

**BELIZE COUNTRY REPORT  
SECOND NATIONAL COMMUNICATION TO THE UNFCCC**

**GREEN HOUSE GASES INVENTORY for the  
LAND USE, LAND USE CHANGE AND FORESTRY SECTOR**

**Ministry of Natural Resources and the Environment**

Oswaldo Sabido

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## ABBREVIATIONS

|                  |   |
|------------------|---|
| kt               | kilotonnes  |
| kha              | kilohectares (1000 hectares)                              |
| dm               | dry matter  |
| ha               | hectare   |
| has.             | hectares  |
| t                | tonnes  |
| CO <sub>2</sub>  | carbon dioxide  |
| m <sup>3</sup>   | cubic meter   |
| CH <sub>4</sub>  | methane   |
| N <sub>2</sub> O | nitrous oxide   |
| Nox              | nitrogen oxide  |
| CO               | carbon monoxide   |
| Gg               | Gigagrammes   |
| MAFC             | Ministry of Agriculture, Fisheries and Cooperatives       |
| IPCC             | Inter-government Panel on Climate Change                  |
| GHGI             | Green House Gas Inventory                                 |
| GHG              | Green House Gas   |
| LULUCF           | Land Use, Land Use Change and Forestry                    |
| FAO              | Food and Agriculture Organization (of the United Nations) |

## **BACKGROUND**

Belize signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. The ultimate objective of the UNFCCC is to stabilize the concentration of greenhouse gases in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. As part of its obligations under the convention, contracting Parties are required to conduct periodic GHG Inventories for submission to the Secretariat. The first GHG Inventory was conducted in 1998 using 1994 as the base year and the Second Inventory currently underway will use the years 1997 and 2000 as the second reporting years to establish a trend.

The GHGI requires that information be accessed from five major economic sectors that impact GHG balances. This includes the Land Use, Land Use Change and Forestry (LULUCF) Sector which in 1994 accounted for 68% of total national GHGI emissions

### **1.0 INTRODUCTION**

The Ministry of Natural Resources and the Environment (MNRE) established a Project Execution Group (PEG), and a Project Management Office (PMO) to oversee the preparation of the Second National Communication. The PMO and the PEG were established in 2006, and operate out of offices located at the CARIBBEAN COMMUNITY CLIMATE CHANGE CENTRE, Lawrence Nicholas Building, in Belmopan.

The National Meteorological Services, (Focal Point for the UNFCCC), supervises activities related to the preparation of Belize's Second National Communication, through technical and administrative support of the PMO.

### **2.0 OBJECTIVES OF CONSULTANCY**

The objectives of the consultancy as outlined in the contract document are:

- a. To Conduct a green house gas inventory of emissions and removals within the LULUCF sector for the reference years 1997 and 2000.

- b. To Re-calculate the emissions and removals within the LULUCF sector that were reported for the 1994 reference year.
- c. Prepare a draft report utilizing the guidelines and formats established by the IPCC.
- d. Submit the draft report to consultations and review as required before submitting the final draft which shall be subject to public consultation.

### **3.0 METHODOLOGY**

The methodology utilized in determining trends in emissions of green house gases originating from anthropogenic changes in land use and changes in forest biomass stocks since 1994 is guided by the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories. These guidelines provide a comprehensive stepwise approach to conducting a national GHGI in three volumes. The Reporting Instructions (Volume 1) provides step by step directions for assembling, documenting and transmitting completed national inventory data consistently. The *Workbook* (Volume 2) contains suggestions about planning and getting started on a national inventory for participants who do not have a national inventory available already and are not experienced in producing such inventories. It also contains step-by-step instructions for calculating emissions of carbon dioxide (CO<sub>2</sub>) methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), halocarbons (HFCs, PFCs), sulphur hexafluoride (SF<sub>6</sub>), ozone and aerosol precursors, from six major emission source categories.

The *Reference Manual* (Volume 3) provides a compendium of information on methods for estimation of emissions for a broader range of greenhouse gases and a complete list of source types for each. It summarizes a range of possible methods for many source types. It also provides summaries of the scientific basis for the inventory methods recommended and gives extensive references to the technical literature. It is intended to help participants at all levels of experience to understand the processes which cause greenhouse gas emissions and removals to occur and the estimation methods used in compiling inventories.

As a Non-Annex 1 country Belize has selected 1997 and 2000 as the subsequent reporting years following the 1994 baseline year. The IPCC inventory methodology is divided into various levels or tiers. Generally, the higher the number designating the tier, the more detailed is the methodology and the more accurate are the emission estimates. Tier 1 represents the minimum, or default, methodology. If sufficient data are available, a Party can also try to apply a higher tier. Tiers 2 or 3 involve more elaborate methods which could be either source category-specific or technology based. These methods require more detailed data and/or measurements for their application.

As was the case in the first GHGI carried out in 1999, the default values for GHG emission provided by the IPCC in *The Workbook* and *The Reference Manual* have been utilized in the absence of national or regional values. The methodology presently utilized in this inventory attempts to utilize a three year average value for the pertinent national statistics which places the reporting year in the middle provided that the data for those years is available or logical. However where there are data gaps or where data is questionable, data from only one or two available years are utilized or in a few cases data has had to be extrapolated to provide some sort of trend analysis.

In many instances data from several sources had to be compared and even interpolated to provide a specific value that was in the deliberation of the consulting team and experts interviewed a realistic representation of the value required.

It should also be noted that a major difference in analysis methodology between the first national GHGI and the present one is the use of more recent software for recording and calculating electronically the worksheets that accompany *The Workbook*.

### **3.1 Changes in Forests and Other Woody Biomass Stocks**

Land use and land-use change directly affect the exchange of greenhouse gases between terrestrial ecosystems and the atmosphere. Changes such as the clearing of forests for use in agriculture or as settlements are clearly associated with changes in land cover and carbon stocks. This sub module deals with the emissions or removals of

carbon (and carbon dioxide) due to changes in forest and other woody biomass stocks affected by human activity. The first step is to estimate the total carbon content in annual growth of logged and planted forests.

### **3.1.1 Area of Plantations**

Data for forest plantations was obtained for the most part from previous Forest Department reports and from private forest plantation owners. The total area of forest plantations have decreased since 1994 due mostly to changes in land use and land tenure of FD plantation stock planted during the period 1948 to 1981 and affecting principally, *Gmelina arborea*, *Tectona grandis*, *Pinus caribbaea*, and *Swietenia macrophylla*.

However, there has been a small offset due to the recent planting of small privately owned plantations of mostly teak (*Tectona grandis*) and Mahogany (*Swietenia macrophylla*). It should be noted here that the consulting team regard FAO estimates for annual increases in forest plantations of 100 ha per year as being somewhat optimistic.

### **3.1.2 Area of Intervened Natural Forests**

The IPCC *Reference Manual* recommends the exclusion from carbon flux calculations of natural, undisturbed forests, where they still exist and are in equilibrium, as they should not be considered either an anthropogenic source or sink. The emphasis therefore is to identify any forest which experiences periodic or ongoing human interventions that affect carbon stocks, such as logged forests. Since most forests in Belize with the exception of very steep or inaccessible areas have been logged in the past 200 years, Castañeda and Santos (1999) made a valiant first attempt in the 1<sup>st</sup> National GHGI to estimate the actual area of forest impacted by logging over the 40 year period prior to 1993 based on the relationship between timber volume production and the estimated average number of trees per hectare which were removed in traditional logging operations. The area that was estimated for logged mixed hardwood forest over the period 1954 to 1994 is 137,831 has. However since this estimated value

is based on volumes of timber removed, it does not address the prevailing practice of repeated logging of the same area more than once in the 40 year period covered by the logging production data. In addition there is the impact of hurricanes non-anthropogenic phenomena on most forest areas in Belize, which has resulted in more intense logging operations over large forest areas in an attempt to salvage wind damaged timber. These salvage operations can go on for up to five years or more in hurricane impacted forests depending on the intensity of the storm.

Furthermore while initial logging off take was limited to two or three high value species, a greater number of “secondary hardwood species” were utilized with the establishment of in-country sawmills and a ban on the export of logs in the 1970’s. It is also safe to assume that especially on the better soils but also on the marginal soils that require more intense management the conversion from forest to agriculture or urban settlements, post logging, was completed if not immediately, then several years thereafter, and more than likely after several logging interventions. This pattern of land use conversion is more appreciable in the north and central Belize and where higher rates of deforestation than was previously estimated have been reported. The increasing trend in the last 20 years to convert more areas of previously logged forest including forest reserves to non-extractive protected areas would appear to reduce the timber producing portion of the national forest estate. The Rio Bravo Conservation and Management Area (RBCMA) is the most prominent example in the north where areas that were logged for over a century have been for a large part placed under non-extractive protection. Another example in the South of Belize is the Cockscomb Basin Wildlife Sanctuary, previously the Cockscomb Basin Forest Reserve and a portion of the Maya Mountain Forest Reserve, both areas with a long successive logging history.

While it is accepted that the area of logging impacted forest subject to faster juvenile growth of natural regeneration in Belize is larger than just the annual extent of forest areas directly impacted by the removal of forest biomass stocks, the assumption made by Castañeda and Santos (1999) of a national area equivalent to 40 years of logging may possess too many uncertainties. The total broadleaf area harvested for timber

during the period 1954 to 1993 as estimated by Castañeda and Santos is 255,471 has and for pine 259,800 has. giving a total of 515,271 has. which is more than the total area of 321,440 has. estimated for sustainable logging (both pine and hardwoods) in Belize i. e. 14% of the total land area.

For the purposes of this section, two criteria seem to be important in determining the area of post logged forest that is accumulating carbon. One is that the logged area has remained under forest cover and two, that the growth rate of the logging impacted/managed forest is still appreciable within a carbon assimilation context. This study therefore proposes that a more realistic time frame to estimate the area of logged forest based on available timber production figures as estimated in the 1<sup>st</sup> National GHGI is 20 years since there is greater certainty of rapid growth of natural regeneration. A second **assumption** is made that the areas where one would expect for the process of natural forest succession to continue occurring post logging or other forestry interventions would in the future be limited to the 14% of our land area that is suitable for sustained timber. If we assume that the longest cutting cycle that will be applied to these forests is 40 years, then the total area logged in the 20 years prior to 1994, 1997, and 2000 is  $(321,440/40)*20$ , which is equivalent to 160,720 has. This latter figure needs to be divided into broadleaf and pine values. LIC (1994) estimates the combined total area of closed pine and open pine as 64, 932 has. This is rounded off to **65,000** has. Harvesting intensities have been greater and the cutting cycles shorter in these forests than in the broadleaf forests and the history of exploitation has started later than in the broadleaf forests. Therefore it is assumed that all of the pine forest in Belize has been intervened for logging in the past 20 years. The area of broadleaf forest that has been subject to logging and is regenerating during the past 20 years is therefore estimated at 95,788 has. This is rounded off to **96,000** has. These values are used for the three reporting years.

As has been pointed out in the previous LULUCF sector GHGI, the above indirect derivation of areas of logged/managed forest prior to the reporting years, involves

assumptions with considerable margins of error. However, it is an important area that warrants further more focused research and analysis.

### **3.1.3 Non- forest trees**

Estimates of woody biomass also include trees which are grown or exist in a non-forest environment. In this context it includes the planting of mostly fruit or shade/ornamental trees mostly in rural village lots or homesteads as well as agro-silvo-pastoral practices that allow for the planting or retention of trees. The methodology utilized in the 1994 inventory to estimate the number of non-forest trees i.e. 5 trees per household multiplied by the number of households in 1997 and 2000. The same values for number of trees as was used on the original 1994 GHGI are used in the re-worked WORKSHEET (See WORKSHEET 5-1s1).

### **3.1.4 Annual Growth rates**

Default values are utilized for Eucalyptus, Teak, and Caribbean Pine. The default for tropical mixed hardwood plantations have been applied to logged mixed natural hardwood forest and to mahogany plantations. The default for Acacia has been used for Gmelina i.e. 15, another fast growing tropical species. The value (6) for logged natural pine forest has been derived from local data. The annual growth rate of ornamental and fruit trees is based on the default value for mixed fast growing tropical hardwood plantations.

If we assume that trees in the hypothetical hardwood plantations are planted 4m x 4m then the density is 625 trees/ha and if the default value for annual accumulation of dry biomass is estimated at 12.5 t dm/yr. then annual dry matter accumulation per tree is estimated at 0.02 t dm/ha/yr which is equivalent to 0.02 kt dm/1000 trees/yr as is used in the WORKSHEET 5-1s2. Note that this last value differs from that originally used for the 1994 reporting year GHGI.

### **3.1.5 Carbon Fraction**

The default value of 0.5 is used throughout to convert dry biomass to carbon content.

### 3.1.6 Commercial Harvest

The following table provides the total timber production provided by the Forest Department (2006). Values for 1996 are missing or considered unreliable. An average of the five years for which data is available is used to estimate total timber production for hardwoods and pine for 1996.

**Table 1: Total Roundwood Production**

| <b>TYPE OF LICENSE</b> | <b>YEAR</b>     | <b>HARDWOOD (m<sup>3</sup>)</b> | <b>ADJUSTED VALUES (m3)</b> | <b>PINE (m3)</b> | <b>ADJUSTED VALUES (m3)</b> |
|------------------------|-----------------|---------------------------------|-----------------------------|------------------|-----------------------------|
| FOREST LICENSES        | 1996            | 7,167.6                         |                             | 6,398.3          |                             |
|                        | 1997            | 8,068.7                         |                             | 4,702.4          |                             |
|                        | 1998            | 9,952.1                         |                             | 3,150.3          |                             |
|                        | <b>SUBTOTAL</b> | <b>25,188.4</b>                 |                             | <b>14,251.1</b>  |                             |
| PRIVATE FOREST LICENSE | 1996            | 10,767.0                        |                             | 465.5            |                             |
|                        | 1997            | 5,996.9                         |                             | 34.6             |                             |
|                        | 1998            | 6,355.2                         |                             | 0.0              |                             |
|                        | <b>SUBTOTAL</b> | <b>23,119.1</b>                 |                             | <b>500.2</b>     |                             |
| SALVAGE PERMITS        | 1996            | 1,602.0                         |                             |                  |                             |
|                        | 1997            | 460.9                           |                             |                  |                             |
|                        | 1998            | 1,989.2                         |                             |                  |                             |
|                        | <b>SUBTOTAL</b> | <b>4,052.1</b>                  |                             |                  |                             |
| ALL LICENSES           | <b>TOTAL</b>    | <b>52,359.6</b>                 |                             | <b>14,751.2</b>  |                             |
|                        | <b>AVERAGE</b>  | <b>17,453.2</b>                 | <b>38,781.0</b>             | <b>4,917.1</b>   | <b>10,925.7</b>             |
|                        |                 |                                 |                             |                  |                             |

|                        |                 |                 |                 |                 |                 |
|------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| FOREST LICENSES        | 1999            | 14,249.8        |                 | 6,174.6         |                 |
|                        | 2000            | 3,567.9         |                 | 8,808.7         |                 |
|                        | 2001            | 5,568.1         |                 | 9,155.5         |                 |
|                        | <b>SUBTOTAL</b> | <b>23,385.8</b> |                 | <b>24,138.9</b> |                 |
| PRIVATE FOREST PERMITS | 1999            | 16,395.9        |                 | 1,921.8         |                 |
|                        | 2000            | 7,247.0         |                 | 18.8            |                 |
|                        | 2001            | 17,840.0        |                 | 352.5           |                 |
|                        | <b>SUBTOTAL</b> | <b>41,483.0</b> |                 | <b>2,293.1</b>  |                 |
| SALVAGE PERMITS        | 1999            | 2,071.5         |                 |                 |                 |
|                        | 2000            | 1,778.6         |                 |                 |                 |
|                        | 2001            | 1,575.1         |                 |                 |                 |
|                        | <b>SUBTOTAL</b> | <b>5,425.1</b>  |                 |                 |                 |
| ALL LICENSES           | <b>TOTAL</b>    | <b>70,293.9</b> |                 | <b>26,432.0</b> |                 |
|                        | <b>AVERAGE</b>  | <b>23,431.3</b> | <b>46,862.6</b> | <b>8,810.7</b>  | <b>17,621.3</b> |

Castañeda and Santos (1999) report in the 1<sup>st</sup> GHGI, that Forest Department volume production figures may represent only 37% of the true total according to Howell (1994).

However while Howell's assumption may be valid for mahogany timber production in the years prior to mahogany being placed on CITES Appendix I, Cho (personal communication 2007) feels that the under-reporting situation has improved considerably since 2000. Nevertheless, there is agreement on Forest Department volume production figures representing an estimated 40%, 45%, and 50% respectively of true total timber volume production figures for 1994, 1997, and 2000. Therefore if the three year average for mixed hardwoods of 17,453.2 m<sup>3</sup> is adjusted accordingly, this figure is bumped up to an estimated 38,781 m<sup>3</sup> for 1997. The area of pine forest logged in 1997 is obtained based on a three year average volume of 4,917 m<sup>3</sup> which gives a value of 10,925.7 m<sup>3</sup>

when the “adjustment factor” is applied. The value of 61,000 m<sup>3</sup> as reported by Castañeda and Santos is used for 1994.

### **3.1.7 Biomass Conversion /Expansion Ratio**

Since values for commercial harvest of forest biomass tend to reflect the volume of that part of the tree or wood that will be utilized or transformed into a wood product, there are two adjustments that must be made. Convert volume (m<sup>3</sup>) to weight (dry matter) expressed in tonnes. Since only the commercial biomass is normally reported, an expansion factor must be used to account for the non-commercial portion of biomass (stumps, limbs, tree tops, small trees) harvested with the commercial biomass and left to decay. The combined default conversion/expansion ratio for logged forest of 0.95 is utilized in the WORKSHEET 5-1S2

### **3.1.8 Total Fuel Wood Consumed**

The value for fuel wood consumption is based on FAO estimates for Central America (1.127 m<sup>3</sup> per capita) multiplied by CSO population estimates for 1994, 1997, and 2000. It is assumed that all fuel wood is cut from the standing forest.

### **3.1.9 Other Wood Use**

Pine poles used for telegraph poles and pilings are part of other wood use as well as round timber used for scaffolding, the construction of rural houses using round timber frames and thatch. The original 1994 value of 0.8 kt is used in the reworked 1994 work sheet. This value is increased in 1997 and 2000 to reflect increases in the rural population and the increasing use of round timber poles for construction of cabanas and palapas in the tourism sector. However, it does not include the production of power poles and pilings as was reported for 1994.

It is evident from WORKSHEET 5-1s3 that there is a net uptake of carbon as a result of changes in forests and other woody biomass stocks.

## **3.2 CO<sub>2</sub> Emissions from Forest and Grassland Conversion**

This sub module reports on net flux of CO<sub>2</sub> in the biosphere as a result of the conversion of forests and grassland to permanent cropland or pasture. This conversion is normally accompanied in the tropics by burning biomass on site or as fuel wood.

It is to be noted that while anthropogenic grassland fires not related to agricultural practices is a major source of emissions in Belize since about 50% of grassland areas including pine savannahs are burnt each year in Belize, there does not appear to be any hard data for calculating this type of emission in the LULUCF sector

### **3.2.1 Area Converted Annually**

Unfortunately there are no reliable systematic **annual institutionalized** data for changes in forest and grassland cover for Belize. Therefore one of the major challenges of this study has been to estimate a realistic value for forest and grassland conversion not only for 1997 and 2000 but also for the 20 years prior to the reporting year. Statistical data is sometimes inconsistent. For example The TFAP (1989) report for Belize reports that estimates for forest cover by Lanly (1981) and those of Hartshorn (1984) both based on the 1978 terminal report of the FAO project BZE/75/008 present significant (5,650 kms<sup>2</sup>) differences. In addition there appear to be inconsistencies in the criteria used to define “forest cover” as compared to natural vegetation cover. These inconsistencies become even more pronounced when applying the accepted IPCC parameters for what is defined as “forest cover”. Unfortunately there are no reliable systematic annual data for changes in forest and grassland cover for Belize, although up to 1987, fairly diligent and consistent agricultural statistics provide an indication of forest cover change. However, Eck (2004) in his Masters Thesis points out to underreporting discrepancies when comparing agricultural statistics to digital estimates of crop cover.

This is further confirmed by Meerman and Cherrington (2005) in their study of land degradation in Belize.

Furthermore while changes in the extent of areas cultivated can be used as to indirectly estimate deforestation rates, the impact of the expansion of urban areas and settlements on forest and grassland conversion has been noticeably increasing in recent years. Most land use conversion studies have traditionally focused on the mainland forest cover.

Since 1989 access (if at times difficult or limited ) to satellite imagery has facilitated the more recent land use/land cover studies at the national level, as well as the more commonly accepted trend analyses. Perhaps the most comprehensive if not definitive study post 1990 is Belize' first national land use study, Fairweather and Gray (1994), which is based on imagery ranging from 1989 to 1992. The data from this study published by the LIC is presented below.

**Table 2 Land Use and Forest Cover: 1989-1992**

| <b>Land/Forest Cover Type</b>                               | <b>Area<br/>(Kms<sup>2</sup>)</b> | <b>Area<br/>(has.)</b> |
|---|-----------------------------------|------------------------|
| Total land area   | 22,960                            | 2296000                |
| Total national territory including coastal waters (sq. km.) | 46,620                            | 4662000                |
| Land area used for agricultural purposes (sq. km.)          | 6,880                             | 688000                 |
| Urban population as percentage of total population          | 51%                               |                        |
|   |                                   |                        |
| <b>Forest Cover</b>   |                                   |                        |
| Area under Forest use (sq. km)                              |                                   |                        |
| Broad leaf forest   | 14,190                            | 1419000                |
| Open broad leaf forest                                      | 120.31                            | 12031                  |
| Pine forest   | 576.25                            | 57625                  |
| Open pine forest  | 73.07                             | 7307                   |
| Thicket and other degenerated broad leaf forest             | 848.38                            | 84838                  |
| Herbaceous and scrub, secondary after clearing              | 188.59                            | 18859                  |
| Bamboo and riparian vegetation                              | 115.27                            | 11527                  |
| Coastal strand vegetation                                   | 24.83                             | 2483                   |
| Mangrove, medium and tall                                   | 78.2                              | 7820                   |
| Mangrove, dwarf   | 234.6                             | 23460                  |

|   |        |           |
|---|--------|-----------|
| Saline swamp, vegetation with palmetto and mangrove | 344.87 | 34487     |
| Marsh   | 419.63 | 41963     |
| Total Natural Vegetation Cover                      | 17,214 | 1,721,400 |

Source: LIC 1994

The other milestone in forest cover analysis is provided by Meerman and Sabido in their ecosystem map of Belize, even though as is to be expected there is more emphasis on identifying ecosystems types.

**Table 3 Major Ecosystems**

| Land Cover Description<br>(2000)  | Area (Ha)           | % of total     |
|-----------------------------------|---------------------|----------------|
| Broadleaf Forests                 | 1 328 447.55        | 61.01          |
| Pine Forests                      | 166 410.98          | 7.64           |
| Herbaceous and scrub              | 1 912.70            | 0.09           |
| Bamboo and riparian<br>vegetation | 7 990.86            | 0.37           |
| Rangeland(Savannah)               | 106 392.00          | 4.89           |
| Coastal strand vegetation         | 549.95              | 0.03           |
| Mangrove                          | 64 848.79           | 2.98           |
| Marsh                             | 61 828.40           | 2,84           |
| Saline swamp                      | 21 792.81           | 1              |
| Urban areas                       | 9 361.94            | 0.43           |
| Agricultural land                 | 367 472.81          | 16.88          |
| Water bodies                      | 40 461.42           | 1.86           |
| <b>TOTAL</b>                      | <b>2 177 470.60</b> | <b>100.00%</b> |

Source: Meerman and Sabido, (2001)

Other studies of note carried out at a sub-national scale include the 1998 remote sensing analysis of land cover and land use in Central Belize by White et al (1998). In this project funded by the UNDP, 1996 satellite imagery was used to interpret and

classify an area in central Belize utilizing digital statistical methods applied to Landsat Thematic Mapper data. Farmland accounted for 6.3 % of the study area. Difiore (2002) as part of her Master's thesis carried out a study in 2001 to classify land cover change over an 11 year period in a corridor 2.07 kms. wide on both sides of the Belize River beginning with its major tributaries, the Macal and Mopan Rivers and terminating at its point of discharge into the Caribbean Sea. Two sets of satellite imagery acquired 11 years apart were classified. These include Landsat 7 Thematic Mapper image acquired March 2001 and Landsat 5 Thematic Mapper image acquired December 1989. It is to be noted that in these sub national studies, considerable ground truthing was carried out. .

Information on the rate of forest cover change in Belize is somewhat conflicting even though there is considerable literature which attempts to provide an analysis of land use issues which are inherently linked to deforestation.

FAO originally reported countrywide deforestation estimates for Belize at 0.2% per year during the 1980's, well below the Central American average of 1.5% per year. However more recent studies show that while deforestation rates for Central America remained at about 1.2% per year from 1990 to 2000, in the case of Belize there was an alarming increase according to FAO to 2.3% per year during the same period (FAO 2001). Difiore (2002) estimates for her area of study a deforestation rate of 2% per year. Sader et al (2001) in a study using high resolution multi-temporal satellite image concluded that forest cover changes in part of the Mesoamerican Biological Corridors in Belize during the 1990's was a more conservative -0. 6%. The table below provides a comparison of rates of deforestation for Belize from different sources.

**Table 4 Comparison of Deforestation Rates from Different Sources**

| <b>Date Ground Condition</b> | <b>Reporting Period</b> | <b>Source</b> | <b>Deforestation/ settlements (has.)</b> | <b>Aquaculture has.</b> | <b>Total Land Cover Conversion</b> | <b>Change/yr (has.)</b> | <b>Percent Change</b> |
|------------------------------|-------------------------|---------------|--|-------------------------|------------------------------------|-------------------------|-----------------------|
|                              |                         |               |  |                         |                                    |                         |                       |

|                               |                 |   |           |         |           |           |       |
|-------------------------------|-----------------|---|-----------|---------|-----------|-----------|-------|
| Non imagery                   | 1984-1994       | MAFC  | 35,051.0  | 3,500.7 | 38,551.7  | 3,855.2   | 0.2*  |
|                               | 1989/92 to 1994 | As reported by FAO (2000) based on White et al (1996) | 78,076.0  |         | 78,076.0  | 24,991.9  | 1.5   |
| SPOT 1989, 1990, 1992         | up to 1992      | As reported by Cherrington & Meerman, 2005            | 225,506.1 | 252.6   | 225,758.7 |           |       |
| Landsat Jan - Feb 2004        | 1992 to 2004    | As reported by Cherrington & Meerman, 2005            | 214,980.0 | 4,201.0 | 219,181.0 | 18,265.1  | 1.1   |
| Landsat 1993, 1996, 1998      | 1992 to 1998    | Meerman & Sabido                                      |           |         |           |           |       |
| Landsat 1996-1998, 1999-2000  | 1992 to 2000    | As reported by Forest Department, 2007                | 161,563.9 | 2,800.5 | 164,364.5 | 20,545.6  | 1.2   |
| Landsat 1996-1998, 1999-2000  | 1997 -2000      | From FD, 2007   | 68,421.0  | 1,050.2 | 69,471.2  | 23,157.1  | 1.3   |
| Landsat Dec. 1989, March 2001 | 1989 - 2001     | Di Fiore, 2002  |           |         |           | 34,428.0  | 2.0   |
|                               | 1990 to 2000    | From FAO FRA 2000                                     | 356177    |         | 356177    | 35,617.70 | 2.1** |

\*Calculated based on 1984 estimates of forest cover

\*\* Calculated based on 1990 estimates of forest cover

In the 1<sup>st</sup> draft of this GHGI report for the LULUCF sector it was decided to use the FAO rate of 2.3 % (35,625 has/year) which is based on a straight line extrapolation in order to provide consistency in extrapolating data, This value was used for both 1997 and 2000. However, after invaluable discussion and review by remote sensing analysis and GIS experts during the workshop for the national validation of the GHGI reports (April, 2007), deforestation rates, and sources for their estimation were re-examined. A review of the above table leads to the conclusion that the FAO linear extrapolation of 2.3% may

be too simplistic for a trend analysis and is not validated by the estimates of deforestation derived from various analyses of remote sensing imagery.

The re-worked value for 1994 forest and grassland conversion is 18,265 has. (-1.1%). The previous estimate used in the 1<sup>st</sup> GHGI was based on estimates of changes in the extent of agricultural crops alone and is obviously underreporting total forest and grassland conversion. The estimated rate of forest and grassland conversion for 1997 is 23,157 has. (-1.3%) and for the year 2000, the estimated rate of conversion is 34,428 has. (-2%) These values are reflected in WORKSHEET 5-2s1 for the respective years.

### **3.2.2 Biomass Before and After Conversion**

One of the significant differences in the reworking of the 1994 GHGI data is that the vegetation type for Belize is reclassified from “Wet/Very Moist” to “Moist with short dry season”.

Biomass values for before conversion are FAO values (211 t dm/ha.) based on a regional study to determine forest biomass loadings per unit area as there are no default values provided for the forest category currently being used for Belize, i.e. moist with short dry season. Default values for biomass after conversion should be higher in the case of citrus, bananas, and sugar cane. However, no national data exists for these crops. Therefore the default value of 10 t dm/ha is used. WORKSHEET 5-2s1 refers.

### **3.2.3 Fractions of Biomass Burnt On-site and Off-site**

In the process of clearing forest cover, not all the slash or debris from the cutting down of trees and other vegetation is completely burnt. Some of the woody material remains on site where it is subject to burning while a portion is removed off-site. Part of this woody material is removed as firewood, and increasingly so in areas where high forest exist, the commercial part of timber trees are removed. IPCC figures suggest that globally about 45% of biomass is burnt on-site after a forest is cleared, 5% is burnt off site, and 50% is left to decay. However, this global approximation does not appear to take into consideration the increasing salvage of roundwood for forest industries in

forest areas being converted to other land uses. Increasing land clearing cost has prompted land owners and contractors in Belize to salvage as much of the economic value of utilizable timber in areas where high forests remain. The proliferation of chain saw logging has also changed milpa practices in the Toledo District where most of the utilizable timber is now being harvested before the slash is burnt. 15 years ago most of this timber was allowed to burn or decay in the newly cleared milpa. In the absence of national data for Belize, and for the purposes of this report, it is estimated that 80% of biomass is burnt on site and 15% is burnt off site and 5% is left to decay. However, the amount of timber removed from salvage areas are already accounted for in WORKSHEET 5-1s2. The IPCC estimates that 90% of the material on-site and off-site that is burnt completely oxidises and immediately releases carbon. However a portion of the biomass (10%) resists complete burning and is converted to charcoal which resists decay for almost 100 years. WORKSHEET 5-2s2 and 5-2s3 refers.

### 3.2.4 Average Area Converted

The 10 year average for the three reporting years is calculated based on the annual average of the difference between 1994 and 1984 multiplied by the corresponding difference in years as is summarized in the following table. This value is estimated in the absence of hard data for the years under review and assumes that the rate of deforestation increases with each year. WORKSHEET 5-2s4 refers

**Table 5 Estimates of 10 year average**

| <b>YEAR</b> | <b>LAND CONVERTED<br/>(has.)</b> |
|-------------|----------------------------------|
| 1984        | 3,855                            |
| 1987        | 8,178                            |
| 1990        | 12,501                           |
| 1994        | 18,265                           |
| 1997        | 23,157                           |
| 2000        | 34,428                           |

WORKSHEET 5-2s5 provides a summary of total annual carbon release from clearing over the 10 year period previous to the inventory year. This value is further converted to gigagrams of CO<sup>2</sup>.

### **3.3 Emissions of Non CO<sup>2</sup> Trace Gases**

Trace gases, methane (CH<sub>4</sub>), carbon monoxide (CO), nitrous oxide (N<sub>2</sub>O) and nitrogen oxide (NO<sub>x</sub>) are emitted from the complete oxidation of biomass (IPCC, 1996). The proportion of oxidized biomass from on-site burning is used in this estimation by utilizing IPCC default values. WORKSHEET 5-3s1 refers.

### **3.4 Abandonment of Managed Lands**

This section attempts to estimate net-CO<sub>2</sub> removals in biomass accumulation resulting from the abandonment of *managed* lands. Only the carbon accumulation in biomass is considered as soil carbon changes are dealt with in another section. Managed lands include:

- Cultivated lands (arable land used for the cultivation of crops)
- Pasture (land used for grazing animals)

Abandoned lands are placed in two time frame categories:

- Lands abandoned during the 20 years prior to the inventory, which would be 1977 and 1980 respectively for the present GHGI.
- Land abandoned between 20 to 100 years prior to the inventory years.

In Belize, carbon removal as part of forest succession and abandonment of previously managed land is difficult to estimate as no detailed systematic inventory of this type of land cover was carried out in the past at a national scale. It is only in the last 17 years or so that periodic estimates based on satellite imagery have been attempted. Therefore it was impossible to obtain any hard data on land that had been cultivated and abandoned between 1974 and 1994, 1977 and 1997 and 1980 and 2000. However, the estimates utilized by Castañeda and Santos (1999) in the first national GHGI for the 1994 reporting year and the discussion on the causes and effects of macro changes in major agricultural activities such as the livestock

industry, the dynamics of milpa agriculture influenced by immigration patterns from our Central American neighbors, are considered relevant as a point of reference even though the hard data is confined to the Rio Bravo Conservation and Management Area. Nevertheless, for the purposes of this inventory, it is believed that the total area covered by the (low activity) soil types on abandoned lands gives a gross indication at the national scale of land that was previously under an active agriculture land use system and then abandoned to revert to secondary forest. These values are summarized in the table below:

**Table 6 Abandoned Lands**

| <b>YEAR</b> | <b>AREA<br/>(has)</b> |
|-------------|-----------------------|
| 1974        | 10,000                |
| 1994        | 15,000                |
| 1977        | 13,700                |
| 1997        | 6,945                 |
| 1980        | 11,500                |
| 2000        | 7,712                 |

Default values are utilized for annual rate of biomass growth on abandoned lands for the American seasonal tropical forest. WORKSHEET 5-4s1 refers.

The lack of any reference or starting point for lands abandoned between 1977 and 1897 did not permit any estimation for this category of abandoned land. There is concurrence with the general assumption made in 1999 that any land cultivated at that time now lies within the national agricultural estate. This is supported by historical demographic/settlement patterns as well as a prevalent early colonial development policy which did not promote agriculture until the mid to late 1950's. WORKSHEET 5-4s2 refers.

### **3.5 CO<sub>2</sub> Emissions or Uptake by Soil from Land-Use Change and Management**

In this sub-module, net CO<sub>2</sub> emissions (sinks and sources) from three processes are estimated:

- 1) Changes in carbon stored in soil and litter of mineral soils due to changes in land-use practices,
- 2) CO<sub>2</sub> emissions from organic soils converted to agriculture or plantation forestry, and
- 3) CO<sub>2</sub> emissions from liming of agricultural soils.

At present, CO<sub>2</sub> emissions or uptake associated with naturally occurring carbonate minerals in soils are not included.

Eight land use management systems are identified for use in the inventory following the default definitions provided in *The Workbook*. Seven are agriculturally impacted. Acreages for pastures were obtained indirectly. The acreage for the other six Land-use Management systems impacted by agriculture was obtained using satellite imagery and agricultural statistics from the MAFC, agro-industry and agricultural producers.

#### **3.5.1 Land Use Management Systems**

The land use management systems utilized represent the major types of land management systems present in Belize as well as the ecosystem types (e.g. forest or savannah) which are being converted to agriculture or have been derived from previous agriculture land use (e.g. abandoned lands ). To a large extent the systems used in this inventory approximate those utilized in the tropical moist with long and short dry season geo-ecological regions. The land use management systems are described by Santos and Castañeda (1999) as follows:

##### **3.5.1.1 Forest /Woodland**

High Activity Soil: The natural vegetation for the Class I and II soils consists of high mixed hardwood forest. The area covered by these soils consists of the total of these

two soil classes minus the areas impacted by agriculture, on high activity soil types which are predominantly sugar cane and irrigated rice.

**Low Activity Soils:** The natural vegetation on low activity soils varies from high mixed hardwood forest which predominates to through various forms of thickets and scrubs according to soil moisture conditions and the degree of transition with the sandy Puletan soil series. They also include the upland pine formations the area is derived from the total ascribed to Class III and IV soils less that included in the High Activity, Sandy, Acquic, and Low Activity Soils impacted by agriculture and including abandoned agricultural lands.

**Sandy soils:** The natural vegetation on the Sandy Soils of the Puletan Series and Caye Sands consist of savannahs including pine savannahs, low scrubs, and grasslands, all subject to frequent burning. It is extensive enough to be considered as a separate management system, but the essential soil quality – very low soil carbon content is addressed by the default value and it is therefore lumped with forest/woodland despite its characteristic physiognomy. The area classified as forest/woodland comprises the total for the two soil series minus that impacted by agriculture. The small areas devoted to aquaculture are ignored.

**Acquic (Wetland):** The natural vegetation of the Peaty Swamps and Mucks range from open swamp forests and swamp thickets to open herbaceous swamps. In 1994 only a very small area of wetland rice was impacting on this soil type.

#### **3.5.1.2 Perennial Plantations**

Perennial plantations include cacao, mango, banana, citrus and sugarcane; sugarcane is herein treated as a perennial since it is an agronomic crop with cropping cycles of up to 15-20 years in Northern Belize. All the sugar cane acreage is classified as high activity soils as it is grown on the Vertisols soils in Northern Belize. All mango plantations are planted in sandy soils. In 1974, citrus was not planted in sandy soils but in 1994, the expansion in citrus groves had spread to sandy soils using higher inputs

and levels of management. Not that the acreage of perennial plantations on sandy soils has been modified from the acreage previously reported in the 1999 GHGI for the 1994 reporting year. On the advice of the Citrus Growers Association's Extension Officer, the acreage of citrus on low activity soils has been reduced by 10% and added to the acreage under sandy soils. It is also noted that the acreage of forests on sandy soils has increased in 1997.

### **3.5.1.3 Pasture**

For 1994, total pasture reported by the MAFC was divided into improved and unimproved on a 20:80 ratio approximately based on estimates provided by local experts. All improved pasture is attributed to Low Activity soil. A portion of unimproved pasture is found on Sandy Soils. Data under unimproved and improved pasture" was developed using the number of head of dairy and beef cattle and multiplied it by a ratio of 2:1 for **acres** in "unimproved" and 1:1 for acres in "improved" pasture. Total acres were of course converted to hectares. Another assumption that was made was that 60% of the total area under pasture is unimproved and 40% is classified as improved.

### **3.5.1.4 Shifting Cultivation**

This acreage was developed from official figures in the Annual Reports of the MAFC. By its nature, this form of agriculture is onerous to assess accurately. It is assumed that all milpa occurs over Low Activity Soils

### **3.5.1.5 Wetland Rice**

True wetland rice (as compared to irrigated rice) is limited to the Toledo District. The area was obtained directly from MAFC staff in Toledo and is comparatively very small. This type of cultivation occurs on acquic soils.

### **3.5.1.6 Mechanized Continuous Cropping**

This category includes irrigated rice, upland rice, and all major grain crops. Irrigated rice is attributed to High Activity Soils. All other crops are found on Low Activity Soils.

### **3.5.1.7 Abandoned Lands**

From data obtained from a study of the Rio Bravo Conservation and Management Area in 1974, Castañeda and Santos concluded that about 19.4% of the total area cleared for agriculture and pasture was and remained abandoned during a period of 20 years or more. Nevertheless this estimate is limited to a private protected area in the north of the country where land tenure and effective land management changes prevented any attempt to re-use abandoned land for agricultural purposes. On a national scale, in land tenure and land use systems which permit re-entry into the same area after a short fallow period, the percentage of abandoned land may be less and varied from year to year. The values in Table 6 are used.

### **3.5.2 Soil Types**

Soil types are derived from the agricultural land use classifications and soil surveys undertaken by King et al (1993), and Wright et al (1959). The following soil type definitions are used:

**3.5.2.1 High Activity Soils:** Only the vertisols (sticky when wet and cracks in the dry) have montmorillonitic 2:1 clay type possess the main criteria for this classification. These correspond to the Class I and II agricultural soil categories

**3.5.2.2 **Low Activity Soils:**** Essentially soils III and IV agricultural soil categories not designated as sandy or acquic

**3.5.2.3 **Sandy Soils:**** These include all soils ascribed to the Puletan series and as Caye sands.

**3.5.2.4 **Acquic (Wetland):**** Peaty swamps and Muck (as classified by Wright et al) are included here.

Table 7: Agriculture Land Use Systems on Main Soil Categories (According to Castañeda 2007)

| YEAR                       | 1974                   | 1994                | 1977                   | 1997                | 1980                   | 2000                |
|----------------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|
| Land Use System            | Land Area (t-20) (Mha) | Land Area (t) (Mha) | Land Area (t-20) (Mha) | Land Area (t) (Mha) | Land Area (t-20) (Mha) | Land Area (t) (Mha) |
| Forest                     | 359,991                | 333,366             | 359,991                | 324,093             | 343,014                | 310,053             |
| Perennial                  | 16,188                 | 43,167              | 16,188                 | 49,517              | 18,616                 | 50,637              |
| Mech Cont. Crops           | 1,821                  | 1,467               | 1,821                  | 4,390               | 16,370                 | 17,310              |
| <b>High Activity Soils</b> | <b>378,000</b>         | <b>378,000</b>      | <b>378,000</b>         | <b>378,000</b>      | <b>378,000</b>         | <b>378,000</b>      |
|                            |                        |                     |                        |                     |                        |                     |
| Forest                     | 1,351,508              | 1,330,038           | 1,348,133              | 1,344,788           | 1,340,848              | 1,342,301           |
| Perennial plant            | 952                    | 1,748               | 627                    | 3,736               | 991                    | 2,528               |
| Unimproved pastures        | 29,135                 | 41,360              | 29,135                 | 20,803              | 33,332                 | 25,041              |
| Improved pastures          | 8,498                  | 12,060              | 8,498                  | 14,803              | 9,567                  | 20,399              |
| Shifting cultivation       | 6,180                  | 5,221               | 6,180                  | 6,600               | 5,892                  | 12,269              |
| Mech. Cont. Crops          | 11,402                 | 12,248              | 11,402                 | 20,000              | 15,545                 | 7,425               |
| Abandoned lands            | 10,000                 | 15,000              | 13,700                 | 6,945               | 11,500                 | 7,712               |
| <b>Low Activity Soils</b>  | <b>1,417,675</b>       | <b>1,417,675</b>    | <b>1,417,675</b>       | <b>1,417,675</b>    | <b>1,417,675</b>       | <b>1,417,675</b>    |
|                            |                        |                     |                        |                     |                        |                     |
| Forest                     | 365,939                | 361,649             | 365,939                | 362,702             | 365,087                | 362,367             |
| Perennial plantations      | 405                    | 2,671               | 405                    | 1,398               | 649                    | 3,927               |
| unimproved pastures        | 4,856                  | 6,880               | 4,856                  | 7,100               | 5,464                  | 4,906               |
| <b>Sandy Soils</b>         | <b>371,200</b>         | <b>371,200</b>      | <b>371,200</b>         | <b>371,200</b>      | <b>371,200</b>         | <b>371,200</b>      |
|                            |                        |                     |                        |                     |                        |                     |
| Forest                     | 60,119                 | 59,896              | 60,119                 | 58,781              | 60,100                 | 58,717              |
| Wetland Rice               | 81                     | 304                 | 81                     | 1,419               | 100                    | 1,483               |
| <b>Acquic Soils</b>        | <b>60,200</b>          | <b>60,200</b>       | <b>60,200</b>          | <b>60,200</b>       | <b>60,200</b>          | <b>60,200</b>       |
|                            |                        |                     |                        |                     |                        |                     |
| <b>Total</b>               | <b>2,227,075</b>       | <b>2,227,075</b>    | <b>2,227,075</b>       | <b>2,227,075</b>    | <b>2,227,075</b>       | <b>2,227,075</b>    |

### 3.5.3 Carbon Stock Values

WORKSHEET 5-5s1 provides for an accounting of changes in soil (and litter) carbon stocks as a function of changes in land-use and agricultural management practices. This forms the basis for calculating CO<sub>2</sub> emissions from mineral soils. It should be

noted that default values utilized are for soil carbon content for **tropical moist forest with short dry season** as this is the countrywide classification presently being utilized for Belize. This varies from the classification of **tropical wet forest** utilized in the 1<sup>st</sup> national GHGI. This change in classification reduced net change in soil carbon in mineral soils.

The default factors for “base factor, tillage factor and input factors” did not change and were applied in the formulae of WORKSHEET 5-5A.

The product of the three combined factors was applied only to the last seven land-use management systems that were impacted by agriculture; they were not applied to forests/woodlands as this was not impacted by agriculture.

#### **3.5.4 Emissions from Liming**

WORKSHEET 5-5s3 calculates annual emissions from liming of agricultural soils. Data for 1994, 1997 and 2000 were obtained from the producer of ground limestone from Spanish Lookout and from the dolomite and ground limestone industry in the Toledo and Stann Creek District. Consumption of white lime (limestone) use was very much reduced with the production of dolomite from the Toledo District decreasing from 1991 metric tons in 1992 to 372 metric tons in 1994.

WORKSHEET 5-5s2 was not filled as it does not apply to Belize.

WORKSHEET 5-5s4 provides for the automatic calculation of total net emissions from agriculturally impacted soils.

## **4 Results**

The LULUCF sector continues to be a major source of carbon emissions in Belize.

### **4.1 1994 Reporting Year Recalculated**

The following table is a summary of the re-calculated worksheets for 1994.

It shows that there was a total emission of CO<sub>2</sub> from the LULUCF sector of 7,483 gigagrams mainly as a result of deforestation and soil carbon from agriculturally impacted soils. Carbon sequestration from forest growth following logging and the regrowth of abandoned lands reduced this quantity by 2,891 Gg to a net emission value of 4,592 Gg.

| <b>Table 8 LULUCF Sectoral Report for National Green House Gas Inventory</b> |                                      |                                     |                      |                          |             |            |
|--|--------------------------------------|-------------------------------------|----------------------|--------------------------|-------------|------------|
| 1994 Reporting Year  | CO <sub>2</sub><br>Emissions<br>(Gg) | CO <sub>2</sub><br>Removals<br>(Gg) | CH <sub>4</sub> (Gg) | N <sub>2</sub> O<br>(Gg) | Nox<br>(Gg) | CO<br>(Gg) |
| Total Land Use Change and Forestry   | 4592                                 | 0                                   | 21                   | 0                        | 5           | 185        |
| Changes in Forestry and Other<br>Woody Biomass                               | 0                                    | -2708                               |                      |                          |             |            |
| Forest and Grassland Conversion  | 5826                                 | 0                                   | 21                   | 0                        | 5           | 185        |
| Abandonment of Managed Lands   | 0                                    | -183                                |                      |                          |             |            |
| CO <sub>2</sub> Emissions and Removals from<br>Soils                         | 1,657                                | 0                                   |                      |                          |             |            |

#### 4.2 1997 Reporting Year

The following table shows that for 1997 there was a total emission of CO<sub>2</sub> from the LULUCF sector of 9,803 gigagrams mainly as a result of deforestation and to a lesser extent from soil carbon in agriculturally impacted soils. Carbon sequestration from forest growth following logging and the regrowth of abandoned lands reduced this quantity by 3,225 Gg to a net emission value of 6,578 Gg.

| <b>Table 9 LULUCF Sectoral Report for National Green House Gas Inventory</b> |                                      |                                     |                      |                          |             |            |
|--|--------------------------------------|-------------------------------------|----------------------|--------------------------|-------------|------------|
| 1997 Reporting Year  | CO <sub>2</sub><br>Emissions<br>(Gg) | CO <sub>2</sub><br>Removals<br>(Gg) | CH <sub>4</sub> (Gg) | N <sub>2</sub> O<br>(Gg) | Nox<br>(Gg) | CO<br>(Gg) |
| Total Land Use Change and Forestry   | 6,578                                | 0                                   | 27                   | 0                        | 7           | 235        |
| Changes in Forestry and Other  | 0                                    | -3099                               |                      |                          |             |            |

|   |       |      |    |   |   |     |
|---|-------|------|----|---|---|-----|
| Woody Biomass                                     |       |      |    |   |   |     |
| Forest and Grassland Conversion                   | 8,803 | 0    | 27 | 0 | 7 | 235 |
| Abandonment of Managed Lands                      | 0     | -126 |    |   |   |     |
| CO <sub>2</sub> Emissions and Removals from Soils | 1,000 | 0    |    |   |   |     |

### 4.3 2000 Reporting Year

The following table shows that for 2000 there was a total emission of CO<sub>2</sub> from the LULUCF sector of 11,950 Gg mainly as a result of deforestation and to a lesser extent from soil carbon in agriculturally impacted soils. Carbon sequestration from forest growth following logging and the regrowth of abandoned lands reduced this quantity by 3,862 Gg to a net emission value of 8,088 Gg.

| <b>Table 10 LULUCF Sectoral Report for National Green House Gas Inventory</b> |                                |                               |                      |                       |          |         |
|---|--------------------------------|-------------------------------|----------------------|-----------------------|----------|---------|
| 2000 Reporting Year   | CO <sub>2</sub> Emissions (Gg) | CO <sub>2</sub> Removals (Gg) | CH <sub>4</sub> (Gg) | N <sub>2</sub> O (Gg) | Nox (Gg) | CO (Gg) |
| Total Land Use Change and Forestry  | 8,088                          | 0                             | 40                   | 0                     | 10       | 349     |
| Changes in Forestry and Other Woody Biomass                                   | 0                              | -3651                         |                      |                       |          |         |
| Forest and Grassland Conversion   | 11,077                         | 0                             | 40                   | 0                     | 10       | 349     |
| Abandonment of Managed Lands  | 0                              | -211                          |                      |                       |          |         |
| CO <sub>2</sub> Emissions and Removals from Soils                             | 873                            | 0                             |                      |                       |          |         |

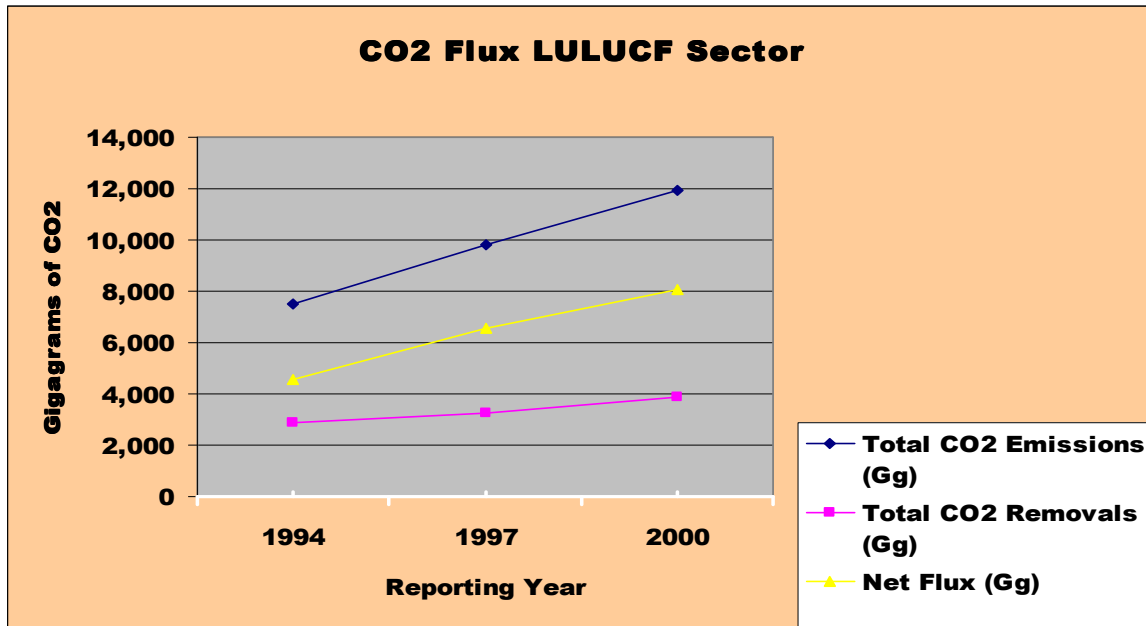
The following table compares emissions from liming (white lime and dolomite) as well as net changes in soil carbon in mineral soils as a result of soil use systems for the three reporting years.

**Table 11 Soil Carbon Emissions**

| Year | Carbon Emissions from Liming (MgC) | Total Net Change in Soil Carbon in Mineral Soils (Tg per 20 years) | Total Annual CO <sub>2</sub> Emission (Gg/yr) |
|------|------------------------------------|--|---|
|      |                                    |  |   |

|      |         |         |           |
|------|---------|---------|-----------|
| 1994 | 654.64  | -9.0265 | 1657.2495 |
| 1997 | 964.74  | -5.4364 | 1000.2105 |
| 2000 | 1161.61 | -4.7400 | 873.2642  |

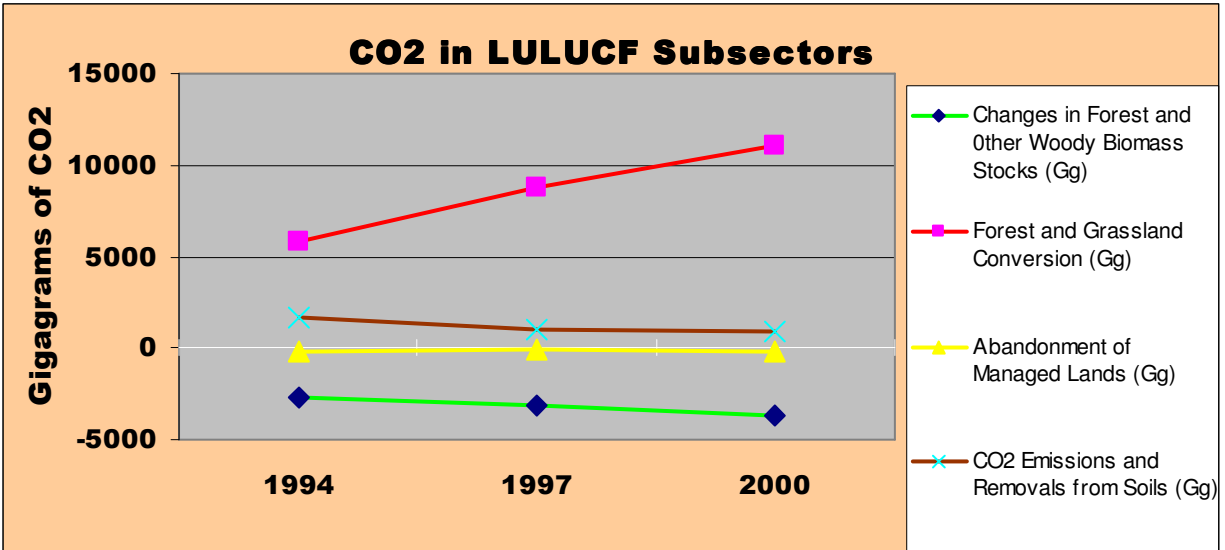
#### 4.4 Trend Analysis



It is

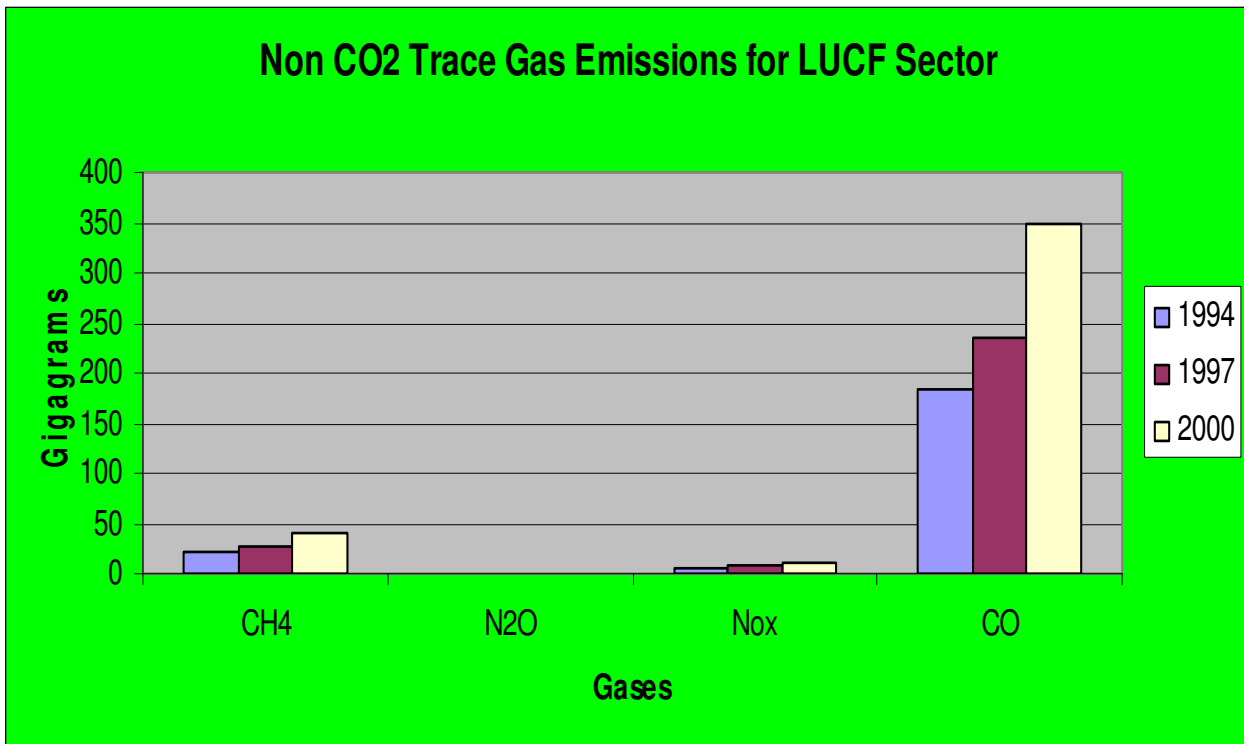
clear from the above chart that there is a progressive increase in net CO<sub>2</sub> emissions by the LULUCF sector in Belize.

From the chart below, it is also apparent that this progressive increase in net CO<sub>2</sub> emissions by the LULUCF sector is linked to increased rates of deforestation and decreasing areas of forest being managed for long term timber production. Note that CO<sub>2</sub> emissions from soils steadily decrease.



The chart below shows that non- CO<sub>2</sub> trace gas emissions steadily increase as would be expected with increased rates of forest and grassland conversion since these gases are principally a by - product of biomass combustion.

These trace gases even though occurring in relatively smaller quantities than CO<sub>2</sub> have a significant impact. In a period of over 100 years, one tonne of methane has the same impact on the climate change process as 26 tonnes of CO<sub>2</sub>. One ton of nitrous oxide has the same impact as 296 tonnes of CO<sub>2</sub>.



## **5 Conclusions and Recommendations**

Belize is not unique in that within our region one of the major sources of greenhouse gas emissions is deforestation. The continued reduction in forest areas that are being logged and /or actively managed will also diminish our capacity to offset emissions from deforestation. Increases in land degradation and increased utilization of land with less productive potential coupled with the present rate of population increase may very well contribute to greater forest conversion. Therefore the continuous monitoring of deforestation incorporating existing data gathering mechanisms and institutions is important to provide baseline information for developing strategies to ameliorate the impacts of these development activities on the climate change process and create adequate adaptation mechanisms. It is also very clear that the compilation of data and its retrieval in an efficiently utilizable format is a major weakness in many, if not most of the public institutions (and to a lesser extent private) that are mandated to maintain a database of information relevant to the particular sector they are charged to administer/manage. It also becomes evident that there is a wide overlap in the type of data that these institutions should be compiling and maintaining and the data necessary to carry out a GHGI for the LULUCF sector. A strategy therefore needs to be developed where the importance of GHGI inventories and other climate change related activities can serve to assist these institutions in leveraging the attention and resources sorely needed to fulfill their sectoral data management responsibilities and at the same time provide timely and consistent, data required to fulfill our national climate change related responsibilities, hopefully at an acceptable economic rate. The Forest Department plays and will continue to play a key role in providing data related to changes in forest biomass stocks.

Therefore a capacity needs assessment review may be necessary in this area, if it has not been done so recently with a view to equipping the department with the necessary resources and institutional mind set to systematically collect and process data in a format useful to all stakeholders.

There are numerous research gaps that presently exist. Some of the essential research is already on-going at a sub-national level but incomplete. In the interim of waiting for the resources to effect national scale research and for the on-going research to mature, an attempt has to be made to utilize existing state of knowledge to provide more realistic parameters than global default values for immediate application. Initially, these may lack rigorous scientific precision, but they can obviously be improved as the necessary research is generated. One suggested priority is to carry out a rapid assessment to establish with greater certainty than has been possible in this GHGI, the national forest area that is recovering from logging and appreciably accumulating carbon.

The level of public awareness and appreciation of how the different development activities in country affect our GHG balance also has to be raised and public perception informed. For example in the LULUCF sector, public perception of logging may be negative in that it is often erroneously equated to deforestation (because it is often mistakenly equated with North American models) and negative environmental impacts, while pristine protected areas are seen as the ideal state even though in the carbon equation natural unmanaged forest free from human intervention are neither a source or a sink.

## ***Bibliographic References and Sources of Information***

Agriculture Department, 1980, "Annual Report and A Summary of Statistics" Ministry of Natural Resources. Belmopan

\_\_\_\_\_ 1995 -2005. "Agricultural Statistics", Ministry of Agriculture and Fisheries

Alder, D. 1989. "Report on Forest Inventory, Productivity, Growth, and Yield, A Report to the Belize Forest Department", Tropical Forestry and Computing Ltd. Oxford, United Kingdom. 214 pp.

Arnold, J. et al. 1987. "Belize Tropical Forestry Action Plan". Overseas Development Administration. London, United Kingdom

Castañeda, A. & Santos C. 1999. "National Green House Gas Inventory - Land Use Change and Forestry". Ministry of Public Utilities, Transport, and Communications. Belmopan, Belize

Central Statistical Office. 2001. "Abstract of Statistics Environmental Statistics for Belize: 2001." Environmental Statistics Unit, Central Statistics Office, Ministry of Budget Management, Investment and Public Utilities. Belmopan, Belize. 115 pp.

Central Statistics Office 1980. "Abstract of Statistics" Ministry of Finance. Belmopan, Belize

Central Statistics Office 1977. "Abstract of Statistics" Ministry of Finance. Belmopan, Belize

Cho, P. 2007. "Report on Procedures and Results, Landsat TM Image Classification and Analysis". Belize SNC Remote Imagery/GIS Technical Support GHG Inventory Service Contract No. 007/2006. Forest Department. Belmopan, Belize 5 pp.

Chomitz, K.M. & and D.A. Gray. 1996. "Roads, Land Use, and Deforestation: A Spatial Model Applied to Belize." Poverty, Environment, and Growth Working Paper No. 5. International Food Policy Research Institute, World Bank. Washington, DC. 26 pp.

Di Fiore, S. L. 2002. "Remote Sensing and Exploratory Data Analysis as Tools to Rapidly Evaluate Forest Cover Change and Set Conservation Priorities Along the Belize River, Belize" Master of Arts thesis, Department of Ecology, Evolution, and Environmental Biology, Columbia University, Washington 68 pp

Eck, E. 2004 "Monitoring Land Use and Land Cover Changes in Belize, 1993 to 2003, A Digital Change Detection Approach". Masters of Science thesis, College of Arts and

Sciences, Ohio University, Ohio 101 pp

Fairweather, P.N. & D.A. Gray. 1994. "The Land Use of Belize: 1989/92." Land Information Centre, Ministry of Natural Resources. Belmopan, Belize. 15 pp.

Food & Agriculture Organization. 2000. "FRA 2000 Annotated Bibliography. Forest Cover Change: Belize." Working Paper 40. United Nations. Rome, Italy. 38 pp.

Iremonger, S. & N.V.L. Brokaw. 1995. "Vegetation Classification for Belize." In: Wilson, R. (Ed.) 1995. "Toward a National Protected Areas Systems Plan for Belize." Synthesis report. Programme for Belize. Belize City, Belize. 114 pp.

\_\_\_\_\_ 1996. "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Vols. I, II, & III". Intergovernment Panel on Climate Change. Mexico City

\_\_\_\_\_ 2003 " Good Practice Guidance for Land Use, Land-Use Change and Forestry". Intergovernment Panel on Climate Change. Vienna, Austria.

King, R.B., Pratt, J.H., Warner, M.P., and S.A. Zisman. 1993. "Agricultural Development Prospects in Belize." Bulletin 48. Natural Resources Institute, Overseas Development Administration. Chatham, United Kingdom. 159 pp.

Meerman, J.C. & W. Sabido. 2001. "Central America Ecosystems Map: Belize." Volume I. Programme for Belize. Belize City, Belize. 28 pp and digital coverage.

Meerman, J.C. & Cherrington, E.A., 2005. "Preliminary Survey of Land Degradation In Belize". Ministry of Natural Resources, Local Government and the Environment, Belmopan. Belize. 64 pp.

Rosado, O. & Tuomasjukka, T. 1998. "Belize Forest Sector Review, 1997". IUCN/CCAD. San Jose, Costa Rica 72 pp

White, W.A., Raney, J., Tremblay, T.A., Crawford, M.M., and S.S. Smith. 1996. "Deforestation in Belize 1989/92-1994/96." Bureau of Economic Geology, University of Texas. Austin, TX. 49 pp.

White, W.A., Raney, J., Tremblay, T.A., Crawford, M.M., and S.S. Smith. 1998. "Remote Sensing Analyses of Land Cover and Land Use, Central Belize". Bureau of Economic Geology, University of Texas. Austin, TX. and Land Information Center, Ministry of Natural Resources and the Environment, Belmopan, Belize 34 pp.

Mr. Melanio Pech, Livestock Officer, Central Farm, January-February, 2007. Personal Communication.

Mr. Harry Parham, Manager, Belize Livestock Producers Association, January, 2007. Personal Communication

Mr. Percy Cho, Forest Officer-Satellite Imagery & Mapping, January-February, 2007, Personal Communication

Mr. Bryan Holland, Manager, Belize Minerals Ltd, Punta Gorda, Toledo, January-February, 2007. Personal Communication

Mr. Abe Dueck, Manager/Owner, Ground White Limestone-Spanish Lookout, Cayo, December, 2006. Personal Communication

Mr. Peter Dyck, Wetland Rice Farmer, Blue Creek, Orange Walk. December 2006. Personal Communication

Mr. G. Hulse, Ex-manager, Big Falls Ranch (Wetland Rice Producer), Belize District, December 2006, Personal Communication

Mr. Darrel Novelo, Forest Officer, Forest Department, 2007, Personal Communication

Mr. Jan Meerman, Director, Belize Tropical Forest Studies Organization, Personal Communication

Mr. Anselmo Castañeda, Consultant, GHGI Agricultural Sector, 2006, Personal Communication

Mr. Earl Green, Project Manager, "Enabling Activities for the Preparation of Belize's Second National Communication (SNC) to The United Nations Framework Convention on Climate Change" Project , 2006, Personal Communication