rise in temperature. Sea-surface temperature changes may affect the marine environment and the climate on the coast. Coastal agriculture will have to contend with persistently higher air and soil temperatures and modified air and soil moisture levels. Rain-producing systems can change resulting in changes in the availability of water for irrigation. Because it is expected that the number of storms will be less but more intense, flood management will become critical in the entire coastal belt.

There is no evidence of a geological component of subsidence (see National Circumstance). However, a preliminary study by John Bassier (1976), ref. Camacho 1988, found that Georgetown may be subsiding at a rate of about 10 mm/yr. He reasoned that the major ground water aquifers are not rechargeable and that the subsidence is due to the "mining" of ground water.

Fishing is done within about 20 km of the coastline. Fishing yields are relatively high and sufficient to satisfy local demands as well as export. There has been no report that nutrient discharges from agricultural lands have significant effects so far on the fish population and on other ecosystems.

Coastal forests are mostly located in the northwestern part of the coastal belt and are very rich in biodiversity. Deer, turtle and several species of birds can be found here.

5.3.5.6 Impact Zones (Extracted from Khan and Sturm, 1994)

Figure No. 5.20 presents a frequency distribution of monthly high water levels at Port Georgetown in the period 1970-1980. The effects of accelerated sea level rise (ASLR) are included. It shows the "flatness" of the curve and subsequently the great increase of the frequency of occurrence for a particular water level. The impact of the ASLR will affect the coastal area in different ways. The coastal area of Guyana is therefore subdivided into two impact zones according to the differences in the population density and the nature of the coastal protection (Figure 5.19). Those two impact zones are:

Impact Zone I: the coastal belt of this region mostly comprises mangrove swamps and its people already know the problems, which come with flood waters. Transportation is mainly by boats and canoes. Houses are built very near to the river water line. The shoreline is expected to retreat with a rise of the sea level and this retreat can be as much as 2.5 km with a rise of 100 cm.

Impact Zone II: in this densely populated region, comprising several islands, there is a combination of concrete and earthen sea defences. The problem of inadequate maintenance of the sea defences has become evident and substantial breaches and overtopping have occurred.

In both zones, the matter of drainage is a current problem. It is therefore necessary that the entire Drainage and Irrigation System be revisited with a view towards implementation of measures to alleviate the almost yearly problem of inadequate drainage during the rainy seasons and during ENSO cold phases.

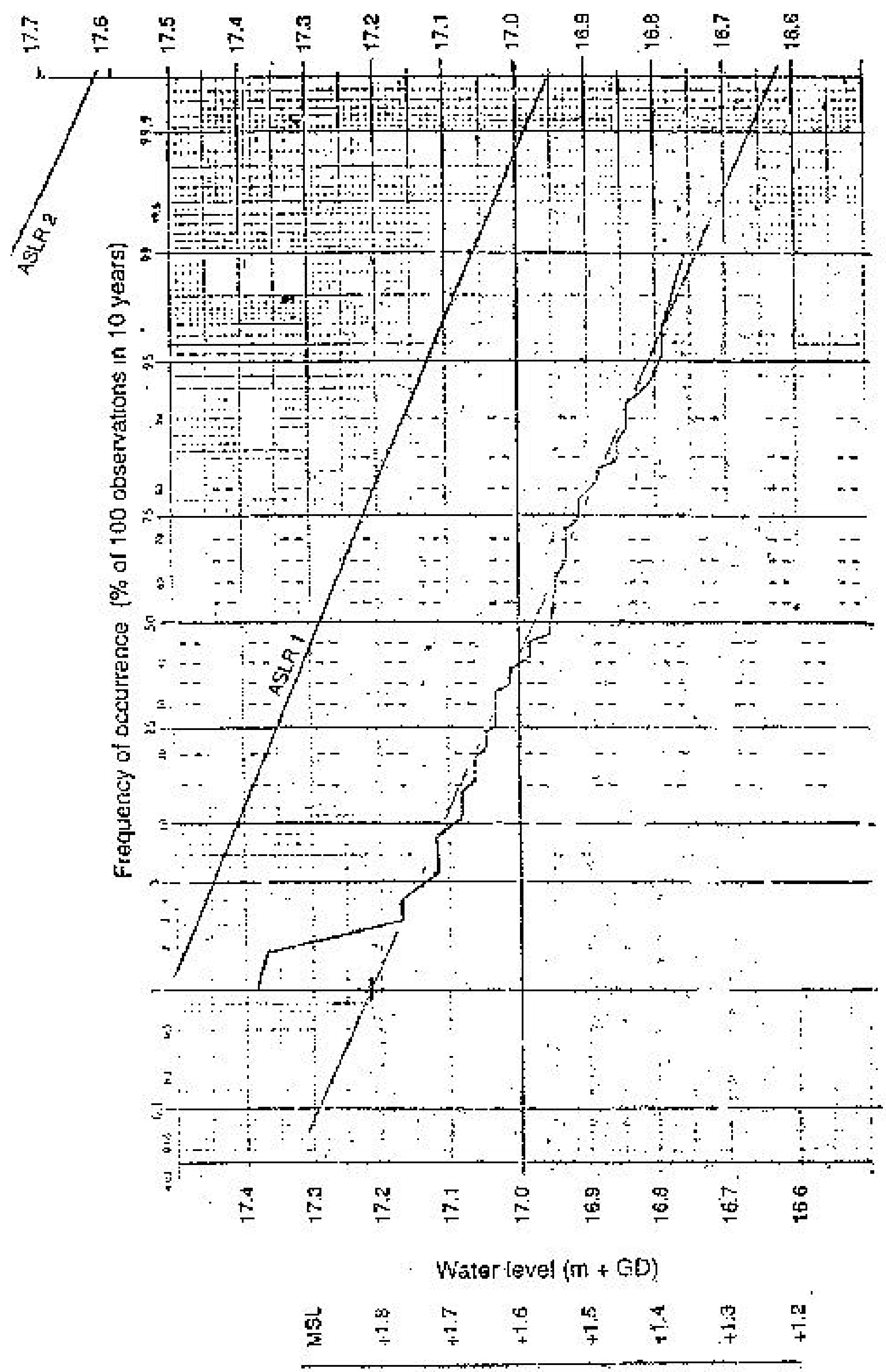


Figure 5.20

Monthly High Water level Readings for Georgetown 1970-1980

ASLR 1: 0.3 m ; ASLR 2: 1.0 m

5.3.5.7 Submergence and Inundation of Coastal Wetlands

The most direct impact of a rise in sea level for Guyana would be the inundation of areas that had been just above the high water level before the sea rose. Coastal wet lands are generally found at elevations below the highest tide of the year and above mean sea level. Thus, wetlands account for most of the land less than 1 m above sea level.

Mangrove forests are found at the interface between the terrestrial and marine ecosystems. They are also found in estuarine wetlands and in tidal reaches of riverine areas. The main species of mangroves found in Guyana include Avicennia germinans (Black mangrove), Rizophora mangle (Red Mangrove), and Laguncularia racemosa (White mangrove). A.germinans known locally as "Courida" is accepted as the main species in the region. Large sections of the Atlantic coast from the Corentyne to the Essequibo Rivers have become monoculture stands of Avicennia.

Mangrove ecosystems are an important coastal resource having a variety of functions and uses, including:

- **Bee keeping**: Approximately 75% of the honey produced in the country is from mangrove areas.
- **Fisheries**: The mangrove swamps are natural breeding and nursery grounds for brackish water shrimp and fin fish species. Estimates of fishing harvest based on mangrove-dependent species are important.
- **Wood**: This is one of the most important uses of mangroves because it provides an easy source of fuel wood. It is used domestically for cooking, for making fences, tents and arbor for gardens.

In addition to their economic use, mangroves play an important role in coastal protection and sea defence. Depending on the width of the strip of mangroves, they can act as barriers to diminish or buffer wave action. Therefore, they play an important role in protection of the sea wall or embankment and reduction of damage to the sea defence system. Mangroves also help to accelerate the process of deposition of soil particles, which are suspended in tidal water thereby raising the level of coastal lands in the intertidal zone.

Mangroves also provide a habitat for a number of different species of phytoplankton, shrimps, crab and manatee as well as birds.

Mangroves are being increasingly threatened in Guyana today. It is unclear which agency has the mandate for mangrove protection and management. As such the use of mangrove forest is not monitored or regulated. There is also a lack of current data on the status of mangroves in terms of distribution, extent and removal. Furthermore, there is a lack of public awareness regarding the importance of mangroves. This makes management of this invaluable resource very difficult.

Much of the destruction of mangroves resulted from conversion of these ecosystems into other uses. This is attributed to mangroves being viewed as wastelands, useless unless converted or exploited directly for cash products. For example, the cutting of mangroves for fuel wood is not done in a sustainable manner. The practice is not supervised and trees are badly damaged in the process. Fishermen also cause local damage by pulling up boats on mudflats in some areas, creating paths through the mangroves. Mangroves are also affected by natural processes such as the cycle of erosion and accretion along the coast. As a result, there is considerable loss of foreshore and mangroves become affected in the process.

While mangroves are likely to play an important role in reducing the impacts of sea-level rise by protecting the coast, this ecosystem may itself be seriously affected by sea level. It seems that mangroves find it hard to cope with rapid sea level because it endangers their way of interacting with the surrounding environment of trapping sediment with their roots. If the sediment is washed away, then the swamp cannot be formed. Instead, what can be observed are individual trees or thin patchy areas in which they cannot survive.

Marine animals, which are of economic importance to man, feed directly on detritus (i.e., shrimps) or feed on detritus feeders (i.e., fish and crabs). Without mangrove and other coastal fringe ecosystems, neither the habitat nor adequate food to support these ecosystems will be available and these populations will decline.

For the rates of sea level rise of the last several thousand years, marshes have generally kept pace with sea level through sedimentation and peat formation. As sea level rose, new wetlands formed inland while the seaward boundary was maintained. Because the wetland area has expanded, one would expect a concave marsh profile, i.e., that there is more marsh area than the area found immediately above the marsh. Thus, if sea level rose more rapidly than the marsh's ability to keep pace, there would be a net loss of wetlands. Moreover, a complete loss might occur if protection of developed areas prevented the inland formation of new wetlands.

5.3.5.8 Coastal Erosion

Processes other than sea level rise also contribute to erosion, including storms, structures, currents, and alongshore transport. Greater wave energy associated with higher sea level will cause increased rates of beach erosion and coastal land loss. Rates of retreat will be influenced locally by a range of factors including nearshore bathymetry, incident wave energy, wave amplitude spectra, wave approach direction, physico-chemical, geologic and morphologic properties of shoreline materials, sediment transport pathways, production rates and sources of eroded sediments.

Sea level rise can also result in the loss of land above sea level through erosion. Bruun has shown that the erosion resulting from a rise in sea level would depend upon the average slope of the entire beach profile extending from the dunes out to the point where the water is too deep for waves to have a significant impact on the bottom (generally a depth of about 10 meters). By comparison, inundation depends only on the slope immediately above the original sea level. Because beach profiles are generally flatter than the portion of the beach just above sea level, the "Bruun Rule" generally implies that the erosion from a rise in sea level is several times greater than the amount of land directly inundated. Bruun found that a 1-cm rise in sea level would generally result in a 1-m shoreline retreat, but that the erosion could be as great as 10 m.

The potential erosion from a rise in sea level could be particularly important to recreational beaches, which include some of Guyana's most economically valuable and intensively used land. Relatively few of the most densely developed beaches are wider than about 30 m at high tide. Thus, the rise in relative sea level of over 60 centimeters projected in the next 40 to 50 years could erode most recreational beaches in developed areas, unless additional erosion response measures are taken.

In Guyana, beach profile measurements collected at a number of beaches show that, while erosion rates, as measured by the retreat of the high ground above the high water mark may be as high as 1.5 meters during a four year period in some cases (See Figure 5.21), accretion, which occurs mainly in mudflats and at the base of shoreline protection structures, may also be as high as 0.5 meters per year as measured at one location (See Figure 5.22).

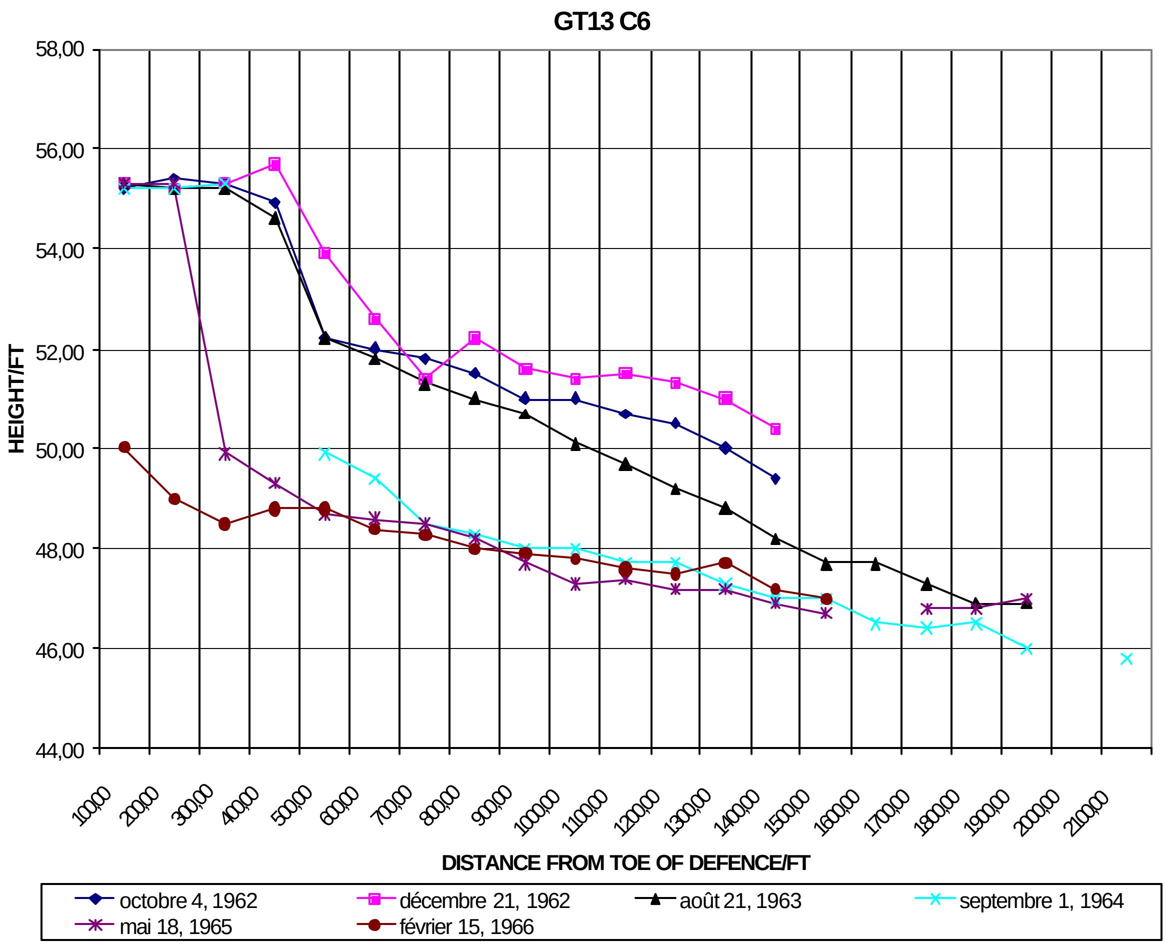


Figure 5.21: Evidence of Beach Erosion in Coastal Guyana

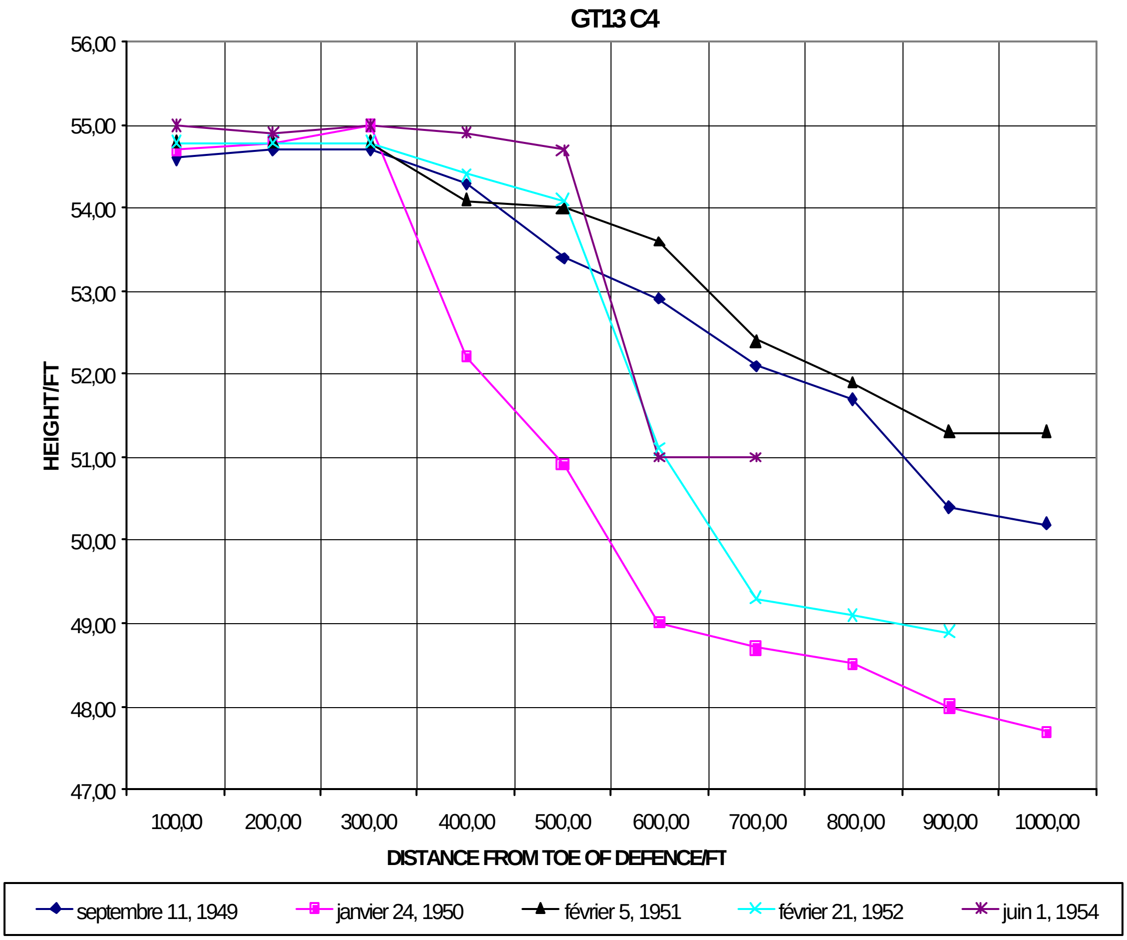


Figure 5.22: Evidence of Coastal Accretion in Guyana

5.3.5.9 Flooding and Storm Damage

A rise in sea level could increase flooding and storm damages in coastal areas for three reasons: erosion caused by sea level rise would increase the vulnerability of communities; higher water levels would provide storm surges with a higher base to build upon; and higher water levels would decrease natural and artificial drainage. This problem has been highlighted in sections 5.3.5.6 and 5.3.5.8.

In addition to community-wide engineering approaches, measures can also be taken by individual property owners to prevent increased flooding. In Guyana, there is neither a government policy in place to restrict development along the coast nor a National Flood Insurance Program to encourage communities to avoid risky construction in flood-prone areas.

5.3.5.10 Increased Salinity in Estuaries and Aquifers

Although most attention is focused on the increased flooding and shoreline retreat associated with a rise in sea level, the inland penetration of salt water could be important in some areas, especially in the flood-prone coastal region of Guyana, where the greatest portion of population and economic activity are located.

A rise in sea level increases the salinity of estuaries like the Demerara, Berbice and Corentyne rivers of Guyana, by altering the balance between freshwater discharges and saltwater intrusion.

The salinity of an estuary represents the outcome of, (1) the tendency for the ocean salt water to completely mix with the estuarine water and, (2) the tendency of fresh water flowing into the estuary to dilute the saline water and push it back towards the ocean. During droughts, the salt water penetrates upstream, as has been observed in the estuary of the Canje river, while during the rainy season, low salinity levels prevails. A rise in sea level has an impact similar to decreasing the freshwater inflow. By widening and deepening the estuary, sea level rise increases the ability of salt water to penetrate upstream.

Saline intrusion will most severely impact the rivers. This is because the density of seawater is higher than river water and therefore this will allow intrusion of saline water higher upstream of rivers. Furthermore, the conservancies are likely to be affected by a rising sea level as well. The economy of the country, which is quite dependent upon agriculture, can be severely affected in the wake of a rise of sea level. Coastal aquifers, whose water tables are close to or below mean sea level, can also be subject to saline intrusions. If these aquifers are exploited for drinking water or agricultural use, then climate-driven sea level rise may create negative impacts for these sectors.

5.3.5.11 Water Resources

Water supply for domestic, industrial and commercial purposes are abstracted from about 170 wells drilled mainly from two aquifers known as the “A” and “B” sands. The water is distributed through a network of pipes estimated at about 3000 miles, laid in urban and rural areas along the coastal plain.

The drainage system is natural and depends on the main rivers, which extend beyond the coast – see Section 5.4.5.2. The major rivers include Essequibo, Demerara and Berbice. Smaller rivers such as Mahaica, Mahaicony, Abary and Canje are also part of the drainage network. All these rivers are within tidal influences of the Atlantic Ocean and this effect is noticeable for some distance upstream. Sea-level rise will exacerbate this condition.

Additionally, to facilitate the country’s agricultural output, irrigation waters are also supplied from water conservancies (i.e., reservoirs). There are four conservancies along the coastal plain: Boerasirie, East Demerara, Tapakuma and Mahaica/Mahaicony/Abary. In the Corentyne, irrigation water for rice, sugar and other crops, is extracted by a number of pump stations along the Canje River in its lower 50 km stretch (which is vulnerable to saline intrusion). This practice can be found on some of the smaller rivers.

The majority of the population is concentrated in a narrow strip along the Atlantic coast. Their main supply of water is the wells located in close proximity to the coastline and therefore the risk of salinization of these coastal wells is highly likely with any sea-level rise.

Seawater intrusion is a common phenomenon today in coastal aquifers. Although Guyana’s coastal aquifer is characterized by some favorable conditions, such as the fact that the clay percentage increases gradually northwards possibly sealing the aquifer from the sea, the risk of salinization due to sea water intrusion should not be ignored. Over-exploitation of the “A” sand's aquifer results in the decline of their piezometric head, as exemplified within the Georgetown area. This might result in a leakage from the upper sand into this aquifer causing further seawater intrusion into the already saline water bodies of the upper sands. Saline water can then migrate downward into the aquifer creating the conditions of an inland moving interface. A similar process might take place between the “A” and “B” sand aquifers.

5.3.5.12 Agriculture

Agriculture is the dominant economic activity on the Guyanese coastal plain. The coastal belt has favourable soil and climate for lowland crops such as sugarcane and rice. Agriculture is a major source of employment, economic growth and foreign exchange in Guyana. In 1997, the Gross Domestic Product (GDP) for agriculture was G$ 53.6 billion (US $297.8 million). The economic contribution of this sector to the national economy is vital and hence the need for sustaining its vitality cannot be overemphasized (Khan and Rahaman, 1998). Almost all of the agriculture products important to national economics are harvested along the coast.

The impacts of global climate change should not be taken lightly in so far as agriculture is concerned. Inundation and salinization associated with sea-level rise could possibly devastate this activity along the coast.

A direct impact of rising sea levels will be the threat of saline intrusion into cultivation fields. Drainage during the raining seasons may require additional and more intensive pumping facilities. The possible intrusion of salt water into the water conservancies and estuaries needs to be examined since these are the prime source of irrigation water.

If weather systems become more intense, then the effect of flooding conditions must be addressed. More frequent El Niño/La Niña events can subject the coast to cycles of drought/flood which can have serious effects on the soil and, therefore, on food production. Cattle and other livestock may not be spared because of the severity of the conditions associated with these rainfall extremes. Apart from the effect on rice and sugar, scarcity of cash crops will be a problem and an economic hindrance.

5.3.5.13 Fisheries

After agriculture, fisheries is the second most important economic activity along the coast. About 6.5 million tonnes of fish were exported in 1998 comprising about 6% of the nation's GDP. The value of fish and fish products for local needs has been also recognized by the Government. The fishing industry has four sub-components: industrial, artisanal, inland aquaculture and ornamental.

Vulnerable resources to sea level include the fish resource itself, wharves/landing sites, co-operative buildings, fishers and mangroves.

More severe and frequent flooding will cause the potential destruction of landing sites and cooperative buildings that are situated along the coast. Fishers must have a place to land their catch for market purposes and this must be a place that is clean and healthy since most of the fish and shrimp caught in Guyana are exported.

The readjustment of mangroves will also affect the fish resources since some of the species caught have nursery areas in the mangroves. If the mangrove forest has to re-establish itself at a new location then valuable fish resources will be lost. At the local level, persons living in rural areas also depend heavily on fish as their source of protein. Hence, a decrease in fish production can see many persons not having this essential nutrient since other alternative sources of protein can be too expensive.

Disruption of coastal and marine ecosystems will also have an effect on species being caught. The Chinese seine fishers will have to move their fish pens nearer to the shore since most of the target species will be closer to the shore. This will include building new fish pens since the older ones will be lost to more frequent flooding or permanent inundation. Biological studies should be conducted to assess the differences, if any, on the biology of the fisheries, checking for growth patterns for example.

Freshwater aquaculture will be impacted from salt-water intrusion. While some species are salt tolerant to some degree (i.e., various Tilapine species) others are not (i.e., hassar). In addition to freshwater species, brackish species will also be impacted on by flooding and erosion caused by sea-level rise. Pond banks will eroded away and cultured fish will escape. Extensive flooding of soil will leach away nutrients, resulting in poor carrying capacity of ponds under extensive and semi extensive production. The introduction of predacious species via flooding into culture operations will result in the inability to practice aquaculture unless painstaking drying and removal activities are carried out. Aquaculture will no longer be a financial viable operation if the introduction of predators cannot be controlled.

5.3.5.14 Human Settlement Infrastructure

Human settlement and infrastructure that are concentrated in the coastal zone of Guyana would, in all likelihood, be vulnerable to climate-driven sea level rise.

Guyana has a population of about 750,000 inhabitants, 90% of which reside on the coastal plain. The population is concentrated in certain locations influenced by the availability of land for housing and other utility services. Higher population densities are observed in Georgetown, the capital city and adjoining areas due to the proximity and closer links with the important urban centre. Major highways and secondary roads are also concentrated on this narrow coastal strip. Georgetown is served by a conventional main sewerage system, which consists of 24 sewerage basins each draining to a dedicated pumping station. In the rest of Georgetown and the coastal plain, sewerage is discharged into septic tanks or pit latrines.

There are developed housing schemes and squatter settlements. This latter has its root in the rural areas where socio-economic conditions are poor and extended households are overcrowded. The Government has improved the allocation of titled house lots but the capacity to accelerate the allocation process is weak. Another problem lies in the fact that the areas identified, legally and illegally, for housing settlements are all in the vulnerable low-lying coastal zone.

Sea-level rise will cause permanent inundation of the entire coastline if no response measures are taken. Houses will be severely damaged by more frequent flooding. In addition, households could suffer from water borne diseases due to contamination of water. It would also seriously affect communications, medical facilities, and transportation infrastructure, which are the basis for human survival.

Sea-level rise may lead to increased erosion, which would cause damage to the foundation upon which houses are built.

Salt-water intrusion will have similar effects on human settlements as described above. In particular, saltwater intrusion affects plant soil and lumber tends to rot faster.

5.3.5.15 Sluice Gates and Sewer Systems

Sluice gates for draining excess water to the ocean are very common in the coastal region of Guyana, parts of which are already below sea level. Sewer systems provide for drainage of surface water from streets in the event of a rainstorm. The sewer system of the city of Georgetown rely on gravity drainage: water flows downhill from the streets into the sewers, then continues toward some outfall area. Should the sea level rise, it could limit the effectiveness of gravity drainage systems and necessitate the installation of mechanical pumping stations to aid drainage of water. This is already being done at present and, indications are that this type of drainage must be intensified.

5.3.5.16 Highways, Roads, and Bridges

Guyana is divided into distinct physiographic regions by its numerous rivers, notably the Demerara, Berbice and Essequibo rivers. Road transport is very common and there are a number of bridges creating nodal links. A rise in sea level of 0.6 m can inundate, weaken, and erode coastal roads. Low-lying roads would be especially jeopardized during storms, risking the lives of motorists. Bridges would be threatened as well. Rising sea levels can also increase bridge structural load, as well as scour bridge foundations.

5.3.5.17 Human Suffering and Loss of Life

Each year floods bring discomfort and losses to thousands of people throughout the coastal region of Guyana. Despite lessons of the past, people continue to settle and build on the coastal plain. The people of Georgetown and surrounding regions of the coastal plain live behind an elaborate system of sluices and dykes. They are therefore even today very vulnerable to flooding from excessive rainfall and from enhanced sea level rise. Further rise in sea levels would most certainly threaten human lives. Flood losses can also be expected to show higher costs.

5.3.5.18 Tourism

Tourism, which is a minor foreign exchange earner in Guyana, could also be adversely affected by global warming and sea level rise.
Guyana's tourist industry is not as developed as the Caribbean countries and it is mainly centered on eco-tourism in the hinterland of the country.

The climate of Guyana is already warm and humid. Besides, Guyana's beaches are not as extensive as those of the Caribbean Sea or for that matter Brazil. If the climate warms to extend the seasonal use of beach facilities in the middle latitudes, and if temperatures and humidity become overbearing, then Guyana may not have a comparative advantage over the northern countries.

Tourist attractions on the coast of Guyana include Georgetown, the capital city and few beaches. Other major tourist attractions include the tropical rain forest, major water falls and rivers which are concentrated in the hinterland regions and therefore less vulnerable to sea level. Guyana can make use of its hinterland attraction in promoting this sector.

Georgetown is situated on the eastern bank of the Demerara River. Most of the city's historical buildings are wooden structures, reflecting the unique 18^{th} and 19^{th} century architecture and are major tourist attractions. Further, the major administrative facilities, hotels and shopping centers are located in Georgetown making this city the "heart" and "brain" of the country.

In Guyana, there are three major shore types: muddy coasts, shell and sandy beaches.

Mud or clay accretionary coasts start as a tidal flat at the landward end of a shoal and extend as much as 0.8 km. As soon as the tidal flat begins to emerge above the high water level, mangroves establish themselves and stabilize the flat.

Sand and shell material transported toward the shoreline during high water levels are deposited in the foreshore region. Sandy beaches occur on the west bank of river mouths and they are not as extensive as the mudflats. They extend for approximately 50 – 70 m during low tide.

Stretches of beach entirely composed of shell fragments occur in several places along the northwestern coast of Guyana. Their average length is about 1,300 m and they extend for a distance of about 100 m (Daniels, 1981). The landward part of these beaches is very old, but on the seaward side, fresh materials are continuously deposited.

Shell Beach is one of the country's major tourism attractions. This area runs from Waini Point in the mouth of the Pomeroon River on Guyana's northern shore. This is the only beach in the world where four species of sea turtles nest: Leatherback, Green, Olive Ridley and Hawksbill. Most other nesting beaches in the world have only one or two species.

Shell Beach is also an important habitat for a large number of other animal species, some of which are now endangered. Blue, Gold and Red bellied Macaws frequent the Shell Beach forests and the mudflats and mangrove lining the shores home to an impressive number of flocks of the striking Scarlet Ibis. Other birds that can be seen mixing with the common egrets and herons are Roseate Spoon-billed and Caribbean Flamingos. Many of Guyana's mammal species can also be found here, such as manatees, jaguars, tapirs, deer and several species of monkeys.

Other beaches include the Number 63 Village Beach located in Corentyne, and others at Hope, Parika, Bushy Park, and Unity Beach. These places are both used for religious and recreational activities. A major part of the Guyanese population is Hindus for whom cremation of the dead is a part of their funeral rites. Hindus conduct the burning of the dead on the beach. They also perform ceremonial rituals on the beach since they hold the ocean to be sacred. These beaches are also used for picnics and playing sports especially during weekends and public holidays.

Georgetown and coastal centres of attraction can be vulnerable to accelerated sea level rise. Rising temperatures and humidity will not help to promote beach activities. In the hinterland, river characteristics may change leading to sites of attraction being modified. However, there may very likely be other newly emerging sites of attraction.

However, successful tourism depends on efficient communications, transportation, networks and other social services. It may be required to have substantial investments in these areas.

5.3.6 Health Effects

Much of what is known concerning how climate change might affect human health has been inferred from correlation of health conditions with weather variables or seasonality. Recent studies have focused on the possible impact that changing climate, season, and weather variables might have on the incidence of disease.

Clear links have not yet been established between climate change and human health. Probably modest effects on human health, however, could occur through:

(1) the direct impact of temperature (heat stress and cardio and cerebro-vascular conditions related to temperature extremes);

(2) climate-related chronic, contagious, allergic, and vector-borne diseases (e.g., malaria and dengue fever); asthma and hay fever, linked to plants or fungi whose ranges and life cycles are strongly affected by climate and weather; and mosquito and tick-borne diseases, such as encephalitis and Lyme disease, especially where conditions are already warm and humid, with poor drainage, as in the coastal region of Guyana;

(3) premature birth, which has an adverse effect on human reproduction;

(4) pulmonary conditions such as bronchitis and asthma related to urban and rural smog that may increase with climate change; and effects of increased ultraviolet radiation on suppression of the immune system - See Table 5.15.

While there is a lack of data in Guyana, there have been reports that skin cancer is on the rise in a region of Guyana inhabited mostly by Amerindians (region 9). This phenomenon seems to suggest that Amerindians, who are repeatedly exposed to solar radiation, are being affected by higher incidences of UV-B radiation and possibly higher surface temperatures.

Table 5.15: Potential Health Impacts of Climate Change in the Coastal Plains of Guyana

Health Impact	Climate Variable Sensitivity	Agent	Vector	Threshold	Increase in Diffusion
Vector-borne Diseases					
1. Malaria	-temperature -rainfall -humidity	Plasmodium	Anopheles mosquito	20 - 30 ^{O} C	+++
2. Dengue Fever	-temperature -rainfall -humidity	Virus	Aedes mosquito	20 - 30 ^{O} C	++
3. Yellow Fever	-temperature -rainfall -humidity	Virus	Aedes mosquito	20 - 30 ^{O} C	+

4. Encephalitis	-temperature -rainfall -humidity	Virus	Mosquito	20 - 30 ^{O} C	+
5.Onchocerciasis	-temperature -rainfall -humidity	Onchoerca Volvulus	Black Fly	20 - 30 ^{O} C	+
Other Infectious Diseases					
1. Cholera	-water temperature	Bacillus	Water	20 - 30 ^{O} C	++
Other Health Outcomes					
1. Climate stress mortality	-temperature -humidity	_	_	33 ^{O} C	+++

+++ very probable; ++ probable; + possible
(adapted from IPCC, 1995; WHO, 1990)

Climate-induced effects on other sectors such as agriculture, fisheries, water and coastal resources, and social and economic conditions might also affect human health. Decreases in food production might result in poorer diets, and rise in sea level and changed precipitation patterns may result in the deterioration of water supplies. Greater numbers of humans could migrate from one area to another, changing the geographic ranges and susceptibility of human populations to many diseases. In general, any event that reduces standards of living will have an adverse impact on human health.

5.3.7 Conclusion

It is evident from the above then, that if anthropogenic climate change were to occur in the manner that AO-GCM's are predicting, several key sectors of the Guyanese economy, including agriculture and forestry, can be adversely impacted. In the forestry sector climate change would influence the distribution of forest species, with savannah replacing more valuable forest stocks in the interior. This change in forest stocks would furthermore compromise the ability of Guyanese forests to act as a removal sink for excess atmospheric CO_2. In agriculture, the yields of sugarcane and rice, the two most economic crops, risk losses under the warmer and, most likely drier, climate of the future.

Guyana's greatest vulnerability to climate change however, is the risk of flooding and inundation deriving from sea level rise in the coastal zone. Most of Guyana's population and economic activities are concentrated in this narrow, fragile, and currently stressed zone. The area is already, for the most part, below the high tide water level. An increase in sea level of about 60 cm then, as projected by AO-GCMs, would further exacerbate the vulnerability of this already fragile zone.

Policy decisions, backed by detailed studies into the response mechanisms required to adapt to the adverse effects of climate change, will be required. These decisions ought to address the direction in which coastal zone development will proceed in the future. That is, should coastal Guyanese ACCOMMODATE, PROTECT OR RETREAT?