# BELIZE

## First National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change

July 2002

# Foreword

The issues of climate change are of profound concern to the people of Belize.

The country's economy is dependent on the climate. Successful agriculture, fishing, timber, and tourism industries rely heavily on a stable, predictable climate. The devastating effects of hurricanes have shown how vulnerable Belize is to the vagaries of the weather. As a low-lying State with the longest barrier reef in the western hemisphere and home to rich tropical rainforests, both hosting very fragile ecosystems, we recognize our responsibility to protect these habitats from the impacts of global climate change and sea level rise.

There is much uncertainty about the effects that global climate change will have on local conditions. Yet, we must make informed decisions to ensure that all sectors of our society can adapt to the impacts of climate change.

The Government thus welcomed the opportunity provided by the Global Environmental Facility to provide the additional resources required by Belize to assess the potential impact of climate change on the country. We must also express our appreciation to the United Nations Development Programme, which facilitated the process. It is especially gratifying to note that the activities required to prepare this National Communication were managed and implemented by local experts.

Through this enabling activity, Belize now has a better grasp of the country's vulnerability to climate change, its contribution to the global greenhouse gas emission cycle, and some appreciation of what further work is required if Belize is to make informed decisions to adapt to climate change.

As a result, Belize considers this an **initial** National Communication. We realize that much more work is required to conduct more detailed vulnerability studies in other sectors. Additional resources will be required to conduct these assessments and to identify and access the technology to adapt to climate change and sea level rise. Subsequent National Communications will contain much more detailed local information on our concerns. Belize now has the local capacity to continue with this work. My Government will provide the resources within its capacity to ensure that this expertise is utilized to the fullest extent possible.

Belize is also prepared to continue working with the international community to negotiate responsibly for strong, achievable and enforceable mechanisms that will control the increasing emissions of greenhouse gases. We are also prepared to utilize the nation's natural resources to assist in the global effort to mitigate the emissions of these gases as long as the measures can be accommodated within the nation's development strategy and ultimately contribute to the socio-economic development of our people.

**Honourable John Briceño**
**Minister of Natural Resources, the Environment, Commerce and Industry**

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## List of Abbreviations and Acronyms

| | |
|---|---|
| AIJ | Activities Implemented Jointly |
| AOSIS | Alliance of Small Island Developing States |
| AVVA | Arial Videotape-assisted Vulnerability Survey |
| asl | above sea level |
| BCES | Belize Centre for Environmental Studies |
| BEL | Belize Electricity Limited |
| C | Celsius |
| CARICOM | Caribbean Community |
| CBD | Convention on Biological Diversity |
| CCAD | Central American Commission on Environment and Development |
| CCC | Canadian Climate Centre |
| CDM | Clean Development Mechanism |
| $CH_4$ | methane |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| CPACC | Caribbean: Planning for Adaptation to Global Climate Change |
| CRRH | Central American Regional Committee for Hydrological Resources |
| CSO | Central Statistical Office |
| DSSAT | Decision Support System for Agrotechnology Transfer |
| ESTAP | Environmental and Social Technical Assistance Project |
| F | Fahrenheit |
| FAO | Food and Agriculture Organization of the United Nations |
| ft | feet |
| GCM | Global Circulation Model |
| GDP | Gross Domestic Product |
| GEF | Global Environmental Facility |
| GFDL | Geophysical Fluid Dynamics Laboratory |
| Gg | gigagrams |
| GHG | Greenhouse Gases |
| GISS | Goddard Institute for Space Studies |
| GWP | global warming potential |
| ha | hectares |
| HFC | hydrofluorocarbons |
| IDB | Interamerican Development Bank |
| ICZM | Integrated Coastal Zone Management |
| INC | Intergovernmental Negotiating Committee |
| IPCC | Intergovernmental Panel on Climate Change |
| KW | Kilowatt |
| KWh | Kilowatt hours |
| LIC | Land Information Centre |
| MAFC | Ministry of Agriculture, Fisheries and Cooperatives |
| Mm | millimeters |
| MW | Megawatt |
| MWh | Megawatt hours |

| | |
|---|---|
| $N_2O$ | nitrous oxide |
| N/A | Not available |
| NGO | Non Government Organization |
| NICU | National Implementation Coordination Unit |
| NMS | National Meteorological Service |
| NMVOC | non-methane volatile organic compounds |
| $NO_x$ | nitrogen oxides |
| NRI | Natural Resources Institute |
| ODA | Overseas Development Agency |
| pa | per annum |
| PfB | Programme for Belize |
| R.K. Beans | Red Kidney Beans |
| RPIU | Regional Project Implementation Unit |
| $SO_2$ | sulphur dioxide |
| sq. km. | square kilometers |
| tC | tons of carbon |
| tC/ha | tons of carbon per hectare |
| UKMO | United Kingdom Meteorological Office |
| UNCED | United Nations Conference on Environment and Development |
| UNDP | United Nations Development Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| US | United States |
| UWICED | University of the West Indies Center for Environment and Development |
| WASA | Water and Sewage Authority |

## EXECUTIVE SUMMARY

### Introduction

The energy that drives the earth/atmosphere system comes from the sun. Most of this energy arrives in the form of short-wave radiation. This radiation passes through the atmosphere virtually unimpeded except for most of the harmful ultraviolet radiation, which is absorbed in the upper atmosphere by ozone. The short-wave radiation is absorbed at the earth's surface, which becomes warmer. The earth in turn radiates most of this energy as long-wave radiation upward into the atmosphere. Certain gases in the atmosphere called greenhouse gases absorb some of this energy. This warms the atmosphere. In the absence of these greenhouse gases, the earth/atmosphere system would be too cold to support life. The excess energy is radiated out to space and the earth/atmosphere system is maintained in radiative balance.

The levels of greenhouse gases remain in equilibrium naturally. Carbon dioxide, the principal greenhouse gas, is soluble in water, and the oceans are its largest reservoir. Carbon dioxide is also an integral part of the plant growth/decay cycle through photosynthesis. However, since the dawn of the industrial revolution, the levels of greenhouse gases have increased. These increases have been scientifically measured at observing sites around the world. The increased levels of greenhouse gases are trapping more of the earth's long-wave radiation producing warmer global temperatures. This has caused the water in the oceans to expand and water stored in the polar ice caps and glaciers to melt, resulting in sea level rise.

In 1988 the Intergovernmental Panel on Climate Change (IPCC) was convened to provide scientific advice and guidance on climate change. In 1995, the IPCC noted that there was sufficient scientific evidence to conclude that mankind was having a discernable influence on the earth's climate.

In 1990, the international community responded to the concerns raised about climate change and convened an Intergovernmental Negotiating Committee (INC) to draft a convention to address climate change. Belize signed the United Nations Framework Convention on Climate Change (UNFCCC) at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil in 1992 together with the leaders of the other Central American nations. This was done to show that Belize recognized that the challenges of climate change were an international matter that required concerted action. Belize ratified the Convention in 1994.

As a signatory, Belize recognizes its common but differentiated responsibility to contribute to the international effort to meet the ultimate objective of the Convention: "*stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system…within a timeframe sufficient to allow eco-systems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner*"(UNFCCC). As a non-Annex I Party, however, Belize must have "*access to the resources to achieve sustainable social and economic development*" (UNFCCC) since as a developing country the overwhelming obligation of the nation is poverty alleviation and sustainable economic development. Therefore, Belize is not obliged to limit its emissions of greenhouse gases.

Among its obligations, Belize is required to periodically prepare a National Communication detailing what measures it is taking to address climate change. This includes a national inventory of sources and sinks of greenhouse gases. In 1998, the Global Environmental Facility (GEF) provided funds through the United Nations Development Programme (UNDP) for an enabling activity to assist Belize in preparing its National Communication.

**National Activities on Climate Change**

The Government of Belize has designated its National Meteorological Service (NMS) as the agency responsible to provide it with technical advice on climate change. A representative of the NMS is its chief technical negotiator on matters related to climate change. Belize participated in Negotiating Sessions of the INC of the Climate Change Convention, and participates in Sessions of the IPCC, Conferences of the Parties of the UNFCCC and sessions of its Subsidiary Bodies, regional meetings on climate change and other meetings at which issues related to climate change are addressed.

Through its membership in CARICOM, Belize is a partner in the Alliance of Small Island States (AOSIS). Its negotiating position is therefore coordinated within this body. Belize is also a member of the Central American Commission on Environment and Development (CCAD). It attempts to reconcile the negotiating positions of these two groups into a larger unified voice to achieve the objectives of the Convention.

In 1994, Belize undertook Climate Change Vulnerability Assessments in Agriculture, the Coastal Zone and Water Resources under the US Country Studies Program. In 1995, Belize became one of the first countries to host a project under the pilot phase of Activities Implemented Jointly (AIJ), the Rio Bravo Carbon Sequestration Project. In 1997, Belize hosted a regional conference on "Climate and Health in the Intra-American Region". Later that year, Belize began implementation of the regional "Caribbean: Planning for Adaptation to Global Climate Change" (CPACC) project. In 1998, Belize implemented the "Enabling Activity to Assist Belize in Preparing its First National Communication to the Conference of the Parties of the UNFCCC".

In accordance with the Convention, Belize chose the year 1994 for its first National Inventory of Sources and Sinks of Greenhouse Gases. The results of the Inventory reveal that Belize is a net sink for greenhouse gases, i.e., it absorbs more than it emits. Yet, it is obvious that Belize is extremely vulnerable to adverse impacts of climate change. Therefore, the national objective must be to identify feasible adaptation options to address climate change.

It is essential that climate change issues be incorporated in the development process of the country. To facilitate that effort Belize has established a Website www.met.gov.bz/climate with information on national activities related to climate change. An interdisciplinary National Climate Committee has been established which follows issues related to climate change and provides advice to the government on related matters.

All agencies are now being urged to incorporate the potential impacts of climate change in their decision-making processes. These include the agencies responsible for biodiversity conservation, emergency management and mitigation, the environmental impact assessment process, and integrated coastal zone management. Legislation is now being drafted for the establishment of National and District Sustainable Development Councils. These Councils will also be included in national efforts to address climate change.

**Next Steps**

The National Meteorological Service will continue to be the lead agency dealing with climate change matters on behalf of the Government of Belize. However, as mechanisms are developed within the Clean Development Mechanism (CDM) and the Kyoto Protocol and other climate change related projects come on stream, it may become necessary to create a body dedicated to climate change issues, or to transfer responsibility to may be transferred to an agency having a greater national development/economic mandate and capacity.

Belize has demonstrated its ability to successfully host and manage a project under the pilot phase of AIJ. The country has the capacity and expertise to undertake other projects that address climate change. It will attempt to attract more projects that utilize the natural resources of the country, especially those involving the transfer of appropriate technology and the development of renewable energy.

**Requirements**

A recurrent theme which arose during the preparation of this First National Communication was the need to sensitise the general public and decision makers, especially the political directorate, on the potential impact of climate change on the country and on the opportunities being offered by the mechanisms of the Convention to address climate change. A comprehensive program on public awareness, education and training is required beyond that which is normally appended to sector specific projects.

Belize has undertaken vulnerability assessments in three sectors. The results were alarming. Further vulnerability assessments are required especially in those sectors of great economic importance such as bananas, citrus, sugar, forestry, biodiversity, and tourism.

If Belize is to contribute to the global effort to monitor climate change and sea level rise, its marine, meteorological and hydrological monitoring networks must be further developed and strengthened. This data is also essential if Belize is to properly monitor the impacts of climate change on the nation and undertake appropriate, cost-effective adaptation measures.

The CPACC project has assisted Belize in its efforts to compile inventories of its coastal resources, make an economic evaluation of those resources and thus quantify their vulnerability. Similar efforts are required for Belize's mainland resources. These are of equal national importance but perhaps of even greater global importance because of their capacity to act as a sink for greenhouse gases.

**Conclusion**

Belize is a young nation striving to improve the quality of life of its people and achieve its development potential in a sustainable manner. The potential adverse impacts of climate change are additional hurdles placed in its path. Belize will continue to work along with the international community together with its traditional allies AOSIS, CARICOM, and CCAD to achieve the ultimate objectives of the Convention.

Belize would like to use its natural resources to assist the world in meeting the challenges presented by climate change as long as such activities meet the development objectives of the nation.

Finally, the country is prepared to work with the international community to identify mechanisms which will facilitate the identification and implementation of adaptation measures required to overcome the adverse impacts of climate change.

# CHAPTER 1

# NATIONAL CIRCUMSTANCE

## Physical Geography

Belize is located on the Central American mainland, forming part of the Yucatan Peninsula and lying between 15°45'and 18°30'north latitude, and 87°30' and 89°15' west longitude. It is bounded to the north by Mexico, to the west and south by Guatemala and to the east by the Caribbean Sea. The total land area is 22,960 sq. km. (8,867 square miles) of which 95% is located on the mainland and five per cent is distributed over more than 1,060 islands. Total national territory (including territorial sea) is 46,620 sq. km. (approximately 18,000 square miles).

Most of the northern half and much of the southern third of the country, plus the entire coastal area and all the islands, are flat and low-lying. Large sections of the coastline have an elevation of less than one metre to a distance of several kilometers inland. In the north, the land rises to an elevation of approximately 250 meters above sea level (asl) in the extreme west of the country. The central part of the country is dominated by the Maya Mountain/Mountain Pine Ridge massif, rising to 1,124m asl (3688 ft) at its highest point.

Northern Belize has a subtropical climate with an annual rainfall of 1,500 mm (60 inches). Southward, the climate becomes increasingly tropical and annual rainfall increases to 3,800 mm (150 inches). The climate is characterized by marked wet and dry seasons separated by a cool transitional period. The rainy season begins in the south in the middle of May and arrives in the north in mid June. It continues through to November, but most locations experience a drier period in August. Some 60% of annual precipitation occurs during this season, produced primarily by tropical systems including tropical cyclones. The cool transition period occurs from November through February. Rainfall declines and approximately 12 cold fronts cross the country during this period. The true dry season is from February to April and is produced by strong anticyclones in the Atlantic that generate a persistent stable south-easterly airflow across the country.

Average maximum temperatures are near 85°F and the lows are in the low 70's. Summers are about 8 degrees warmer than winters. The diurnal temperature range in the interior is greater than that along the coast, where it is moderated by the sea breezes. For example, minimum temperatures in the interior are about 5 degrees cooler than those at coastal locations. The mountainous regions are also cooler, exhibiting a fall in temperature of 10 degrees Celsius per km (5°F/1000 ft.). Humidity hovers around 80% throughout the year, although it is somewhat lower during the months of the dry season.

Belize lies within the hurricane belt. Historically, tropical storms and hurricanes have affected the country once every three years. Belize City, the former capital, was destroyed twice by hurricanes in the 20$^{th}$ century. Hurricanes can affect any part of the country but are more frequent in the north.


BELIZE
MEXICO
MEXICO
GUATEMALA
USA
Cuba
Mexico
Guatemala
Honduras
Pacific Ocean
El Salvador
Nicaragua
Corozal
COROZAL
Orange Walk Town
San Pedro
NORTHERN HIGHWAY
ORANGE WALK
BELIZE
Belize City
WESTERN HIGHWAY
Belmopan
COASTAL ROAD
Santa Elena
San Ignacio
Benque Viejo
HUMMINGBIRD HIGHWAY
CAYO
Dangriga
STANN CREEK
CARIBBEAN SEA
SOUTHERN HIGHWAY
TOLEDO
Monkey River Town
Punta Gorda
LEGEND
WaterBody
Major Settlements
Major Roads
Rivers/Creeks
District Boundary
International Boundary
N
W
E
S
Scale: 1:800,000
20000
0
20000
40000 Meters
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BELIZE
Prepared: June, 2002

The geology is calcareous over the entire northern part of the country and the Maya Mountains. Granites and metamorphic rocks occur elsewhere. The natural vegetation is predominantly moist and wet subtropical broadleaf forest, including mangroves on the coast. Savannahs and open pine formations, subject to frequent burning, occur on some granites and wherever Pleistocene alluvia cover the underlying limestone. There are also large wetland areas on the lowlands and coastal plains. Offshore, the Belize Barrier Reef is the second largest in the world and the largest in the Western Hemisphere. The greater part of its extent lies within Belizean territorial waters.

## Demography

The last full population census took place in 2000. Population censuses are conducted every ten years, and during inter-censual Labour Force Surveys are conducted and mid-year population estimates are made. There is therefore information specific to the 1994 baseline year and adequate information to describe recent trends.

In 2000, the population stood at 249,800, rising to 256,800 in 2001. The major determinants of Belizean demographics are, however, high fertility rates plus the effects of high emigration and immigration levels. These factors must be taken into account in assessing the significance of the population census figures and estimates. For its size, the population is also culturally diverse. In the north (Corozal and Orange Walk Districts), it is predominantly mestizo and Spanish speaking. In the Belize District, it is English-speaking Creole. The Cayo District in the centre of the country is more mixed. All four districts have Mennonite communities, which form a distinct German-speaking cultural element. In the south, the majority population in the Stann Creek District is Garifuna while more than 65% of the inhabitants of the Toledo District are Maya. Three Mayan languages are spoken across the country.

The age and structure of the Belizean population has remained fairly constant over the years. The population is relatively "young", with over 40% below 15 years of age and less than 5% over 65 years old. Fertility rates are high but falling: from 7 children/woman in the 1960s to 5 children/women in the mid-80s and down to 3.2 children/woman in 2000. There is also a falling mortality rate (7.8/1000 in 1969 to 4.9/1000 in 2000), falling infant mortality rate (51.2/1000 in 1960 to 17/1000 in 2000) and increasing life expectancy (from 69 in the 1970s to 72 in the 1980s and 74 in 1990s). The influence of immigration and emigration is superimposed on these basic characteristics. Some 14% of the population are immigrants from neighbouring Central American countries, contributing to the population growth rate of 2.8% per annum since 1991. This is similar to the growth rate (2.6% p.a.) from 1980-1990 and compares with 1.6% for the previous decade (1970-1980) when emigration exceeded immigration. Emigration also affects the sex ratio. Although the overall ratio is almost exactly 50:50, there is a 5% difference in favour of women in the 15-44 age group and a 15% difference in the 20-24 age group. Essentially, a greater proportion of young men leave the country. Up to 1980, the urban population was larger than the rural (54:46% in 1970, 52:48% in 1980). This reversed to 48:52% ratio in favour of the rural population in 1991 and 2000 – a direct consequence of Central American immigrants settling in the countryside.

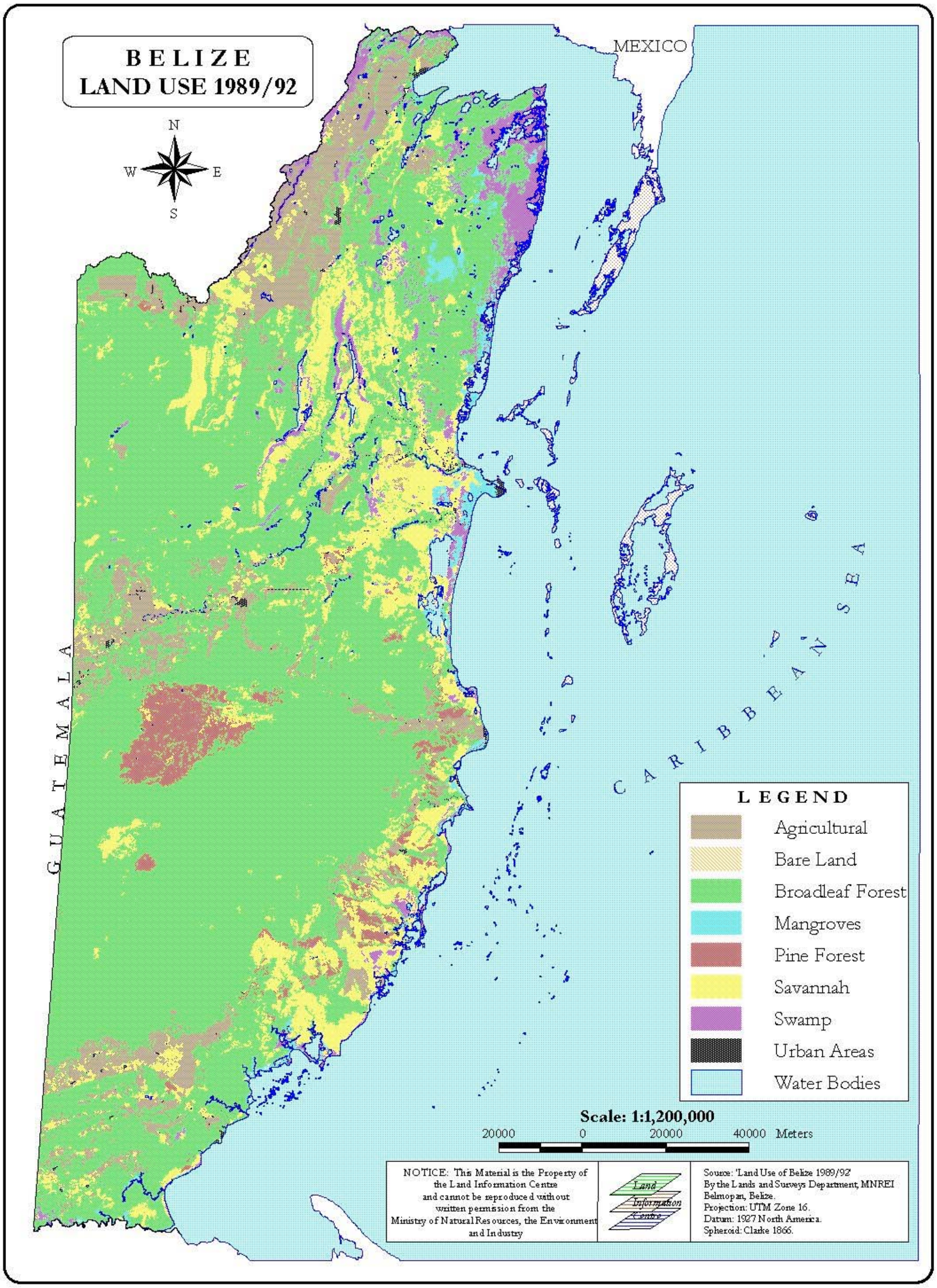
Another important statistic is that 45% of the population lives in the coastal zone, the region most vulnerable to climate change impacts.

**Land Use**

In 2000, approximately 121,500 people (48.6% of the population) lived in nine towns; 54,000 lived in the main economic centre, Belize City, and the remainder in urban centres ranging from 13,800 to 4,400 people (Orange Walk and Punta Gorda Towns respectively). Rural population densities in the districts ranged from 13.6 to 3.5 per square kilometre (Corozal and Belize Districts respectively), averaging at 5.6 per square kilometre. This is low but disguises the fact that the population is concentrated in the better agricultural areas. There, the population densities are comparable to those in neighbouring countries (e.g. Honduras). Conversely, large areas are practically devoid of inhabitants through inhospitable terrain, difficult access, or land ownership patterns. In fact only 33% of the country is considered suitable for agriculture and half of that requires careful management. The population is distributed accordingly. This results in localized pressure, and marginal lands are being brought under agriculture in such areas.

The most striking characteristic of Belize is that over 70% of the country remains under natural vegetation cover. The utilization pattern of natural vegetation is therefore a crucial part of national land use. In 1994, protected areas with some form of legal underpinning covered 767,000 ha (33.4% of the country). Of this area, and dividing the large privately owned Rio Bravo Conservation and Management Area into its functional national park and forest reserve components, 38% is under management regimes for biodiversity conservation, education, visitation, and research. The remainder is within forest reserves, allowing extractive use. Even here, however, some 50% of the area is treated as protected forest due to slope or soil moisture constraints. Four forest areas (out of seventeen) are now under controlled management regimes intended to ensure sustainable use, of which one is certified under Forest Stewardship Council guidelines. Introduction of all but one of these management systems post-date the 1994 baseline year. The area outside the protected area network comprises government and privately owned lands. Here, land use includes protection (often associated with eco-tourism ventures), selective timber extraction under minimal control, and some extraction of non-timber forest products. Although many areas are difficult to access, virtually none can be considered pristine although human impacts may be slight.

In terms of vegetation cover, 73% (approximately 1.3 million ha) of the natural vegetation comprises high broadleaf forest formations. High mangrove formations add another percentage point. Thickets (which at least in northern Belize have been shown to carry a surprisingly high biomass content approaching that of high forest) comprise a further 3.5%. Deforestation, primarily for agriculture but also for other economic ventures especially on the coast, occurs mainly at the expense of these three vegetation


BELIZE
LAND USE 1989/92
N
W
E
S
MEXICO
GUATEMALA
CARIBBEAN SEA
LEGEND
Agricultural
Bare Land
Broadleaf Forest
Mangroves
Pine Forest
Savannah
Swamp
Urban Areas
Water Bodies
Scale: 1:1,200,000
20000 0 20000 40000 Meters
NOTICE: This Material is the Property of the Land Information Centre and cannot be reproduced without written permission from the Ministry of Natural Resources, the Environment and Industry
Land Information Centre
Source: 'Land Use of Belize 1989/92'
By the Lands and Surveys Department, MNREI
Belmopan, Belize.
Projection: UTM Zone 16.
Datum: 1927 North America.
Spheroid: Clarke 1866.

types. Ministry of Agriculture statistics used in the GHG Inventory indicate that clearance averaged 3,505 ha per year over 1984-94. A 1994 study (White, et. al., 1994) however, gave much higher rates (25,000 ha per year) for the end of the period, suggesting that the Ministry of Agriculture figures underestimated clearance, that clearance was accelerating, or that both conditions applied. Furthermore, some 9% of the deforestation was identified as occurring in the protected areas, indicating a general inadequacy of resources to implement policy. Closed and open pine forests comprise another 7.5% of natural vegetation cover. These formations are subject to regular burning, some natural, but mostly set by man, and are almost wholly confined to the forest reserves. Indeed, the difference between open and closed cover appears to be entirely dependent upon the efficiency of fire control. Where fires are frequent and uncontrolled, the pine forest tends to give way to open savannah formations although edaphic factors (e.g. seasonally high water tables) also play a role. Such lands make up another 8% of the natural vegetation cover and any given area may be burnt every 3-5 years if not more frequently.

The remaining land area of Belize (some 688,800 ha) is dominated by agriculture. The statistics on agricultural land use are not very reliable, but it was reckoned in 1994 that approximately 24,300 ha were devoted to sugar cane, primarily in the north of the country. A further 11,300 ha was planted in citrus tree crops, principally in the Stann Creek valley, while banana plantations occupied 2,400 ha in both the Stann Creek and Toledo Districts. The remaining 650,000 ha were under arable crops including rice (approximately 5,000 ha) or pasture. This area includes lands under intensive mechanized systems, particularly under Mennonite ownership, permanent agriculture in smallholdings, or shifting agriculture (milpa), which includes a fallow period of re-growth over several years. Smallholdings and milpa accounted for approximately half the production but most of the area. The livestock herd is dominated by non-dairy cattle and swine.

In 1993 it was foreseen that agricultural expansion was not likely for the main export crops, and that future production increase for arable crops (and the forest clearance required) would tend to occur where the mechanized systems were in place in the northern and central parts of the country. This may be true in general terms but does not take account of the needs of the small farmers, many of whom (especially recent immigrants) do not have ready access to land. Increasing land pressures where the rural population is concentrated are leading to shorter fallow cycles and declining yields, further increasing the amount of land needed to maintain production. In turn, more labour must be devoted to staple foods and less to cash crops. An increasing number of communities in southern Belize are falling into this spiral. Pressures upon marginal land are expected to intensify and are already apparent where the rising trends in rural population growth are most advanced.

It is believed that Belize has petroleum deposits and several exploratory wells have been drilled. No commercial fields have been discovered yet, but the Government is encouraging further exploration. Other mineral reserves include limestone and dolomite, currently used primarily for road-stone and agricultural purposes.

## Political Organization

Belize is a sovereign state governed under the principles of parliamentary democracy based on the Westminster model. The Prime Minister and Cabinet form the executive branch while the National Assembly forms a bicameral legislature comprising a 29-member elected House of Representatives and a 12-member appointed Senate. There are six administrative districts (Corozal, Orange Walk, Belize, Cayo, Stann Creek, and Toledo). The administration of affairs in these districts are conducted by a combination of city (where appropriate), town and village councils. Belize City has a nine member elected council, whereas Belmopan City and the town and village councils have seven-member elected Councils.

The country is a member of the United Nations, the British Commonwealth, the Organization of American States, the Non-Aligned Movement, the Caribbean Community and the Association of Caribbean States and the Central American Integration System.

## National Policy

The National Goal is to manage the internal affairs of the country and promote the kind of socio-economic development that ensures improvement in the quality of life and the general well being of its citizens and positions the country favourably in the international economic community. Intermediate goals include:

- Increasing the national wealth through economic growth in the context of sustainable development;
- Developing human resources and alleviating poverty through education and the generation of knowledge, improvement in health care services, improvement in the prevention and control of crime and promotion of overall human development, for all Belizeans, with special attention to the marginalized and impoverished;
- Facilitating and accelerating development and the contribution of the productive sector in the delivery of services required for human development;
- Improving the efficiency, the accountability and the impact of the public sector in the delivery of public services.
-

The general development strategy, therefore, is to provide an enabling environment for private investment and to focus on areas that are complementary in the social services and basic infrastructure sectors. The “enabling environment” consists of the economic, physical, legal, regulatory, and institutional framework within which businesses operate. Sustainable use of natural resources, conservation of biodiversity, and the general maintenance of high environmental quality are also emphasized. Throughout, there is recognition that the government is not solely responsible for achievement of development goals. All sectors of society have the right and the responsibility to play an active part. Emphasis is therefore placed on participation by civil society in general, including NGOs and the private sector.

**National Economy**

The national economy is small and open, and based primarily on agriculture, agro-industry and services (mainly tourism). As of 2001, the GDP at current market prices stood US$805.0 mn, with per capita GDP of US$3,135. GDP growth during the nineties averaged 4.6% and, notwithstanding three natural disasters and the September 11 attack which had global economic effects, growth over 2000 and 2001 averaged 7.7%.

| **Population, Employment and Income** | | | | | |
|---|---|---|---|---|---|
| | **1994** | **1998** | **1999** | **2000** | **2001** |
| POPULATION AND EMPLOYMENT | | | | | |
| Population (Thousands) | 211.0 | 238.0 | 243.0 | 249.8 | 256.8 |
| Percentage Population in Rural areas | 49.3% | 49.6% | 51.4% | 51.4% | 51.4% |
| Population density per sq. km. | 9.2 | 10.4 | 10.6 | 10.9 | 11.2 |
| Employed Labour Force (Thousands) | 62.4 | 73.3 | 77.8 | 83.7 | 86.8 |
| Unemployment Rate (%) | 9.0% | 14.3% | 12.8% | 11.1% | 9.3% |
| Population in absolute poverty | 13.4% | | | | |
| Life Expectancy at birth (years) | 72 | | | | |
| Literacy rate | 13.4% | | | | |
| INCOME | | | | | |
| GDP at Current Market Prices (US$mn) | 552.0 | 629.6 | 688.0 | 773.0 | 805.0 |
| Per Capita GDP (US$) | 2,616 | 2,645 | 2,831 | 3,094 | 3,135 |
| Real GDP Growth (%) | 1.4 | 1.8 | 6.5 | 10.8 | 4.6 |
| Share of Primary Activities in GDP | 20.3% | 19.6% | 19.8% | 18.2% | 16.8% |
| Agriculture | 14.7% | 14.2% | 13.9% | 12.9% | 11.3% |
| Forestry and Logging | 2.5% | 1.6% | 1.9% | 0.6% | 1.1% |
| Fishing | 2.5% | 3.2% | 3.4% | 4.0% | 3.7% |
| Mining | 0.6% | 0.6% | 0.6% | 0.7% | 0.7% |
| Share of Secondary Activities in GDP | 24.6% | 22.7% | 22.4% | 23.2% | 23.7% |
| Manufacturing | 14.1% | 13.5% | 12.7% | 13.3% | 13.4% |
| Electricity & Water | 3.7% | 3.4% | 3.3% | 3.3% | 3.2% |
| Construction | 6.8% | 5.8% | 6.4% | 6.6% | 7.1% |
| Share of Services Activities in GDP | 55.2% | 57.8% | 57.8% | 58.7% | 59.5% |
| Trade, Restaurants & Hotels | 17.4% | 18.9% | 20.4% | 22.1% | 21.4% |
| Transport & Communications | 10.3% | 10.4% | 10.4% | 9.9% | 10.5% |
| Finance & Insurance | 6.5% | 6.9% | 6.5% | 7.0% | 7.1% |
| Real estate & Business services | 5.7% | 6.6% | 6.2% | 5.9% | 6.1% |
| Public Administration | 13.3% | 12.7% | 12.2% | 11.8% | 12.3% |
| Community & Other services | 6.1% | 6.5% | 6.0% | 5.5% | 5.6% |
| Less Imputed Bank Charges | -4.1% | -4.2% | -3.9% | -3.5% | -3.5% |

Source: Central Statistical Office

The vulnerability of the economy was very much evident by the effect of the withdrawal in 1994 of the British Garrison that was stationed in country. This led to an immediate reduction in gross domestic expenditure by 5% and lent further urgency to the long recognized need to diversify the market base. As can be seen by the increases in GDP shares in the Table below, this need for diversification has been somewhat addressed by continuous growth in the trade, restaurants and hotels (tourism), the fishing (particularly aquaculture-shrimp farming), and the finance and insurance (including offshore banking) sub-sectors. Whilst the population size and density has increased, 2001 unemployment of 9.3% was comparable once again to the mid nineties level.

Throughout the nineties and up to 2001, the balance of trade deficit has increased consistently to US$191.5 mn. This deficit has been somewhat offset by net inflows for services and net remittances or unrequited transfers. During 2000 and 2001, net capital and financial flows were recorded at US$205.8 mn and US$144.6 mn, respectively.

The traditional agricultural production and commodity exports that have long benefited from preferential market access are facing increasing challenges due to deepening trade liberalization at the global level. Furthermore, imports of machinery and manufactured goods have increased significantly from the 1980s but, arguably, a sizeable proportion of these imports have failed to contribute to overall productivity. On the other hand, tourism net earnings have remained relatively stable over the past three years, despite the passage of three major natural disasters over Belize and the attack on the World Trade Centre in New York, both of which would have had significant impact on travel activities.

## Social Indicators

Belize is categorized as a developing country with a medium Human Development Index (0.806 in 1995).

In 1994, the labour force (i.e. those in, available for, or seeking employment) stood at 70,870 people or 33% of the population. Of these, 13% were unemployed. Mean income was US$385 per month (median US$310 per month) and some 70% of the labour force was male. On a national basis, 25% of all households are poor and 10% extremely poor. Pockets of severe poverty were identified in the Cayo and Toledo Districts, reflecting the distribution of the most economically disadvantaged groups in Belizean society – recent Central American immigrants and the Maya Indian population (which also includes recent immigrants). Unemployment and income are directly related to levels of education. It has also been found that the poorest groups have less access to education and training opportunities, reducing the chances of escaping poverty in the next generation.

Basic adult literacy levels stood at 74% in 1980, falling to 70% in 1991 (which has been attributed to the effects of recent immigration) and rising again to 75% in 1996. Belize offers basic education of 8 years of primary education in 280 schools, 4 years of secondary education in 30 secondary schools, and limited tertiary education in 11 institutions, concentrating on community college level but including bachelor's programmes. Access to education and the quality of both facilities and teaching are causes of concern. Low standards of teaching English as a second language is a particular concern. All teaching from infant grade is in Standard English but 90% of the population speak another language or non-standard English at home. In 1991, the mean level of schooling in the population above 25 years of age was 7.2 years. Some 16% received secondary or higher education. In 1996/97, 42% of secondary school age children were not in the educational system. The drop-out rate from primary school is 1.3%; 20% do not pass on to secondary school, and the secondary school drop-out rate is also 20% annually. Figures for 1991 show that 21% of the urban student population had attained secondary school education while the equivalent statistic among their rural counterparts was 6.5%.

Belize has seven government and two private hospitals. There is also a network of health centres and rural health posts, supplemented by mobile clinics. These mobile clinics account for 40% of primary health care. The infant mortality rate is still considered unacceptably high and varies greatly across the country, reflecting disparities in living conditions and services. In 1992, infant mortality in the Toledo District was more than twice that of the nation. In 1994, there was 100% coverage of adequate and safe potable water supplies in urban areas, falling to 69% in the countryside. Meanwhile, 39% of the population had adequate sanitation facilities. For the rural population, the figure was 22%. Available information suggests that the incidence of infectious diseases associated with deficiencies in water supply and sanitation is increasing. Malaria had been thought to be under control but increased dramatically during the 1990s. Belize now has the highest reported malaria rate per capita in Latin America. It is believed that the disease costs the country US$800,000 per year in control costs and lost productivity. Cholera and dengue have both recently re-appeared as sporadic outbreaks while diarrhoea is also a problem. As in all the social indicators, Cayo and Toledo stand out as being particularly affected.

The majority of Belizean households consist of 5 or more people, tending to be larger in rural areas. As 63% of all dwellings have 2 bedrooms or fewer, overcrowding is identified as an issue.

In terms of government expenditure, a third of the 1994 budget was taken up with social services. The largest single category within social services expenditure was on education (6% of GDP) followed by health (5% of GDP). Of this, however, only 24% went to primary health and preventative programmes. Economic services accounted for almost 9% of GDP and public debt charges accounted for 5.5%.

## Implications for Climate Change Issues

Belize signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and ratified it in 1994. In view of the possible opportunities presented by mechanisms developed under the Convention, Belize has attempted to keep abreast of developments to the degree its resources permit. There are Belizean representatives on the IPCC working groups, and delegates regularly attend IPCC meetings. Delegates also attend Conferences of the Parties (COP) and Subsidiary Body Sessions of the COP of the UNFCCC and most regional meetings involving the Central American and CARICOM states. It does not, however, have a formal climate change office. The National Meteorological Service is the focal point for all matters related to climate change.

Since ratification, Belize has participated in actions under the Convention in two ways:

*i)* *Assessment and monitoring of climate change impacts*. Vulnerability assessments have been undertaken on staple crop yields, coastal vulnerability to sea level rise, and on the water resources of the Belize River Valley. In the first two cases, negative impacts are foreseeable while the results of the third are ambivalent. Belize is also participating in the "Caribbean: Planning for Adaptation to Climate Change" (CPACC) project, initiated by CARICOM with the support of the Organization of American States and the Global Environment Facility. The Belizean contribution to this regional project is coral reef monitoring. Other components include regional climate and sea level monitoring, assessment of coastal resources, assessment of coastal vulnerability, economic valuation of coastal resources, and formulation of economic and regulatory proposals to address the issue.

ii) *Participation in the Pilot Phase of Activities Implemented Jointly (AIJ).* The Rio Bravo Carbon Sequestration Pilot Project was established in 1995, field managed by a Belizean NGO with funding from six North American energy sector companies passed through an international NGO as funds manager. This project was the first Land Use Change/Forestry project under the Pilot Phase to be fully funded. From the Belizean viewpoint, participation was intended to explore the potential for such projects to generate credible GHG benefits through private sector partners, equitably shared between interested parties. It has shown that at the individual project level the overall concept is robust and can deliver sustainable development gains. $CO_2$ benefits can be measured reliably on the ground. (195,681 tons of carbon are sequestered annually.) Issues of "leakage" and "additionality" are fully addressed. While respecting contrary views, the experience indicates that well-designed and implemented forestry based projects, including sequestration projects, are a viable approach that can produce swift GHG benefits. It is also accepted that, being cheaper, they may divert attention from other forms of approach and are therefore probably best used as part of a balanced portfolio of project types delivering a spread of development, GHG mitigation, and climate change adaptation benefits.

In summary, Belize is a country with extensive, low-lying, coastal areas vulnerable to natural disasters through tropical cyclones and flooding. Furthermore, the economy is small and concentrated, along with most centres of population, in the very areas that are most vulnerable. Following the threat posed by Hurricane Mitch in October 1998, there has been a review of hurricane preparedness and procedures to mitigate the effects of natural disasters. The scenario of a major disaster such as Hurricane Mitch, and more recently hurricanes Keith and Iris, has served to sensitise the government and general public to climate change issues, mitigation, and especially adaptation.

Four main implications arise from the national circumstances:

i) The population is increasing. Expenditure to meet social requirements may therefore also be expected to rise if poverty is to be alleviated and the general well being of the people is to be enhanced. At the same time, the economy is small, fragile, and increasingly challenged. Furthermore, the country is vulnerable to climate change impacts. These provide strong incentives to pursue new opportunities presented by mechanisms of financial and technical resource transfer developed under the UNFCCC and direct them towards national sustainable development priorities. Given the vulnerability of the country, it must take particular interest in approaches that offer speedy and reliable benefits.

ii) Given its forest cover, the greatest opportunities for Belize lie in the land use and forestry sectors including maintenance of the sequestered stock. Applying the aboveground woody biomass data of 141 tC/ha found in northern Belize to the entire country (and so certainly underestimating given the higher forest types in the south), the high forest formations represent a standing stock in the order of 183 million tC in the wood alone. This is not secure regardless of a national policy that assumes maintenance of a relatively high proportion of forest cover as long as resources are inadequate to implement that policy. Tactical considerations may indicate that other types of mitigation action should be emphasized at this stage, but forestry activities and indeed the more controversial carbon sequestration should be maintained as options where the projects are rigorously designed.

**Land Use, Agriculture and Forest Cover**

| | **1994** | | **1994** |
|---|---|---|---|
| *Land Use* | | *Forest Cover* | |
| Total land area (sq. km.) | 22,960 | Area under Forest use (sq. km) | |
| Total national territory including coastal waters (sq. km.) | 46,620 | Broad leaf forest | 14,190 |
| Land area used for agricultural purposes (sq. km.) | 6,880 | Open broad leaf forest | 120.31 |
| Urban population as percentage of total population | 51% | Pine forest | 576.25 |
| *Livestock population* | | Open pine forest | 73.07 |
| Non-dairy cattle | 51,097 | Thicket and other degenerated broad leaf forest | 848.38 |
| Dairy cattle | 1,882 | Herbaceous and scrub, secondary after clearing | 188.59 |
| Poultry | 5,516,766 | Bamboo and riparian vegetation | 115.27 |
| Sheep | 2,688 | Coastal strand vegetation | 24.83 |
| Swine | 24,224 | Mangrove, medium and tall | 78.20 |
| Goats | 320 | Mangrove, dwarf | 234.60 |
| Horses | 4,527 | Saline swamp, vegetation with palmetto and mangrove | 344.87 |
| | | Marsh | 419.63 |

iii) Belizean development policy emphasizes broad participation by civil society and creation of an enabling environment for private investment and enterprise. In fact, it is explicit that responsibility for achieving development goals is shared among government, the private sector, and society at large. This ethos favours use of flexible mechanisms, market based approaches, and private sector initiatives in implementing mitigation and adaptation measures.

Notwithstanding the points made above, the vulnerability of the country to the foreseeable adverse physical, environmental, and economic impacts of climate change indicates that priority attention be directed towards adaptation measures. Mitigation options are desirable where they provide the resources to address national development goals, but adaptation is of paramount importance. Lack of specific information on the exact (as against the general) nature of the threats, however, represents an important constraint on the design of appropriate actions at this time.

## References


Belize Climate Change Project, Belize 1994 National Greenhouse Gas Inventory, 1999

Central Bank of Belize, Annual Report 2001.

Central Statistical Office, Major Findings: Population Census 2000, September 2001.

Central Statistical Office, Abstract of Statistics 2001, November 2001.
Central Statistical Office, Abstract of Statistics Belize 1998, August 1998

National Biodiversity Committee, Belize National Biodiversity Strategy, September 1998

National Human Development Advisory Committee, Belize National Human Development Report 1997

Smith, D.T. and Panton, W. F. *On the Climate of Belize and Some Implications for National Economic Development*, Belcast Journal of Belizean Affairs-Vol. 3, Nos. 1&2, June 1986

Walker, S. H., Summary of Climatic Records for Belize, 1973, Foreign and Commonwealth Office, Overseas Development Administration

Programme for Belize in Collaboration with the Inter-American Development Bank, Towards a National Protected Areas Systems Plan for Belize, 1995.

Food and Agriculture Organization of the United Nations, Water Resources Management Policy, Planning and Organization – Belize, Final Report, November 1994

USIJI Uniform Reporting Document: Activities Implemented Jointly Under the Pilot Phase, **Rio Bravo Carbon Sequestration Pilot Project**, 1999

# CHAPTER 2:

# NATIONAL GREENHOUSE GAS INVENTORY

## Background

Certain gases in the atmosphere, called greenhouse gases (GHGs), absorb infrared radiation emitted by the earth. This is a natural process that keeps the surface of the planet and the atmosphere warm and makes life on earth possible. Natural GHGs include carbon dioxide ($CO_2$), methane ($CH_4$), carbon monoxide (CO), nitrous oxide ($N_2O$), other nitrogen oxides ($NO_X$), a range of volatile organic compounds other than methane (NMVOCs), and sulphur dioxide ($SO_2$). It has, however, now been shown beyond reasonable doubt, that human activity is increasing emissions and concentrations of these GHGs in the atmosphere, and introducing powerful new ones such as hydrofluorocarbons (HFCs). More heat is being trapped, and this is producing global warming, precipitating global climate change. Changes of the order predicted over the next 100 years will have major impacts on ecology and every aspect of social and economic life throughout the world.

The preparation of National Greenhouse Gas Inventories is part of the international response to the threat of climate change. The intent is to document, country by country, and hence globally, the net amount of GHGs that is produced or removed (in identified “sources” and “sinks”), the sectoral activity responsible, and the gases involved within each sector. The inventory is limited to emissions and removals through human activity or natural processes modified by human activity. Purely natural processes are therefore excluded. The inventory thus characterises the national pattern of GHG emission and removal attributable to human activity. This, together with the assessment of vulnerability to climate change, facilitates the formulation of national policies on climate change issues and fulfils national obligations under the UNFCCC.

## The Inventory Methodology

Information must be compared globally. Therefore, all countries are required to use a standard methodology, developed by the Intergovernmental Panel on Climate Change (IPCC), and countries must report using a Common Reporting Framework. The inventory is divided into five sectors corresponding to the major GHG emitting and removing processes around the world – energy, industry, agriculture, land use change and forestry, and waste management. A sixth sector, solvent and other industrial processes, is identified, but the methodology has yet to be defined. Non-Annex I Parties may choose 1990 or 1994 as the baseline year for the initial inventory. Belize has chosen 1994, since the information available for that year is superior in content and accuracy. Subsequent inventories will track emission trends and will document the development path of the country.

The methodology has been developed for use throughout the world and therefore shows definite weaknesses when applied to the specific circumstances in any given country. This is particularly true of the assumptions and default values, which may not capture national characteristics effectively. The notes to the inventory provided in the **Belize 1994 National**

**Greenhouse Gas Inventory** describe where conditions may differ in the assumptions, and also indicate where and how local defaults are devised and used. Such information can then be used for further refinement of the general methodology itself. The result is that the GHG inventory gives a first estimate of emissions and removals rather than precise figures. Nevertheless, this estimate is sufficiently revealing to be used with confidence as a basis for policy-making.

**Overview of the GHG Inventory**

Belize is a net remover (sink) of GHGs from the atmosphere. In 1994, tree growth in logged forests, plantations, and on cleared lands absorbed approximately 6 million metric tons of $CO_2$ per year, against a total emission of all GHGs estimated at just less than 3 million metric tons.

Of the five sectors in the inventory, land use change was the greatest single contributor (69%) to total GHG emissions, primarily from release of CO2 by burning during clearance and from the soil during cultivation. The energy sector was the second largest contributor (21%), primarily from fossil fuel use in road transportation and energy production. It should be remembered that the inventory year (1994) predates the introduction of the Mollejon hydro-electric facility. Waste management contributed 9% and agriculture 2%. The contribution from industrial processes was insignificant, at less than 0.1% of total national emissions. This pattern reflects conditions of a country with an extensive logged forest estate and relatively small economy dominated by agricultural production and services rather than heavy industry.

**Total Volumes of Emissions by Sector**

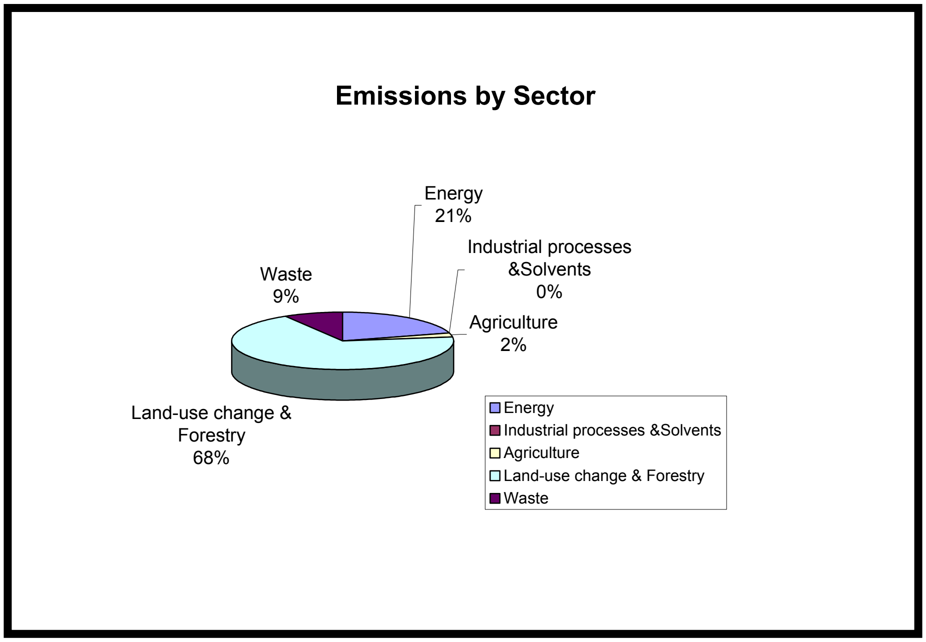
| GREENHOUSE GASES | Gigagrams | Percentage of total |
|---|---|---|
| **Energy** | 617.528 | 21 |
| **Industrial processes & Solvents** | 1.735 | <0.1 |
| **Agriculture** | 58.807 | 2 |
| **Land-use change & Forestry** | 2056.365 | 69 |
| **Waste** | 259.66 | 9 |

## Green House Gas Inventory (1994)

| GHG Source and Sink Category | $CO_2$ Emission | $CO_2$ Removal | $CH_4$ | $N_2O$ | $NO_x$ | CO | NMVOC | $SO_2$ | HGFC | PFC | $SF_6$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total (Net) Emission** | | **-3576.19** | **271.512** | **0.596** | **5.597** | **122.472** | **3.72** | **0.53** | **0** | **0** | **0** |
| **1. Energy (Total-Sectoral Approach)** | **597.773** | **0** | **0.211** | **0.015** | **2.926** | **13.794** | **2.279** | **0.53** | | | |
| *A. Fuel Combustion* | *597.773* | | *0.211* | *0.015* | *2.926* | *13.794* | *2.279* | *0.53* | | | |
| Energy Industry | 136.053 | | 0.085 | 0.012 | 1.104 | 2.485 | 0.143 | | | | |
| Manufacturing/Construction Industry | 39.983 | | 0.001 | 0.001 | 0.126 | 0.006 | 0.003 | | | | |
| Transport | 312.961 | | 0.03 | 0.001 | 1.577 | 11.231 | 2.119 | | | | |
| Other | 108.776 | | 0.095 | 0.001 | 0.119 | 0.072 | 0.014 | | | | |
| *B. Fugitive Emissions from Fuels* | *0* | | *0* | *0* | *0* | *0* | *0* | *0* | | | |
| Solid Fuels | | | | | | | | | | | |
| Oil and Natural Gas | | | | | | | | | | | |
| **2. Indusrial Processes (Total)** | **0.294** | **0** | **0** | **0** | **0** | **0** | **1.441** | **0** | **0** | **0** | **0** |
| *A. Mineral Products* | *0.294* | | | | | | *0.343* | | | | |
| *B. Chemical Industry* | | | | | | | | | | | |
| *C. Metal production* | | | | | | | | | | | |
| *D. Other production* | | | | | | | *1.098* | | | | |
| *E. Halocarbons and Sulphur Hexafluoride (Production)* | | | | | | | | | | | |
| *F. Halocarbons and Sulphur Hexaflouride (Consump.)* | | | | | | | | | | | |
| *G. Other* | | | | | | | | | | | |
| **3. Agriculture (Total)** | **0** | **0** | **5.184** | **0.521** | **1.063** | **52.039** | **0** | | | | |
| *A. Enteric Fermentation* | | | *2.837* | | | | | | | | |
| *B. Manure Management* | | | *0.244* | | | | | | | | |
| *C. Rice Cultivation* | | | *0.032* | | | | | | | | |
| *D. Agricultural Soils* | | | | *0.491* | | | | | | | |
| *E. Savannah Burning* | | | *1.626* | *0.015* | *0.532* | *42.695* | | | | | |
| *F. Agric. Residue Burning* | | | *0.445* | *0.015* | *0.531* | *9.344* | | | | | |
| *G. Other* | | | | | | | | | | | |
| | **1991.601** | **-6165.86** | **6.473** | **0.044** | **1.608** | **56.639** | **0** | | | | |

## Green House Gas Inventory (1994)

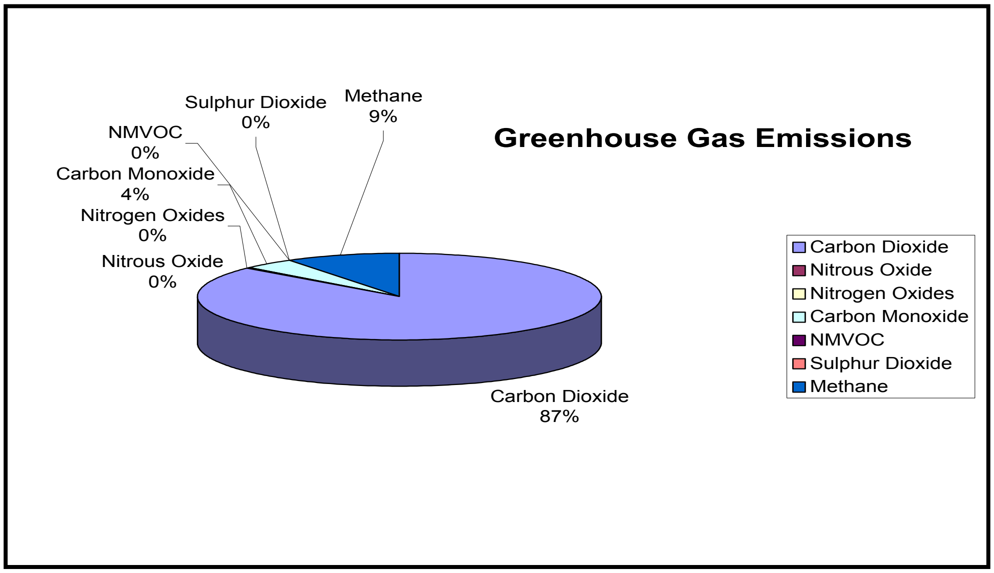
| GHG Source and Sink Category | $CO_2$ Emission | $CO_2$ Removal | $CH_4$ | $N_2O$ | $NO_x$ | CO | NMVOC | $SO_2$ | HGFC | PFC | $SF_6$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **4. Land Use Change and Forestry (Total)** | | | | | | | | | | | |
| *A. Changes in Woody Biomass Stocks* | | *-5750.72* | | | | | | | | | |
| *B. Forest and Grassland Conversion* | *1666.54* | | *6.473* | *0.044* | *1.608* | *56.639* | | | | | |
| *C. Abandonment of Managed Lands* | | *-415.14* | | | | | | | | | |
| *D. $CO_2$ Emissions/Removals from Soils* | *325.061* | | | | | | | | | | |
| *E. Other* | | | | | | | | | | | |
| **5. Waste (Total)** | **0** | **0** | **259.644** | **0.016** | **0** | **0** | **0** | | | | |
| *A. Solid Waste Disposal on Land* | | | *1.107* | | | | | | | | |
| *B. Wastewater Handling* | | | *258.537* | *0.016* | | | | | | | |
| *C. Waste Incineration* | | | | | | | | | | | |
| *D. Other* | | | | | | | | | | | |




Total GHG emissions do not, however, reflect the relative impacts of the different gases on the atmosphere. Methane ($CH_4$) has a greenhouse effect 24.5 times, and nitrous oxide ($N_2O$) 320 times more powerful than $CO_2$. This can be captured by converting the tonnage of each gas to its $CO_2$ equivalent by multiplying by the appropriate global warming potential (GWP) factor. The GWP is based on the relative radiative forcing of each gas and its lifetime within the atmosphere. This emphasises the importance of methane and nitrous oxide sources and changes the picture substantially. The emissions by gas and their $CO_2$ equivalents are given in the following table.

***Greenhouse gas emissions by Gas***

| GREENHOUSE GASES | Gigagrams | Percentage of Total | GWP Factor | $CO_2$ Equivalent |
|---|---|---|---|---|
| Carbon dioxide | 2589.668 | 86.493 | 1.0 | 2589.668 |
| Methane | 271.512 | 9.051 | 24.5 | 6652.044 |
| Carbon monoxide | 122.472 | 4.090 | N/A | N/A |
| Nitrogen oxides | 5.597 | 0.187 | N/A | N/A |
| Non methane volatile organic compounds | 3.720 | 0.124 | N/A | N/A |
| Nitrous oxide | 0.596 | 0.020 | 320.0 | 190.72 |
| Sulphur dioxide | 0.500 | 0.017 | N/A | N/A |




The use of GWP shows that Belize, although a net GHG sink, still contributes to global warming by emitting approximately 9.5 million $CO_2$ equivalent units, but absorbing only 3.5 million. This is almost entirely due to methane emission through waste management, and especially from septic tanks, which outweighs the effect of $CO_2$ uptake through tree growth. The contribution of industrial waste could not be assessed properly and therefore could not be taken into account. However, the indications are that it is an even more important source of methane emission than the domestic waste sector.

Essentially, the key sectors in Belize are Land Use Change/Forestry and Waste Management, followed by Energy.

**Sectoral Assessments**

**Energy**

Energy sector emissions are all due to fossil fuel use. The inventory uses two methods – reference (based on imports, exports, and changes in stocks of petroleum products) and source category (breaking down sales of petroleum products by sector). There are a limited number of fuel importers and both methods depended upon sales data. The results differed significantly, primarily because changes in stocks held across the country could not be assessed. The source category information is considered more reliable, is more useful for analysis, and is therefore used here.

Energy sector information falls into three categories:

- national fossil fuel use, where all emissions count against the national inventory;

- international bunker fuels, where the fuel is used outside Belize. These are counted for global statistics but not attributed to the country;
- biomass fuels, where $CO_2$ is ignored (assumed to be reabsorbed by regeneration of the vegetation) but other GHGs are counted.

Practically all emissions (97%) are of $CO_2$. Road transport was the most important single emitting activity (328 Gigagrams, representing 53% of sectoral emissions and 11% of total national emissions), followed by energy production (136 Gigagrams, 22% of sectoral emissions and 5% of total national emissions). The international bunker fuel emissions are modest and primarily attributed to aviation fuel. Biomass proved to be an important energy source in Belize, in the form of fuel wood primarily for residential use, and bagasse (cane waste) for energy production in the sugar industry. This demonstrates that two important energy production activities in Belize are already conducted by techniques that do not contribute to major greenhouse gas emissions. Since 1994, the Mollejon hydro-electric facility has added a third important non-contributing element.

**Industry**

Industrial emissions are produced by a range of processes and are similarly varied in type. In Belize they consist of $CO_2$ from heating limestone for lime production, and Non-Methane Volatile Organic Compounds (NMVOCs). NMVOCs are given off in food production, especially in the cooking of sugar in rum distilling, brewing, and baking. They are also emitted (as the pungent smell) during road asphalting.

The NMVOCs were the primary form of emission (83%) but the entire sector is a minute source. The most powerful industrial sector greenhouse gases are the HFCs which are used in air-conditioning, refrigerators, fire extinguishers, etc. In 1994, these functions were filled by CFCs which, although not GHGs, do contribute to ozone depletion and have since begun to be phased out. Subsequent inventories may therefore show an increase in the use of HFCs.

**Agriculture**

Agricultural GHG emissions include methane ($CH_4$), nitrous oxide ($N_2O$), other nitrogen oxides ($NO_X$), and carbon monoxide (CO).

The most important emitting activity is savannah burning which, although illegal in Belize, is often a standard form of land management for grazing in other countries and is therefore included in this sector. The $CO_2$ from the burning is assumed to be reabsorbed by regeneration or, if it results in total land degradation, is captured in the Land Use Change sector. The other gases are counted and represent 76% of sectoral emissions (approximately 44,500 tons), primarily as CO. Other emitting activities include domestic livestock production ($CH_4$ emitted as flatulence or from manure), rice production in flooded fields ($CH_4$ from decomposition under the water), fertilising of soil ($N_2O$ from fertiliser breakdown) and cane burning (a range of GHGs but primarily CO).

$CH_4$ and $N_2O$ have a relatively high global warming potential but the entire sector makes a small contribution (2%) to total emissions and remains of minor importance even when GWP is taken into account. This may change to some degree in future inventories. The global warming potential of CO cannot yet be assessed but is believed to be high. Rice production has expanded since 1994 and will increase $CH_4$ emission. Furthermore, the basic agricultural statistics (crop production, areas under cultivation) used for the inventory, although official, are viewed with some caution and may be under-estimates.

**Land-Use Change/Forestry**

This is the most important sector in terms of total emissions, which are predominantly of $CO_2$, but also include $CH_4$, $N_2O$, $NO_X$, and CO. It is also the sector that accounts for removal of $CO_2$ from the atmosphere, more than offsetting all other emissions and making Belize a net GHG sink.

Various activities stimulate tree growth, which removes $CO_2$ from the atmosphere. Logging and fuel wood collection remove timber from the forest, releasing its carbon as $CO_2$, but keeping the forest in a dynamic state of regeneration as it recovers. Plantations and silvicultural practices (e.g. fire control) also result in tree growth, as does tree-planting in gardens. Woody vegetation re-establishes itself on land that has been cleared and then left untouched. After accounting for timber removal and timber growth, the net result indicates that the national biomass stock (literally the mass of wood in its trees) is increasing at approximately 6 million tons per year. This is a rough estimate, and more local information is required to refine it. However, it is probably conservative. The establishment of citrus orchards, for example, has not been taken into account.

Emissions are dominated by the effects of forest clearance for agriculture. Some 1,700,000 tons of GHGs (58% of the national total, primarily of $CO_2$) are emitted from burning and decay of the fallen timber. The other important emission is of $CO_2$ from the forest soil as it comes under cultivation, both from liming and reduction in organic carbon content. A further 325,000 tons of GHG per year is emitted from this source, which contributes 11% of the national total.

**Waste**

The main emission from the waste sector is $CH_4$, from decomposition of waste and sewage under conditions with limited oxygen. Paradoxically, the most unsightly and polluting forms of waste disposal contribute least to GHG emissions. Dumping in the open or releasing raw sewage result in decomposition in the presence of air.

The main emission in the sector is $CH_4$ from septic tanks. These are used throughout the rural areas and also to a considerable degree by urban households, given that the sewage systems are either non-functional (Belmopan), connected to a relatively low proportion of households (Belize City and San Pedro), or absent (most other population centres). Emissions are calculated at approximately 258,000 tons per year, or 9% of the national total. In terms of global warming potential, the sector becomes much more important, contributing

67% of total emissions converted into $CO_2$ equivalent units and outweighing the removal effect of tree growth.

Obtaining reliable information on industrial waste was impossible. There is, however, every indication that it is very high. Industrial waste includes sludge and wastewater, but also accumulations of waste agricultural products during processing that is either left to decay or periodically burnt. This includes bagasse not used for energy production and citrus waste after juice extraction.

**Conclusions**

The inventory results confirm that the extensive forest estate renders Belize a net "sink" or absorber of atmospheric greenhouse gases. The UNFCCC already makes a clear distinction between industrialized countries and the "Non-Annex I Parties" such as Belize, recognizing that the latter have a priority commitment to poverty alleviation and sustainable development rather than mitigation of greenhouse gas emissions on their soils. This position is reinforced, in the case of Belize, by the fact that it already absorbs more GHG than it emits by a considerable margin. However, although the country may not have an obligation in this regard, it certainly has a strong interest in the process of GHG emission mitigation due to its vulnerability to the adverse effects of climate change. It also has a strong interest in pursuing additional means of achieving its development goals.

***Principal Greenhouse Gases by Sector***

| ACTIVITY | Total GHG (Gg) | Principal Gas (%) | % of total GHG emission | % of total emissions converted to GWP |
|---|---|---|---|---|
| Biomass stock change (vegetation growth in forest) | 5750.721 | $CO_2$ (100) | -192 | -61 |
| Abandoned land (vegetation growth after clearance) | 415.14 | $CO_2$ (100) | -14 | -4 |
| Forest conversion to agriculture | 1731.304 | $CO_2$ (96) | 58 | 18 |
| Fossil fuel use- Transport | 327.919 | $CO_2$ (95) | 11 | 3 |
| Emissions from soils after forest clearance | 325.061 | $CO_2$ (100) | 11 | 3 |
| Domestic wastewater (septic tanks) | 258.537 | $CH_4$ (100) | 9 | 67 |
| Fossil fuel use – Energy production | 139.892 | $CO_2$ (98) | 5 | 1 |
| Burning savannahs | 44.868 | $CO_2$ (95) | 1 | <1 |
| Fossil fuel use- manufacturing & construction | 40.11 | $CO_2$ (99) | 1 | <1 |
| Field burning of agricultural residue | 10.335 | CO (90) | <1 | N/A |
| Livestock-enteric fermentation | 2.837 | $CH_4$ (100) | <1 | 1 |
| Solid waste disposal on land | 1.107 | $CH_4$ (100) | <1 | 1 |

Emission mitigation projects could present useful vehicles for achieving these goals, as part of the overall package designed to fulfil national obligations under the UNFCCC as well as adapting to a new climatic regime. This is particularly the case where the mitigation actions, which may be developed under the emerging Clean Development Mechanism, are also structured to deliver high climate change adaptation benefits. In the event, ninety percent of emissions measured in GWP units come from only six activities – deforestation, the use of septic tanks, transportation, energy production, agricultural soils, and savannah burning. Industrial waste is also almost certainly another major source of emissions. Forestry and tree-growth are major removers of GHGs and offset emissions. These stand out as priority areas for analysis, but not to the exclusion of other options that might deliver more modest GHG emission reductions but offer high social, economic or other environmental benefits.

**References**

Belize Climate Change Project, Belize 1994 National Greenhouse Gas Inventory, 1999

Intergovernmental Panel on Climate Change, Climate Change 1995, The Science of Climate Change, 1995

Intergovernmental Panel on Climate Change, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Volumes I, II and III, 1996

United Nations Framework Convention on Climate Change, 1992

# CHAPTER 3:

# VULNERABILITY AND ADAPTATION

The United Nations Framework Convention on Climate Change (UNFCCC) recognizes that Belize is one of those countries most vulnerable to the adverse impacts of climate change.

- It has a long, low-lying coastline (Art. 4.8 (b))
- It has over 1,060 small islands (Art. 4.8 (a))
- It has the second longest barrier reef in the world and 17,276 sq. km. of forest cover, each of which support fragile ecosystems (Art. 4.8 (c and g))
  - It is very prone to natural disasters, especially hurricanes (Art. 4.8d)).

Therefore, in addressing climate change, Belize has identified the assessment of the country's vulnerability to climate change and the formulation of adaptation measures as its highest priorities.

Climate change scenarios project an increase in the global mean surface temperature of 1° to 3.5 °C by 2100. This will cause the waters in the oceans to expand and some of the water stored permanently in the polar ice caps and glaciers to melt. These will all contribute to a rise in sea level. Globally, sea levels are expected to rise by 20 to 100 cm by 2100.

The projected increase in the surface temperature is expected to produce a more vigorous hydrological cycle. Both the rainy and dry seasons could be affected. One could be longer and the other shorter. Rain events could become more intense. The dry season could become drier resulting in droughts.

The global changes in climate will not be uniform. Global circulation models (GCMs) suggest that the changes will vary by latitude, longitude and region. The changes are also dependent on the amount of greenhouse gases being injected into the atmosphere.

The computer models used to create the future climate scenarios are also very crude. Belize is usually less than the size of one grid. Thus, one value is assigned to the entire country, which is totally unrealistic. The results of the models also differ among themselves.

Therefore, it is impossible to predict what changes in climate or sea level are likely to occur in Belize during the next century.

## Coastal Zone

Change in relative sea level is not a new phenomenon to the coastal zone of Belize. Evidence of paleo-sea level rise, repeated transgressions and regressions can be observed as relict shorelines within the geomorphology of the coastal plains, and as remnants of coral islands (banks) on the continental shelf. Although the effect of sea level rise might have been exacerbated in some areas by subsidence or ameliorated by uplift and isostatic rebut, the changes were gradual. Thus, the coastal areas adapted spontaneously to those changes. The projected sea level rise of 20 to 100 cm during the new century is alarming and will undoubtedly impact on both developed and undeveloped coastal areas if appropriate adaptation measures are not implemented.

A sea level rise of this magnitude is expected to inundate wetlands and low lands, accelerate coastal erosion, exacerbate coastal flooding, threaten coastal structures, raise water tables and increase the salinity of rivers and aquifers.

Within the past two decades, the rate of development in coastal areas has increased almost exponentially to accommodate the growing tourism industry and the expansion of coastal communities. This development has placed significant stress on coastal physical resources. This is evident in the increasing instances of deteriorating water quality, inadequate waste disposal, coastal erosion consequent to sand mining from beaches and rivers, and inappropriate siting of coastal structures. Today, 45% of the population resides in the coastal zone. The annual rate of population growth is projected at 6.9%. This indicates that there is a considerable demand for suitable land for housing construction and to meet the communities' expansion requirements.

Shoreline erosion is identified as a critical issue in the four coastal districts, (Corozal, Belize, Stann Creek and Toledo), and on the more developed offshore islands such as Ambergris Caye and Caye Caulker. The traditional sources of sand for land reclamation and construction have been from rivers and beaches. Unfortunately, the present demand for sand and gravel far exceeds the capacities of these sources.

**Coastal Erosion**

Acknowledging that coastline erosion is already considered a major concern, it is inevitable that accelerated sea level rise would exacerbate the rate of erosion and possibly destroy all our existing beaches within this new century. Research undertaken under a US Country Studies Program vulnerability assessment reveals that a 4 cm rise in sea level over the next 25 years would have a low impact. A 50 cm rise would claim over half the existing beaches, while a 100 cm rise in 100 years would destroy over 90% of these beaches.

**<u>Inundation</u>**

Approximately 60% of coastal areas are already inundated. Considering that most of the mainland coastline between the existing communities is wetland dominated, a one-meter rise in sea level would transform the wetlands to lakes. Dry land within a few meters of high tide levels would provide potential areas for new wetland formation.

In Belize City, residential areas such as Vista del Mar, Bella Vista, Belama and Fort George that are constructed on drained and reclaimed wetlands are extremely vulnerable to the projected sea level rise. Similarly, the infrastructure developments in most of the other coastal communities like Dangriga, Corozal Town, the Placentia

Peninsula, Ambergris Caye and the other offshore islands are currently threatened by even a 20 cm rise in sea level. If these communities are to cope with rising sea level, a constant supply of large volumes of sediment would be required. The sources of supply of natural and alternative sediment to these areas have been significantly reduced. Protecting these urban areas might require the construction of sea walls and dikes that could withstand the impacts of the projected sea level rise through the new century.

Coastal Flooding

Coastal areas would become more vulnerable to flooding. A meter rise in sea level would provide a higher base for storm surges to propagate further inland. This would also enable weaker storms to have an effect on areas that would otherwise be affected only by stronger storms. Accelerated erosion along the central coastline would leave some properties more vulnerable to the local wave climate during high tides.

If sea level rise were accompanied by an increase in precipitation, the flood plains of the Rio Hondo, New River and Belize River would remain flooded most of the year because the higher sea level would reduce the drainage efficiency of the coastal plains. Similarly the flood plains of central and southern Belize that are in closer proximity to the inundated coastline would also experience more frequent and intense flood events.

Flooding in northern Belize affected the quality of sugar cane and the net production of sugar in 1998. The temporary displacement of a few families from several villages in the northern districts as a result of floods caused by hurricane Mitch and floods in June 1999 is a clear indication of what would happen given the projected climate change scenario.

Saltwater Intrusion

Saltwater intrusion is a major concern on most of the offshore islands and in several communities on the coastal plains. The problem at this time is not a direct effect of sea level rise, but rather the growing demand for potable water in coastal areas. The tertiary, sedimentary and quaternary alluvial aquifers of the coastal plains yield large quantities of brackish to saline water. In many instances the freshwater aquifers are perched above the saline water, and this is the water source on which some coastal communities rely. The projected sea level rise through the next century together with increased abstraction rates will lead to higher incidences of seawater intrusion in the aquifers. Agricultural lands on the coastal plains could experience a salinity problem as the sea level rises.

The possible over-abstraction of water on Caye Caulker, Ambergris Caye, Tobacco Caye, Seine Bight and Placentia might have led to the salinization of their water tables. Some of the islands were equipped with desalination plants to avoid the problem. Villages like Seine Bight and Placentia are dependent on water piped from Independence Village. This water supply is also vulnerable to over-abstraction and salt-water intrusion.

Belize City gets its water from an area just upstream from where the water is salty during the dry season. A rise in sea level would enable saltwater to penetrate further upstream and would threaten the city's water supply. Other rivers, bays, wetlands and aquifers could also be impacted and would threaten human uses of water and be harmful to some aquatic plants and animals.

**Human Settlements**

Belize has a population estimated at 250,000. Approximately 45% reside in the coastal zone. The four coastal districts of Corozal, Belize, Stann Creek and Toledo have large urban and rural development zones that are prone to seasonal flooding and inundation. All these districts have human settlements concentrated in areas that range from 0 to 5 meters above sea level. The projected sea level rise during the new century will permanently inundate most cayes, including the heavily populated Ambergris Caye (average elevation of 2 feet). The mainland several kilometers inland of the coastline will also be inundated. Flooding would seriously affect communications, infrastructure and housing. For settlements like Belize City, that are dependent on surface and ground water, seawater intrusion will have a significant impact.

**Agriculture**

Inundation and salinization of agricultural lands through salt water intrusion or tidal influences in rivers from which water is abstracted for irrigation is a major potential threat consequent to sea level rise.

**Aquaculture**

Currently most of the aquaculture operations are situated along the coastline in areas that are prone to seasonal inundation. Such areas are suitable because of the favourable sediment composition and ease of water abstraction. The impact of the projected sea level rise on aquaculture development is twofold. Firstly, sea level rise will increase coastal erosion and the erosion of dikes of some aquaculture ponds. This could in turn lead to increased turbidity and decline in water quality in the immediate area. Secondly, a higher mean sea level could result in the relocation of aquaculture farms to higher and more suitable areas. Even though a higher mean sea level does not imply higher tidal fluxes, it could increase the potential for cage aquaculture along certain segments of the coastline.

The impact of more intense and more frequent storms and increased precipitation pose a greater threat to aquaculture than sea level rise. Storms are the leading cause of pond destruction, while excessive rain could readily alter the salinity of ponds and affect the net production of the farms.

**Water Resources**

With a meter rise in sea level, none of the remnant cayes in Belize will have a source of potable ground water. Some of the coastal plains will experience high levels of seawater intrusion and rising water tables. This will lead to a drastic decrease in the volume of the fresh water lens and intensify the potential for contamination of the lens from domestic and industrial waste. Surface water sources could be enhanced only if the climatic variation favours an increase in rainfall in the country.

Coastal habitats, including coral reefs, sea grass beds, mangroves and littoral forests are all vulnerable to the adverse impacts of climate change. These in turn will have impacts on fisheries, tourism and biodiversity.

**Corals Reefs**

Healthy corals are expected to keep up with projected sea level rise. However, they are susceptible to both high sea temperature and wave action from storms. Corals presently live at or near their upper temperature tolerance level. Thus, with just a small rise in temperature, many species of coral will respond by expelling their zooxanthellae or symbiotic algae, in a process known as “bleaching”. Two mass bleaching events occurred in Belize in recent memory, in 1995 and 1998. These events coincided with elevated sea temperature, light wind and increased solar radiation. Fifty two percent of corals were affected. Many corals suffered full or partial mortality. Bleaching weakens the coral’s ability to resist pathogens and competitors. Black band and coral plague diseases in corals are correlated to warmer water temperatures. Coral disease is prevalent in many sections of Belize’s reefs. Future global warming could cause an increase in the frequency and severity of coral bleaching.

The concentration of carbon dioxide is expected to double or triple by 2100. Much of the additional carbon dioxide will be dissolved in the oceans. The additional carbon dioxide could reduce the ability of the corals to deposit their limestone skeletons. This will affect the structure of the reef, which would obviously hinder their ability to “keep up” with sea level rise and remain in the photic zone.

Coral reefs, particularly branching corals, are very susceptible to storm damage. The Belize reefs suffered extensive damage in 1998 as a result of hurricane Mitch. Coupled with the bleaching episode, the reefs experienced “catastrophic losses”. Global climate change may produce an increase in the strength, size and frequency of hurricanes.

Loss of coral reefs will have a severe negative effect on its role as a habitat. This will result in a related loss in fisheries production. The fishing industry in Belize was worth over BZ$39.4 million in export earnings in 1998. The industry provides substantial employment, currently involving a fleet of 354 licensed fishing boats, and 1,910 licensed fishers. Fish is also a critical source of protein for many coastal communities. It is based primarily on reef species such as spiny lobster, conch, snapper and grouper.

Similarly, loss in the percentage of coral cover with a concomitant loss in reef-related species of invertebrates and fishes will lead to a general decline in the attractiveness of reef sites used for snorkelling and SCUBA diving. Presently, the majority of tourism in Belize is marine based, with approximately 70% of hotels located in the coastal zone. Over 60% of visitors are interested in visiting the cayes. Tourism accounts for over 15% of GDP, is the largest source of foreign exchange earnings, and generates significant employment. Thus, any decline in marine tourism will have a direct effect on the economy of the country.

With a loss in coral cover there will also be a related loss in biodiversity. Coral reefs are one of the most diverse systems on earth, and the reefs of Belize comprise some of the best in terms of general reef health and diversity in the Caribbean region.

The barrier reef provides an important natural "breakwater", protecting the low-lying coastline from wave energy. Any structural loss to the reef could reduce this protective effect, leading to an increase in coastal erosion. Reduced coral growth will also lead to decreased amounts of carbonate sand available to replenish beaches, exacerbating the higher rate of erosion expected due to sea level rise.

**Sea Grass Beds**

Elevated sea surface temperatures may affect sea grass beds. In addition, any increase in rainfall will result in increases of freshwater runoff, which could negatively impact sea grass beds. In reality, however, the most important threats to this habitat are from human activities such as dredging, land reclamation and pollution.

Sea grass beds provide important nursery areas for many fish species, including many commercially important species such as lobster and conch. The juveniles of many species are sensitive to changes in salinity and temperature. Thus, fish production could suffer if this habitat were significantly affected.

Sea grass beds are also important feeding grounds for manatees and marine turtles. Thus, any loss in their productivity could affect these species and lead to a loss in biodiversity in general.

**Mangroves**

Since mangrove ecosystems are inter-tidal, changes in sea level will affect these communities. The most vulnerable in Belize are those mangroves that occur on the cayes, and the fringing mangroves along the coast. Generally, mangroves can cope with sea level rise where the rate of sedimentation exceeds the rate of sea level rise. Therefore, the impacts will depend on the sediment flux in the particular area. Many mangrove forests will adapt by landward migration or compression of their zonation. However, this adaptive capacity may be limited in some areas by increasing levels of human activity such as aquaculture farms, roads and other infrastructure, which could block the landward migration.

Changes in precipitation and seasonality could alter the productivity and zonation of mangroves. Studies at Twin Cayes have shown that by the accumulation of leaf litter alone, these islands have managed to keep pace with normal sea level rise. With accelerated sea level rise however, low mangrove islands such as Drowned Cayes will be eroded, leading to weakening of trees, die-back and wind throws.

In contrast, mangroves along rivers with large watersheds and thus larger amounts of sediment input will be less vulnerable to the impact of sea level rise. Examples of these are the Rio Hondo, New River, Sibun and Belize Rivers. On the other hand, mangroves associated with rivers with smaller catchments may be more at risk. These include the Sittee, Deep, and Moho Rivers and Golden Stream. Mangroves along lagoons, which receive sediment primarily from incoming tides, will be at moderate risk.

Mangroves are being lost to urban expansion for residential development, coastal tourism development and coastal subdivisions. In former mangrove areas that have been filled, oxidation of peat can lead to a decline in the land level, making such areas even more susceptible to flooding.

Any loss of mangrove would affect fisheries production as they provide important nurseries for many commercially important species. Furthermore, many near-shore species of finfish that are dependent on mangroves are important for recreation and sport fishing. These include tarpon and snook.

Mangroves also provide habitat for a variety of species. Therefore, a loss in mangrove cover would represent a loss in biodiversity.

Perhaps the major loss would be in terms of the service mangroves provide in coastal protection from storm surges and in flood control.

**Land Use Change and Forestry**

Seventy percent of Belize remains under natural vegetation cover. In 1994 767,000 ha or 33.4% of the country were in protected areas. Clearance occurs at approximately 1% per annum. About 9% of this occurs in the protected areas, revealing the inadequacy of monitoring and enforcement measures.

Approximately twelve forest fires are reported annually. However, control measures in place restrict the area lost to forest fires.

The IPCC Second Assessment Report projects that globally one third of the existing forest area will undergo major changes. Fortunately, the tropics will experience this least. Climate change is expected to occur at a rapid rate relative to the rate at which forests grow, reproduce and re-establish themselves. Most forests, as ecosystems are less vulnerable to climate change than the more mobile members/inhabitants of the same system.

Temperatures are expected to rise, and could lead to the migration of some species. Past migrations have been in the order of 4 to 200 km per century. Therefore, the species composition of the forest is likely to change. Entire forests may disappear, while new ecosystems may become established as a result of new species composition. The standing biomass of forests may be affected because of frequent outbreaks of pests and pathogens whose ranges may increase. The frequency and intensity of wildfires may also increase.

There is presently no comprehensive land use plan or policy in place. As a result, there are cases where agricultural crops are cultivated on lands, which will not be sustainably productive. Housing developments are created on unsuitable coastal sites. Forests are sacrificed for infrastructural projects whose social, economic and environmental benefits are short lived and not cost effective. A Comprehensive Land-Use Management Plan must be developed and adopted using the assessments, studies and draft plans such as Wright and King's Land Use Surveys, the Land and Survey Department's Special Development Areas and the work done by the Environmental and Social Technical Assistance Project (ESTAP). The plan should also provide for the management, protection and sustainable development of privately owned forested areas and provide for agricultural, industrial and residential developments.

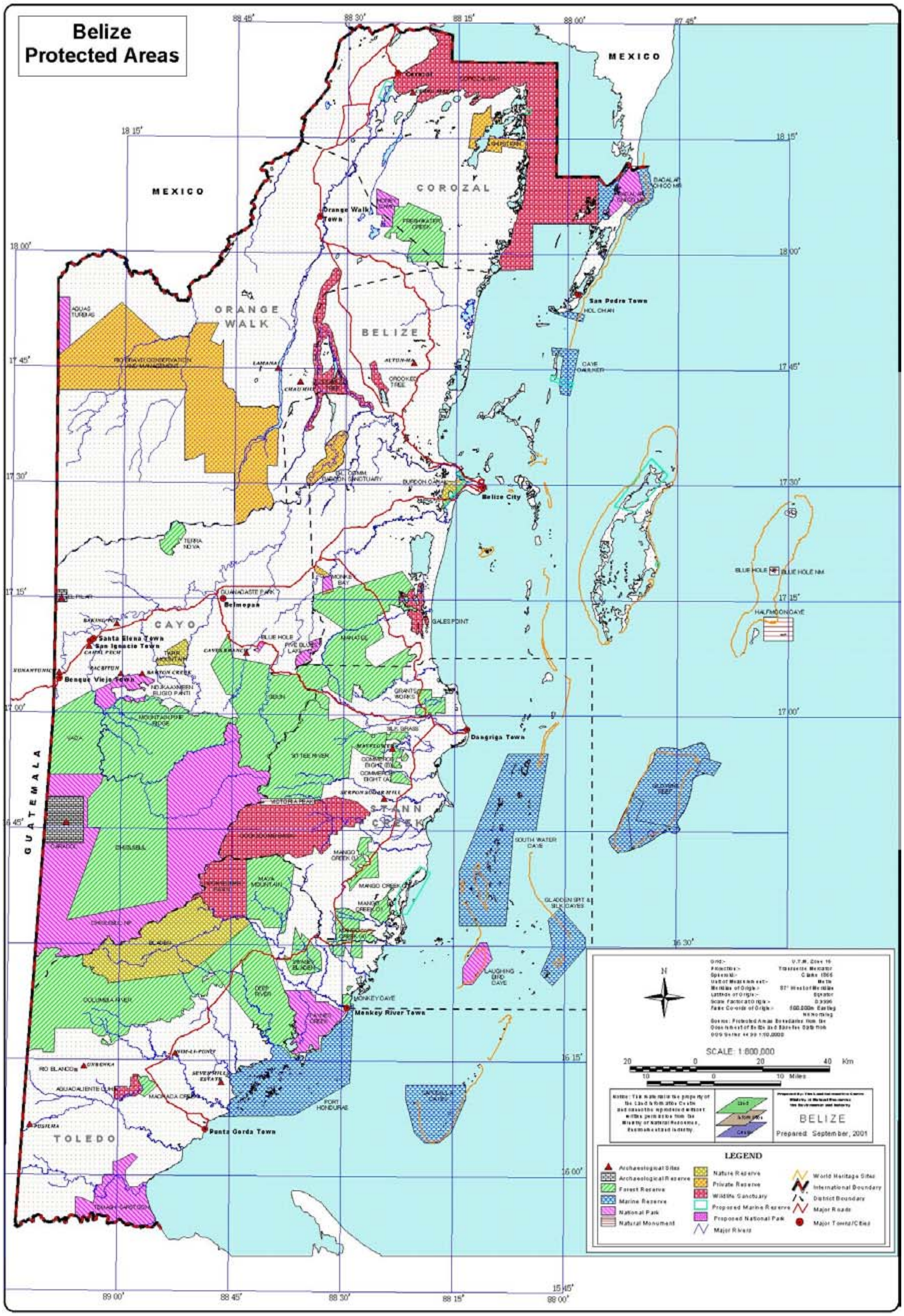
The Land Use Management Plan should be supplemented by a Forest Management Plan. Proper forest management practices reduce the negative impacts of ordinary timber exploitation, reduce the risk and/or rate of deforestation, help to regenerate natural forests, and enhance the ability of the forest to sequester carbon. A large portion of the forest assets of the country is privately owned. Therefore, the Plan should encompass both public and private forest resources.

The Forest Laws of Belize make provision for the declaration of Fire Management/Control areas. Adequate resources must be allocated to implement the controls already in place and to implement mitigation measures to reduce the intensity and extent of wildfires. A National Fire Management Plan should be developed and implemented to strengthen the mitigation and response systems and incorporate community monitoring and participation in vulnerable areas near towns and villages.

**Biodiversity**

Belize recently completed its First National Report to the Convention on Biological Diversity (CBD) and National Biodiversity Strategy and Action Plan. Belize's documented biological resources on the mainland as of September 1998 include 576 bird species, 163 species of mammals, 122 species of reptiles, 116 species of total inland fish, 43 species of freshwater fish, 158 species of molluscs, 42 species of amphibians, 288 species of butterflies, 176 species of odonata, and 10 species of other insects. Two amphibians and one reptile are documented as endemic. There are an estimated 4,000 species of native flowering plants of which 2,500 are dicotyledons and 1,500 are monocotylendons. To date 615 species of these plants have been found to have medicinal value.

The coastal zone of Belize contains 75% of the Mesoamerican Barrier Reef System. Coastal Belize is host to 594 genera and 1,040 species of organisms; while in marine areas, there are 634 genera and 1,302 species.


Belize
Protected Areas
MEXICO
COROZAL
ORANGE WALK
BELIZE
CAYO
STANN CREEK
TOLEDO
GUATEMALA
Orange Walk Town
San Pedro Town
Belize City
Belmopan
Santa Elena Town
San Ignacio Town
Benque Viejo Town
Dangriga Town
Monkey River Town
Punta Gorda Town
BLUE HOLE NM
HALF MOON CAYE
SOUTH WATER CAYE
GLADDEN SPIT & SILK CAYES
LAUGHING BIRD CAYE
PORT HONDURAS
SCALE: 1:800,000
BELIZE
Prepared: September, 2001
LEGEND
Archaeological Sites
Archaeological Reserve
Forest Reserve
Marine Reserve
National Park
Natural Monument
Nature Reserve
Private Reserve
Wildlife Sanctuary
Proposed Marine Reserve
Proposed National Park
Major Rivers
World Heritage Sites
International Boundary
District Boundary
Major Roads
Major Towns/Cities

The threats to biodiversity and habitat identified by The Belize National Biodiversity Strategy and Action Plan include:

- industrial and infrastructure development
- unsustainable exploitation practices
- introduction of exotic species, and
- natural disasters.

The root causes of the first three of these threats include human population growth and migration, lack of appreciation of the importance of biological resources by the public, the lack of adequate policies, weak enforcement of existing legislation and a culture of consumerism.

**Biodiversity**

Belize's biodiversity is highly vulnerable to climate change. New combinations of species will arise since species have different competing abilities, migration rates and response capacities to disturbances. This "reorganization" in species composition will affect the functioning of these ecosystems.

Many species may be able to disperse fast enough to keep up with projected climate change provided they can disperse through continuous, relatively undisturbed, natural ecosystems. This demonstrates one of the important consequences of the fragmentation of natural ecosystems.

Depending on the rate of climate change, other niche parameters may not change at the same rate as climate, resulting in novel habitat combinations.

Changes in relative timing of seasonal events during the yearly cycle may have strong negative impacts on many species, especially migratory ones.

Invasion of alien species into natural ecosystems is an increasing problem worldwide which is likely to be exacerbated by climate change. Disturbance and dieback will probably increase as more long-lived organisms such as trees are displaced from their optimal environmental envelopes and are subjected to increasing pressure from land use change. An increase in disturbance will lead to more ecosystems in early successional states, resulting in a generally "weedier", structurally simpler biosphere with fewer systems in more ecologically complex, old growth.

Markedly different effects of climate change on species composition will occur within individual landscapes because of local effects on soil, land use and topographical variation.

**Ecosystems**

Belize's ecosystems are also vulnerable to climate change. The coastal wetlands and mangrove forests are sensitive to sea level rise and storms. Island ecosystems are not only sensitive to sea level rise and storms, but also to temperature changes. Coral reefs are sensitive to sea surface temperature and storms. Tropical forests are sensitive to drought, seasonality, fire regimes and hurricanes.

There are no coastal or inland beaches in Belize with an elevation above one meter. If sea level rise were to occur at a rate of 2 cm per annum, the following impacts can be anticipated:

the disappearance of sandy beaches as habitat for benthic organisms which would be displaced,
the displacement of biodiversity (flora and fauna)
those strictly marine
those strictly of the inter-tidal zone (black and white mangrove)
those strictly of freshwater,
the displacement of associated fauna of the mangrove ecosystem which is the basis of the food-chain of coastal and marine ecosystems,
the displacement of the aquaculture industry with an estimated capital investment of approximately BZ$32.4 million and annual estimated production of BZ$13 million,
protected areas, which are strictly marine, will be less impacted by climate change than those with mangrove components,
35 species of documented Ascidians (of high bio-prospecting value in cancer research) in Belizean waters will be impacted by temperature rise unless these organisms evolve and are able to adapt during the next 50 years,
the reef ecosystem will be impacted. Surveys after hurricane Mitch revealed that the reef was heavily impacted. It was very difficult to distinguish between the physical damage produced by Mitch, coral bleaching and disease,
higher sea surface temperatures will increase the incidences and extent of coral bleaching episodes. Bleaching induces partial tissue mortality, which may decrease the structural integrity of the reef framework, and decreases the ecological competitiveness of corals and other symbiotic organisms, and
commercial fishing presently valued at BZ$39.4 million per year will be impacted.

Sea level rise will force the population (45% of Belize’s population) within the coastal zone to move inland. This inland mobility will further increase the existing pressure on Belize’s biological resources in the hinterland, especially by infrastructure development, advancement of the agriculture frontiers, and the increased use of forest sector products.

The livelihood of the rural inhabitants, estimated at 50% of the national population, is supplemented by hunting, ornamental plant and orchid collection, medicinal plant collection and commercialisation/low level industrialization. The value of these biological resources has not been quantified. This lack of quantitative and economic data is in itself a threat to the sustainable use of these biological resources. This increases their vulnerability since that data is essential if adaptation measures are to be applied.

Forest resources face the same threat. Timber harvests are based on logical estimates. There is presently no inventory of the timber resources of Belize.

**Water Resources**

Climate change is expected to intensify the hydrological cycle in Belize. Precipitation, evaporation and transpiration are likely to be affected. However, there is great uncertainty about the extent and magnitude of the changes. The variation in these components will impact on the availability and quality of water throughout the country.

Although there is a water assessment programme in place, the monitoring programme is not comprehensive. It focuses primarily on surface water above the coastal zone. It is therefore impossible to analyse the behaviour of the hydrological cycle adequately.

It is believed that the aquifers hold an extensive and excellent supply of groundwater. The exploration of the phreatic aquifers has proven that there are abundant water supplies stored in this underground zone. Attempts to exploit the deeper aquifers have been relatively unsuccessful since there is no data on their depths and capacity, the scarcity of drilling equipment and high drilling costs. There is no network of observation wells. Exploration and abstraction are generally unmonitored and unregulated.

There is no comprehensive water-quality monitoring programme in the country. Several agencies monitor water quality for their own purposes. These include the Department of the Environment, Public Health Bureau, Fisheries Department, Coastal Zone Management Institute, the Water and Sewage Authority, and environmental NGOs.

Water is considered a free resource and available for the general benefit of all. Its use is varied and does not consider the concerns and needs of others or of its sustainability. The water resources resulting from internationally shared watersheds are deemed to belong to the countries involved. The proportional ownership and level of responsibility for its protection have not been addressed.

Belize has the highest available water per capita in Latin America at 80.8 thousand cubic meters per second. As a result, little economic value has been placed on this natural resource. Its utilization is generally unregulated and not monitored. The conservation of water is not a priority in Belize as can be seen in the domestic and industrial water use practices.

**Potable Water Supply**

The majority of potable water for urban centres is taken from surface water and subsequently treated. For offshore communities, the supply is from the freshwater lens and desalination plants. In rural communities, without access to streams, potable water is provided by wells drilled in phreatic aquifers. Water supply is supplemented by rainwater stored in cisterns.

A project has just begun which will double and later quadruple the water supply for Belize City. Other communities are also experiencing shortages of potable water and there are proposals to increase their capacities. The supply in the Independence/Mango Creek area is expected to be quadrupled to meet the expected demand created by tourism and development on the Placencia Peninsula and surrounding communities.

The projected sea level rise will cause an encroachment of the saline-freshwater interface upstream and narrow the freshwater lens, threatening the water supply for urban and rural communities in the coastal zone. Coastal communities in the north and in the Independence/Mango Creek area will be especially affected. Rivers like the New River and the Rio Hondo with low gradients and straight courses will be especially affected by the encroachment of the saline-freshwater interface.

Sea level rise will also threaten the berms for the sewage lagoons in Belize City and San Pedro. Other coastal communities use septic tanks and pit latrines. Rising sea levels will drown these systems, as well as the pumping stations and sewage lines resulting in the pollution of coastal and river waters and threatening the underground supplies.

If there is an increase in rainfall and consequent streamflow, the sediment load on the waterways will reduce the quality of the water.

Agriculture

The agriculture sector uses a significant quantity of water for irrigation of bananas, citrus and rice. Irrigation activities are unregulated and do not require permits. There are no restrictions on the volume of water abstracted. No consideration is given for the equitable distribution of the available water resources for irrigation purposes.

Greater rainfall will result in increased soil erosion, reducing the availability of topsoil for agriculture. It will also increase the sediment load, reducing the quality of water for livestock and irrigation. On the other hand, reduced rainfall will increase the demand on water for both rain-fed and irrigated agriculture.

There is complete dependence on rainfall by small farmers and very limited use of irrigation by even large farmers. Farmers, now, understand the importance of having irrigated agriculture due to their success on a limited scale with new commodities. Poor drainage, in a similar fashion, has been contributing to a limited cropping season, low yields and low product quality which all results in high fluctuations of farm income. Henceforth, the Ministry of Agriculture is promoting the use of irrigation in several programmes and projects to intensify agricultural productivity in fruits and vegetables. A sugar cane diversification programme in northern Belize is also promoting the use of irrigation. Furthermore, it is expected that the *"Buy in Belize and Buy Belizean programmes"* will accelerate the demand for agricultural produce and increase thus demand for irrigation water.

**Hydroelectric Power**

Belize is well endowed with potential sites for the generation of hydroelectricity. A medium size run-of-the-river facility was erected at Mollejon on the Macal River in 1995 and supplies the nation with 18 MW of power under peak operation. This represents as much as 30% of the nation's demand. A much smaller plant at Blue Creek on the Rio Hondo provides 15KW of power to the Mennonite Community. Two tourist resorts operate micro hydro facilities on Privassion Creek for their own use. Environmental clearance has been granted for the development of a 3 MW plant near Resumadero on the northern tributary of the Rio Grande in the Toledo District.

Plans are under way for the construction of a 25 meter high storage dam at Chalillo on the Macal River to supply water to the facility at Mollejon. The structure is expected to provide an additional two million cubic meters of water to the plant during the dry season.

Higher temperatures will increase evaporation and transpiration during the dry season, reducing the water available in the reservoirs. This could contribute to emergency situations at this time of the year, especially if there are competing demands on the water resources by other sectors.

**Land Use**

The coastline retreat and loss of lowlands due to sea level rise will increase activities on the slopes. There will be increased removal of forest cover to accommodate the relocation of coastal communities, industries, and farmlands. The clearing of slopes for farmland will lead to increased erosion and higher concentrations of suspended sediments, fertilizers, herbicides, and pesticides in streamflows, degrading the quality of water. This would be exacerbated by higher rainfall.

Water is an essential and integral component for sustenance of life. Changes in the hydrological cycle will generate repercussions on all sectors. It is therefore imperative that Belize's water resources be managed in an integrated manner, responding to the requirements of all sectors.

Potential adaptation measures include:

the relocation of point sources for potable water in the coastal zone to points above the influence of saline intrusion especially in the Mango Creek/Independence area,

the use of cisterns for the storage of rainwater in the northern urban areas and offshore communities,

the relocation of the solid waste sites to areas above the zone of influence of sea level rise, especially for Belize City and offshore communities,

the development of an effective means of disposal of domestic waste water and excreta,

the adoption of forest management plans for protection against increased soil erosion,

the adoption of agricultural practices based on a water availability quota system,

the vesting of ownership of the nation's water resources in the state,

the establishment of an extensive database of the nation's water resources,

the establishment of an institutional framework capable of integrating water policy formulation, strategy, management and development,
the preparation of a national water resources plan,
the development of managerial and technical expertise to fulfil the obligations of the water management system,
the development of financial mechanisms to ensure the financial viability of an effective water resources management organization,
the promotion of the effective and efficient use of water,
the guaranteed provision of water for domestic consumption in the event of scarce water resources, and
the promotion of cooperative mechanisms with neighbouring countries for the management, development and protection of shared resources.

## Agriculture and Food Security

In 1994, Belize had a total of 8,753 farmers, 94% being "small farmers" with holdings under 10 acres. By mid 1999 that number had risen to 11,000 of which 75% were "small farmers". Approximately 265,000 acres or 5% of the total land area of the country is farmland, of which 146,000 acres are for crops and 119,000 acres are under pasture.

Sugar, bananas, and citrus are the traditional export crops and account for the largest share of foreign exchange earnings. Their combined contribution to the agricultural GDP and total earnings exceed 9.6% and 81% respectively. Sugar continues to be the most important of the three.

The main domestic food crops are rice, corn, and red kidney beans. The table provides a summary of the land area under cultivation from 1980 to 1997.

**Table: Area under cultivation, 1980-1997 ('000 acres)**

| Area | 1980 | 1985 | 1990 | 1995 | 1997 |
|---|---|---|---|---|---|
| Sugar Cane | 61 | 58 | 59 | 65 | 60 |
| Oranges | … | 10 | 31 | 48 | 49 |
| Grapefruit | … | 3 | 9 | 8 | 8 |
| Corn | 26 | 32 | 24 | 26 | 42 |
| Rice | 8 | 6 | 5 | 11 | 15 |
| R.K. Beans | 6 | 5 | 10 | 8 | 10 |
| Bananas | 2 | 2 | 6 | 5 | 5 |

Source: **Min of Agriculture, Fisheries and Cooperatives, 1999**

## Demography

The last population census for Belize was conducted in 1991. In 1994, the population was estimated to be 211,000, and by mid 1997, it was estimated at 232,000. The growth rate has remained steady at 2.8% per annum. Decreases in infant mortality, increasing life expectancy, immigration, and migration have all contributed to this trend.

The Central Statistical Office has issued three population growth scenarios for Belize: low, medium, and high population growth. Under these scenarios, the mean population doubling time was estimated to be 27 years. At that rate, the population of Belize would be just under one million by 2100. The population density would change from 8.2 inhabitants per kilometre in 1990 to 41 inhabitants per kilometre in 2100. Future birth and death rates and economic status were not considered. However, the population is very young and the baby boom will come to reproductive age within the next 15 to 30 years.

The demands for food and the pressure on Belize's natural resources will be compounded by the negative impacts of climate change on all sectors.

**Land Clearing and Agriculture**

The rate of land clearing for agriculture increased from 22,230 acres per year in the late 1980's to about 61,750 acres in the late 1990's. It is estimated that 15,000 to 30,000 acres of closed forest are cleared annually for agriculture. Class 4 land (recommended for forest management and plantation) is already being used for agriculture. Unless this trend is reversed, only steep or otherwise unsuitable land will be under forest cover within the next 50 to 100 years. If clearance of the steep slopes of the Maya Mountains is not discouraged, particularly along the Hummingbird Highway, central Belize will eventually become deforested. This would lead to flooding of prime agricultural land, degradation of water resources, decrease in Belize's carbon stock, decrease in biodiversity, and increased vulnerability to climate change.

**Environmental Effects of Land Clearing for Agriculture**

| Event | Impact |
|---|---|
| Permanent soil loss through sheet erosion and gullying (eg. citrus cultivation) | Extensive valley bottom and valley side clearance, plus artificial drainage along new road section of the Hummingbird Highway, resulting in higher flash floods and greater risks of flooding |
| Suspected contamination of freshwater by agrochemicals | Becoming more widespread in the citrus and banana growing areas; also in the north |
| Eutrophication of waterways by discharge from food processing plants and sugar factory | Increasing in the Stann Creek and Orange Walk Districts |
| Blocking of streams by bulldozed forest debris, reducing freshwater flow | Severe flooding in the wet season and drying up of creeks in the dry season (North Stann Creek Valley) |
| Forest clearance of slopes subject to erosion for milpa and citrus | Soil erosion and sedimentation in the Stann Creek and Cayo Districts |
| Inequitable land distribution as population increases | Increased use of marginal lands and intrusion into forest reserves |

Source: **Natural Resources Institute (NRI) Report, Bull. 48 1993**

**Milpa Cycle**

In Belize there are four main farming practices: shifting cultivation, sedentary farming, mixed farming (crop and livestock), and livestock production. The milpa system is a form of shifting cultivation. Farmers clear some acreage of forest, burn it towards the end of the dry season and plant corn and/or rice when the rains start. Approximately 7.1 acres of forest are cleared per farmer per year. The standard length of the fallow period was 8 years in the early 1980's, but decreased to 7 years by the mid 1980's. The land is used for a maximum of two years, then it is left to fallow. The standard length of the fallow period is 5.2 years. The fallow period is declining because of increasing demands for food and subsequent pressure on land.

To maintain this slash and burn cycle, each farmer requires 35 acres of land. It is estimated that 0.66 acres of mature forest per farmer per year is cut and enters the milpa cycle. In the Toledo District some 6,000 to 7,000 acres of forest/wamil (broad leaf forest re-growth) are cleared each year for the milpa farming of corn and rice.

Traditionally, the milpa system had a fallow period of 30 to 40 years, and included multi-cropping of legumes and cover crops. Today, it has evolved into a mono-cropping system with a short fallow period. This shorted regeneration period has reduced the soil fertility with each cropping cycle and has increased soil erosion.

This practice has resulted in land clearing on the fringes of forest reserves and on hillsides in the Stann Creek and Cayo Districts. Milpa farming and citrus cultivation have increased the vulnerability of the soil to erosion and contributed to the degradation of rivers and streams in these areas.

More than 6,000 persons practice milpa farming countrywide. They are predominantly Maya Mopan and Ketchi peoples located primarily in the Cayo and Toledo Districts. The influx of Central American refugees in the late 1980's and early 1990's increased this practice in the Cayo and Stann Creek Districts where most of them settled. Furthermore, more than 60% of all rice and corn farmers would be considered milpa farmers.

If the productivity and intensity of farming practices on lands already in the agriculture cycle are increased on a sustainable basis, the need to clear additional forest can be minimized or eliminated. This would maintain the forest as a carbon sink and reduce emissions from land clearing and agricultural soils. A wilful move away from shifting cultivation to sedentary agriculture will be necessary in the future, if Belize is to be self-sufficient in food production and competitive on the open market.

**Aquaculture**

Aquaculture activities have increased significantly in coastal Belize during the past 15 years. In fiscal year 1989/90 a total of 160,000 lbs of white farmed shrimp tails were produced on 684 acres. In 2001, production increased to 7.1 million lbs.

generating BZ$48.9 million on 5,200 acres. The trend seems to be toward increased farmed shrimp to lessen the pressure on marine shrimp and to satisfy the external market; it is forecasted that acreage will have expanded to more than 7,500 acres by 2003. However, one of the challenges facing the industry is that projected sea-level rise may undermine aquaculture infrastructure and displace farms inland with the retreating shoreline, increasing the pressure on the land.

**Irrigation and Water Use**

Belizean farmers depend on seasonal rains for a good harvest. During the past few years, all banana and papaya farms together with a significant proportion of rice fields have installed irrigation systems to offset soil moisture deficit during the dry season and be competitive. There are over 7,000 acres under irrigation. The installations consist of drip, sprinkler, flood irrigation systems and micro-dams on streams & rivulets near farming communities to provide water for small-scale irrigation.

The Ministry of Agriculture, Fisheries and Cooperatives recognizes the potential for irrigation to increase yields, particularly for cash crops and vegetables. The challenge is to find the most appropriate and efficient irrigation technology to produce high quality cash crops that will be competitive on the open market. The technology must be cost effective and within the reach of farming communities and cooperatives. Belize will then be able to produce cash crops like peppers, papaya, and vegetables throughout the year and tap into these niche markets.

The Ministry is presently studying the feasibility of constructing micro dams on streams and rivulets near farming communities to provide water for small-scale irrigation systems.

A comprehensive policy and implementation strategy on irrigation and water use in agriculture must be developed. Efficient irrigation technology is an adaptation measure, which can be used to reduce the vulnerability to climate change and control weeds and pests. It is also a mitigation measure to reduce emissions of GHGs from agricultural soils.

**Agricultural Policy**

The Government of Belize in its **MAFC 1999 Draft Policy Report** for the agricultural sector identified six broad objectives:

1. Promote sustainable agricultural and rural development.
2. Increase the competitiveness of the agricultural sector.
3. Accelerate diversification in production and exports.
4. Increase food production, enhance food security and improve the nutritional status of the population.
5. Strengthen inter-sectoral linkages.
6. Improve income distribution and equity.

The **Report** also identified some inter-related factors that will determine agricultural and rural development in the near and distant future. They include globalization, regional trade and integration, changes in international markets for traditional Belizean products, stewardship of environmental and natural resources, democratization and decentralization. Globalization and free trade are threatening Belize's traditional exports. Domestic and export markets will continue to set the pace and direction of the development process. Policies and strategies must be devised to prepare the agricultural sector to compete globally.

The **Report** recognizes the increasing environmental cost of production and development. Both agricultural and non-agricultural activities are threatening the natural and environmental resource base of the nation. Some of the negative impacts include deforestation, depletion of fish stocks, soil erosion, pollution of rivers and streams, accumulation of solid waste, and a shortening of the milpa cycle. The Ministry is formulating policies that will integrate macroeconomics, trade, investment, community development, and natural resource and environmental policies with regional and international agreements and obligations.

The long-term development strategy for sustainable agriculture must maintain a focus on the efficient use and management of the natural resource base upon which agriculture depends. Future population growth will increase the stress on an already fragile environment, as the demand for food increases. Climate change will add to the stress. The negative effects of climate change will only be lessened through timely and appropriate adaptation strategies whose benefits must outweigh any additional cost. Many adaptation strategies actually complement economic growth in future climate change scenarios.

**Vulnerability**

An agricultural vulnerability study was conducted in 1995 under the US Country Studies Program. Future climate scenarios 1 and 2° Celsius warmer accompanied by a ±20% change in precipitation were selected. A crop simulation model "Decision Support System for Agrotechnology Transfer" (DSSAT3) was used to simulate the yield of upland rice, beans and maize under these climates. The model projected a 14 to 19% reduction in yield for beans, a 10 to 14% reduction for rice, and a 17 to 22% reduction for maize.

The temperature rise shortened the growing period of the crops, which lowered their yields. Changes in precipitation did not affect the growing season. However, it did affect the yield, especially that of maize.

**Results of DSSAT3 crop simulation of Beans, Rice and Maize**

| Crop | Scenario Name | Season Length (days) | Temp change (°C) | % change in precip | Yield (kg/ha) | % change in Yield |
|---|---|---|---|---|---|---|
| Dry beans C3 | Baseline | 87 | 0 | 0 | 1353.61 | |
| | Carib A | 85 | +2 | +20 | 1163.68 | -14% |
| | | 85 | +2 | -20 | 1092.64 | -19% |
| Rice | Baseline | 124 | 0 | 0 | 3355.50 | |
| C3 | Carib A | 113 | +2 | +20 | 3014.40 | -10% |
| | | 113 | +2 | -20 | 2887.50 | -14% |
| Maize | Baseline | 104 | 0 | 0 | 4510.64 | |
| C4 | Carib A | 97 | +2 | +20 | 3736.57 | -22% |
| | | 97 | +2 | -20 | 3759.43 | -17% |

Source: The Impact of Climate Change on Maize, R.K. Beans and Rice Production in Belize, 1997, Tzul, et. al.

The study did not incorporate the effect of carbon dioxide fertilization on yield, which could offset some losses.

The study recommended the following adaptation measures:

- conduct research on maize, beans and rice to develop more heat resistant varieties that would perform better in a shorter season,
- develop adequate infrastructure for appropriate irrigation systems,
- improve crop management practices,
- update climate change scenarios as better models with finer resolutions become available, and
- compile DSSAT coefficients for R.K. Beans, the more popular variety in Belize.

The US Country Studies Program also funded a vulnerability study on the coastal zone. Sea levels were projected to rise by 50 cm by 2075. This would result in the encroachment upstream of the saline/freshwater interface, especially in the low lying basins of the New River and Rio Hondo in the north. This would have dire consequences on agricultural enterprises in the Corozal and Orange Walk Districts, especially sugar production. Similar effects could occur in the Independence/Mango Creek area, impacting negatively on the banana industry.

Coastline retreat and beach inundation would transform savannahs and coastal farmlands into swamps and wetlands. Freshwater for human use and irrigation would become saline as the saline/freshwater interface shifts further upstream, contaminating surface water and phreatic aquifers. New agricultural lands and sources of potable water would have to be identified inland. This scenario would put more pressure on the limited agricultural land and could force farmers to use marginal lands and slopes, increasing the need for intensive but sustainable crop management practices.

Sugar cane is not expected to be affected significantly by climate change. It tolerates a wide range of temperatures and thrives in well-drained, calcerous soils. It is a C4 crop and could benefit from carbon dioxide fertilization. The potential adaptation measures are all no-regrets measures:

- improve cropping systems,
- use sub-surface drip irrigation,
- utilize wetlands in drier conditions,
- improve infrastructure (drainage, feeder roads, factory),
- improve harvesting and transportation,
- introduce crop rotation/diversification to improve cash flow and soil conservation,
- acquire, encourage and use new technology for processing sugarcane by-products, and
- change the attitude and practices of cane farmers.

The carbon dioxide fertilization effect and consequent water use efficiency are expected to promote the proliferation of invasive weeds. However, the impact on crops will depend on how enhanced-growth weeds compete with enhanced-growth crops. Of the 86 plant species that contribute 90% of world food supplies, 80 are C3 plants, while 14 of the 18 worst weeds are C4 plants. C3 species are expected to benefit from $CO_2$ enrichment at the expense of C4 species. However, most weeds of warm season crops originate in the tropics or warm temperate areas and respond to small increases in temperature. Inter-specific competition is expected between weed species and crops, which will be disadvantageous to C4 crop species, since these benefit less from $CO_2$ enrichment. It will therefore cost more to control weeds affecting C4 crops. Production costs per acre could increase.

Some adaptation measures are:
- improve weed management practices,
- develop genetically improved crop varieties that take maximum advantage of existing climatic conditions,
- use improved herbicides that are effective in warmer conditions, and
- use natural and biological weed control technology.

Climate change will influence the distribution and degree of infestation of insect pests. These will impact both directly on the life cycle of insects and indirectly through climatic effects on hosts, predators, competitors and insect pathogens. Insect species characterized by high reproductive rates are generally favoured.

In Belize, these would be the r-strategest which are generally small, plyphagous and adapt rapidly to selective pressures. They include some major crop pests such as: mites, scabs, mealybug, aphids, white flies, and thrips. Two factors influence insect population. These are biotic factors, which include death and birth rates, and abiotic factors, which are dictated by climatic conditions. Some effects of global warming on insects include changes in:
- geographical range,
- population growth rate,
- number of generations per annum,
- length of growing season,
- crop-pest synchronization,

- inter-specific interactions,
- dispersal and migration ability of host plant and refuge sites, and
- over-wintering.

The r-strategist develops rapid resistance to pesticides and survives on whatever food resources are available. The k-strategist insects are larger and will also adapt to climate change, especially if the changes are gradual. Integrating insect pests with weeds in warmer climatic conditions may favour proliferation of weeds, which would provide more hosts for insects. The r-strategist tends to thrive in hot and humid conditions. They are vulnerable in showery weather, since eggs, nymphs and adults may be washed away or drowned. R-strategist insects migrate when food becomes scarce. Climate change is expected to produce more extreme weather and could induce more insect dispersal and migration. An increase in locust migration is already being noted in Central America. There is also concern about those insect species that increase their population size by producing an extra generation each year or expanding their ranges in warmer climates.

Climate change will foster more insect vectored diseases. Fungal and bacterial diseases thrive in humid conditions while fewer incidences of disease are noted in drier weather. Some examples of diseases that may become more prevalent under a warmer, wetter climate are viral diseases like *citrus tristeza*, fungal diseases such as anthracnose, and bacterial diseases such as xanthomonas.

The effects of weeds, pests, and diseases on crop production will increase in a warmer climate and may elevate production costs for many of Belize's cash crops. Among the adaptation measures to be considered are:

- more research into and development and procurement of pest and disease resistant crop varieties,
- improved biological control programs, and
- improved agronomic practices to take advantage of crop-pest synchronization.

## Energy

In 1994, all of Belize's electrical requirements were being met by diesel generating plants located in the major municipalities. There have been two significant developments since that time. In 1995, a 25 MW run-of-the-river facility on the Macal River was commissioned. Secondly, Belize's electrical grid was connected to Mexico. These developments have met most of the country's increased demand for electricity, which rose 9% annually from 93,340 MWh in 1990 to 171,626 MWh in 1998. Belize Electricity Limited (BEL) distributed 213,681,060 kWh in 1998 of which BEL generated 54.2% by diesel, the hydropower facility provided 30.9%, and 14.9% was imported from Mexico. However, all of Belize's demands have still not been met. There are still several communities in the rural areas, which do not have access to a reliable supply of electricity because they are too far from the grid.

Low lying coastal communities in Belize are vulnerable to sea level rise. Generating facilities in Belize City, Corozal Town, Dangriga, Punta Gorda, and Caye Cauker face the danger of inundation.

Changes to the hydrological cycle will affect the main hydropower facility on the Macal River and its proposed storage facility upstream, several micro facilities, and a proposed facility in the Toledo District. Increased rainfall will increase the volume of water available for generation. However, the volume of silt and other obstructive materials in the flow will also increase, reducing the efficiency of the generating facilities. A reduction in rainfall will decrease the flow. The flow would be further reduced if the demands for agriculture or potable water were given higher priority and water is drawn off upstream.

Climate change is expected to increase the demand for electricity. A rise in air temperature will increase the demand for air conditioning, enhance evaporation and therefore increase the demand for pumping water for irrigation, increase the demand for refrigerating food, and increase the electrical distribution losses. Pumping stations may have to be installed in communities vulnerable to sea level rise, which will create a new demand.

Even without climate change considerations, Belize's energy demands will rise as it strives to meet its development potential and alleviate poverty.

Recognizing Belize's vulnerability, the Government has created a multi-disciplinary committee within the Ministry of Public Utilities, Energy, Communications and Immigration under the leadership of the Office of Electricity Supply to prepare an energy policy and strategy for the country. It will identify and promote the most viable energy options available to the country, harnessing the country's natural resources and by-products such as baggasse from sugar, banana, citrus and forestry waste, and other renewable sources of energy in addition to hydro.

The electrical distribution system, which is primarily by overhead power lines, is especially vulnerable to the effects of hurricane force winds. Switching to an underground distribution system could reduce some of this vulnerability. However, sea level rise could render that option vulnerable to inundation.

**Disaster Preparedness**

Lying within the tropics at the western side of the Caribbean Sea, Belize is prone to the direct and indirect effects of hurricanes. Several major hurricanes have struck the country. During the past 100 years, Belize City was destroyed twice. The most devastating and deadly factor of these hurricanes was the storm surge, which was estimated to be 10 to 15 feet high in hurricane Hattie in 1961. This prompted the country to undertake the ultimate adaptation measure in the late 1960's, creating a new capital 50 miles in the interior of the country.

Reliable hurricane records for the Caribbean date back to 1871. During that period, Belize has been struck over 40 times by tropical cyclones, ranging from tropical depressions to hurricanes, a return period of three years. The country's vulnerability increases from south to north. A Storm Hazard Assessment prepared by the Caribbean Disaster Mitigation Project showed that the return period for Punta Gorda was 5.73 years falling to 3.7 years at San Pedro, Ambergris Caye.

The same study utilized the output from a hurricane computer model called "The Arbiter of Storms" (TAOS) to generate wind hazard maps for the country. While only coastal locations were vulnerable to hurricane force winds in a Category 1 hurricane, the entire country was vulnerable to hurricane force winds in a Category 5 hurricane.

Historically, the high tides associated with hurricanes at landfall, called the storm surge, account for 90% of casualties around the world. Belize is especially vulnerable to storm surge. The continental shelf is about 15 miles from the mainland providing a shallow bathymetry, which allows a high wave to be generated by the low pressure and strong onshore wind. Coastal Belize is also very flat. This allows the storm surge to move several miles inland before it meets any significant elevation. The coastline also has several bays, which funnels the water creating even higher local surges. The TAOS model predicts a storm surge of 20 feet in Belize City for a Category 5 hurricane. Other locations could get storm surges approaching 25 feet.

Some climate change scenarios project an increase in the frequency and strength of hurricanes. This would have devastating implications for Belize, both as a human security concern and economically. In 1974, Belize was in the process of developing a banana industry when hurricane Fifi struck and totally wiped it out. Four years later hurricane Greta wiped out the country's second effort. The subsequent quiet twenty-year period has allowed a profitable industry to develop and grow. Increased hurricane activity associated with climate change could easily wipe this out as was so vividly demonstrated by hurricane Mitch in Honduras in 1998.

The country is also vulnerable to recurrent floods. Annual floods in the south frequently isolate communities for short periods. More devastating floods occur along the Belize River. Several communities and rich farmlands are threatened and require rescue and rehabilitation efforts. In the higher elevations, the runoff is rapid. However, in the flatter terrain along the coast and in the north, runoff is very slow and flooding can last for several weeks. The more vigorous hydrological cycle expected with climate change could increase the frequency and magnitude of these flooding events.

Belize last experienced a major episode of drought in 1975. It affected agriculture, cattle ranching and the availability of potable water. The availability of potable water has become an almost annual concern for several communities toward the end of the dry season as aquifers run low and there is a serious threat of saline intrusion. Intake pipes in rivers have also come dangerously close to being exposed. Coastal and urban communities continue to expand. Extended dry seasons could be the final factor that triggers a disaster.

The close call with hurricane Mitch in 1998 exposed the country's vulnerability to hurricanes. Belize had experienced a twenty-year period without any real hurricane threat. As a result, the country had become complacent. Many hurricane mitigation activities had lapsed resulting in increased vulnerability. Subsequent to the threat of Hurricane Mitch, government undertook a major initiative in disaster preparedness. It created an office of disaster preparedness (the National Emergency Management Secretariat) with a full-time staff and introduced new legislation via the National Emergency Act 2000. Furthermore, funding was has been secured to train and equip the NEMO staff and members of the various ministries that make up the National Emergency Management Organization. Furthermore, a new Operations Center is being erected in Belmopan and new hurricane shelters are planned in major towns and cities. Existing shelters are being retrofitted and plans are underway to create satellite communities in the interior on high ground safe from flooding. These are also intended to serve as refuges during hurricane emergencies. These measures have already proved to be instrumental in Belize's ability to safeguard life and property, as subsequent to the Hurricane Mitch threat, Belize was ravaged by two category four hurricanes (Keith and Iris) and a tropical storm (Chantal).

Further mitigation measures include the refinement of the country's hazard maps. One limiting factor is the lack of detailed topographic maps for the country. The best maps presently have contour intervals of 20 meters. It is therefore impossible to predict how far inland a storm surge will penetrate, what structures are vulnerable and to what extent. Flood plain mapping efforts for rivers are similarly hindered. Detailed topographical data is essential if Belize is to properly assess its vulnerability and formulate effective adaptation and mitigation options.

**References**

Avella, Evaristo, Mitigation Measures and Adaptation to Climate Change in the Waste Sector, Wilderness Group Consultants, Final Report, Belize Climate Change Project,

Belize Audubon Society, Cross Sectoral Adaptation Assessment, Biodiversity, Final Report, Belize Climate Change Project, September 1999

Castaneda, Anselmo, Mitigation and Adaptation Assessment, Land Use Change and Forestry, Final Report, Belize Climate Change Project, September 1999

Fernandez, Mario, Mitigation Measures and Adaptation to Climate Change in the Transport Sector, Final Report, Belize Climate Change Project, September 16, 1999

Frutos, Ramon and Tzul, Francisco, Mitigation-Adaptation: Agriculture Sector, Final Report, Belize Climate Change Project, August 9, 1999

Gibson, Janet and Ariola, Eugene, Coastal Zone Adaptation to Climate Change, Coastal Zone Management Authority and Institute, Final Report, Belize Climate Change Project, September 1999

IPCC, Climate Change 1995, Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses, Contribution of Working Group II to the Second Assessment Report on the Intergovernmental; Panel on Climate Change, World Meteorological Organization and United Nations Environment Programme, Geneva, Switzerland and Nairobi, Kenya

IPCC, Climate Change 1995, The Science of Climate Change, Contribution of Working Group I to the Second Assessment Report on the Intergovernmental Panel on Climate Change, World Meteorological Organization and United Nations Environment Programme, Geneva, Switzerland and Nairobi, Kenya

IPCC, The Regional Impacts of Climate Change, An Assessment of Vulnerability, A Special Report of the Intergovernmental Panel on Climate Change Working Group II, World Meteorological Organization and United Nations Environment Programme, Geneva, Switzerland and Nairobi, Kenya

Lizaraga, Manuel Jesus, Energy Sector Report, Mitigation and Adaptation, Final Report, Belize Climate Change Project, August 15, 1999

Neumann, Charles J., Jarvinen Brian R., Pike Arthur C. and Elms, Joe D., Tropical Cyclones of the North Atlantic Ocean, 1871-1986, (Third Revision), National Oceanic and Atmospheric Administration, Asheville, N.C., September 1987

OAS, Storm Hazard Assessment for Belize, Storm Surge and Wind Hazard Maps, Organization of American States and United States Agency for International Development, Washington D.C., USA

Stevens, R. P., Disaster Preparedness and Adaptation in Response to the Effects of Climate Change, Final Report, Belize Climate Change Project, August 1999

United Nations Framework Convention on Climate Change, 1992

Williams Jr., Rudolph S., Hydrology/Water Resources, Final Report, Belize Climate Change Project, September 1999

# CHAPTER 4:

## SYSTEMIC OBSERVATIONS AND RESEARCH

Weather observations in Belize date back to 1882. During the subsequent 80 years, various organizations and individuals made meteorological observations for their own purposes. In the 1960's the Meteorological Section of the Civil Aviation Department began making observations in a more systematic manner. This later evolved into the National Meteorological Service, which consolidated the observing stations into a national network. The threats of hurricanes in the 1960's and 70's stimulated the development of the Service and its observation programme.

The observation network consists of 21 weather stations and 11 rainfall stations. This does not provide sufficient coverage to adequately monitor the climate of the country. The 11 rainfall stations must be upgraded to full weather observing stations and 12 new stations must be installed to provide adequate coverage.

Since 1980 Belize has maintained a cooperative upper air observing station with the United States of America.

Systematic hydrological observations date back to the late 1970's. There are only 25 sites being monitored, which also do not provide adequate coverage of the nation's surface water resources. There is no systematic water quality program for the country's freshwater resources. The Coastal Zone Management Institute and the Fisheries Department maintain a water quality programme for the coastal zone, which consists of 75 monitoring sites. The Public Health Bureau and the Water and Sewage Authority monitor sources of potable water. Belize's groundwater is not being monitored. The absence of a comprehensive monitoring programme makes it impossible to assess the nation's water resources properly, assess its vulnerability and hence recommend adaptation and mitigation measures.

There are no comprehensive marine/oceanographic observation programmes in Belize. The National Meteorological Service maintained a tide gauge for over twenty years in Belize City. This system was upgraded in 1998 through the CPACC Project. The Met. Service also maintained three tide gauges on the outer barrier islands. These gauges were destroyed by Hurricane Mitch in 1998. These stations also monitored sea temperature. There are no wave recorders in the country. Ocean current measurements are sporadic and are undertaken by agencies for project specific purposes. The absence of a comprehensive monitoring programme is significant given Belize's vulnerability to sea level rise and the importance of the coastal zone to the economy of the country.

It is therefore imperative that the meteorological and hydrological monitoring programmes in Belize be expanded and upgraded and comprehensive water quality and marine/oceanographic monitoring programmes be developed and implemented.

**Research**

Belize is presently participating in two projects and has completed a third, which will improve our understanding of the implications of climate change in Belize.

Vulnerability Assessments under the US Country Studies Program

In 1994, Belize joined its Central American neighbours in a climate change vulnerability assessment study funded through the US Country Studies Program. This endeavour was facilitated by Belize's membership in the Regional Committee of Water Resources (CRRH). Vulnerability assessments were undertaken for the following three sectors in all seven countries: agriculture, coastal zone, and water resources.

Climatologists and meteorologists from the region met in a series of national and regional workshops to assess the results of four global circulation models (GCM's) which simulated the future climate in an atmosphere with a doubled carbon dioxide concentration in 75 years. The GCMs used were those from the Geophysical Fluid Dynamics Laboratory (GFDL), the Canadian Climate Center (CCC), the United Kingdom Meteorological Office (UKMO), and the Goddard Institute for Space Studies (GISS). The resolutions of the models could not adequately depict the regional climates in an area consisting of a narrow landmass with a considerable vertical profile surrounded by large bodies of water. They predicted an increase in mean air temperature of 2°C in the region. There was no definite signal noted for rainfall. The group decided to use a 1 to 2°C temperature increase and a ±10 to 20% variation in rainfall.

The Department of Agriculture and the National Meteorological Service undertook the vulnerability assessment for agriculture in Belize. Personnel were trained at national and regional workshops on the function and use of crop simulation models developed by Decision Support System for Agrotechnology Transfer. The models simulated physiological crop responses to climatic parameters, soil, and crop management. The three major staples in the Belizean diet were selected: rice, beans and maize. The "DSSAT v3" CERES crop simulation model was used for the "PIO X 304 C" variety of maize and "CICA8" variety of upland rice. The "DSSAT v3" CROPGRO simulation model was used for the dry bean cultivar "CARIOCA" since the model did not have the agronomic variables for Red Kidney Beans, the most popular variety in Belize. The models assumed that there were no limits on nutrients; pests were controlled, and there were no catastrophic events. The yields also simulated dry-land rain-fed conditions. Although atmospheric concentrations of carbon dioxide would have doubled to produce these scenarios, the models did not incorporate this, or its expected $CO_2$ fertilization effect.

The models predicted a decline in yield of 10 to 20% for the eight scenarios of the three crops. The team recommended that the scenario for R.K. Beans be run whenever the agronomic coefficients for this variety in the model became available. They also recommended that the scenarios be updated whenever better GCMs with finer resolutions became available. Finally, the team recommended that research be undertaken to identify heat resistant cultivars that would grow well in shortened seasons.

Coastal Zone

The Belize Center for Environmental Studies (BCES), an environmental non-government organization (NGO) was contracted to undertake the vulnerability study of the coastal zone. It consisted of an Aerial Videotape-assisted Vulnerability Analysis (AVVA) to assess vulnerability to sea level rise. The shoreline of mainland Belize was selected because of population considerations, the level of infrastructure development, and the economic importance of the shoreline. The consultant was trained in the methodology in a series of regional workshops.

The AVVA methodology consisted of a video of the shoreline taken by a professional videographer from a small airplane flying parallel to the coast at elevations of 100 and 500 feet. The record was combined with ground truth to ascertain coastal topography, geomorphology, and physiographic characteristics. This information was sketched on a 1:250,000 base map together with the extent of low-lying lands that could be impacted by storm flooding and inundation resulting from sea level rise. Preliminary assessments were made of areas undergoing erosion, inundation, saltwater intrusion and increased storm flooding from the videotapes, groundtruthing at selected sites and by conducting informal interviews with residents from coastal communities.

The Bruun rule was applied to estimate erosion of the shoreline.

$$R = GS\,[L/(B + h)]$$

where: R = shoreline recession caused by a sea-level rise S
h = depth of closure
B = beach ridge height
L = active profile width from dune height to depth of closure
G = overfill ratio (assumed to be 1)

Sea level rises of 4, 30 and 50 cm were projected over the next 25, 50 and 100 years respectively.

The results indicated that there would be minor impact within 25 years. However, by the end of the century, 50 to 100% of the beaches would have been lost due to erosion.

The exercise assumed uniform global sea level rise with no regional or local effects. Thus, sedimentation, subsidence, tectonics and oceanographic factors were not incorporated.

No estimate could be made of the potential land loss due to inundation. The elevation maps available for Belize have a vertical resolution of 20 meters. It was therefore impossible to make estimates of the one-meter contour line and project the extent of inundation.

The consultant recommended the following activities to properly assess coastal vulnerability and propose adaptation measures:

1. Obtain high-resolution contour maps of the coastline to estimate land loss due to inundation.
2. Obtain sedimentation data for specific watersheds to improve erosion/deposition relationships
3. Establish wave-recording stations along the coast to gather wave height data essential for proper application of the Bruun rule.
4. Expand and improve the network of tide stations to observe relative sea-level rise.

The consultant also recommended that erosion occurring in Belize City, Dangriga, Monkey River, Moho River and Barranco be monitored and addressed. Sand mining in Dangriga should be curtailed. Filling and sea wall construction may be warranted in Belize City as an adaptation measure. The Hydrological Unit of the National Meteorological Service and the Coastal Zone Management Authority and Institute should be the lead agencies charged to implement the recommendations with the support of the Housing and Planning Department and interested NGOs. Finally, he recommended that the coastline of Belize be videotaped at low altitudes annually to assess and monitor land use change.

Water Resources

A vulnerability analysis of the Belize River Basin was undertaken by the National Hydrological Service. This basin was chosen because it has the most hydrological data; it is the largest basin; it is the source of water for over 50% of the population, and it has the most fertile agricultural lands in the nation. Economic activity in the basin consists of tourism, citrus farming, and fruit, vegetable, livestock, poultry and rice production.

A hydrological computer model CLIRUN 3 was used to simulate the runoff assuming changes in precipitation of ±10 and 20% and changes in potential evapotranspiration produced by temperature increases of 1 and 2°C.

The model projected an increase in runoff in excess of 150% in certain months when precipitation was increased. The reductions in runoff were not as dramatic when the precipitation was decreased, falling by less than 50% in the most affected months.

The implications of these scenarios are mixed and complex. Two scenarios predict an increase in streamflow, enhancing the viability of hydropower generation, especially of run-of-the-river facilities like the Mollejon Plant on the Macal River. Construction costs of future plants should decrease, or their potential capacities increase. Another scenario projects a decrease in flow during the rainy season and an increased flow in the dry season. This also enhances the viability of run-of-the-river facilities. The scenario predicting a general decline in streamflow would reduce the effectiveness of hydropower facilities. However, this also makes them subject to fewer flood events and less costly flood mitigation measures.

Three scenarios project an abundant source of potable water for the nation. The fourth suggests that the nation will experience difficulties in meeting future demands. New freshwater reserves will be difficult to locate.

Two scenarios predict an increase in flooding events. Another predicts a reduction in the availability of water requiring the implementation of water management policies and regulations. The other scenario projects such a large deficit that alternative and/or non-traditional sources of water supply will have to be identified and exploited.

Increased flow will increase the water available for irrigation. However, this will reduce the attractiveness of the water for tourism. Droughts will reduce the availability of water for irrigation. Yet, it will be beneficial for tourism if the present dry season remains unchanged. Increased streamflow would be detrimental to public health since it would increase the mobility of disease vectors. This could lead to an increase in incidences of diseases such as dengue fever and malaria.

CPACC Project

Belize is presently participating in a regional project, **Caribbean: Planning for Adaptation to Global Climate Change (CPACC)**. This is a "Stage 1" adaptation project being funded by the Global Environmental Facility (GEF) for twelve CARICOM states. The objective of the project is to build regional and national capacity in climate change. This is being achieved through training at national and regional workshops, a public awareness campaign and the implementation of the projects' nine components. Four of the components are regional while five are pilot projects. All countries participate in the regional components, but each country participates in only one pilot component. The experiences of the pilot activities are shared during implementation and at the culmination of the project.

Nationally, the project is coordinated by a National Implementation Coordination Unit (NICU) comprised of the major government, non-government and academic institutions involved in coastal zone management activities in Belize. A Regional Project Implementation Unit (RPIU) within the University of the West Indies Center for Environment and Development (UWICED) manages the project regionally.

Component 1 installed a network of eighteen tide gauges and automatic weather stations in the Caribbean. Belize received one of these stations, which is being managed by the National Meteorological Service and is located on the Port Authority pier in Belize City. The data will contribute to an understanding of relative sea level rise in the Caribbean and Belize.

Component 2 established a database to serve as a clearinghouse for the information generated by the project. This will become extremely useful for future studies on climate change in Belize. The database is housed at the Coastal Zone Management Institute. The Land Information Center (LIC) in the Ministry of Natural Resources, Environment and Industry has been identified as a backup repository.

Component 3 compiled an inventory of coastal zone resources for the country. This activity was already being addressed by the Coastal Zone Management Authority. CPACC is improving and consolidating this effort in Belize.

Component 4 will draft a generic policy framework for integrated coastal zone management (ICZM) legislation. Although Belize drafted ICZM legislation in April 1998, it can be enhanced and strengthened especially in areas dealing specifically with climate change and its possible impacts. The legislation also requires regulations and CPACC may be able to assist in this area. Legal assistance is also required in specific areas such as building controls. The relevant agencies such as the Housing and Planning Department could benefit from this activity.

Component 5 is a pilot component on coral reef monitoring in which Belize is participating along with the Bahamas and Jamaica. Three sites have been selected for monitoring twice yearly. The methodology involves making videotapes of the coral reef in transects 10 feet by 10 feet. Each species is identified and the data □nalyses□. The Fisheries Department is the lead agency for the data collection, while the Coastal Zone Management Institute □nalyses and stores the data. There are other coral reef monitoring programs in the country, which are being coordinated by the Fisheries Department.

This activity is especially timely since Belize recently experienced two major coral bleaching episodes in 1995 and 1998. Hurricane Mitch also wrought significant damage to the reef in 1998. These incidences left the reef vulnerable to disease. Coral reefs are believed to be excellent indicators of climate change since they respond to changes in temperature, turbidity and solar radiation.

The other components are all pilot components. Component 6 will prepare vulnerability and risk assessments; Component 7 will conduct an economic evaluation of coastal ecosystems. Component 8 will formulate economic and regulatory approaches to environmental protection, and Component 9 prepared the St. Vincent and the Grenadines' First National Communication to the UNFCCC. Although Belize is not participating in these components, it benefits by attending as many training sessions as possible and by networking with the implementing agencies.

If the results of this project warrant it, Belize and other participating states may then request funding for a Stage 2 adaptation project. CPACC has also served as a mechanism in coordinating the region's efforts in the climate change negotiation process.

<u>Rio Bravo Carbon Sequestration Project</u>

Belize was one of the first countries to participate in the pilot phase of Activities Implemented Jointly (AIJ), hosting the Rio Bravo Carbon Sequestration Project. This project which began in 1995 is being implemented by Programme for Belize (PfB), an NGO that manages a large tract of land in north western Belize. The project enabled PfB to acquire a 13,000 ha parcel of land, which had been on the market and would have been converted to irrigated rice cultivation. The funds were provided by a group of American power companies, which also provided funding for conservation, forest management, and sustainable forestry.

Permanent sampling plots were established on the land. Winrock International trained project staff to conduct carbon inventories. A baseline inventory was conducted in 1996. This provided excellent carbon inventory data as well as related forestry and land-use data which contributed to the 1994 GHG Inventory. Additional inventories will be carried out in years 3, 5, 7 and 10. These will be even more important to subsequent National Inventories.

In 1995 and 1996, 807,468 tons of carbon dioxide was captured. This increased to 1,524,967 tons in years four and five.

## Conclusions

Belize has undertaken only three vulnerability studies. It is essential that additional studies be undertaken in areas such as biodiversity, health, fisheries, forestry and tourism. The major agricultural export commodities may also be vulnerable to the adverse impacts of climate change. Studies should therefore be conducted in aquaculture, bananas, citrus and sugar cane production, and recommendations made for adaptation strategies.

Coral reefs have already been identified as excellent indicators of climate change. Other biological or natural indicators may exist in the country. These should be identified and monitoring programmes initiated as soon as possible.

Finally, to properly assess the country's vulnerability and recommend any meaningful adaptation measures, it is essential that accurate, high-resolution topographical and bathymetric data for the country be acquired or generated. For the coastal zone these should be in the order of 1-foot contour intervals, while at the higher elevations inland, they should be in the order of 10 to 20-foot intervals.

## References

Cayetano, E., An Assessment of the Vulnerability of Belize's Coastline to Sea Level Rise, 1997, Belize Center for Environmental Studies, Comite Regional de Recursos Hidraulicos, Comision Centroamericano del Ambiente y Desarollo, US Country Studies Program, Proyecto Centroamericano Sobre Cambio Climatico

Panton, W.F., Water Resources Sector, 1996, National Hydrological Service, Comite Regional de Recursos Hidraulicos, Comision Centroamericano del Ambiente y Desarollo, US Country Studies Program, Proyecto Centroamericano Sobre Cambio Climatico

Tzul, F., Evans, F., Frutos, R. and Hulse, J., The Impact of Climate Change on Maize, R.K. Beans, and Rice production in Belize, 1997, Agriculture Department and National Meteorological Service, Comite Regional de Recursos Hidraulicos, Comision Centroamericano del Ambiente y Desarollo, US Country Studies Program, Proyecto Centroamericano Sobre Cambio Climatico

Organization of American States, **Caribbean: Planning for Adaptation to Global Climate Change (CPACC) Project Document**

Organization of American States, **Storm Hazard Assessment for Belize, Storm Surge and Wind Hazard Maps**

USIJI Uniform Reporting Document: Activities Implemented Jointly Under the Pilot Phase**, Rio Bravo Carbon Sequestration Pilot Project**, 1999

## CHAPTER 5:

## EDUCATION, TRAINING AND PUBLIC AWARENESS

In Belize, climate change is perceived by many as an issue for the developed world, without great significance for the country. Unfortunately, this perception is shared not only by the public but also by many policymakers. This is unfortunate since Belize is extremely vulnerable to the adverse impacts of climate change. Climate change issues are now impacting on virtually all sectors of the economy. These include agriculture, coastal zone management, disaster preparedness, energy, fishing, forestry, tourism, and transportation. Stakeholders in these fields should incorporate climate change into their decision making processes. In addition, the climate change negotiation process and the Clean Development Mechanism could offer options to address the adverse impacts of climate change on these sectors and assist the country in meeting its development objectives.

The enabling activities for the preparation of the First National Communication provided an opportunity to heighten awareness in the country about climate change. A public awareness campaign was launched early in the project cycle. A Climate Change Brochure was prepared and circulated. A Climate Change Information Package was reproduced and distributed. A series of radio spots was aired on the national radio station, Radio Belize. Climate change was featured on one television programme and three radio talk shows.

The process of preparing the First National Inventory of Sources and Sinks of Greenhouse Gases provided training to the inventory team. The individuals and organizations, which provided the data, were also exposed to climate change issues. The consultants who conducted the vulnerability, adaptation and mitigation analyses were also incorporated into the public awareness effort. A series of five national workshops were conducted during the preparation of the National Communication. These also exposed large audiences to the issues associated with climate change.

A Website www.met.gov.bz/climate has been created, which contains information on national activities on climate change. It is linked to the regional CPACC Project Website as well as that of the UNFCCC.

A National Climate Committee has been convened and assigned the responsibility of remaining abreast of developments related to climate change and providing the nation and government with information and advice on the subject.

The CPACC Project also offers an opportunity to heighten public awareness about climate change. The project was featured in a display commemorating the 50th Anniversary of the Organization of American States (OAS), the executing agency of the project. Documentaries highlighting components of the project have been aired on local television stations and the project has been the topic of several radio shows. A consultant is presently preparing a set of generic climate change education material, which will be distributed throughout the region. The material will be adapted to meet local and national needs and distributed within the twelve participating countries. The Project is also assisting the University of the West Indies in developing a post-graduate climate change programme that may be inaugurated in the September 2000 academic year.

In 1995, as Belize was conducting its vulnerability studies under the US Country Studies Program several individuals and organizations were also exposed to the issues associated with climate change. Unfortunately, the national workshop at which the results of the studies were presented was poorly attended.

Climate change has not yet been incorporated into the school curricula, although other environmental and ecological subjects are now being taught. On the other hand, climate change is making inroads informally. It has become a popular topic for school projects and at science fairs.

There is much more that needs to be done to heighten public awareness and to incorporate climate change into the decision making process. This was a theme emphasized by the consultants and participants at the National Vulnerability, Adaptation and Mitigation Options Workshop held in October 1999. The group stressed the importance of developing a comprehensive public awareness and education programme. They noted with concern the normal practice of appending public awareness campaigns in most projects as an afterthought. Such a campaign should be the objective of a project or a specific component of a project with an identified budget. In addition, they emphasized the need to develop mechanisms to incorporate climate change within the national decision making process.

The country is presently drafting legislation to form National and District Sustainable Development Councils. These Councils must include climate change among the issues they consider. These could serve as a mechanism to ensure that climate change is included in the development process. Other mechanisms include the activities on conservation of biological diversity, the environmental impact assessment process, disaster mitigation activities, and integrated coastal zone management.

The threat of hurricane Mitch in 1998 prompted decision-makers in Belize to increase their disaster preparedness activities. Climate change will probably not provide such a spectacular event to stimulate action.

# CHAPTER 6:

# ADAPTATION AND MITIGATION OPTIONS

Belize has been identified as one of those countries most vulnerable to the adverse impacts of climate change. It is therefore imperative that adaptation measures be identified for its most vulnerable sectors and that steps be undertaken for the implementation of the more viable options.

While the 1994 National Inventory of Greenhouse Gases reveals that the country is a net absorber of GHGs, Belize will not shirk from its responsibility to contribute to the global effort to mitigate emissions of these gases, and conserve and promote its sinks.

Adaptation and mitigation options identified by sector are listed below.

## Coastal Zone

| **Activity** | **Benefits** |
|---|---|
| 1. Establish setbacks for undeveloped coastal areas | Reduced incidence of property loss due to erosion and inundation |
| | Autonomous adaptation of coastline |
| | Ecosystems migrate |
| | Aesthetic value of coastal maintained |
| | |
| 2. Construct and improve seawalls | Property damage and loss reduced |
| | Shoreline of developed areas protected |
| | |
| 3. Beach nourishment | Economically important beaches protected |
| | Intrinsic character of areas and their communities maintained |
| | Shoreline protected |
| | |
| 4. Relocate vulnerable coastal communities | Vulnerability of residents reduced |
| | |
| 5. Prepare post-disaster reconstruction plans | Reconstruction on severely damaged coastal properties discouraged |
| | |
| 6. Monitor relative sea level rise and local wave climate | Data available for making informed decisions |

| | |
|---|---|
| | Reliable wave data available for prediction of sediment transport and engineering coastal structures |
| | |
| 7. Monitor shoreline | Rates of shoreline erosion or accretion measured |
| | |
| 8. Develop education and public awareness campaign | Public understand the need for adaptation measures |
| | Decision makers incorporate adaptation measures in sectoral development strategy |

**Water Resources**

| **Activity** | **Benefits** |
|---|---|
| 1. Develop a national water management system | Coordinated and sustainable use of water resources |
| | |
| 2. Obtain comprehensive knowledge of nation's water resources | Water resources used appropriately |
| | |
| 3. Prepare a national water resources plan | Usage prioritized based on availability and demand |
| | |
| 4. Promote effective and efficient use of water | Cost and waste reduced |
| | |
| 5. Develop local management and technical expertise | Management of water resources improved |
| | |
| 6. Relocate point sources of potable water in the coastal zone to points above influence of saline intrusion | Water supply safeguarded |
| | |
| 7. Encourage use of cisterns | Alternate source of water available |
| | |
| 8. Relocate waste disposal sites above influence of sea level rise | Risk of contamination of aquifers reduced |
| | |
| 9. Adopt forest management plans | Water quality and quantity improved |
| | Flood risk reduced |
| | |
| 10. Adopt agricultural practices based on availability of water | Yields increased |

| | |
|---|---|
| | |
| 11. Cooperate with neighbouring countries in the management of shared water resources | Equitable protection and use of water resources ensured |

**Agriculture and Food Security**

| Activity | Benefits |
|---|---|
| 1. Strengthen national research institutions | Crops, cultivars and farming practices suitable for new climates identified |
| | |
| 2. Relocate agricultural activity away from the coastal zone | Investments safeguarded and losses reduced |
| | |
| 3. Provide timely and reliable agroclimatological and seasonal forecasts | Increased yields and reduced losses |
| | |
| 4. Introduce changes to the traditional planting and sowing dates | Increased yields and reduced losses |
| | |
| 5. Introduce new varieties or species | Increased yields and reduced losses |
| | |
| 6. Reduce tillage | Reduced cost |
| | Soil fertility maintained and soil conserved |
| | Lower emissions of GHGs from soil |

**Land Use Change and Forestry**

| Activity | Benefits |
|---|---|
| 1. Develop a comprehensive land use policy | More efficient use of land |
| | Improved agricultural activity; reduced erosion and land abandonment |
| | Lower emissions of GHGs |
| | |
| 2. Introduce forest management plans | Increased absorption of $CO_2$ |
| | Reduced deforestation |
| | Biodiversity and water resources protected |
| | Supply of timber ensured |
| | Reduced erosion |
| | Increased revenue |
| | |
| 3. Promote agroforestry | Land used more efficiently |
| | |

| | |
|---|---|
| 4. Restore abandoned agricultural lands | Additional GHG sinks created |
| | |
| 5. Establish tree plantations | Increased GHG absorption |
| | Additional source of revenue created |
| | Alternate timber supply created |
| | Reduced pressure on natural forests |
| | |
| 6. Develop national forest fire management plan | Fewer wildfires and reduced savannah burning |
| | Reduced losses as a result of forest fires |
| | Lower GHGs emissions and enhanced sinks |
| | Wildlife protected |
| | Forest quality maintained |

**Biodiversity**

| **Activity** | **Benefits** |
|---|---|
| 1. Adopt National Protected Areas System Plan (NPASP) officially | Ecological structure and processes maintained |
| | Fragmentation and destruction of habitats reduced |
| | |
| 2. Establish and consolidate four proposed national biological corridors into the Mesoamerican Biological Corridors Project | Reduced habitat fragmentation and increased connectivity among habitat blocks |
| | Increased acreage available as a carbon sink |
| | Employment created in all six districts through sustainable development activities |
| | Watershed conserved |
| | |
| 3. Enforce the laws regulating conservation and use of biological resources in the marine and terrestrial ecosystems | Lower anthropogenic pressures |
| | Long-term survival of species ensured |
| | |
| 4. Establish and maintain protected areas | Long-term survival of species ensured |
| | Effective coverage of important species |
| | Improved land use and conservation of watershed |
| | Additional acreage made available as a carbon sink |

| | |
|---|---|
| | More sites made available for ecotourism |
| | |
| 5. Actively manage wild populations outside protected areas | Long-term survival of species ensured |
| | More attractions for ecotourism created |
| | |
| 6. Maintain captive populations (zoos, botanical gardens, arboreta, aquaria, etc.) | Species available for study and population maintained to prevent their extinction |
| | Increased tourist attraction |
| | Heightened public awareness about the importance of climate change and its impacts |
| | |
| 7. Establish germplasm storage | Guaranteed supply of indigenous species to replant in new areas replacing those impacted by climate change |
| | Species available for use (medicinal, etc.) |
| | |
| 7. Include biodiversity conservation into adaptation strategies of other sectors | Coordinated implementation of adaptation strategies |
| | Elevated level of awareness among developers of need to balance development and conservation |

**Energy**

| **Activity** | **Benefits** |
|---|---|
| 1. Develop a comprehensive national energy policy incorporating climate change | Guaranteed supply of affordable, clean, reliable energy |
| | |
| 2. Establish a multidisciplinary energy committee | Comprehensive national energy policy formulated |
| | Reliable advice on all matters related to energy available |
| | |
| **3.** Identify potential indigenous sources of energy | Reliable source of energy available |
| | |
| 4. Relocate power plants, substations and distribution lines above low lying coastal zones | Security of energy supply ensured |
| | |

| | |
|---|---|
| 5. Decentralize power production and distribution facilities | Risk spread |
| | |
| 6. Switch electrical distribution system from above ground to below ground | Fewer disruptions caused by wind storms such as hurricanes |

**Transportation**

| **Activity** | **Benefits** |
|---|---|
| 1. Ban visible emission of fumes | Reduced emissions of GHGs |
| | Improved air quality and consequently reduced health risks |
| | |
| 2. Improve infrastructure | Use of smaller fuel efficient vehicles encouraged |
| | Optimal speed for fuel efficiency promoted |
| | Reduced dust and improved air quality with reduced health risk |
| | Business promoted as communication is enhanced |
| | |
| 3. Prioritize mass transport in urban areas | Reduced emissions of GHGs as person to vehicle ratio increases |
| | Reduced congestion |
| | Reduced petroleum imports |
| | |
| 4. Ensure access to public transportation | Reduced emissions of GHGs as person to vehicle ratio increases |
| | Reduced congestion |
| | Reduced petroleum imports |
| | |
| 5. Segregate non-motorized modes of transport | Use of bicycles and bicycle paths promoted |
| | Reduced emissions of GHGs |
| | Reduced imports of petroleum products |
| | Reduced congestion |
| | Alternate mode of transport for low income families promoted |
| | |
| 6. Improve traffic control | Reduced emission of GHGs |
| | Reduced use of petroleum products |
| | Accidents reduced |
| | |
| 7. Institute formal parking controls or fees | Smoother flow of traffic |

| | |
|---|---|
| | Reduced emissions of GHGs |
| | Reduced use of petroleum products |
| | Use of vehicles discouraged |
| | Creation of parking lots resulting in creation of additional jobs in the formal economy |
| | |
| 8. Encourage importation of fuel efficient vehicles | Reduced emission of GHGs |
| | Reduced use of petroleum products |
| | Lower cost of travel |
| | |
| 9. Encourage use of four stroke outboard engines | More efficient use of fuel |
| | Lower noise level |

**Waste Management**

| **Activity** | **Benefits** |
|---|---|
| 1. Implement methane recovery at landfill | Reduced emission of GHG |
| | Alternate source of energy |
| | |
| 2. Expand sewage system in Belize City | Reduced emission of methane |
| | Decreased use of septic tanks |
| | Improved environmental health conditions |
| | Aquifers protected |
| | |
| 3. Expand sewer treatment lagoons for Belize City | Reduced threat of overflow resulting in anaerobic conditions favourable for the generation of methane |
| | Improved environmental health conditions |
| | |
| 4. Encourage residents to connect to sewer system in Belize City and San Pedro | Reduced emission of methane |
| | Decreased use of septic tanks |
| | Improved environmental health conditions |
| | Aquifers protected |
| | |
| 5. Upgrade sewage treatment system in Belmopan | Reduced emission of methane |
| | Decreased use of septic tanks |
| | Improved environmental health conditions |
| | Aquifers protected |

| | |
|---|---|
| | |
| 6. Increase effectiveness of effluent standards | Disposal of untreated effluents controlled |
| | Reduced emission of methane |
| | Environment protected |
| | |
| 7. Establish secondary treatment systems (minimum) for new residential sites | Reduced emission of methane |
| | Decreased use of septic tanks |
| | Improved environmental health conditions |
| | Aquifers protected |
| | Increased property value |
| | |
| 8. Discourage construction of new townships in coastal areas | Reduced impact on coastal zone |
| | |
| 9. Discourage construction of new residences within inland coastal plains | Water resources protected |
| | |
| 10. Create economic and commercial activities away from coastal areas | Population encouraged to move inland away from vulnerable coastal areas |
| | Fragile coastal zone protected |

**Disaster Preparedness**

| **Activity** | **Benefits** |
|---|---|
| 1. Acquire detailed topographical maps | Areas vulnerable to inundation as a result of sea level rise identified |
| | Areas vulnerable to storm surge identified |
| | Flood plain maps created |
| | Feasibility of protective structures (dykes) determined |
| | |
| 2. Establish network for monitoring sea level, tides, waves and currents | Vulnerability of coastline to erosion and inundation quantified |

**References**


Avella, Evaristo, Mitigation Measures and Adaptation to Climate Change in the Waste Sector, Wilderness Group Consultants, Final Report, Belize Climate Change Project,

Belize Audubon Society, Cross Sectoral Adaptation Assessment, Biodiversity, Final Report, Belize Climate Change Project, September 1999

Castaneda, Anselmo, Mitigation and Adaptation Assessment, Land Use Change and Forestry, Final Report, Belize Climate Change Project, September 1999

Fernandez, Mario, Mitigation Measures and Adaptation to Climate Change in the Transport Sector, Final Report, Belize Climate Change Project, September 16, 1999

Frutos, Ramon and Tzul, Francisco, Mitigation-Adaptation: Agriculture Sector, Final Report, Belize Climate Change Project, August 9, 1999

Gibson, Janet and Ariola, Eugene, Coastal Zone Adaptation to Climate Change, Coastal Zone Management Authority and Institute, Final Report, Belize Climate Change Project, September 1999

Lizaraga, Manuel Jesus, Energy Sector Report, Mitigation and Adaptation, Final Report, Belize Climate Change Project, August 15, 1999

Stevens, R. P., Disaster Preparedness and Adaptation in Response to the Effects of Climate Change, Final Report, Belize Climate Change Project, August 1999

Williams Jr., Rudolph S., Hydrology/Water Resources, Final Report, Belize Climate Change Project, September 1999