7

Climate Change

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7.1 Introduction

Climate change is one of the most alarming problems facing humanity today. As scientists and policy makers at the global arena grapple with this issue, developing countries are also sorting out the implications of climatic shifts to their people, economy, and environment.

The Earth's surface temperature this century is as warm or warmer than any century since at least 1400 AD (Nicholls et al. 1996). By the year 2100, the average surface temperature is projected to increase by 1.4-5.8°C while sea level is expected to rise by 9-88 cm (IPCC 2001). Greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), and chlorofluorocarbons (CFCs) absorb thermal radiation emitted by the earth's surface. If more GHGs are emitted into the atmosphere they absorb more heat, which, in turn, could lead to a change in the world's climate.

Among the GHGs, CO_2 is the most abundant and is responsible for more than half the radiative forcing associated with the greenhouse effect (Watson et al. 2000; Schimell et al. 1995). Forest ecosystems play an important role in the climate change problem because they can both be sources and sinks of atmospheric CO_2. They can be managed to assimilate CO_2 via photosynthesis, and store carbon in biomass and in soil (Watson et al. 2000; Brown 1998; Brown et. al. 1996). Thus, any change in forest land cover could either positively or negatively affect the amount of CO_2 in the atmosphere.

Similarly, the agricultural sector could also exacerbate climate change. For example, paddy fields and livestock emit methane, one of the principal GHGs. On the other hand, any change in climate including extreme weather events will have a direct bearing on the growth and yield of crops and livestock. Consequently, the food security of the country may be threatened.

In the Philippines, the study of climate change and agriculture, food security, and natural resources is relatively young. In the last five years, a number of researches have been conducted focusing on the role of Philippine forests on climate change (e.g., Lasco and Pulhin 2000; Lasco and Pulhin 2001; Lasco et al. 2002). Similarly, the impacts of climate change on water resources and agricultural resources in the Philippines have been recently investigated (Lantin 1996, etc.).

In view of the threat posed by climate change, a comprehensive assessment of the LLB should look into the contribution of the basin either to exacerbate or mitigate the rise in GHG in the atmosphere. In addition, it will provide an analysis of local problems at the global scale. Because of resource constraints, the main focus of this assessment will be on the agricultural and land use change and forestry (LUCF) sectors.

This chapter attempts to provide answers to the following questions:

- What are the impacts of current activities in agriculture and LUCF sectors on greenhouse gas emissions and removals?
- What are the key drivers leading to increase/decrease in GHG emissions and removals by sinks?
- How will climate change affect the natural resources of the LLB?
- What are the human responses to adapt to and mitigate climate change?
- What are the implications of future scenarios to climate change?

7.2 Contribution of the Agricultural and LUCF Sectors to National Emissions and Removals

7.2.1 The Agriculture Sector

The Philippines relies heavily on domestic agricultural production to support its burgeoning population. The sector accounts for 21 percent of Gross Domestic Product (GDP) and employs 46 percent of the total labor force (ADB 1998). Rice and corn are the primary staple crops. Of the total agricultural area of 129,000 km², 31 percent is devoted to rice while 21 percent is planted to corn.

Agriculture contributes to GHG emissions through various ways. For example, anaerobic decomposition of organic material in paddy fields and enteric fermentation of herbivores produce CH_4.

GHG emissions from the Philippine agricultural sector is significant, accounting for 33 percent of all non-LUCF emissions and second only to the energy sector. It has been estimated at 33 Mt of CO_2-equivalent was emitted in 1994 (Table 7.1). A related study based on 1990 data showed a slight lower emission levels. It will be noted that the leading cause of GHG emission is rice cultivation. This is because of irrigated rice fields which emit CH_4 at the rate of 2.3 kg ha^{-1} day^{-1} (230 kg km^{-2} day^{-1}).

7.2.2 The Land Use Change and Forestry (LUCF) Sector

When the Spanish colonizers first set foot in the Philippines in 1521, 90 percent of the country was covered with lush tropical rainforest (around 270,000 km² out of 300,00 km² total land area). By the year 1900, there were still 70 percent or 210,000 km² of forest cover (Garrity et al. 1993; Liu et al.

Table 7.1. GHG emissions from the Philippine agricultural sector.

Sub-Sector	CO2-equivalent Emissions (kt)	
	1994 GHG Emissions*	1990 GHG Emissions**
Rice cultivation	13,364	11,899
Domestic livestock	10,498	8,703
Agricultural residue burning	581	422
Agricultural soils	8,680	5,676
Grassland burning	6	18
Total	**33,130**	**26,718**

*Philippines Initial National Communication 1999
**ADB 1998

1993). However, by 1996 there were only 61,000 km^2 (20 percent) of forest remaining (FMB 1997). Thus, in the last century alone, the Philippines lost 149,000 km^2 of tropical forests. The average deforestation rate from 1969 to 1973 was 1,700 km^2 per year (Forest Development Center 1987). For the past 20 years, it was about 1,900 to 2,000 km^2 per year (Revilla 1997). However, in the last few years it was estimated to be in the vicinity of 1,000 km^2 (Lasco and Pulhin 1998). The direct and indirect causes of deforestation include shifting cultivation, permanent agriculture, ranching, logging, fuel wood gathering, and charcoal making (Kummer 1990).

Forestlands are important sources of water for irrigation, hydroelectric power, industrial use, and household use. Philippine forests have extremely high floral and faunal diversity. They harbor 13,000 species of plants, which comprise 5 percent of the world's total of plant species (DENR/UNEP 1997). With continued deforestation, some species previously occurring in certain areas are now endangered or even extinct. In fact, the Philippines is one of the biodiversity "hot spots" of the world (McNeely et al. 1990).

They are also home to millions of inhabitants. There are about 20 million Filipinos living in upland watershed areas, half of whom are dependent on shifting cultivation for livelihood (Cruz and Zosa-Feranil 1987). Soil erosion and degradation are serious problems in the country where it is estimated that 83,000 km^2 out of 300,000 km^2 of land are severely eroded (EMB 1990).

Quantification of the contribution of the Philippine LUCF sector to GHG emissions and removals started as early as November 1991 (Francisco 1997). Since then, the estimates have been progressively updated in response to new methodologies as prescribed by the IPCC and the availability of new data. The most recent inventory is the 1994 inventory as contained in the 1999 Philippines' Initial National Communication.

Table 7.2 shows a comparison of the results of the 1994 inventory relative to two previous inventories using 1990 as base year. It will be noted that the LUCF sector turned from a huge net source of GHG to a slight sink in the latest inventory. Such dramatic shift in the LUCF is not unique to the Philippines. A recent analysis of the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat revealed that the LUCF estimates of Annex 1 countries have varied widely over the years (Ravindranath et al. 2000). This illustrates the importance of sources of information in the computation of the C budget of a country as part of its commitment under the UNFCCC to conduct national GHG inventory. The LUCF sector can turn from source to sink or vice-versa depending on the data used.

On the basis of the new data, GHG uptake/emissions were recalculated using the 1996 IPCC Revised Guidelines, the same method used in earlier inventories. A comparison of the results showed that the LUCF sector is a significant net sink (-107 Mt CO_2 equivalent) based on the 1997-98 land cover data. It is a much higher net sink compared to the 1994 inventory (-0.126 Mt CO_2 equivalent) (Table 7.3). The findings are also consistent with, although a little lower than, the previously performed calculation (142 Mt CO_2 equivalent).

Total LUCF sector carbon sequestration is a little higher than the total net GHG emission of the Philippines from all sources (101 Mt in 1994). This shows the importance of Philippine forests in climate change mitigation as they practically absorb all the fossil fuel emissions of the country.

Table 7.2. Total emissions from the LUCF sector of the Philippines (Gg CO_2 equivalent).

Source	1990 Inventory (1997 US Country Studies)	1990 Inventory (1998 ALGAS)	1994 Inventory (1999 Philippine Nat. Comm.)
Change in forests and biomass stocks	-48,654	2,622	-68,323
Forest and grassland conversion	120,738	80,069	68,197
Abandonment of managed lands	-1,331	-1,331	Not determined
Net emissions	70,753	81,360	-126
Total Philippine emissions	128,620	164,103	100,738
% of total Philippine emissions	55.01	49.58	-0.13

References: Francisco 1997; Murdiyarso 1996; ADB 1998; Philippines' Initial National Communication 1999.

Table 7.3. Comparison of results between the 1994, 1997-1998 inventories and this study.

Source	CO_2 Equivalent (kt)		
	1994 Inventory (Philippine Nat. Comm. 1999)	1997-98 Inventory (Lasco and Pulhin 2001)	1997-98 Inventory (this study)
Biomass growth	-111,000	-222,000	-218,000
Harvests	42,000	31,000	27,000
On site and off-site burning	36,000	23,000	43,000
Decay	33,000	23,000	40,000
Net absorption	-126	-142,000	-107,000

7.3 Overview of the IPCC GHG Inventory Methods

7.3.1 Agriculture Sector

Agricultural production activities contribute to GHG emissions. For example, rice paddy fields and animal husbandry contribute to methane concentration in the atmosphere. In the LLB, agriculture is the dominant land use accounting for 1,986.40 km^2 or more than 50 percent of the basin's total land area.

The IPCC method for the inventory of GHG emissions from agricultural activities deal with the following:

- Methane emissions from enteric fermentation and manure management systems;
- Methane emissions from rice cultivation;
- Release of non-CO_2 trace gases from savanna burning;
- Release of non-CO_2 trace gases from agricultural burning; and
- Trace gas emissions from agricultural soils.

7.3.1.1 Methane emissions from enteric fermentation and manure management systems

Methane from enteric fermentation is produced in herbivores as a by-product of the digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the blood stream. Both ruminant animals (e.g., cattle, sheep) and some non-ruminant animals (e.g., pigs, horses) produce methane, although ruminants are the largest source.

Methane from the management of animal manure occurs as the result of its decomposition under anaerobic conditions. These conditions often occur when a large number of animals are managed in a confined area (e.g., dairy farms, beef feedlots, and swine and poultry farms).

7.3.1.2 Methane emissions from rice cultivation

Anaerobic decomposition of organic material in flooded rice fields produces methane, which escapes to the atmosphere primarily by diffusive transport through the rice plants during the growing season. The parameters that affect methane emissions vary widely both spatially and temporally. At the current level of understanding, a reported range in methane emission levels for a country is more realistic than a single number.

7.3.1.3. Release of non-CO_2 trace gases from savanna burning

Savannas are tropical and subtropical formations with continuous grass coverage. The burning of savannas results in instantaneous emissions of carbon dioxide. However, because the vegetation regrows between the burning cycles, the carbon dioxide released to the atmosphere is reabsorbed during the next vegetation growth period. The burning of savannas also releases gases other than CO_2, including CH_4, carbon monoxide (CO), N_20, and oxides of nitrogen (NO_x).

7.3.1.4 Release of non-CO_2 trace gases from agricultural burning

Large quantities of agricultural residues are produced from farming systems worldwide. Burning of crop residues in the fields is a common agricultural practice in the Philippines. It has been estimated that as much as 40 percent of the residues produced in developing countries may be burned in fields. It is important to note that some crop residues are removed from the fields and burned as a source of energy.

7.3.1.5 Trace gas emissions from agricultural soils

Agricultural soils may emit or remove N_2O. It is possible to calculate N_2O emissions from agricultural systems including: 1) direct emissions of N_2O from agricultural soils (including glasshouse systems farming and excluding effects of grazing animals); 2) direct soil emissions of N_2O from animal production; and 3) indirect emissions of N_2O from nitrogen used in agriculture.

7.3.2 LUCF Sector

The role of forests and land use change in GHG emissions and removals vary depending on the situation of a specific region. To determine the contribution of LUCF, the IPCC has developed guidelines for the national inventory of GHG emitted and absorbed by forest land (Houghton et al. 1996). This is to help standardize the methods of all Parties to the UNFCCC in the conduct of their GHG inventories. The key parts of the GHG inventory for the LUCF sector are (Figure 7.1):

- Changes in forest and other woody biomass stocks
- Forests and grassland conversion
- Abandonment of managed lands

The activity data most commonly needed in all worksheets are those pertaining to area of forest/landuse, growth/ conversion rates, biomass stocks, carbon fraction/content, and harvests/extraction rates.

7.3.2.1. Changes in forest and other woody biomass stocks

Biomass is about 50 percent carbon by dry weight. The IPCC method calculates the net uptake of CO_2 by estimating the annual increment of biomass as well as harvests in natural forests and tree plantations (Houghton et al. 1997). Wood harvested for fuelwood, commercial timber, and other uses is also estimated as significant quantities may be gathered informally for traditional fuelwood consumption.

The net carbon uptake due to these sources is then calculated. If the figure is positive then this counts as a removal of CO_2, and if the figure is negative, it counts as an emission.

7.3.2.2 Forests and grassland conversion

Forest conversion to permanent agriculture or pasture is a common activity in the Philippine uplands. Tropical forest clearing is usually accomplished by cutting undergrowth and felling trees followed by burning biomass on-site or as fuelwood. By this process some of the biomass is burned while some remains on the ground where it decays slowly. Of the burned material, a small fraction (5-10 percent) is converted to charcoal which resists decay for 100 years or more, and the remainder is released instantaneously into the atmosphere as CO_2. Carbon is also lost from the soils after conversion, particularly when the land is cultivated.

7.3.2.3. Abandonment of managed lands

This sub-module deals with net-CO_2 removals in biomass accumulation resulting from the abandonment of managed lands. Carbon accumulation on abandoned lands is sensitive to the type of natural ecosystem (forest or grasslands) which is regrowing. Therefore abandoned lands regrowing should be entered by type. When managed lands are abandoned, carbon may or may not reaccumulate on the land. Abandoned areas are therefore split into those which reaccumulate carbon and those which do not regrow or which continue to degrade. Only natural lands which are regrowing towards a natural state are included.

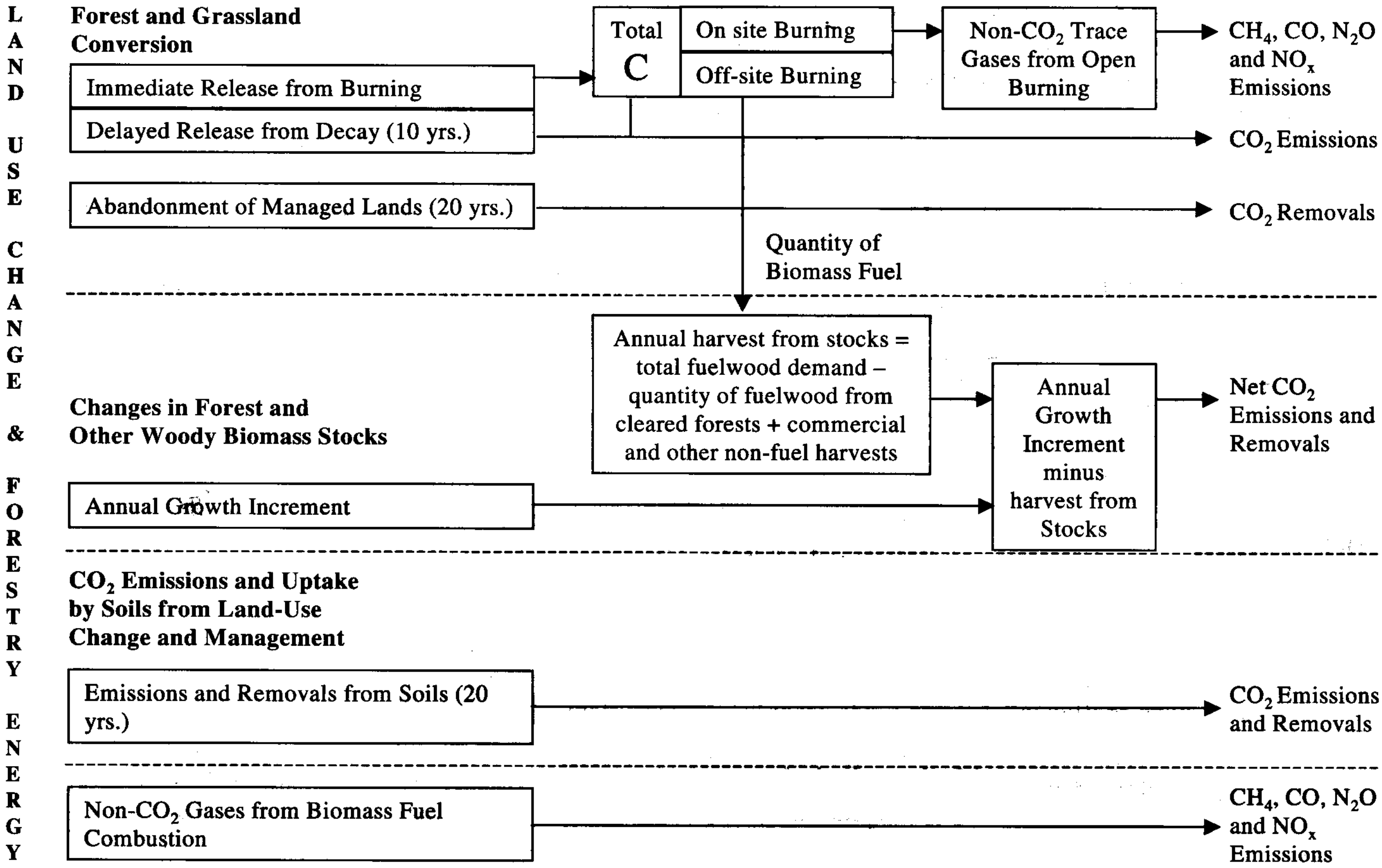

Figure 7.1. Overview of the IPCC GHG inventory method for the LUCF sector (Houghton et al. 1997).

7.4 GHG Inventory for the Base Year (2002)

7.4.1 Agriculture Sector

The LLB is basically an agricultural area. As of 2000, agricultural land utilization covers about 1,509.66 km^2 or 40 percent of the watershed's total land area of 3,813.12 km^2. The major agricultural crop grown in the area is rice. As of 1997, there are a total of 117,017 t of rice produced in the basin.

Agriculture contributes to emissions of greenhouse gases through a variety of processes. Methane is produced in herbivores as a by-product of enteric fermentation and through decomposition of manure under anaerobic conditions. Anaerobic decomposition of organic material in flooded rice fields produced methane, which escapes to the atmosphere primarily by transport through the rice plants. The burning of savannas results in emissions of CO_2 and CH_4, CO, N_2O, and NO_x. Burning of agricultural wastes in the field is a significant source of emissions of CH_4, CO, N_2O, and NO_x.

On the average, population growth rate is 2.3 percent. This means that the study area has to increase agricultural production for self-sufficiency and to meet the demand for industrialization. An increase in production, however, would lead to an increase in the emissions of GHGs.

The sources of GHGs are the following:

- Methane emissions from enteric fermentation and manure management systems;
- Methane emissions from rice cultivation;
- Release of non-CO_2 trace gases from savanna burning;
- Release of non-CO_2 trace gases from agricultural burning; and
- Trace gas emissions from agricultural soils

Emission coefficients

Default values of emissions factors for enteric fermentation and manure management were adopted from Gibbs and Johnson (1983) and Crutzen et al. (1996). In the study site, most of the animals are classified as nondairy, which are used to provide draft power and some milk. The emissions factors used in estimating CH_4 emissions are given in Table 7.4.

The emissions factors for rice under different water regimes were derived from the results of field experiments conducted by IRRI in Los Banos, Laguna and Philippine Rice Research Institute (PhilRice) in Muñoz, Nueva Ecija. Average methane emission across sites for irrigated conditions are 2.3 kg ha^{-1} day^{-1} (230 kg km^2-day^{-1}) while 0.40 kg ha-day^{-1} (40 kg km^2-day^{-1}) rainfed condition (Table 7.5).

In the case of savanna burning, factors used in th computation are based on the IPCC default value for Tropica Asia. There are about 406.45 km^2 of savanna (humid wit annual rainfall >700 mm) in the study site which are burne once every three years. The emissions ratios used i calculating GHGs from savanna burning are shown in Tabl 7.6.

Table 7.4. Emission coefficients used to calculate methane emissions from livestock.

Animal Type	Enteric Fermentation (kg CH_4 head-day^{-1})	Manure Management (kg CH_4 head-day^{-1})
Carabao	56	3.00
Cattle	44	2.00
Hot	1	7.00
Goat	5	0.22

Table 7.5. Emissions coefficients for rice fields according to ecosystem.

Rice Ecosystem	Methane Emissions (kg CH_4 ha-day^{-1})	Data Source	Area Under Category (ha)
Irrigated	2.3	IRRI	1,961
Rainfed	0.4	IRRI	1.421

Rice and sugarcane are the two major crops grown in the study site which are subject to field burning. In computing the released gases from burning of these crops, the following IPCC default values are used:

- Fraction of biomass oxidized = 0.9 (for both crops)
- Carbon Content (fraction)
  Rice = 0.42
  Sugarcane = 0.45
- Nitrogen-Carbon Ratio
  Rice = 0.014
  Sugarcane = 0.02 (similar to maize)

The emissions of trace gases from soils are a result of microbial and chemical transformations. In estimating trace gas emissions from agricultural soils, the following sinks of N_2O are considered: mineral fertilizer application, crop residue incorporation, and the indirect emissions from atmospheric deposition of ammonia (NH_3) and other NO_x and leaching or runoff of N in soils.

It is estimated that for every kg of N applied as mineral fertilizer, 1.25 ± 1 percent is released to the atmosphere as N_2O. The amount of N excreted per head of livestock (Table

Table 7.6. Emissions ratios for savanna burning calcula tions (IPCC 1995).

Compound	Emission Ratios
CH_4	10.44
CO	10.96
N_2O	11.51
NO_X	12.10

7.7) is derived from the IPCC value for Asia and the Fa East (1966). For crop residues left in the field, it is assume that the fraction of N is 0.015 kg N kg^{-1} dry biomass. A emission factor of 0.01 kg N_2O-N kg^{-1} is used to estimat the fraction of the N content of fertilizers which volatilize t the atmosphere as NH_3 and NO_x. About 30 percent of th fertilizer N in soils is lost through leaching or runoff. Th amount of N_2O-N produced is estimated at 2.5 percent c the leached N.

In the updated methodology, an additional source wa included: N_2O emissions from animal waste managemer system (AWMS) (IPCC 1996). Only the number of animals are needed and the AWMS to estimate N_2O emissions. The amount of N excretion per head and per type of animal and the AWMS are in Table 7.7.

7.4.2 GHG Emissions and Removals from the LUCF Sector

Of the total basin area, forest lands occupy 730 km² of which only 190 km² are actually covered with forests. The rest (540 km²) are mainly denuded lands with grass and annual crops.

The remaining forests are mainly secondary forests, with perhaps some remnants of the original old growth forest. They are increasingly under siege as demand for wood and other forest products soar in the heels of a rapidly rising population. Grassland areas are utilized for grazing. These places are dominated by cogon grass (*Imperata cylindrica*) whose immature shoots are good animal feeds. Some privately-owned grasslands inside alienable and disposable areas are also used for this purpose.

The LLB has the distinction of harboring the nearest intact forest reserve to Metro Manila, namely, the Makiling Forest Reserve (MFR). The reserve is a world-famous center for education and research hosting numerous national and international institutions. It also contains a rich array of plant species, comparable to old-growth forests in Southeast Asia (Luna et al. 1999).

GHG emissions from the LUCF sector due to anthropogenic activities include land use conversions and deforestation activities. These activities affect the amount of carbon in the atmosphere through biomass burning, decay, and carbon release from the soil. However, the LUCF sector becomes a sink of carbon when there is biomass growth of existing forest and non-forest stands, and biomass regrowth in abandoned lands.

7.4.2.1 Data inputs

Total carbon uptake of the LUCF sector represents the total amount of carbon absorbed by the LUCF sector due to biomass growth. The annual growth rates expressed in tons dry matter per hectare per year (t dm ha^{-1} yr^{-1}) of each land use type are derived from the values reported by Lasco et al. (1998, 1999, 2000), Kawahara (1981), and Kungu (1993). The values for fraction of carbon in the biomass are from the studies conducted by Lasco et al. (1998; 1999; 2000; 2001). The assumptions used in the GHG inventory of Laguna Lake Basin is presented in Table 6.8, and the annual growth rate and carbon content of each land use type used in this study are shown in Table 7.9.

LUCF sector emits carbon whenever biomass is removed through harvesting and land use conversion. Value for roundwood harvests is derived from the Forestry Statistics published by the DENR, while the fuelwood data is from the Food and Agriculture Organization (FAO). Since the value of the roundwood harvest is expressed as m³, wood density is needed to convert it into biomass. Wood density value used for this study is 0.57 t dm m^{-3} because this is the recommended value for Asian broadleaf species (Brown 1997).

An expansion ratio of "3.0" is used because it is assumed that harvest production efficiency is 33 percent (Villarin et al. 1999). This means that for every ton of wood harvested, three tons of woody biomass are actually removed from the forests.

During conversion of forests to other land uses, biomass loss occurs. Volume of biomass loss depends on the initial and final use of the land. Much biomass is lost whenever a forested area is converted to grassland areas. Area converted annually is derived by examining the area for each land use for the two time periods. Biomass density values used in this

Table 7.7. Default values for N excretion and manure-N production in different AWMS.

Animal Type	N Excretion (kg N head-year^{-1})	Percent of Manure Production per AWMS		
		Liquid System	Solid Storage and Drylot	Pasture Range and Paddock
Cattle	40.0	0	83	17
Poultry	0.6	27	73	0
Goats	12.0	0	100	0
Swine	19.0	17	83	0
Carabao	40.0	0	99	1

Table 7.8. Assumptions used in GHG inventory (Lasco and Pulhin 2000).

Forest Land Use	Carbon Content of Biomass (%)	Total Above-ground Biomass (t ha^{-1})	Rate of Above-Ground Biomass Change (t ha^{-1} yr^{-1})	Sources of Data
Old-growth forest (OGF)	44.7 (Visayas)	OGF 446 in Visayas Mossy forest 272 in Luzon All others*50% of OGF	2.1 in Visayas	Lasco et al. 1999 Lasco et al. 2000; this study
Second-growth forest	43, 45 (Luzon) (Mean = 44)	279, 499 in Luzon 262 in Mindanao (Mean = 347)	7.81 in Luzon 5.2 in Mindanao (Mean = 6.5)	Lasco et al. 1999; this study Kawahara et al. 198
Brushlands	45.3 for wood (Visayas)	65 in Visayas	9.4 in Visayas	Lasco et al. 1999
Grasslands	44.5 (Visayas)	29 in Visayas	9.4 in Visayas	Lasco et al. 1999
Agroforestry	45 *Gliricidia sepium*-based alley cropping (Luzon) 45 *Gmelina arborea* and cacao multistorey system (Luzon)	Multistorey system (Luzon): 236 Alley cropping (Luzon): 68 Fallow system (Visayas): 32 (Mean 112)	Improved fallow (Visayas): 6.0	Lasco et al. 1998a, t Kungu 1993

Table 7.9. Annual growth rate and carbon content of various land uses (Lasco and Pulhin 2000).

Land Use	Annual Growth Rate	Carbon Content
Old Growth	2.10	0.45
Residual	6.50	0.44
Upland farms	6.00	0.45
Brushland	9.40	0.45
Grassland	0.00	0.40

study are based on the results of the studies conducted by Lasco et al. (1998, 1999, 2000). Table 7.10 shows the biomass density values for each land use type.

There are three main activities in the land use conversion that release GHGs at different time scales: on-site burning (for clearing purposes), off-site burning (for domestic/ industrial fuelwood), and biomass decay. Fraction of cleared forest biomass that is burned on-site, off-site, and left to decay are shown in Table 7.11. Sources of data for fraction of forest biomass burned on-site and off-site are IPCC (1997) and United Nations Development Programme - Energy Sector Management Assistance Programme (UNDP-ESMAP) (1992), respectively. Values for fraction left to decay are based on the assumptions of Villarin (1999).

Deforestation not only causes the emission of CO_2 rather it also release other gases such as CH_4, CO, N_2O, and NO_x. While only CH_4 and N_2O are GHGs, CO and NO_x are al accounted for because they have the potential to alter tl chemical balance of the atmosphere. Computation of the trace gases are gathered based on the emission ratios or tl ratios of these gases to the total amount of carbon release

Table 7.10. Biomass density values for each land use type

Land Use	Biomass Density
Old Growth	446
Residual	347
Upland farms	112
Brushland	65
Grassland	29

Table 7.11. Fraction of biomass burned on site, off-site and left to decay.

Land Use	Carbon Released				
	On site Burnng		Off-site Burning		
	Fraction of Biomass Burned on Site	Fraction of Biomass Oxidized on Site	Fraction of Biomass Burned Off-site	Fraction of Biomass Oxidized Off-site	Fraction Left to Decay
Old Growth	0.4	0.9	0.1	0.9	0.45
Residual	0.4	0.9	0.1	0.9	0.45
Upland Farms	0.4	0.9	0.1	0.9	0.45
Brushland	0.4	0.9	0.1	0.9	0.45
Grassland	0.4	0.9	0.1	0.9	0.45

Table 7.12. Emission ratios for open burning of forests.

Compound	Ratio	Range
CH_4	0.012	0.009 - 0.015
CO	0.06	0.04 - 0.08
N_2O	0.007	0.005 - 0.009
NO_X	0.121	0.094 - 0.148

in the burning process. These emission ratios are shown in Table 7.12.

7.4.2.2 GHG emissions and removals by LLB

7.4.2.2.1 Agriculture sector

In the agriculture sector of the LLB, sources of emission include: 1) domestic livestock; 2) ricefields; 3) grassland burning; 4) burning of agricultural residues; and 5) agricultural soils.

Emissions from Domestic Livestock

Among the animals present in the LLB, cattle exhibit the highest CH_4 emission from enteric fermentation followed by the carabao. The high value is not attributed to the number of cattle and carabao present in the area rather it is due to the high emission factor for enteric fermentation of these animals. Cattle and carabao have total population of 140,000 and 117,000 heads, respectively. Despite the exceedingly large number of swine in the area, the CH_4 emissions from enteric fermentation amounts only to 2,345 t yr^{-1} which is about 30-35 percent of the emissions from the cattle and carabao. Again, the reason for this is the low emission factor for enteric fermentation of the swine.

Aside from enteric fermentation, animal wastes also contribute to methane emission. Total methane emission from this source amounts to 15,895 t yr^{-1}. Around 69 percent of this emission comes from the manure of the swine while 24 percent comes from the cattle. The remaining 7 percent of the total methane emission is shared by the carabao, sheep, goats, and horses.

Animal wastes also excrete nitrogen. Total annual nitrogen excretion of animals amounts to 59,507.5 t. Almost half of this value is contributed by the swine while the smallest portion is supplied by sheep. Nitrogen emission under pasture system is 1,472.6 t yr^{-1} while under solid storage and liquid system, nitrogen emissions are 47,534 t yr^{-1} and 9,689.7 t yr^{-1}, respectively.

Methane Emissions from Rice Fields

Rice paddies in Laguna have two water management regimes: irrigated and rainfed. Irrigated farms contain the large portion of the rice paddies in the province. It constitutes about 198 km^2 or 98 percent of the total rice fields. Using emission coefficient of 2.3 kg ha^{-1} day^{-1} (230 kg km^{-2} day^{-1}), methane fluxes from this type of rice field totals to 5.2 kt yr^{-1}.

Rainfed rice fields covers an area of 4 km^2 only or 1.98 percent of the total rice paddies. In terms of its contribution to annual methane emission, it releases 0.16 t. Overall, total methane emission from rice fields is 5.2 kt yr^{-1}.

Prescribed Burning of Grassland

Burning of grassland areas results to release of trace gases such as CH_4, CO, N_2O, and NO_x. In the LLB, CO comprises the largest of the trace gases emitted due to grassland burning. Total CO emitted is 19.71 t or 95 percent of the total trace gas emission. Methane emission amounts to 0.75 t, while N_2O and NO_x emission measure around 0.01 t and 0.34 t, respectively.

Field Burning of Agricultural Residues

Most farmers in the Philippines burn agricultural residues as a site preparatory activity. However, doing such activity results to release of trace gases such as CH_4, CO, N_2O, and NO_x. Results of the GHG inventory in the LLB shows that smoldering of agricultural residues resulted to emission of 2,988.3 t of CO, 142.3 t of CH_4, 118.8 t of NO_x, and 3.3 t of N_2O.

Emission from Agricultural Soils

Sources of nitrogen emission from agricultural soils in LLB are mainly due to application of fertilizer both from synthetic source and animal wastes. Total synthetic fertilizer used in the LLB is 32.4 t N, resulting to total emission of 0.40 t N_2O-N. Emission from grazing animals amounts to 0.05 kt N_2O.

Aside from direct emission from fertilizers, nitrogen is also released indirectly through atmospheric deposition of NH_3 and NO_x. Results of GHG inventory in LLB indicate that there are 0.12 kt N_2O-N emitted resulting from atmospheric deposition.

About 30 percent of the nitrogen in the fertilizer applied in agricultural soils is also lost through leaching and run-off. Thus, there is a total of 0.4 kt N_2O-N that is leached in th agricultural soils of LLB.

In sum, agriculture sector has total CH_4 emissions of 48 k 0.9 kt N_2O, 0.1 kt NO_x, and 3 kt CO or 1,298.7 kt of CO Among the sectors, domestic livestock accounts for th largest contributor of CO_2 emissions while the lowest is th from grassland burning (Table 7.13).

7.4.2.2.2. Land use change and forestry

Biomass growth in the LLB resulted to the sequestration c more than 2,000 kt of CO_2 from the atmosphere (Table 7.14 about 3 percent of nation's total removals by sinks based i the 1994 GHG inventory.

However, the LLB is a net source of GHG, emitting abo 924 kt CO_2-equivalent in the year 2000 (Table 7.14). Th can be attributed to the high fuel wood consumption by th residents of the basin (0.46 m^3) which negated the amou of carbon sequestered by the growth of trees. In additio burning and decay contributed to GHG emission in the basi This is primarily due to clearing of forests for agricultur purposes.

In contrast, national GHG inventories show that the countı as a whole is a slight to a huge net sink of carbon (Tab 7.14). This implies that something must be done in the LL to either decrease emissions and/or enhance removals t enable to mitigate climate change.

7.5 Potential Impacts of Climate Change in the LLB

Prediction of potential climate change in the next century still largely conjectural and varies with the simulation mode used. However, scientists are agreed that the earth's clima is already changing as a result of the rise of GHG in th atmosphere.

Table 7.13. Summary of the emissions of GHG from agriculture sector (in kt).

Source	Emission Type				CO_2 Equivalent	% Share
	CH_4	N_2O	NO_x	CO		
Domestic livestock	33.1	0.0			694.2	53.
Rice cultivation	14.8				310.4	23.
Grassland burning	0.0	0.0	0.0	0.0	0.0	0.
Agricultural soils		0.9			290.1	22.
Total	**48.0**	**0.9**	**0.1**	**3.0**	**1,298.7**	**100.**
CO_2 Equivalent	**1,007.6**	**291.1**				

Table 7.14. CO_2 equivalent emissions and uptake of the LUCF sector in the LLB for the year 2000.

Sub-sector	CO_2 Equivalent Emissions (+) and Uptake (-) (kt)
Change in Forest/Woody Biomass	800
Biomass Growth	-,2,148
Roundwood/Fuelwood Harvests	2,948
Forest/Land Use Change	124
On Site Burning	52
Off-Site Burning	12
Decay	59
Total	**924**

In the Philippines, modeling work by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) under a 2 x CO_2 (doubling of CO_2 concentration from the current 360 ppm) scenario showed that the temperature will increase by at least 2-3°C in the Southern Tagalog region where the LLB is located (Table 7.15). Likewise, precipitation will increase by as much as double the present amount.

7.5.1 Impact on Water Resources

The availability of water is an important prerequisite to optimum agricultural production. Climate change is also predicted to affect the water resources of the country. Because of high rainfall, the country is endowed by abundant water supply. However, because of varying distribution of rainfall and degradation of watershed areas, some parts of the country experience lack of water or its opposite, flooding.

The agricultural sector is the major user of water in the country consuming 248 M m^3 equivalent to 86 percent of the country's water demand per day to irrigate about 120,000 km^2 of land. Thus, any change in water supply due to climate change will have an impact on agricultural productivity.

A preliminary study was conducted on the impacts of climate change on two watersheds (Angat and Lake Lanao) in the Philippines (Jose 1996). In Angat watershed, the effect of climate change using three global change models (GCMs) showed varying effects on surface runoff ranging from -12 percent to 32 percent. It was also shown that water runoff is more sensitive to change in precipitation than in temperature. In Lake Lanao watershed, the three GCMs predicted mostly increasing rainfall and temperature. This scenario will lead to a generally declining amount of water runoff. Similar to Angat, the amount of runoff is also more sensitive to change in precipitation rather than temperature.

The foregoing study showed how water supply is vulnerable to changes in climate, especially to the amount of precipitation. While these results are preliminary, it is clear that agricultural productivity is at risk from either a declining water supply or too much water from the watersheds which could lead to flooding.

Table 7.15. Temperature change and rainfall ratio in the Philippines based on the Canadian Climate Centre Model (CCCM) (2 x CO_2 scenario).

	Region	Temperature Change (°C)	Rainfall Ratio
1	Ilocos	<2	1.0-1.5
2	Cagayan Valley	<2	1.0-1.5
3	Central Luzon	2-3	1.0-2.0
4	Southern Tagalog	2-3	1.6-2.0
5	Bicol	2-3	1.0-1.5
6	Western Visayas	2-3	1.6-2.0
7	Central Visayas	2-3	1.6-2.0
8	Eastern Visayas	2-3	1.0-2.0
9	Western Mindanao	2-3	1.0-1.5
10	Northern Mindanao	2-3	<1.0-1.5
11	Eastern Minadanao	>-	<1.0
12	Southern Mindanao	2-3	1.0-1.5

To date, there has been no study quantifying the impacts of climate change on the water resources of the LLB. This is a knowledge gap that needs to be filled soon.

7.5.2 *Impacts on Agricultural Production and Food Security*

Agricultural production is highly sensitive to climate because crop growth and development are determined by rainfall pattern and temperature range among others. A few studies have been conducted in the Philippines primarily by IRRI to assess the potential impacts of climate change to rice and corn production using various GCMs.

The results of the study show that (The Philippines Initial National Communication 1999):

- Rice showed a generally slight increase in yield (e.g., 3.15 percent and 5.38 percent in the first and second crop of IR 64 using CCCM)
- Corn yields tended to decline (e.g., 12.64 percent and 7.07 percent in the first and second crop, respectively, of PS 3228 using CCCM).

These results have been attributed to the difference in physiology of these two crops. Rice is a C-3 plant which would respond to the increase in CO_2 concentration in the atmosphere. On the other hand, corn is a C-4 plant which would not respond to CO_2 concentration, but the increase in air temperature will enhance respiration and shorten maturity period.

On the national scale, various model show conflicting results ranging from 6.6 percent increase to a -14 percent decline. Scientific evidence is still rudimentary at this point. However, it is almost certain that a changing climate will affect the level of agricultural production in the country.

7.5.3 *Impacts on Forest Resources*

Forests are highly dependent on climate since they are limited by water availability and temperature. In fact, the survival of many species depends on temperature with a range of +12°C to -60°C (IPCC 2002). A sustained increase of 1°C in mean annual temperature could cause changes in species composition. Trees are also sensitive to water availability. There are limits to which species can migrate unassisted.

Global vegetation models (BIOME, MAPSS, IMAGE) do not agree on whether tropical forests will increase or decrease (IPCC 1996, 2002). But any major shift in rainfall pattern will affect distribution of vegetation types. Under enhanced CO_2, tropical evergreen broadleaf forests could readily establish after deforestation. Decreased rainfall coul accelerate loss of dry forests to savanna. Shifts in rainfa patterns could increase conversion of forests to agricultur land by increasing migration from areas affected by drough erosion, etc. Productivity will increase or decrease dependin on the amount of rainfall.

Under various GCM scenarios, tropical forest areas in th Philippines will likely expand as temperature an precipitation increase in many parts of the country. Th increase in the frequency of droughts and floods due t changes in El Niño episodes will likely render many are unfit for agricultural crop production (Cruz 1997). Togeth with the growth in population and the shrinkage of arabl lands, the pressure to open forestlands for cultivation coul heighten.

Grasslands and other areas dominated by shrub species coul become more vulnerable to fire with increase in mean a temperature. This could be aggravated if these areas a subjected to prolonged dry periods which are likely und an altered El Niño pattern. Frequent fires will make the already marginal lands more difficult to rehabilitate.

Temperature change may lead to a loss of a few species plants and animals that may significantly erode th biodiversity of these forests. The coastal areas especiall mangrove forests will be at risk of being damaged by th projected increase in siltation due to the increase in so erosion in the uplands. This is on top of the risk of bein completely wiped out by sea level rise. Finally, changes i temperature and precipitation may result to the outbreak pests and diseases.

On the specific impacts of climate change on the fore resources of LLB, no study has been conducted yet.

7.6 Responses: Policies, Programs and Activities t Enhance Adaptation to and Mitigate Clima Change

Policies and programs on climate change in the Philippin are usually confined to the National Capital Region (Met Manila), parts of which lie in the basin. There are no polici or programs directly addressing climate change for the LL However, there are many policies and programs that a relevant either in enhancing adaptation to climate change in helping mitigate climate change.

7.6.1 *Agriculture*

The following are policy options in order to cope with clima change.

7.6.1.1 Adaptation options

A variety of adaptation options are recommended to effectively respond to the perceived impacts of climate change. Since the climate change scenario for the year 2070 is expected to bring about changes in rainfall, temperature, CO_2 concentration, and the frequency of extreme meteorological events such as floods, droughts, and typhoons, the following response strategies for the agricultural sector are recommended:

- Development of stress-tolerant varieties through plant breeding and biotechnology;
- Development of new farm management techniques that will respond to the management of crops under stressful conditions and the management of plant pests and diseases;
- Adaptive design and development of efficient farm tools and implements; and
- Improvement of post-harvest technologies which include among others the utilization and processing of farm products, by products and agricultural wastes.

Further recommended is the design and installation of a management information system (MIS) for agriculture which would provide timely and accurate information on climate hazards and their likely impacts to agricultural activities. The proposed MIS must be able to provide the following:

- The nature of climate variability particularly rainfall;
- Effects of climate change on other physical processes, e.g., soil erosion, pests, etc.;
- Effects of crop yields from farm production, food pricing and supply, farm income; and
- Effective policy response to changes in land use, plant breeding, etc.

7.6.1.2 Mitigation options

Mitigation options that will tend to decrease net agricultural emissions are grouped into short and long-term strategies:

7.6.1.2.1 <u>Short-term strategies</u>

- Improved management of livestock wastes
- Judicious use of production and growth-enhancing agents
- Integrated pest management technologies
- Conversion of agricultural wastes into biofertilizer
- Better management of irrigation systems

7.6.1.2.2 <u>Long-term strategies</u>

- Comprehensive approach in rice cultivation (e.g., proper management of water regions, efficient use of fertilizers, improved management practices, improved cultivars, alternative crops, etc.)
- Improved livestock systems
- Use of alternative agricultural systems
- Adoption of farm technology packages which promote the use of non-conventional energy sources (e.g., solar dryers, wind driven pumps, waves and tidal wave energy, etc.)

The aforementioned will follow the strategies articulated in the Philippine strategy for sustainable development to wit:

- Integration of Environmental Considerations (including climate change) in decision-making. This means a shift from traditional single sector planning/decision-making exercises to multi-sectoral planning/decision approach (including climate change considerations). Analytical tools and methodologies that are environmentally and climatically friendly will be installed and strengthened.
- Proper pricing of natural resources based on the cost of replenishment, increasing their supply and providing appropriate substitutes in order to improve resource management.
- Property Rights Reform. The "open access" scheme has promoted exploitation. The access rights will be assigned to communities who in turn will be responsible for its protection for sustained productivity.
- Establishment of Integrated Protected Areas System for the conservation of wildlife and unique ecosystems threatened by the impact of climate change and population pressures. Protection/conservation would be for scientific, educational, cultural, and historical values.
- Rehabilitation of Degraded Ecosystem to include reforestation of denuded watersheds, mangrove re-plantation, clean-up and control of pollution, and revival of biologically dead rivers.
- Strengthening of Residuals Management in Industry (Pollution Control) by installing not only "end-of-pipe" control systems but also wastes minimization, resource recovery, recycling, and appropriate by-product design that save on materials and energy.
- Promotion of Environmental Education that will enable citizens to understand and appreciate the complex nature of the environment and the role they have to play and to develop social values that are strongly supportive of environmental protection.
- Strengthening of citizen's participation and constituency building. Potential victims of climate change should be involved in the design process.

Setting of priorities

The priority actions that would mitigate the adverse effects of greater rainfall variability, stronger tropical storms, and surges include:

- Strengthening of disaster mitigation preparedness of the LLB from basin to village level, to minimize the adverse impacts of tropical cyclones, storm surges, floods, and droughts;
- Formulation and implementation of an LLB land use plan that will incorporate the occurrence of natural hazards resulting from climate change; and
- Building and upgrading institutional capacities to implement the various national response strategies.

The proposed set of priority actions that would contribute to global efforts to slow down or stop climate change is:

- Use of market-based instruments in promoting the development of environmentally friendly industry and energy sources.

Follow-up program of action

The follow-up program of action includes research needs and technical assistance and investment packages.

Research needs

Research needs identified is focused on the present day and projected climate change constraints in agriculture and the GHG emissions in the population centers of the LLB.

On a short-term basis these researches include:

- varietal improvement and selection of superior drought tolerant varieties, high yielding and early maturing, resistant to pests and diseases, and suitable in given farming systems and manageable under different stress conditions; and
- development of farm tools and implements that are flexible or resistant to climate changes. An example is the *tapak-tapak* or foot pump and axial flow pump used to pump out excess water from low-lying areas to areas that need irrigation water.

On a long-term basis:

- The conduct of continuing case studies of areas where climatic constraints will be a major problem in agricultural production. The use of crop-climate models and satellite technology in the determination of crop potentials, assessment of present conditions, and prediction an monitoring of crop yields in a large scale.
- Investigation of the combined impact of increase CO concentration, higher temperature and rainfall i agricultural systems.
- Development of methods to assess the full socioeconomi and political implications of impacts and responses, an their interactions with the other policy issues at the LLE and at the regional and national levels.

Technical assistance

Technical assistance needs are: 1) technology developmer for limiting GHG emissions; 2) policy reforms and executior and 3) creation of public awareness.

7.6.2 Land Use Change and Forestry

7.6.2.1 Strategies to decrease GHG emissions

Key mitigation strategies that could be implemented in th LLB to decrease the GHG emissions from the LUCF sectc include:

- Reduction of illegal wood harvesting and fuelwoo gathering from the natural forest without a replantin program.
- Control the burning of forests through such activities a shifting cultivation.
- Conservation of carbon stocks in the remaining fore ecosystems. There are a reported 190 km^2 of forest cov left in the basin (LLDA 1995). Several studies have show that forest ecosystems in the basin contain substanti amount of carbon (Figure 7.3). By preventing th destruction of these "carbon banks", emission of GHG reduced. Conservatively assuming a carbon density of 15 t C ha^{-1} (1.5 t C km^{-2}), the remaining forests of the basi contain 2,850 kt C (10,460 kt CO_2). This is equivalent about 20 percent of the 1994 GHG emissions from th energy sector of the entire country.

There are existing policies and programs that contribute the above. The DENR has banned logging in all old grow forests and protected forests in the country since 1992 (DA 12 series of 1992; RA 7586 The National Integrated Protect Areas Systems Act). While illegal cutting of tree have be reported, no logging permit has been issued in the fore areas within the basin (based on 1997 official forest statistics, FMB 1998) presumably because they are all pa of protected forests.

One of the biggest programs launched by the government protect existing forested areas is the Community-Bas

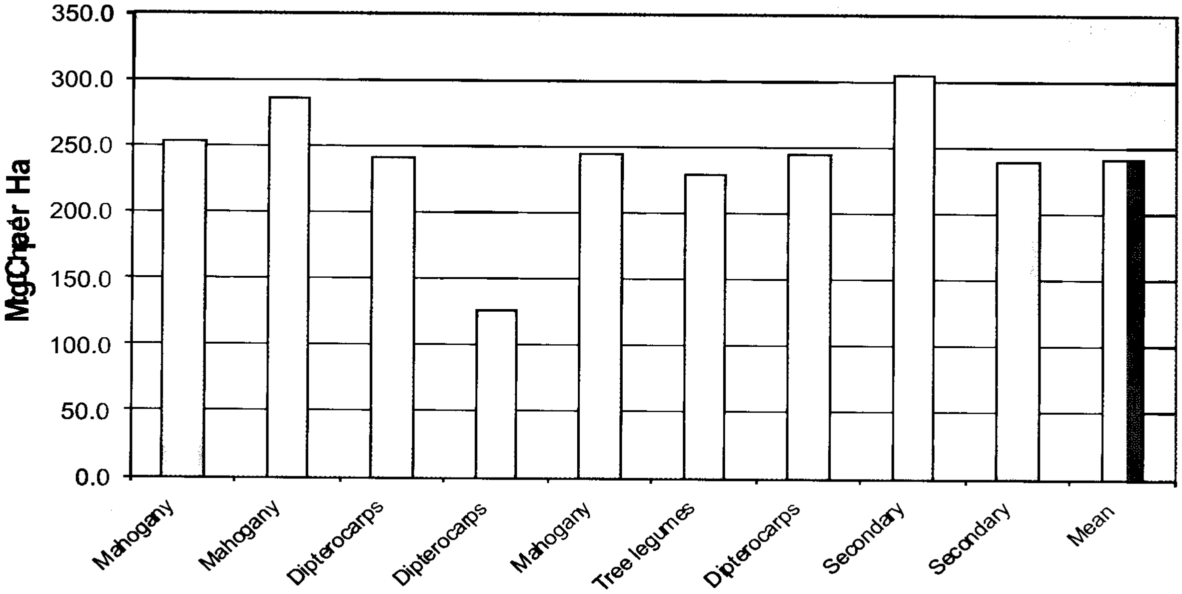

Figure 7.3. Carbon stocks of Mt. Makiling forest types.

Forest Management (CBFM). Launched on July 1995, CBFM integrated the different community forestry projects of the country through the issuance of Executive Order (EO) 263 and DAO 96-29. Objectives of the CBFM include: 1) to democratize resource access; 2) to improve socioeconomic welfare of upland communities; and 3) to promote the sustainability of the forest resources. Currently, there are a total of 4,956 CBFM sites all over the country covering an area of 57,000 km^2 (FMB 2001).

Another strategy introduced by the government to protect the country's forest resources is the establishment of the Multi-sectoral Forest Protection Committee (MFPC). The MFPC is composed of representatives from various sectors of the community such as other government agencies and institutions who come and join together to be partners in the government's forest protection efforts. Among the duties of the MFPC are to: 1) serve as a collection point for information on illegal forestry activities; 2) regularly receive and discuss reports from DENR specific to routine and special monitoring apprehension and prosecutional activities; 3) advise DENR and other relevant parties on these activities; 4) publicize the committee's discussions and findings, except where treated as confidential; 5) oversee the public awareness and other alternative livelihood progress; and 6) mobilize the members' network in support of forest protection activities.

7.6.2.2 Strategies to enhance removals by sinks

Key mitigation strategies that could be implemented in the LLB to enhance removals by sinks include:

- Reforestation and tree planting in the denuded grassland areas of the LLB. Currently, there are 540 km^2 of open lands in the basin. If planted, these lands have the potential to sequester more than 1,338 kt CO_2 yr^{-1} from the atmosphere [assuming biomass growth rate of 15 t ha^{-1} yr^{-1} (0.15 t km^{-2} ha^{-1})], more than enough to turn the basin to a net GHG sink.
- Establishment of sustainable tree farms to supply the wood and fuel wood requirements of the local communities in the basin. There is almost zero emission when the trees cut are replaced immediately. In other words, the carbon emitted by wood burning and decay is re-absorbed by the planted trees. Of course, the timing of release and absorption are different so that these are not exactly the same as far as the atmosphere is concerned.

The rate of reforestation activities for the basin is not known. However, there are indications that this is not significant. In 1997, only 6.71 km^2 have been reported in all the provinces in Region 4A (where the basin falls under), about 1 percent of total area reforested nationwide (FMB 1998). Similarly, only 4.03 km^2 of tree farms have been established in the entire region. Clearly, the potential of the basin to sequester carbon has not been fully utilized.

The Philippine government through the DENR has already embarked on a number of reforestation programs from 1910 up to the present. These programs did not only rehabilitate degraded lands but also increased the capacity of the Philippine forests to become sinks of carbon. From purely government initiated reforestation projects, the DENR involved other sectors of the society starting in 1976. Forest communities, private sectors, non-government organizations, and local government units became actively involved in forest rehabilitation activities. From 1960 up to 2002, area planted totaled to about 170,000 km². About 70 percent of which were planted by the government sector and the remaining 30 percent were contributed by the non-government sector (Pulhin and Peras 2002).

7.6.2.3 Research and training

The LLB is home to national and international training institutions that have conducted research and training programs in climate change. IRRI has conducted research on methane emissions from rice paddy fields, including measures to reduce emissions. UPLB is at the forefront of research efforts to quantify carbon stocks and rate of sequestration in Philippine forests. Many studies have been conducted already in the basin, specifically in the MFR (Lasco and Pulhin 2003; Lasco et al. 2001a; Lasco et al. 2001b; Juarez 2001; Racelis 2000; Zamora 1999; Lasco et al. 2000; Lasco et al. 2001; Aguiero 2002; Tamayo 2002; Lasco et al. 2003). In addition, the university has also integrated climate change issues in its instructional programs. National and international training courses have also been sponsored.

7.6.2.4 Land use planning

A key prerequisite in the rational and systematic development of the basin is a comprehensive and integrated land use plan. A master plan for the whole basin has been prepared in 1995. Among its many recommendations that will help mitigate climate change are (LLDA and UPLB 1995):

- land use planning and allocation in forest lands
- protection of remaining forests
- reforestation and agroforestry development

Additionally, master development plans have also been developed in two watersheds: the MFR (CFNR 1995) and the Caliraya-Lumot watershed (NPC 1998). Among the recommendations in these plans are protection of existing forests and rehabilitation of degraded lands through reforestation and agroforestry.

7.7 Drivers of Change: Factors Affecting the Increase/Decrease of GHG Emissions and Removals by Sinks

7.7.1 Agriculture Sector

Rice production must increase to meet the demand of an increasing population. Lantin (2003) revealed that growing irrigated rice with less soil submergence and increas diversification in rice-based systems which includes growi in aerated soil will reduce methane emissions. However, th could lead to increased emissions of nitrous oxide – a mo potent GHG. Furthermore, rice production with less sc submergence and increased rotation with upland crops c also enhance risk of nitrate contamination of groundwat and surface waters, which arises when excess use of fertilizer leads to nitrate formation and concomitant leachin Site-specific nutrient management (SSNM) preven excessive rates of N fertilization and avoids risk of nitra contamination of groundwater and surface water. SSN involves use of crop residues and simultaneous nutrient a pest management.

Dry shallow tillage immediately after harvest of rice enabl aerobic decomposition of rice residues, thereby avoiding t negative effects of residue decomposition in submerged soi on early crop growth and methane emissions (Lantin 200

7.7.2 LUCF Sector

Over the years, the landscape of the LLB has chang dramatically. For instance, the forest cover has shrunk 145.16 km² in 2000 from about 725.80 km² in 1966 (LLD 2003). These lost forested areas were most likely convert into grasslands and built-up areas. From 232.26 km² in 196 grassland areas expanded to 406.45 km² while built-up are that are not present in the 1966 land use data occupies 2000 a total of 8.42 km².

The main driving forces that has contributed to the chan in forest cover and the consequent rise in GHG emissio from LLB are (LLDA 2003):

- urbanization and industrial development
- shifting cultivation
- illegal logging
- mining and quarrying
- uncontrolled land conversion

All of the above generally contribute to the loss of for cover and thereby increased GHG emissions.

On the other hand, there have been programs to help reve this trend by conserving existing forest cover and ev expanding forest cover. For example, the MFR is an excell example of conservation. By working with lo communities, UPLB has succeeded in preserving the carb stocks in these forests by minimizing deforestation. addition, the government has launched reforestation and t planting programs in the region where LLB is located. date, there are about 10 km² of reforested areas and tree fa in Region 4A (FMB 1998). However, how much of th are within the basin is not known.

The Caliraya Lumot watershed is another example of conservation. The NPC, the agency that has jurisdiction over the watershed, developed the 25-year comprehensive land use plan for Caliraya Lumot watershed. Among the components of the plan are rehabilitation and protection of the watershed. Under the rehabilitation program, cogonal/grasslands and secondary forests with poor regeneration and regeneration potential will be revegetated with appropriate tree species in cooperation with other stakeholders, i.e., communities, resort owners. In cultivated areas, however, agroforestry farms shall be developed.

Under the forest protection program, the NPC will hire more forest guards to patrol the watershed. Adequate transportation and communication facilities shall be provided to the forest guards.

References

ADB, 1998: *Asia Least-Cost Greenhouse Gas Abatement Strategy: Philippines*. Asian Development Bank, Manila, Philippines, 228pp.

Brown, S., J. Sathaye, M. Cannel, and P. Kauppi, 1996: Management of forests for mitigation of greenhouse gas emissions, Chapter 24. In: *Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses,* R.T. Watson, M.C. Zinyowera, and R.H. Moss (eds.). Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge and New York, Cambridge University Press, pp. 775-797.

Brown, P., 1998: *Climate, Biodiversity and Forests: Issues and Opportunities Emerging from the Kyoto Protocol.* Washington D.C., World Resources Institute.

Cruz, M.C. and I. Zosa-Ferahil, 1988: Policy implications of population pressure in the Philippines. Paper prepared for the World Bank study on Forestry, Fisheries and Agricultural Resource Management. University of the Philippines, Los Banos, Philippines.

Cruz, R.V.O., 1997: Adaptation and mitigation measures for climate change: impacts on the forestry sector. In: *Proc. Consultation Meeting for the International Conference on Tropical Forests and Climate Change*. Environmental Forestry Programme (ENFOR), CFNR, UPLB, College, Laguna, Philippines.

DENR/UNEP, 1997: *Philippine Biodiversity: An Assessment and Action Plan*. Makati City, Philippines, Bookmark Inc.

EMB, 1990: *The Philippine Environment in the Eighties.* Environmental Management Bureau. DENR. Quezon City, Philippines, 302 pp.

FMB, 1997: *Forestry Statistics* (1996). Forest Management Bureau, Quezon City, Philippines.

Forest Development Center, 1987: Towards a Successful National Reforestation Program. Policy Paper No. 24, University of the Philippines College of Forestry, Laguna, Philippines.

Francisco, R., 1997: Greenhouse Gas Sources and Sinks from Philippine Agriculture, Land Use and Forestry. Paper presented at the Synthesis Workshop on Greenhouse Gasses, Aerosols, and Land Use and Cover Change in Southeast Asia. Taipeh, Taiwan. 15-19 November 1997.

Freed and Driscol, 1997. GHG Emission Factors for Management of Selected Materials in Municipal Solid Waste.

Garrity, D.P., D.M. Kummer and E.S. Guiang, 1993: *The Upland Ecosystem in the Philippines: Alternatives for Sustainable Farming and Forestry.* National Academy Press, Washington DC.

Houghton, J.T., L.G. Meira Filho, B. Lim, K. Treanton, I. Mamaty, Y. Bonduki, D.J. Griggs and B.A. Callander (eds.), 1997: *Greenhouse Gas Inventory Workbook.* Intergovernmental Panel on Climate Change (IPCC), Organization for Economic Co-operation and Development (OECD) and the International Energy Agency (IEA), Paris, France, pp. 5.1-5.54.

IPCC, 1996: *Second Assessment Report.* IPCC, Geneva, Switzerland.

IPCC, 2002: *Third Assessment Report.* IPCC, Geneva, Switzerland.

Jose, A.M., L.M. Sosa and N.A. Cruz, 1996: Vulnerability assessment of Angat Water Reservoir to Climate Change. *Water, Air and Soil Pollution,* **92,** 191-201.

Kummer, D.M., 1990: Deforestation in the Post-war Philippines. Ph.D. dissertation, Boston, MA, Boston University.

Lantin, R.S., 2003: *Rice Production: Sustainability and Environmental Concerns.*

Lasco, R.D., J.S. Lales, M.T. Arnuevo, I.Q. Guillermo, A.C. de Jesus, R. Medrano, O.F. Bajar and C.V. Mendoza, 2002: Carbon dioxide (CO_2) storage and sequestration of land cover in the Leyte Geothermal Reservation. *Renewable Energy,* **25**, 307-315.

Lasco, R.D. and F.B. Pulhin, 2003: Philippine forest ecosystems and climate change: Carbon stocks, rate of sequestration and the Kyoto Protocol. *Annals of Tropical Research*, **25(2)**, 37-51.

Lasco, R.D. and F.B. Pulhin, 2001: Forestry mitigation options in the Philippines: application of the COMAP model. *Mitigation and Adaptation Strategies to Global Change*, **6**, 313-334.

Lasco, R.D. and F.B. Pulhin, 2000: Forest land use change in the Philippines and climate change mitigation. *Mitigation and Adaptation to Climate Change Journal*, **5**, 81-97.

McNeely, J.A., K.R. Miller, W.V. Reed, R.A. Mitternmeier, and T.B. Werner, 1990: *Conserving the World's Biological Diversity*. IUCN, Gland, Switzerland; WRI, CI, WWF-US and the World Bank, Washington DC.

Murdiyarso, D., 1996: Inventory of Asian greenhouse gas emissions and sinks in 1990. In: *Greenhouse Gas Emission Inventories*, Braatz et al. (eds.) Kluwer Academic Publishers, Dordrecht. Pp. 147-160.

Nicholls, N., G.V. Gruza, J. Jouzel, T.R. Karl, L.A. Ogallo, and D.E. Parker, 1996: Observed climatic variability and change, Chapter 3. In: *Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses*, J.T. Houghton, L.G. Meira Filho, B.A. Callander, N.Harris, A. Kettenberg, and K. Maskell (eds.), Contribution of Working Group I to the Second Assessment Report of the Intergovernment Panel on Climate Change, Cambridge and New Yorl Cambridge University Press, pp. 137-192.

Ravindranath, N. H., R. D. Lasco, and P. Sudha. 200(Assessment of GHG Inventories from the LUCF Sect of Annex 1 Countries. *Mitigation and Adaptatio Strategies to Global Change*, 00, 1-22.

Revilla, A.V., 1997: Working Paper for the Forestry Polic Agenda for the Incoming Administration. College (Forestry and Natural Resources, University of th Philippines at Los Baños, Laguna, Philippines.

Schimmel, D., I.G. Enting, M. Heimann, T.M.L. Wigley, I Rayneud, D. Alves, and U. Seigenthler, 1995: CO_2 an the Carbon Cycle. In: *Climate Change 1994: Radiati Forcing of Climate Change and an Evaluation of th IPCC IS92 Emision Scenarios*, J.T. Houghton, L.G. Mei Filho, J. Bruce, H. Lee, B.A. Callander, E. Haites, N Harris, and K. Maskell (eds.), Published for the IPC(Cambridge University Press, Cambridge, pp. 35-71.

The Philippines' Initial National Communication On Clima Change, 1999: Republic of the Philippines.

Watson, R.T., I.R. Noble, B. Bolin, N.H. Ravindranath, D. Verado and D.J. Dokken (eds.), 2000: *Land Use, Lan use Change, and Forestry*, Published for th Intergovermental Panel for Climate Change, Cambridg University Press, Cambridge, 377pp.