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Greenhouse Gas Inventory Development in Asia

－ Experiences from Workshops on Greenhouse Gas Inventories in Asia －

Edited by Chisa Umemiya

Center for Global Environmental Research

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National Institute for Environmental Studies, Japan

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Chisa Umemiya
Greenhouse Gas Inventory Office of Japan
Center for Global Environmental Research (CGER)
National Institute for Environmental Studies (NIES)
16-2 Onogawa, Tsukuba, Ibaraki 305-8506 Japan
Fax: +81-29-858-2645
E-mail: www-gio@nies.go.jp

Copies available from:

Center for Global Environmental Research (CGER)
National Institute for Environmental Studies (NIES)
16-2 Onogawa, Tsukuba, Ibaraki 305-8506 Japan
Fax: +81-29-858-2645
E-mail: cgerpub@nies.go.jp
http://www-cger.nies.go.jp

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Foreword

It is widely recognized that increases in emissions of greenhouse gases (GHG) are the primary cause of climate change and its impacts. To help guide policies and strategies, GHG inventories that can provide accurate information of these emissions and trends are critically important.

The United Nations Framework Convention on Climate Change (UNFCCC) entered into force in March 1994 for the world to consider how to mitigate climate change and to address the issues that have arisen due to unavoidable temperature increases. Under the Convention, all parties develop and publish a national GHG inventory. Almost all parties have submitted at least one national inventory to UNFCCC and are on their way to preparing subsequent inventories.

In Asia, the Workshop on GHG Inventories in Asia (WGIA) has been organised annually since November 2003 with support from the Ministry of the Environment, Japan. The purpose of WGIA is to create opportunities for government officials and researchers who are engaged in GHG inventory development to exchange information and share their own experiences. It has been found that these exchanges are extremely valuable, as participating countries share many similarities which affect GHG emissions despite their varied experiences.

The Center for Global Environmental Research (CGER) was established in 1990 within the National Institute for Environmental Studies in Tsukuba, Japan. The primary mission of CGER is to contribute to the enhanced scientific understanding of global environmental changes and to elucidate and provide solutions for alarming environmental problems. CGER has been actively working to achieve its goal by conducting global environmental research, providing research-support facilities, and implementing global environmental monitoring.

This CGER report serves to compile the essential information which resulted from past WGIAs and by doing so provide the most up-to-date information on GHG inventory development in the Asia region. It is our hope that this CGER report proves useful for those who work in the field of climate change and related issues, and that it contributes to further progress in inventory development in countries in Asia and the world.

August 2006

Yasuhiro Sasano
Director
Center for Global Environmental Research
National Institute for Environmental Studies

Preface

In late 2003, greenhouse gas (GHG) inventory-related researchers and government officials from countries in the Asia region met at the 1^{st} Workshop on GHG Inventories in Asia (WGIA) to share experiences and discuss issues for the development of GHG inventories. Since then, we have continued this exchange of information and strengthened our network with the hope that WGIA could support inventory development in the region, in addition to what is being done at the national level.

In February 2006, at the 3^{rd} WGIA, the group generated concrete discussion outcomes for the inventory development of different sectors. We decided to compile into one comprehensive report the essence of the information that we have exchanged at past WGIAs.

The purposes of this report are, therefore:

1) To present a list of action items necessary for the improvement of GHG inventories in the region,
2) To compile information that has been shared at WGIA,
3) To record the history of WGIA.

This report consists of a number of articles produced by those who participated in the 3^{rd} WGIA. Also, other participants of the 3^{rd} WGIA provided their comments. Although all of their names cannot be listed here, I would like to extend my gratitude for their excellent contributions to this report and their continuous support of WGIA activities.

I hope that this report is able to provide you with useful and important information on inventory development in Asia. I am now most confident that our network will continue to work closely on improving the quality of inventories in the region.

August 2006

On behalf of all contributors and colleagues,

梅宮 知佐

Chisa Umemiya
Assistant Fellow
Greenhouse Gas Inventory Office of Japan
Center for Global Environmental Research
National Institute for Environmental Studies

List of Acronyms and Abbreviations

AD	activity data
ALGAS	Asia Least-cost Greenhouse Gas Abatement Strategy
C	carbon
CDM	Clean Development Mechanism
CH_4	methane
CIS	Commonwealth of Independent States
CO	carbon monoxide
CO_2	carbon dioxide
DOC	degradable organic carbon
EF	emission factor
EFDB	Emission Factor Database
eq	equivalent
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
GWP	global warming potential
HFC	hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land-Use Change and Forestry
MSW	municipal solid waste
N	nitrogen
N_2O	nitrous oxide
NC	national communication
NH_3	ammonia
NIES	National Institute for Environmental Studies
NMVOCs	non-methane volatile organic compounds
NO_X	nitrogen oxides
PFC	perfluorocarbon
QA	quality assurance
QC	quality control
RF	removal factor
SF_6	sulphur hexafluoride
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WGIA	Workshop on Greenhouse Gas Inventories in Asia

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EXECUTIVE SUMMARY

The United Nations Framework Convention on Climate Change (UNFCCC) entered into force in March 1994 for nations all over the world to start considering how to deal with the serious challenges caused by climate change. As of June 2006, 189 nations have ratified the Convention.

Under the Convention, all parties must develop and publish a national inventory of greenhouse gases (GHG) not controlled by the Montreal Protocol. GHG inventories are extremely important as they can provide information on trends in GHG emissions and removals, which allows policy makers to develop measures more effectively and reliably to reduce GHG emissions. GHG inventories are developed according to the guidelines of the Intergovernmental Panel on Climate Change (IPCC).

Although these IPCC guidelines contain “default” emission factors and activity data to enable all countries to construct inventories, the parties are encouraged to make efforts to develop their own emission factors and activity data as the “default” values may not represent a particular country’s circumstances. The intensity of each country’s efforts is likely to vary widely as it depends on national conditions. Therefore, information exchange among countries is considered effective to help countries improve the quality of their GHG inventories.

“The Workshop on Greenhouse Gas Inventories in Asia (WGIA)” has been organised annually since November 2003 with the support of the Ministry of the Environment, Japan. The major purpose of WGIA is to assist countries in the Asia region in developing and improving inventories by promoting information exchange in the region.

WGIA includes government officials and researchers from around 12 countries in the region and other experts from relevant international organisations such as the UNFCCC Secretariat and the Technical Support Unit of the IPCC National Greenhouse Gas Inventories Programme. The participating countries in the latest WGIA held in February 2006 in Manila, Philippines were: Cambodia, China, India, Indonesia, Japan, Korea, Lao PDR, Malaysia, Mongolia, Philippines, Thailand, and Vietnam.

The most recent outcomes of WGIA can be classified into three types: (1) updating each other on the national status of inventory development; (2) sharing national efforts and practices; and (3) identification of common issues and possible solutions, by sector.

(1) Updating each other on the national status of inventory development

Selected points of updated information for inventory development are as follows:

- Countries are making their own progress in improving the quality of their GHG inventories following their Initial National Communication.
- Most are either already working on or planning to start work on their Second National Communication soon, and aim to complete the work within two or three years.
- Countries vary widely in institutional resources available for GHG inventories.
- Most countries are not yet satisfactorily using UNFCCC software/ manuals/guidebooks for their inventories.
- Many countries plan to develop or refine their own national emission factors.

(2) Sharing national efforts and practices

The four sectoral groups of Energy, Agriculture, Land Use, Land-Use Change and Forestry (LULUCF), and Waste shared a variety of existing practices which are likely to be useful and applicable to other nations. The practices were related to:

- Direct measurement and experiment to estimate country-specific emission and removal factors
- Approach to collect more accurate activity data
- More complex and therefore reliable estimate methodologies
- Data verification
- Institutional arrangement

(3) Identification of common issues and possible solutions, by sector

The four sectoral groups also identified the issues and possible solutions that were shared by the participating countries (see Table 1).

Although various efforts, including on-going and future activities, for improving the quality of inventories have been identified, the participating countries all agreed that there exists a high possibility for regional activities to contribute to the improvement of inventories. Adding to the current style of information exchange in annual meetings, the countries proposed the following initiatives that could be taken in the future in the network of WGIA.

i) More active and practical information exchange on activity data, emission factors, estimation methodologies etc., by creating:
   - regional tables or databases (possibly accessible over the Internet)
   - working groups of regional experts in specific areas

ii) Strong collaboration among regional experts, which could allow the realisation of:
   - regional research projects to estimate region-specific emission factors, a regional standard measurement manual, etc.
   - regional GHG monitoring stations
   - more funding

iii) Enhanced contribution to the other regions and global communities
   - information transmission through the WGIA website, publications, etc.
   - inputs to the IPCC Emission Factor Database

Table 1 List of common challenges and possible solutions

Sector	Challenge	Possible solution
Energy	Collection of activity data	Share experiences on collecting data specifically focusing on the areas of: transportation (travel distance); power plants; heavy industry
	Development of improved emission factors	Make tables for the values of country-specific emission factors with basic assumptions adopted
	Implementation of quality assurance/quality control (QA/QC)	・Make different databases for comparison ・Describe routine processes and task allocation to implementing agencies
	Implementation of uncertainty assessment	Follow-up and update data and information
Agriculture	Development of region-specific emission factors for the Asian region	・Develop and implement regional research projects ・Collaborate with experts ・Share databases and expertise
	Establishment of a network of monitoring station for GHG emissions	
	Funding for research and capacity building in the region	
LULUCF	Different level of detail in forest categories and strata between states/provinces	Encourage local research agencies/universities to engage in this research area and seek endorsement from local/relevant authorities for the work
	Difficulty in defining appropriate number of destructive sampling which is cost-effective	Get additional data from other sources (national inventories of other countries in the region, related studies, students' theses)
	Difficulty in developing good activity data and emission factors for the key categories which might not be cost-effective	Apply the 2000 IPCC Good Practice Guidance (GPG) in a number of regions/provinces that contribute to the GHG emissions in those categories
	Frequent change of personnel working on inventories	・Institutionalize GHG inventory work, at least at the level of national focal point ・Develop reference manuals in local languages
Waste	Lack of accurate waste generation amounts and DOC (degradable organic carbon); lack of detail and accurate information about waste treatment and management levels	・Encourage local research agencies/universities to do site measurements in waste areas and to collect detailed information of waste treatment management levels ・Seek support from local/relevant authorities for inventory work ・Set up a database of activity data (including historical data)
	Difficulty in getting appropriate k values and DOC parameters in different countries	・Get additional data from other sources (national inventories of other countries in

	or regions	the region, related studies, and students' theses) ・Share information with other countries in the same region
	Uncertainty related to migrating human populations in urban areas	・Apply the 2000 IPCC Good Practice Guidance (GPG) in a number of regions/provinces that contribute to GHG emissions ・Conduct site measurement and sample analysis ・Conduct uncertainty analysis with the Monte Carlo simulation method
	Lack of consistency of working groups in waste sector domestically and internationally	・Institutionalize GHG inventory work, at least at the level of national focal points ・Develop reference manuals in local languages ・Establish an international network for cooperating in the waste sector

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Chapter 1

INTRODUCTION

1.1 Background

1 GHG Inventories under the UNFCCC

The world adopted the UN Framework Convention on Climate Change (UNFCCC) in 1992. Two years later, in 1994, the Convention entered into force. Today, 189 nations are party to the Convention.

Article 4, paragraph 1(a) and Article 12, paragraph 1(a) of the Convention provide for the parties to develop and publish a national inventory of greenhouse gas (GHG) emissions and removals not controlled by the Montreal Protocol:

> *[All Parties...shall:] Develop, periodically update, publish and make available to the Conference of the Parties, […] national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol…*
>
> (Article 4, paragraph 1(a))

> *[…each Party shall communicate...] A national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol….*
>
> (Article 12, paragraph 1(a))

These inventories are considered to provide fundamental information that can help determine appropriate response measures to reduce GHG emissions. Reporting requirements are different between Annex I and non-Annex I parties to the Convention. For example, while Annex I countries are required to report annual inventories, non-Annex I countries are committed to report for the year 1994, or alternatively for 1990 for the initial national communication and for the year 2000 in the second national communication.

GHG inventories are developed according to the guidelines of the Intergovernmental Panel on Climate Change (IPCC), including *the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* and *IPCC Good Practice Guidance for Land Use, Land-Use Change, and Forestry*. These IPCC guidelines present not only estimation methods for emissions by sources and removals by sinks, but also “default” emission and removal factors and “default” activity data to enable all countries to develop inventories, despite the lack of country-specific information. However, given that these “default” emission and removal factors and activity data are not always appropriate to represent particular countries’ situations, countries are encouraged to make efforts to develop their own data to increase the quality of inventories. Information exchange on these countries’ efforts is therefore desired.

2 GHG Inventories from Participating Countries

All countries participating in the Workshop on Greenhouse Gas Inventories in Asia (WGIA) have submitted at least one national GHG inventory to UNFCCC. Among the participating countries, Japan is the only Annex I party, and is therefore committed to develop and publish annual inventories. The other countries have submitted inventories for the initial national communication, while the Republic of Korea has submitted its inventory for the second national communication. Table 1.1 summarises inventory submission from the participating countries.

Table 1.1 Summary of inventory submission from participating countries (as of June 2006)

Country	Annex I/ Non-Annex I	Latest inventory submitted to UNFCCC	Submission date
Cambodia	Non-Annex I	Initial national communication	08/10/02
China	Non-Annex I	Initial national communication	10/12/04
India	Non-Annex I	Initial national communication	22/06/04
Indonesia	Non-Annex I	Initial national communication	27/10/99
Japan	Annex I	Japan's 2006 National Greenhouse Gas Inventory	25/05/06
Republic of Korea	Non-Annex I	Second national communication	01/12/03
Lao PDR	Non-Annex I	Initial national communication	02/11/00
Malaysia	Non-Annex I	Initial national communication	22/08/00
Mongolia	Non-Annex I	Initial national communication	01/11/01
Philippines	Non-Annex I	Initial national communication	19/05/00
Thailand	Non-Annex I	Initial national communication	13/11/00
Viet Nam	Non-Annex I	Initial national communication	02/12/03

* Source: UNFCCC, 2006a and UNFCCC, 2006b

1.2 Workshop on Greenhouse Gas Inventories in Asia (WGIA)

1 Background and Objectives

The Workshop on Greenhouse Gas Inventories in Asia (WGIA) was held in Phuket, Thailand in November 2003, following the IGES/NIES Workshop on GHG Inventories for Asia-Pacific Region[1]. The second WGIA was held in Shanghai, China in 2005 and the third in Manila, Philippines in 2006.

The primary objective of WGIA is to assist countries in Asia in developing and improving their inventories by promoting information exchange at the regional level. WGIA also aims to create strengthened relationships between government officials and researchers who are involved in inventory development in a given country by calling them together to the workshops. Furthermore, WGIA disseminates the knowledge and information accumulated through its activities to other communities in and outside the region via, for example, the WGIA website[2].

[1] http://www.iges.or.jp/en/cp/output_all/workshops/GHG/index.html

[2] http://www-gio.nies.go.jp/wwd/wgia/wgiaindex-e.html

2 Running the Workshop

2.1 Contents of the Workshop

The National Institute for Environmental Studies (NIES, Japan) is in charge of designing the workshops based on ideas provided by participants through questionnaires and other email-based discussions. Also, given that WGIA are held annually, the themes of the workshops are largely based on the outcomes from the previous workshop.

Each workshop runs for approximately two days. Typically, the first day of the workshop consists of two sessions on separate themes and the second day of another session for discussion of overall workshop results and suggestions for future activities (Table 1.2). Participants are generally seated together for the workshop, except for one session during the 3rd WGIA in which participants were divided into 4 sectoral discussion groups.

Table 1.2 Titles of the sessions on selected themes from the 1st to 3rd WGIA

	Titles
1st WGIA	・ Reports by participating officials on the development of national systems for gathering information regarding the inventories ・ Reports by participating experts on technical issues relating to the preparation of inventories
2nd WGIA	・ Update on the status of the Asian inventories ・ Sharing useful information and experiences in GHG inventory preparation
3rd WGIA	・ Updates on GHG inventories in Asia region ・ Country practices, by sector

2.2 Financial Sources

Japan's Ministry of the Environment sponsors WGIA, including the participation of the representatives from countries in Asia[3]. The approximate amount of its support is 9 million JPY for each workshop.

2.3 International Cooperation

Linking WGIA activities with global or regional activities is a major element of WGIA. In this regard, WGIA has enjoyed rewarding relationships with relevant international organisations, such as the UNFCCC Secretariat, the Technical Support Unit of the IPCC National Greenhouse Gas Inventories Programme (IPCC NGGIP), and the Asia-Pacific Network for Global Change Research (APN).

3 Participants

As a general rule, the participants of WGIA include one government official and one researcher from each country in Asia. Some countries nominated only one participant. There were twelve participating countries in the 3rd WGIA: Cambodia, China, India, Indonesia,

[3] Representatives of the Republic of Korea participated in WGIA with their own expenses as the country is the OECD member country. Also, one researcher from Thailand participated in the 2nd WGIA with the funds from the Asia-Pacific Network for Global Change Research CAPaBLE Programme.

Japan, Republic of Korea, Lao PDR, Malaysia, Mongolia, Philippines, Thailand, and Vietnam.

A representative of the UNFCCC Secretariat usually participates in WGIA. The representatives of the other international organisations mentioned above have also taken part in WGIA.

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Chapter 2

REGIONAL CHARACTERISTICS

2.1 Identification of Regionally-Significant Source/Sink Categories in Asia

Chisa UMEMIYA and Tomoyuki AIZAWA
Center for Global Environmental Research, National Institute for Environmental Studies,
16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan

Abstract:

The UN Framework Convention on Climate Change (UNFCCC) requires that all parties to the Convention report a national inventory of greenhouse gas (GHG) emissions and removals. Countries are encouraged to improve the quality of GHG inventories, including the development of the country-specific emission factors and activity data. The intensity of efforts varies depending on national circumstances. Activities to support the efforts of each country by using a regional framework have been carried out, including the Workshops on GHG Inventories in Asia (WGIA). This study aimed to identify the regionally-significant source/sink categories in inventories of the Asia region and analyze the regional characteristics of those categories in order to suggest activities for future WGIA events. The study identified the regional key categories of the Asia region as, such as: CO_2 from "Changes in Forest and Other Woody Biomass Stocks", CO_2 from "Fuel Combustion: Energy", CH_4 from "Rice Cultivation", and CO_2 from "Forest and Grassland Conversion". It also found out that those categories can be explained by the ecological and cultural circumstances unique to the Asia region.

1 Introduction

The UN Framework Convention on Climate Change (UNFCCC) requires that all parties to the Convention report a national inventory of greenhouse gas (GHG) emissions and removals following the guidelines of the Intergovernmental Panel on Climate Change (IPCC), with different reporting requirements for Annex I and non-Annex I nations (UNFCCC, 1992; 2003; 2004). Annex I nations are required to report annual inventories whilst non-Annex I parties are requested to report inventories for 1994, or for 1990 for the initial national communication and for 2000 in the second national communication (UNFCCC, 2003; 2004).

While the IPCC guidelines provide "default" emission factors and activity data to enable all countries to prepare inventories, regardless of the availability of data in their countries, they also encourage parties to make efforts to develop their own emission factors and activity data to make inventories that are more reliable (UNFCCC, 2003; 2004). The intensity and progress of the efforts that countries make or intend to make differ by country, depending on the national circumstances.

There are activities to support national efforts to improve the quality of inventories by promoting exchange of information and experiences among countries in the same region. For example, the UN Development Programme (UNDP) implements regional projects, such as Capacity Building for Improving the Quality of Greenhouse Gas Inventories, in the Europe/CIS and the West and Francophone Central Africa regions, with the funds from the Global Environment Facility (GEF) (GEF, 2001; 2002). In the Asia region, "Workshops on GHG inventories in the Asia (WGIA)" has been organised annually since 2003 with the support of the government of Japan (MoEJ et.al, 2003; 2005).

When conducting activities to promote the effective exchange of information to assist national efforts to improve inventories, it is important to identify which categories of emission sources and sinks should be targeted, because emission factors, activity data, and estimation methods are different from one category to another. Moreover, since resources to prepare inventories are limited in almost all countries, it is necessary to give priority to certain source/sink categories that have significant impacts on the accuracy of inventories in the region. In this article, based on the inventories submitted by countries in the Asia region, we will identify the source/sink categories that are considered to be significant in terms of their impacts on the accuracy of inventories in the region. We will then discuss the regional characteristics of those key source/sink categories by comparing them with the key categories of other regions.

2 Methodology

To identify the regionally-significant source/sink categories for the Asia region, we followed the methodology introduced by the UNDP-GEF regional capacity building project in the Europe/CIS region. The GHG inventories of 11 countries participating in WGIA were used in this study (see Table 2.1).

Table 2.1 Sources of GHG inventories of countries used under this study

Sources	Year of inventory	Countries
Initial National Communication	1990	Lao PDR
	1994	Cambodia, India, Indonesia, Mongolia, Philippines, Thailand, Vietnam
Second National Communication	2001	Republic of Korea
GHG inventory	1995	Japan
ALGAS[1] Report	1990	China

1 ALGAS = ”Asia Least-cost Greenhouse Gas Abatement Strategy”

The methodology first applies the level assessment of the Tier 1 method to quantitatively identify the key categories of each nation in accordance with the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF) (IPCC, 1996; 2003). The Tier 1 level assessment method calculates the contribution of emissions and removals in absolute values of each source/sink category to the national total GHG emissions and removals (removals from sinks were counted in absolute values and summed up with emissions from sources) then reallocates categories in the order of magnitude of the calculated contributions. In the reallocated list, key source/sink categories including LULUCF are identified as those that, when all contributions have been summed up, come to 95% of the total contributions.

After analyzing the key source/sink categories of each nation, the top five categories identified as the national key source/sink categories were identified and the frequency of a category being identified as a top-five key category was noted. The categories that appeared with a higher frequency were then identified as regionally-significant source/sink categories.

When applying the IPCC key source/sink categories, it is necessary to determine the appropriate level of detail for the categories to be assessed. To compare the results of the key category analysis of each nation across a region, the level of detail of categories should be set as the one which inventories of all nations can fulfill. In this study, to decide the aggregation level of source/sink categories, when one or two countries did not meet a certain level of detail whilst the rest satisfied the level, emissions and removals of the categories in the inventories of those countries were estimated by applying the ratios of such categories in the inventories of neighboring countries.

3 Results and Discussions

The regionally-significant source/sink categories for the Asia region that were identified under this study and those identified under the UNDP-GEF regional project for the Europe/CIS region are shown in Table 2.2. In the analysis of the UNDP-GEF project in the Europe/CIS region, the categories of the LULUCF sector were not considered. Nonetheless, due to the ecological conditions in the Europe/CIS region, natural resources are not abundant in many countries in the region, therefore one can assume that even if the categories of LULUCF were included in the analysis of the UNDP-GEF regional project in the Europe/CIS region, they would not be identified as regionally-significant source/sink categories.

Table 2.2 The regionally-significant source/sink categories in the Asia and Europe/CIS regions

	Asia				Europe/CIS[1)]			
#	IPCC Categories[2)]		GHG	Freq.[3)] (of 11)[4)]	IPCC Categories		GHG	Freq. (of 12)[5)]
1	5.A	Changes in Forest and Other Woody Biomass Stocks	CO_2	9	6.A	Solid Waste Disposal on Land	CH_4	7
2	1.A.1	Fuel Combustion: Energy	CO_2	8	1.B.2	Fugitive Emissions from Fuels: Oil and Natural Gas	CH_4	7
3	4.C	Rice Cultivation	CH_4	7	4.A	Enteric Fermentation	CH_4	6
4	5.B	Forest and Grassland Conversion	CO_2	7	1.A.3.b	Fuel Combustion: Transportation - Road Transportation	CO_2	6
5	1.A.2	Fuel Combustion: Manufacturing Industries and Construction	CO_2	6	4.D	Agricultural Soils	N_2O	5
6	1.A.3	Fuel Combustion: Transport	CO_2	5	1.A.1	Fuel Combustion: Energy	CO_2	3
7	4.A	Enteric Fermentation	CH_4	3	1.B.1	Fugitive Emissions from Solid Fuels	CH_4	3
8	5.C	Abandonment of Managed Lands	CO_2	3	4.B	Manure Management	N_2O	2
9	1.A.4	Fuel Combustion: Other Sectors (e.g. commercial, residential)	CO_2	3	1.A.2	Fuel Combustion: Manufacturing Industries and Construction	CO_2	2

1) Taken from GEF (2001).
2) Adopted from IPCC (1996).
3) Freq. = Frequency of the countries that identify the category as one of their top five key categories.
4) Total number of the countries studied in the Asia region.
5) Total number of the countries studied in the Europe/CIS region.

None of the four categories with the highest frequencies in the Asia region corresponds with any of those in the Europe/CIS region. It is obvious that emissions and removals from the LULUCF sector (particularly removals from changes in forest and other woody biomass stocks) are remarkably significant in the Asia region. The significance of methane emissions from rice cultivation in the Asia region indicates how widely rice is grown in the region. On the contrary, in the Europe/CIS region, it is highly likely that cows or sheep would be the major food sources, which leads to high methane emissions from enteric fermentation. The regional significance of CO_2 emissions from fuel combustion is higher in the Asia region than in the Europe/CIS region.

In the Europe/CIS region, the methane emissions from solid waste disposal on site are the most significant, followed by the methane emissions from fugitive emissions. The latter allows one to assume oil and natural gas have been extracted in the region.

The number of countries which report emissions and removals from the selected categories and the percentage share of the regional emission and removals from each of those categories to the total regional emissions and removals in the Asia region are shown in Table 2.3. The four categories which were identified as regionally-significant source/sink categories with the highest frequency were reported by almost all nations and account for around 45% of the total emissions and removals of the region. It is noteworthy to realise that the categories of “Abandonment of managed lands” and “CO_2 emissions and removals from soil” were reported by less than half of the selected countries. One of the possible reasons for this would be the lack of necessary data for the estimation of emissions and removals. For Japan, which did not report the emissions and removals from those two categories, reliable data were not available for calculation.

Table 2.3 The regionally significant source/sink categories in the Asia region with the number of country reports and impacts to the total regional emissions and removals of each category

#	IPCC Categories[1)]		GHG	Freq.[2)] (of 11)[3)]	Countries	No. of reports[4)]	Impacts[5)] (%)
1	5.A	Changes in Forest and Other Woody Biomass Stocks	CO_2	9	Cambodia, China, Indonesia, Japan, Korea, Lao PDR, Mongolia, Philippines, Vietnam	11	12.2
2	1.A.1	Fuel Combustion: Energy	CO_2	8	China, India, Indonesia, Japan, Korea, Mongolia, Philippines, Thailand	11	18.9
3	4.C	Rice Cultivation	CH_4	7	Cambodia, China, India, Lao PDR, Philippines, Thailand, Vietnam	10	5.6
4	5.B	Forest and Grassland Conversion	CO_2	7	Cambodia, Indonesia, Lao PDR, Mongolia, Philippines, Thailand, Vietnam	11	8.7
5	1.A.2	Fuel Combustion: Manufacturing Industries and Construction	CO_2	6	China, India, Indonesia, Japan, Korea, Thailand	10	19.0
6	1.A.3	Fuel Combustion: Transport	CO_2	5	India, Japan, Korea, Philippines, Thailand	10	7.5
7	4.A	Enteric Fermentation	CH_4	3	Cambodia, India, Mongolia	11	4.1
8	5.C	Abandonment of Managed Lands	CO_2	3	Indonesia, Mongolia, Vietnam	5	0.4
9	1.A.4	Fuel Combustion: Other Sectors (e.g. commercial, residential)	CO_2	3	China, Japan, Korea	10	8.7
10	4.D	Agricultural Soils	N_2O	1	Cambodia	9	1.3
11	5.D	CO_2 Emissions and Removals from Soil	CO_2	1	Vietnam	4	0.0

1) Adopted from IPCC (1996).
2) Freq. = Frequency of the countries that identify the category as one of their top five key categories.
3) Total number of the countries studied in the Asia region.
4) The number of countries which gave reports in each category.
5) The percentage share of the emissions and removals in absolute values of the region for each category to the total emissions and removals of the region.

4 Conclusion

This study identified the regionally-significant source/sink categories for the Asia region as: CO_2 from “5.A. Changes in Forest and Other Woody Biomass Stocks”, CO_2 from “1.A. Fuel Combustion: Energy”, CH_4 from “4.C. Rice Cultivation”, and CO_2 from “5.B. Forest and Grassland Conversion”. It was found out that the identified regionally-significant categories possess regional characteristics which can be proved by the ecological and cultural circumstances of the region. This indicates that it would be more effective if regional efforts to develop and improve inventories, including WGIA, are focused on these key regional categories. It was also uncovered that there exist certain categories, like CO_2 from “5.C Abandonment of managed lands” and “5.D CO_2 emissions and removals from soil”, which were identified as the regionally-significant source/sink categories but have only been reported by a small number of countries. Therefore, information transfer in those categories should be particularly enhanced among countries in the region.

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Chapter 3

COUNTRIES' STATUS - GOOD PRACTICES AND BARRIERS

3.1 Cambodia

Chan Thou CHEA
Ministry of Environment
#48, Preah Sihanouk Blvd, Phnom Penh, Cambodia

1 History of GHG Inventories in Cambodia

The Kingdom of Cambodia ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 18 December 1995 and it entered into force on 16 March 1996. As a developing (non-Annex I) party to the UNFCCC, Cambodia does not have any greenhouse gas (GHG) reduction obligations. However, the country is committed to voluntary participation in GHG reduction projects and therefore it acceded to the Kyoto Protocol on 4 July 2002. This makes Cambodia eligible for hosting GHG emission reduction activities under the Clean Development Mechanism (CDM).

From 1999 to 2003, Cambodia started the implementation of the Climate Change Enabling Activity Project (CCEAP Phase I and II), funded by the Global Environment Facility (GEF) via the United Nations Development Programme (UNDP). The project is considered to be the first step taken by Cambodia towards the implementation of the UNFCCC. It contributed to developing the enabling environment for the RGC (Royal Government of Cambodia) to fulfill its commitments under the UNFCCC as well as to strengthen its capacity to deal with climate change issues. Its achievements culminated with the production of Cambodia's Initial National Communication, which was submitted to the 8th Conference of the Parties (COP) in 2002. The document presents the results of the national GHG inventory for 1994, GHG mitigation options, and an assessment of vulnerability and adaptation to climate change. CCEAP phase II is focused on improving activity data and emission factors in the forestry sector in Cambodia with the main objectives of developing a database on emission factors, improving activity data, developing local emission factors, and conducting uncertainty analyses on the GHG inventory.

As a signatory to the UNFCCC, Cambodia is obliged to undertake its national GHG inventory in accordance with Article 4.1.a of the Convention. The GHG inventory is one of three major components of the project; the other two being GHG abatement analysis and vulnerability and adaptation components. The inventory was carried out by the National Technical Committee (NTC) members which include representatives from the Ministry of Environment, the Ministry of Agriculture, Forestry and Fisheries, the Ministry of Public Works and Transportation, the Ministry of Water Resources and Meteorology, the Ministry of Industry, Mines and Energy, and Royal University of Phnom Penh.

In 2005, the APN (Asia-Pacific Network for Global Change Research) funded project under the CAPaBLE program has been conducted in Cambodia with the main objective of improving the estimation of GHG emissions and removals from Land Use, Land-Use Change, and Forestry (LULUCF). The results of this study will contribute to the preparation of Cambodia's Second National Communication.

2 Overview of the Inventories

The Initial National Communication included an inventory of greenhouse gas emissions by sources and removals by sinks prepared for the base year 1994 and presented emission projections from 1994 to 2020. Cambodia's 1994 greenhouse gas inventory quantified anthropogenic emissions by sources and removals by sinks of carbon dioxide, methane and nitrous oxide. The inventory covered five sectors: (1) energy, (2) industrial processes, (3) agriculture, (4) waste, and (5) land use change and forestry. Since local emission factors did not exist for Cambodia, the study used a combination of default values from the Intergovernmental Panel on Climate Change (IPCC) and values developed in other Southeast Asian countries. In 1994, Cambodia emitted some 59,708 Gg and removed some 64,850 Gg of CO_2-equivalent. Thus Cambodia was a net carbon sink country with a net total carbon removal of 5,142 Gg of CO_2-equivalent. Land use change and forestry accounted for most of the emissions and removals of greenhouse gases in 1994. LULUCF represented 81.2% of greenhouse gas emissions, followed by agriculture with 15.5% and energy with 2.8%.

Table 3.1 Summary of 1994 Greenhouse Gas Inventory of Cambodia (Gg)

SECTOR AND SOURCE CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
I. ENERGY							
A. Fuel Combustion Activities							25.63
1. Energy Industries	331.31	0.02	0.00	0.91	0.07	0.02	
2. Manufacturing Industries	6.53	0.00	0.00	0.02	0.00	0.00	
3. Transport	825.25	0.14	0.01	7.55	52.54	9.93	
4. Commercial/Service	26.50	0.00	0.00	0.04	0.01	0.00	
5. Residential	82.49	0.01	0.00	0.12	0.02	0.01	
B. Biomass Emissions*	7,773.54	23.96	0.32	8.06	403.91	47.58	
SUB TOTAL (A+B)	1,272.08	24.13	0.33	16.69	456.56	57.54	25.63
CO_2 EQUIVALENT	1,272.08	506.82	102.44				
TOTAL CO_2 EQUIVALENT	**1,881.35**						
II. INDUSTRY							
A. Cement	49.85						0.03
B. Food and Beverages						0.02	
C. Pulp and Paper				0.01	0.03	0.22	0.03
SUB TOTAL (A+B+C)	49.85	0.00	0.00	0.01	0.03	0.24	0.06
CO_2 EQUIVALENT	49.85	0.00	0.00				
TOTAL CO_2 EQUIVALENT	**49.85**						
III. AGRICULTURE							
A. Domestic Livestock		184.79	3,88				
B. Rice Cultivation		150.40					
C. Grassland Burning		1.98	0.02	0.88	51.90		
D. Agricultural Residue Burning		2.09	0.05	1.81	43.86		
E. Agricultural Soils			7.13				

SUB TOTAL (A+B+C+D+E)		339.25	11.08	2.70	95.76		
CO_2 EQUIVALENT		7,124.26	3435.89				
TOTAL CO_2 EQUIVALENT	**10,560.15**						
IV. WASTE							
A. Solid Wastes		5.90					
B. Domestic/Commercial Wastewater		0.66					
C. Industrial Wastewater		0.21					
D. Human Sewage			0.42				
SUB TOTAL (A+B+C+D)		6.77	0.42				
CO_2 EQUIVALENT		142.23	131.16				
TOTAL CO_2 EQUIVALENT	**273.39**						
V. LAND USE CHANGE AND FORESTRY							
A. Change in Forest/Woody Biomass	-64,850.23						
B. Forest/Land Use Change	45,214.27	74.77	0.51	18.58	654.20		
SUB TOTAL (A+B)	-19,635.96	74.77	0.51	18.58	654.20		
CO_2 EQUIVALENT	-19,635.96	1,570.08	159.34				
TOTAL CO_2 EQUIVALENT	**-17,906.54**						
TOTAL NAT'L GHG EMISSIONS	**-18,314.03**	**444.92**	**12.35**	**37.97**	**1,206.54**	**57.78**	**25.69**
EQUIVALENT CO_2	**-18,314.03**	**9,343.39**	**3,828.85**				
TOTAL NAT'L CO_2-eq. UPTAKE	**-5,141.79**						

*CO_2 emissions from biomass are not included in the total (IPCC).

The projection of greenhouse gas emissions to the year 2020 was carried out using the Long-range Energy Alternatives Planning system (LEAP) developed by the Stockholm Environment Institute. Industry was excluded from projections under the assumption that mainly light industries, such as garment and food processing would be developed. Emissions from wood used as fuel by households were not included and were assumed to be absorbed by the forestry sector. The Initial National Communication projected that by 2000, Cambodia would become a net emitter of greenhouse gases.

3 Institutional Arrangement

In Cambodia, the institutional implementation arrangement of the National GHG Inventory under the CCEAP project is as follows:

The Ministry of Environment (MoE) is the UNFCCC Focal Point for Cambodia, and it played the role of a national implementation agency and took overall responsibility for the implementation of the activities. Technical and advisory assistance from UNDP-GEF was coordinated with all concerned government agencies, public institutions, private stakeholders, and NGOs.

The Project Steering Committee established under the CCEAP was used for the overall implementation of the national GHG inventory. The inventory was carried out by the National

Technical Committee (NTC) members which included representatives from the Ministry of Environment, the Ministry of Agriculture, Forestry and Fisheries, the Ministry of Public Works and Transportation, the Ministry of Water Resources and Meteorology, the Ministry of Industry, Mines and Energy, and Royal University of Phnom Penh.

4 Methodology, Good Practices, and Capacity

For Cambodia, as a developing country (a Non-Annex I party to the UNFCCC), it is mandatory that the national GHG inventory cover three main greenhouse gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). However, in this first national GHG inventory, other gases such as carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NOx), and non methane volatile organic compound (NMVOC) were also considered whenever data were available. Following the recommendation of the UNFCCC Secretariat, the Cambodian National GHG inventory was developed using the 1996 revised IPCC methodology with the base year of 1994. Each of the GHGs has different contributions to the total greenhouse effect, which can be expressed as global warming potential (GWP). The GWP is expressed in tonnes (or units) of CO_2 equivalent (CO_2-eq.) emissions per tonne (or unit) of GHG emissions. Methane (CH_4) has 21 tonnes of CO_2-eq. per tonne of methane emitted. Nitrous oxide (N_2O) has 310 tonnes of CO_2-eq. per tonne of N_2O emitted. The methane and nitrous oxide emissions were converted to tonnes of CO_2-eq. by multiplying the methane emissions (in tonnes) by 21 and the nitrous oxide emissions (in tonnes) by 310.

The basic approach for calculating emissions of a particular gas from a particular sector is based on the following equation:

Emission = Activity Data x Emission Factor

In some cases, activity data needed for developing the inventory for a certain sector were not available. In such cases, the data were estimated from related available data by using several assumptions and these are referred to in this study. In other cases, some activity data were available in the reporting format of the concerned governmental institutions and NGOs/IGOs. However, some uncertainties still exist due to the current weak data management in most ministries. Local emission factors were also not available. In most cases, the emission factors used for the analysis were IPCC default values or emission factors developed by regional countries such as Thailand, Philippines or Indonesia. The Philippine Reference Manual for the National GHG Inventory was also adapted for use in Cambodia.

5 Problems, Constraints, and Future Plans

Findings from this study suggested that in addition to the limited technical capacity of the national staff, the main difficulties Cambodia faced in establishing its National GHG inventory were the lack of data and local emission factors. Some non-available activity data were derived using assumptions. Most emission factors used in the study were either IPCC default values or emission factors developed by neighbouring countries such as Thailand, Philippines and Indonesia. Therefore, in the future, it will be necessary to perform research on ways to improve activity data and develop local emission factors for important sectors such as LULUCF. Data availability, data reliability and the absence of local emission factors are the main issues and constraints in the preparation of the greenhouse gas inventory.

Cambodia submitted its proposal for the Second National Communication under the United Nations Framework Convention on Climate Change to UNDP-Cambodia in late 2005. The Second National Communication, which will include the GHG inventory, will be implemented in late 2006.

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3.2 India

Sumana BHATTACHARYA
Natcom Project Management Cell, Winrock International India
1, Navjeevan Vihar, New Delhi 110017, India

1 History of GHG Inventory Preparation in India

Estimations of anthropogenic GHG emission inventories in India began on a limited scale in 1991. The estimations were expanded and revised and the first definitive report for the base year 1990 was published in 1992 (Mitra, 1992). Since then, several papers and reports have been published which have upgraded the methodologies for estimation, included country-specific emission factors and activity data, and accounted for new sources of emissions and new gases or pollutants (Mitra , 1996; ALGAS, 1998; Garg et al., 2001; Mitra and Bhattacharya, 2002). The most comprehensive GHG inventory was reported in 2004 as part of India's National Communication to the UNFCCC (NATCOM, 2004). The chronology of the inventory preparation in India is depicted in Table 3.2.

Table 3.2 Chronology of Inventory Development

Gases	**CO_2 and CH_4**	**CO_2 and CH_4**	**CH_4**	**CO_2, CH_4 N_2O, NO_x, CO, NMVOC**	**CH_4**	**CO_2, CH_4 N_2O**
Sectors	Fossil Fuel Rice Animals	Transport Coal mines 1992 CH_4 campaign Animals - Tier-II	Seasonally integrated approach and new classification of rice fields based on water regimes developed	Additional sources: Biomass burning, cement production, oil & natural gas, Manure, crop residue, soils and MSW	1998 methane campaign & CH_4 coefficients organically amended soils	Mostly all sources
Emission Factor	Used Published EF	Used Published & also developed for rice	Developed EF for various water regimes	IPCC default + own published	EF developed for organically amended soil	EF developed for key sectors
Base Year	1990	1990	1990-1995	1990-1995	1998	1994
References	Mitra, 1991	Mitra, 1992	Parashar et al., 1998	ALGAS India, 1998	Gupta et al., 1999	NATCOM, 2004

The *first inventory* was made for the base year 1990 (Mitra, 1991), and was limited to estimates of CO_2 emissions from coal, petroleum and natural gas and CH_4 emissions from rice fields and animals. In 1992 this inventory was further expanded to include transport sector emissions, and a nation wide measurement campaign was launched to capture CH_4 emissions from domestic livestock, specifically, cows, buffalos and goats. This work established the fact that the body weight and feed intake of Indian ruminants is very low compared to ones reared in the colder regions of the world and hence despite the huge population of ruminants, the CH_4 emissions from this sector were relatively low. The total emission of CH_4 from this source was estimated as 7.1 million tons (Mitra, 1992) compared to the USEPA estimate of 10.8 million tons.

The *second inventory* reviewed CO_2 emissions from coal, petroleum, and natural gases, and emissions from biomass burning using carbon emission factors based on expert judgment. Also emissions of CO_2 from the road transport sector and coal mining were introduced. Additionally in the second inventory, non-CO_2 emissions including those for CO, NOx, HC, and particulate were also calculated. The second inventory consolidated the results of the 1991 nation-wide campaign to measure methane emissions from rice paddy fields. It was estimated that Indian rice paddy fields emitted 4+2 million tons per year (Parashar et al., 1996), as opposed to estimates made by USEPA of 37.8 million tons. Repeated measurements in later years have not indicated much variation in this value.

The *third GHG inventory* was prepared under the aegis of the Asia Least cost Greenhouse Gas Abatement project (ALGAS, 1998). The inventory was prepared using the IPCC guidelines for the preparation of National Greenhouse Gas inventories (IPCC, 1996) covering the following sectors: Energy; Industrial Processes; Agriculture; Land Use, Land-Use Change and Forestry; and Waste. The emission factors used were either based on indigenously developed emission factors or the IPCC default values. This inventory used the country specific net calorific values of Indian coal for the first time, namely that of coking coal, non-coking coal, and lignite. These have been subsequently revised in the fourth GHG inventory reported as a part of the India's Initial National Communication to the UNFCCC.

2 Overview of the Latest National GHG Inventory

A comprehensive inventory of Indian emissions from energy, industrial processes, agriculture activities, land use, land use change and forestry and waste management practices has recently been reported in India's Initial National Communication to the UNFCCC for the base year 1994. Table 3.3 summarizes this GHG inventory. In 1994, 1228 million tons of CO_2 equivalent emissions took place from all anthropogenic activities in India, accounting for 3 per cent of the total global emissions. About 794 million tonnes, i.e. about 63 per cent of the total CO_2 equivalent emissions was emitted as CO_2, while 33 per cent of the total emissions (18 million tonnes) was CH_4, and the remaining 4 per cent (178 thousand tonnes) was N_2O. The CO_2 emissions were dominated by emissions due to fuel combustion in the energy and transformation activities, road transport, cement and steel production. The CH_4 emissions were dominated by emissions from enteric fermentation in ruminant livestock and rice cultivation. The major contribution to the total N_2O emissions came from the agricultural soils due to fertilizer applications. At a sectoral level, the energy sector contributed 61 per cent of the total CO_2 equivalent emissions, with agriculture contributing about 28 per cent, and the rest of the emissions were distributed amongst industrial processes, waste generation, and land use, land use change, and forestry.

Table 3.3 Summary of greenhouse gas emissions in Gg (thousand tonnes) from India in 1994 by sources and sinks

Greenhouse gas source and sink categories	CO_2 (emissions)	CO_2 (removals)	CH_4 emissions	N_2O emissions	CO_2 equivalent emissions*
All Energy	679470		2896	11.4	743820
Industrial Processes	99878		2	9	102710
Agriculture			14175	151	379723
Land use, Land-use change and Forestry	37675	23533	6.5	0.04	14292
Waste			1003	7	23233
Total National Emission (Gigagram per year)	**817023**	**23533**	**18083**	**178**	**1228540**

*Converted by using Global warming potential (GWP) indexed multipliers of 21 and 310 for converting CH_4 and N_2O respectively; *Source:* NATCOM, 2004

Fifteen key categories were identified and are listed in descending order of their contribution to the total GHG emissions in 1994. The largest contributor to national GHG emissions is energy and transformation, contributing 29 per cent of the total emissions, followed by industry (12.3 per cent) and transport (7 per cent) in the energy sector. Similarly, in the agriculture sector, enteric fermentation and rice cultivation are the key sources that emit about 12.5 per cent and 7 per cent of the total emissions respectively. In the industrial process sector, steel and iron production and cement manufacturing processes are the key sources, each contributing about 3.6 and 2.5 per cent of the total national emissions.

The status of the GHG inventory, in terms of the percentage of emissions each sector has contributed to the total emissions, type of emission factors used, the methodology used i.e Tier I, II or III is listed in Table 3.4.

Table 3.4 Existing status of the 1994 Indian GHG inventory prepared for India's Initial National Communication to the UNFCCC

Sources of emission	CO_2 equivalent (Gg)	Percentage of total emissions	Cumulative emission (Gg)	Cumulative emission vs. total emission (%)	Tier used	EF used
Energy and transformation industries	355037	28.9	355037	28.9	Tier I	CS
Enteric fermentation	188412	15.3	543449	44.2	Tier II	CS
Industry	150674	12.3	694123	56.5	Tier I	D
Rice cultivation	85890	7.0	780013	63.5	Tier II	CS
Transport	80286	6.5	860299	70.0	Tier I	CS

Emission from soils	45260	3.7	905559	73.7	Tier I	D
Iron and steel production	44445	3.6	950004	77.3	Tier I	D
Energy use in residential sector	43918	3.6	993922	80.9	Tier I	D
Biomass burnt for energy	34976	2.8	1028898	83.7	Tier I	D
All other energy sectors	32087	2.6	1060985	86.4	Tier I	D
Cement production	30767	2.5	1091752	88.9	Tier I	CS
Energy consumed in Commercial/institutional	20571	1.7	1112323	90.5	Tier I	D
Manure management	20176	1.6	1132499	92.2	Tier I	D
Ammonia production	14395	1.2	1146894	93.4	Tier I	D
Land use, land-use change and forestry	14292	1.2	1161186	94.5	Tier I	D
Coal mining	13650	1.1	1174836	95.6	Tier III	CS
Oil and natural gas system	12621	1.0	1187457	96.7	Tier I	D
Municipal solid waste disposal	12222	1.0	1199679	97.7	Tier I	D
Domestic waste water	7539	0.6	1207218	98.3	Tier I	D
Lime stone and dolomite use	5751	0.5	1212969	98.7	Tier I	D
Agricultural crop residue	4747	0.4	1217716	99.1	Tier I	D
Nitric acid production	2790	0.2	1220506	99.3	Tier II	CS
Human sewage	2170	0.2	1222676	99.5	Tier I	D
Lime production	1901	0.2	1224577	99.7	Tier I	D
Industrial waste water	1302	0.1	1225879	99.8	Tier I	D
Ferro alloys production	1295	0.1	1227174	99.9	Tier I	D
Aluminium production	749	0.1	1227923	99.9	Tier I	D
Carbide production	302	0.0	1228225	100.0	Tier I	D
Soda ash use	273	0.0	1228498	100.0	Tier I	D
Black carbon and styrene prod.	42	0.0	1228540	100.0	Tier I	D

3 Institutional Arrangements

A broad-based participatory approach was adopted for estimating the national GHG emission inventories under the aegis of the project on "Enabling Activities for Preparation of India's Initial National Communication". About 34 research and development institutions, universities, and non-governmental organizations were engaged in this activity and the entire exercise was executed by the Ministry of Environment and Forests, Government of India under the aegis of the project on enabling activities for the preparation of India's initial national communication to the UNFCCC. The inventory preparation for each sector was coordinated by a lead institute and the measurement activities for developing indigenous emission factors were coordinated by a leading researcher. Figure 3.1 represents the institutional arrangement.

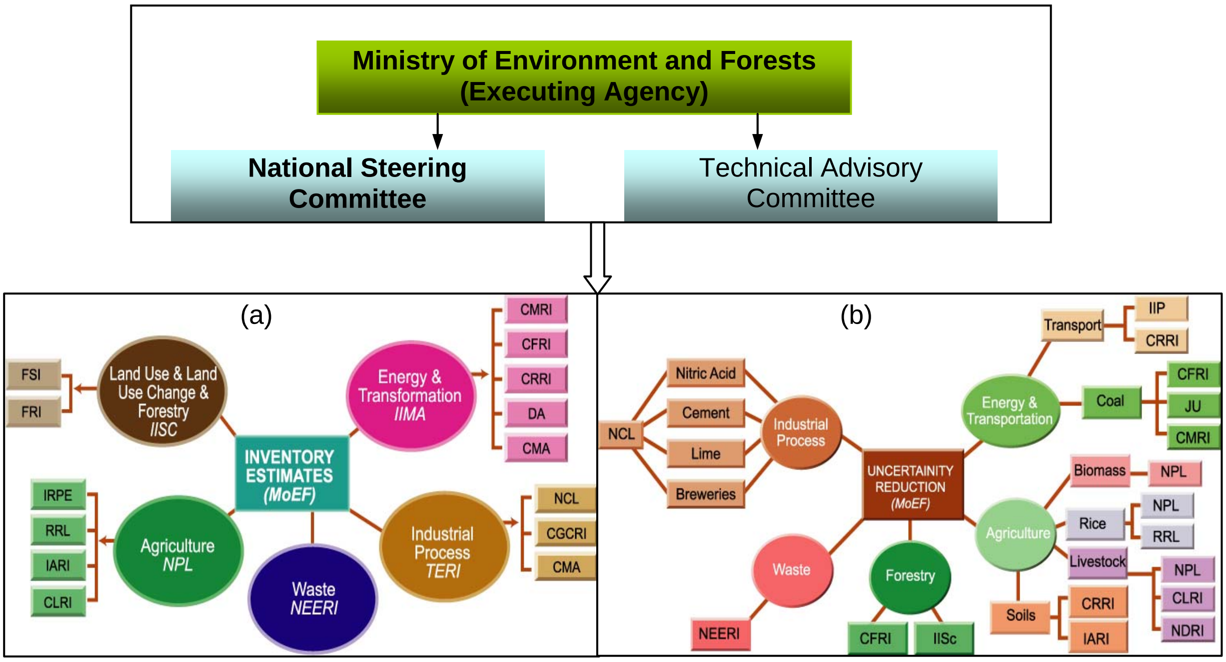

Figure 3.1 Institutional network for developing GHG emission inventory. (a) Institutions involved in GHG emission estimates, (b) Institutions involved in measurements of emission factors.

4 Methodology and Good Practices

The standard IPCC 1996 methodologies were used to estimate the national GHG emission inventories for 1994. The choice of Tier I, Tier II or Tier III methodologies for estimating emissions from different sectors depended on the availability of relevant activity data and indigenous emission factors for each sector. Application of Tier I methodology corresponded to sectors where aggregate activity data and IPCC default emission coefficients were used; Tier II methodology mainly corresponded to the sectors where sub-sector activity data and indigenously developed emission factors for Indian conditions were available, and Tier III was used only in the agriculture sector for estimating CH_4 emission from enteric fermentation and rice cultivation where long term data on age distribution of animals and CH_4 emission from all possible water management practices for growing rice were available.

In order to have the most reliable inventory, the primary activity data for various sectors were sourced from the annual reports of different ministries of the Government, and have been further verified with publications from various departments, industry associations and papers published by different authors. Sources considered for emission estimates include combustion of coal, oil products and natural gas, oil and natural gas extraction/refining/processing, coal mining, transport – road and rail, electric power generation, steel, and biomass burning. The industrial sector emission sources include manufacturing of cement, brick and nitric acid. The agriculture sector includes GHG emissions from rice cultivation, livestock related emissions, use of nitrogen fertilizers and burning of crop residue. Lastly, the waste sector includes emissions from the landfills and wastewater disposal. The detailed references can be found in the Initial National Communication document (NATCOM, 2004).

About 26% of the emissions were estimated using indigenously developed country specific emission factors; the rest were estimated using IPCC default emission factors. For combustion of coal, most of the emissions estimated used indigenous emission coefficients. For combustion of oil, natural gas and biomass, only default emission factors were used. A comparison of the GHG inventory reported in the Initial National Communication with respect to the one prepared in a former effort (ALGAS, 1998), indicates that the improvements and refinements made in the latter are in terms of inclusion of more emission sources in the energy sector such as combustion in industrial, commercial, institutional, and residential sectors. Furthermore, the inclusion of sources in the industrial process sector such as the production of lime, lime stone and dolomite use, soda ash use, ammonia, carbide, iron and steel, ferro-alloys, aluminum, black carbon, styrene, etc., has added to the comprehensiveness of the GHG inventory. The inclusion of country-specific emission factors and use of higher levels of disaggregation has made the inventory more robust. GHG emissions from about quarter of the source categories reported in the initial national communication were based on the country-specific emission factors, developed during the project period.

The emission factors thus developed were the net calorific value (NCV) based CO_2 emission factors for combustion of coking coal, non-coking coal and lignite (Choudhury et al., 2004) which took into account the wide variation in the ash content, moisture content and petrographic makeup of Indian coal types; the CO_2 emission factors for the transport sector (Singh et al., 2004a) which captured the different types of vehicles, their vintages and fuel mix plying on Indian roads; the production technology specific (dry, wet and semi dry) CO_2 emission factor for cement production (Rao et al., 2004); the N_2O emission factor for nitric acid production (Rao et al., 2004) based on measurements carried out at small and large production plants; the CH_4 emission factor for all coal mining processes (Singh et al., 2004b) such as surface mining as well as underground mining for various levels of gassiness in coal seams; CH_4 emission factors for enteric fermentation (Swamy et al., 2004) in dairy and non-dairy cattle capturing the typical low level of feed intake by Indian cattle in comparison to the cattle from the western countries; and CH_4 emission factors from rice cultivation (Gupta et al., 2004) for various water management practices pursued by farmers in India. The QA/QC procedures followed for measurements include calibration of standard samples and inter-calibration of instruments. The emission factors thus developed are listed in Table 3.5.

Table 3.5 List of indigenous emission factors developed for estimating national GHG emission inventory

		Emission Factor (EF)	Reference
Indian Coal			
	NCV TJ/Kt	EF t CO_2/TJ	Choudhury et al., 2004
Coking coal	24.18±0.3	25.53	
Non-coking coal	19.63±0.4	26.13	
Lignite	9.69±0.4	28.95	
Road Transport sector			
Gasoline		TCO_2/Tj	

2W/3W		43.9 ± 7.3	Singh et al., 2004a
Car/Taxi		61.5 ± 4.0	
Diesel Oil			
MCV/HCV		71.4 ± 0.55	
LCV		71.4 ± 0.5	
Coal Mining			
Underground mining		M^3CH_4/ton	
Mining	Degree I	2.91	Singh et al., 2004b
	Degree II	13.08	
	Degree III	23.64	
Post mining	Degree I	0.98	
	Degree II	2.15	
	Degree III	3.12	
Surface mining			
During Mining		1.83	
Post mining		0.23	
Cement manufacturing			
		tons/ton of clinker	
		0.534 - 0.539	Rao et al., 2004
Nitric acid production			
		kg per ton of N_2O	
Medium pressure plant		6.48 – 13.79	
High pressure plants		1.54 – 4.13	
Dual pressure plant		0.24 – 0.57	Rao et. al., 2004
Enteric fermentation			
		g CH_4 / animal	
Dairy cattle	Indigenous	28±5	Singh et al., 2004 & Swamy et al., 2004
	Cross bred	43±5	
Non dairy cattle (Indigenous)	0-1yrs	9±3	
	1-3 year	23±8	
	Adult	32±6	
Non-dairy cattle(Cross Bred)	0-1 year	11±3	
	1-2 ½ year	26±5	
	Adult	33±4	
Dairy buffalo		50±17	
Non-Dairy buffalo	0-1 year	8±3	
	1-3 year	22±6	
	Adult	44±11	
Sheep		4±1	
Goat		4±1	

Rice Ecosystem		
	g CH_4/m^2	
Upland	0	
Rain fed Flood Prone	19.0±6.0	
Rain fed, Drought Prone	7.0±2	
Irrigated, Continuously Flooded	17.5±4.0	Gupta et al., 2004
Irrigated Single Aeration	6.6±1. 9	
Irrigated Multiple Aeration	2.0±1.5	
Deep Water	19.0±6.0	

5 Problems, Constraints, and Future Plans

Improvement in the estimation methodologies for some of the key sectors, development of new country specific emission factors and refinement of some of the existing emission factors and activity data are essential for reducing uncertainties in the GHG inventory estimates. The strategy for developing the country specific emission factors includes either direct measurement or estimation of the EFs, based on secondary data sources for the key sources selected. Similarly, targeted surveys will be conducted to improve the activity data as well as estimation of EFs (e.g. feed intake patterns of domestic dairy livestock will be evaluated through surveys which will lead to improved activity data as well as a bottom up estimation of EFs from this source using standardised IPCC 1996 methodology). The refinements and the rationale for refinements are shown in Table 3.6.

Table 3.6 Activities proposed for reducing uncertainties in inventory estimation (CS: country specific emission factors, D: IPCC default emission factors; R: revision envisaged)

Sources of emission	**EF used in INC**	**Status of EF envisaged**	**Activities proposed**	**Rationale**
Energy and transformation industries	CS	R	o Refine NCV of different types of coal o Determine technology specific point source level EFs of CO_2, CO and NO_X for thermal power plants	o Inadequate sample size taken in INC o Thermal power plants are the key category within the energy and transformation sector.
Enteric Fermentation	CS	R	o Sample survey of age wise domestic livestock population, feed type, milk production in various climate regions of India o Develop CH_4 EF for enteric fermentation through estimation and measurement	o It is a key category in the agriculture sector. o In INC, appropriate activity data was not available to make a correct assessment. o The sample size for which measurements were taken was small, and could not be validated through estimates because lack of activity data.

Rice Cultivation	CS	R	Undertake CH_4 flux measurements in hotspot areas	This is the second largest GHG emitting category amongst all the agriculture categories. As the emission from this source is dominated by emissions from hotspots, therefore it is proposed to investigate the EFs from these regions.
Transport	CS	R	o Conduct survey to apportion the fossil fuel used in various types of road vehicles o Refine EFs from different kinds of gasoline and diesel driven vehicles by incorporating driving cycles	These two approaches will be used to reconcile the top down and bottom up emission estimates from this source.
Emission from Soils	D	CS	o Development of N_2O EFs from different soils	This is a major source of N_2O emission amongst all the categories.
Iron and steel production	D	CS	o Plant level assessment of CO_2 EFs (resulting from combustion of fuel & production process)	It is a fast growing sector of the economy in addition to being a major source of CO_2 emission.
Cement production	CS	R	Plant level assessment of CO_2 EFs due to production process	It is a fast growing sector of the economy in addition to being a major source of CO_2 emission.
Ammonia production	D	CS	Determine plant level CO_2 EF	Key category – not targeted in INC.
Land use, Land-use change and Forestry	D	CS	o Develop land use change matrix o Assess biomass stock, carbon fraction of biomass, biomass growth rates of various types of species (crops/forests) to be considered under this category	A key category, and targeted to apply the GPG LULUCF (2003) guidance in the inventory estimation process in SNC.
Oil and natural gas system	D	D	Develop methodology for assessing data on a regular basis on oil and natural gas transport, storage, venting and flaring	Not a key category, but the consumption of oil and natural gas shows the highest growth rate compared to other fossil fuels, so efforts will be made to streamline assessment of activity data.

Municipal Solid Waste Disposal			o Assess per capita MSW generation, composition and handling process o Generate EFs for managed and unmanaged landfill areas	Rapid urbanization resulting in increased generation of waste and changed composition
Industrial Waste Water	D	CS	Chemical analysis of waste water in selected key industries	Rapid growth of certain industries like paper, pulp, beverage etc.

The data gaps encountered in the latest GHG inventory include - availability of detailed data on the various fuel types used in unorganized, informal, and small scale industry sectors; data on coal consumption in aluminum production, ceramics and glass. Some of the sub categories under chemical industries could not account for the non-energy product use of fuel. Industries such as electronic industries were not covered. Biomass consumption data was extrapolated based on small studies carried out earlier in some parts of the country. In the transport sector, age-wise distribution of vehicles is a grey area, which masks the actual emissions from this source. Furthermore, in the agriculture sector, the age and weight-wise distribution of dairy and non-dairy cattle, manure statistics, uncertainty in water regimes in rice fields (especially in the matter of separating irrigated fields with single and multiple aeration) are some of the uncertainties still associated with this sector. In the waste sector, details of annual municipal solid waste (MSW) generation, quantity dumped and dumpsite characteristics of MSW for major sites were not available. In some cases interpolation becomes necessary, as calendar year data are not available, e.g., the livestock census is available only every five years. Further the national level activity data used to date do not capture the diversities of the various activities in India. Hence, they were not region-or-condition specific, and therefore, have inherent uncertainties associated with them. Therefore, the next step will certainly be collection of detailed activity data for the above-mentioned sectors.

For ensuring the sustainability of the inventory process, it is necessary to have a National Inventory Management System (NIMS). NIMS will need to address the requirements of documentation, archiving and continuous updating of databases as well as the QA/QC and uncertainty management issues of the inventory. Thus the activities to be pursued for NIMS will need to include the development of systemic tools and procedures. This will entail activities such as (1) development of procedures for documenting methodologies, (2) creating a database of emissions factors, activity data and assumptions, (3) data management and collection, (4) strategies for data generation and improvement, (5) systems for data archiving and record keeping, (6) mechanisms for synchronization and cross-feeding between emission inventories, (7) national energy balances and relevant sector surveys, (8) providing guidance for technical peer reviews, and (9) procedures for QA/QC and uncertainty management. NIMS should also design a web-based management system that will provide access to databases and through web-based modules disseminate information on the steps of inventory management and the tools of inventory management to be used for each sector i.e. modules for QA/QC and uncertainty analysis, the steps of peer review, etc.

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3.3 Malaysia

Azman ZAINAL ABIDIN and Siti Indati MUSTAPA
Policy Analysis and Research Management, Pusat Tenaga Malaysia
Level 8, Bagunan Sapura @ MINES, 7 Jalan Tasik,
The Mines Resort City, 43300 Seri Kembangan, Selangor, Malaysia

1 GHG Inventory in Malaysia

Malaysia signed the United Nations Framework Convention on Climate Change (UNFCCC) on 9 June 1993 and ratified it on 17 July 1994. The Government has established a National Steering Committee on Climate Change comprising the Ministry of Natural Resources and Environment as Chair, and representatives from academic, public, and private sectors to help meet its obligations under the Convention.

Although Malaysia, as a non-Annex I country, has no obligations to reduce the GHG emissions, it is important that information on GHG emissions is maintained and updated to provide scenarios for future planning. Meaningful actions to mitigate GHG emissions require regular updates on the GHG inventory to support informed decision-making. The national GHG inventory was established during the preparation of the Initial National Communication (NC) to the UNFCCC, which was based on a 1994 database. The inventory has not been updated since.

The current exercise is an attempt to update the GHG inventory in preparation for the Second NC to the UNFCCC. The base-year for this second inventory is 2000. While the 1994 inventory used the 1995 Intergovernmental Panel on Climate Change (IPCC) Guidelines, the 2000 inventory is based on the much-improved Revised 1996 IPCC Guidelines.

2 National Communications: Malaysia's Experience

2.1 Initial National Communication

The Initial NC was prepared in 1994 under the UNDP/GEF Project. The report and inventory contained the following:

1. National Climate Change Scenarios
2. Malaysia National Greenhouse Gas Inventory 1994
3. Assessment of the Impacts of Climate Change on Key Economic Sectors in Malaysia
4. Mitigation Options for Climate Change and Public Education
5. Awareness of Climate Change Issues

Based on these five reports, Malaysia's initial NC was prepared. After the Cabinet had reviewed and approved the draft, the initial National NC was launched on 18 July 2000 and submitted to the UNFCC secretariat on 22 August 2000.

In 1994 (as illustrated in Figure 3.2), the energy sector in Malaysia was the major source of anthropogenic GHG emissions, accounting for about 68% of the total GHG emissions (144,314 Gg). This situation was due to the high dependency of the energy sector on fossil fuels.

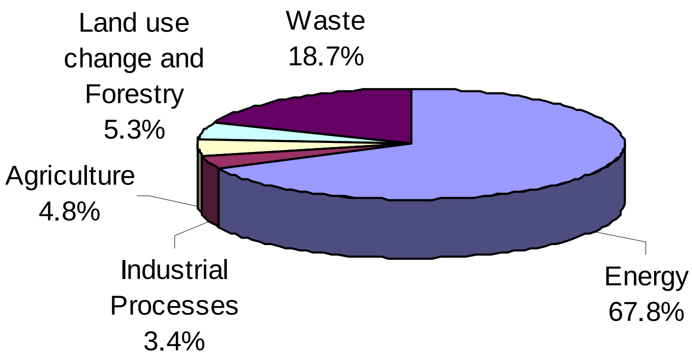


Fig. 3.2 Greenhouse Gas Emissions in Malaysia by Source in 1994 (Initial National Communication, 2000).

2.2 Second National Communication

The preparation of the Second NC was commissioned in August 2004. The initial GHG inventory has been a significant benchmark for the second national inventory. As for the Second NC, a much better foundation has been put in place in the preparation of the current inventory, in that more improved guidelines i.e. the Revised 1996 IPCC Guidelines, have replaced the older 1995 IPCC Guidelines used in the first inventory. Data collection, both in terms of quality and quantity, has also improved. Sectors and activities which were previously not accounted for have been included in the current inventory. The GHG inventory for the second NC is expected to be completed in July 2006 for internal review by the National Steering Committee.

3 Institutional Arrangement

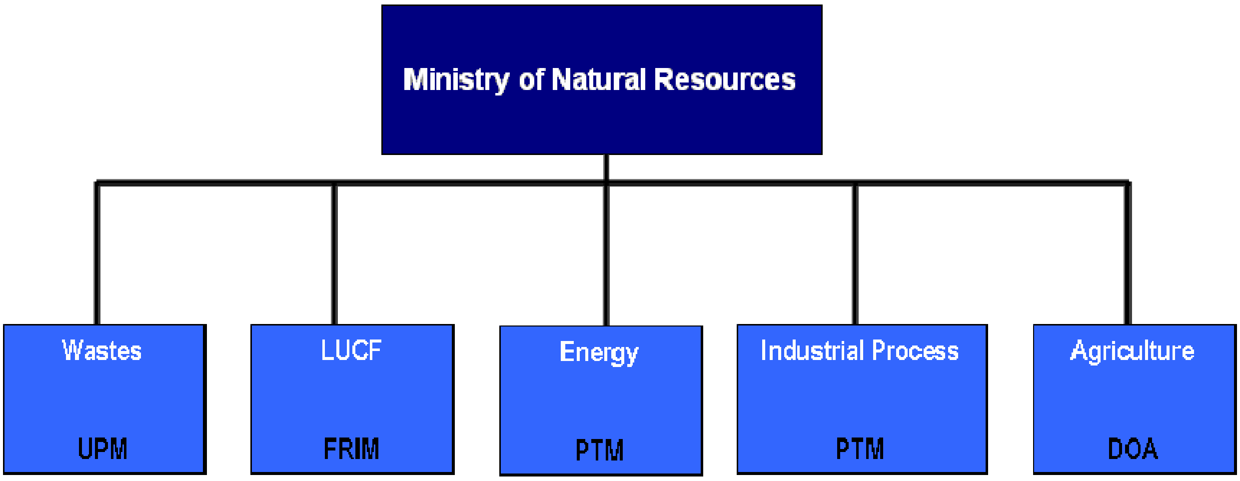
In preparation for the Second NC, various agencies and institutions were given the tasks of carrying out estimations on GHG emissions, as indicated in Figure 3.3.

The Waste sector was assigned to the Universiti Putra Malaysia (UPM), Land Use Change and Forestry (LUCF) was undertaken by the Forest Research Institute of Malaysia (FRIM), Energy and Industrial Processes were both assigned to the Pusat Tenaga Malaysia (PTM) and the Agriculture sector to the Department of Agriculture (DoA).

4 Issues and Future Plans

Currently, all the emission factors used are adopted wholly from the IPCC guidelines, as local emission factors are not available. This does pose some degree of uncertainty in the calculations as the IPCC default values tend to be addressed to a wide region, rather than country specific. The differences in defining certain terminologies also affect the accuracy of the national GHG inventory. Attempts will be made over time to address these problems, especially those connected with data collection and assembly. Future inventories will likely face fewer limitations and as the situation improves over time, so will the technique to be reflected in subsequent guidelines from the IPCC.

Despite the fact that much improvement has been made since the last inventory, there is still a need to strengthen the institutional capacity for the collection and collation of GHG data. Future research to establish local emission factors will also be encouraged and undertaken to further improve the accuracy and precision of the inventory.



UPM – Universiti Putra Malaysia
FRIM – Forest Research Institute of Malaysia
PTM – Pusat Tenaga Malaysia (Malaysia Energy Centre)
DOA – Department of Agriculture

Fig. 3.3 Institutional Arrangement for GHG Inventory.

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3.4 Mongolia

Bujidmaa BORKHUU
Institute of Meteorology and Hydrology
Juulchny Gudamj-5, 210646, Ulaanbaatar, Mongolia

1 History of GHG Inventories in Mongolia

Mongolia signed the Framework Convention on Climate Change at the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992. In 1999, Mongolia ratified the UNFCCC and in 2000, the Kyoto Protocol. In response to UNFCCC requirements, Mongolia has prepared a National Inventory Report of current emissions.

Mongolia prepared its first greenhouse gases (GHG) inventory in 1996 for the base year 1990 under the US Country Studies Programme, which was updated within the Asia Least-Cost Greenhouse Gas Abatement Strategy (ALGAS). As part of the enabling activities for preparing the Initial National Communication (GEF/UNEP) in 1998, the GHG inventories were updated to the base year 1994. Mongolia's Initial National Communication was reviewed by the National Communication Support Program and the UNEP Collaborating Center on Energy and Environment.

2 Overview of the Latest Inventories

The Initial National Greenhouse Gas Inventory Report presents the national inventory of greenhouse gas emissions and removals from 1990 to 1998. The components covered are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The report and IPCC reporting tables were prepared in accordance with the UNFCCC reporting Guidelines on Annual Inventories. The methodology used in calculations of emissions is harmonised with the Guidelines for National Greenhouse Gas Inventories and those of the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories published by the Intergovernmental Panel on Climate Change (IPCC).

The main sources of data were the Statistical Yearbooks and other publications issued by the related government and international organizations. In most instances the main obstacle was the lack of reliable data for the calculations. It was possible to obtain only general activity data, such as fuel consumption, cement production, domestic animal population, area of cultivated land, etc. and some factors for the energy content of Mongolian coal and the oxidation coefficient of fuel burned for power generation. In most cases, specialized data such as emission factors and country-specific emission ratios of gases have not been worked out for Mongolia.

The quality of activity data on the emissions for different years and sectors is variable. It is not possible to quantify the margin of error, and the estimates are mainly expert estimates.

In 2005 some recalculations were performed for the Second National Communication under the Project for "Capacity Building for Improving National GHG Inventories in Eastern Europe and CIS" (RER/01/G31). These include Transportation and Waste sectors. The purpose of the recalculation was to improve accuracy and completeness; therefore, the inventory of all years is currently estimated using the same methodology, adjusted statistical data, and emission factors. Net emissions of GHGs emitted in 1990-1998 in Mongolia are presented in Figure 3.4.

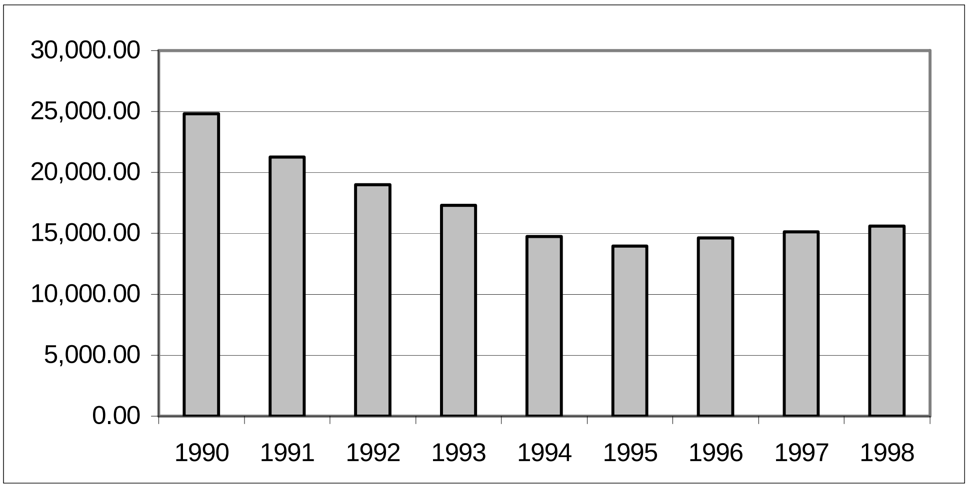

Fig. 3.4 Net emissions of GHGs in CO_2 equivalents, Mongolia.

As one can see from Figure 3.4, emissions of GHGs have decreased significantly in the 1990s, largely due to decreases in fossil fuel consumption as a result of the transition from a socialist economy to a market economy. From 1990 to 1998 the net emissions have decreased by 37%. Emissions and removals of greenhouse gases for the years 1990–1998 are shown in Table 3.7.

3 Institutional Arrangement

The Institute of Meteorology and Hydrology is responsible for the inventories and National Communications. Eight to ten specialists from different research institutes and universities are involved in this work.

This report presents the national inventory of greenhouse gas emissions and removals from 1990 to 1998. The components covered are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Data on F-gases – hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) – were not provided. Therefore, emissions of that kind were not estimated, though a data collection system is currently under development. Estimates of the emission data for nitrogen oxides (NOx), carbon monoxide (CO), non-methane and volatile organic compounds (NMVOCs) were also included in the inventory data.

Table 3.7 CO_2 emission and removal, 1990-1998 (1000 t)

Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998
Emission									
1.Energy: Combustion	13,349	11,968	10,410	9,832	8,570	8,046	8,883	9,210	8,963
2.Industry	301	173	119	81	95	95	95.7	100.8	98.1
3.Forests: Biomass harvest	3,234	2,527	2,461	2,462	2,359	2,195	2,696	2,486	2,829
4.Grassland Conversion	4,363	4,325	4,325	4,376	3,940	3,940	3,666	3,769	3,884
Total emission	21,247	18,993	17,315	16,751	14,964	14,276	15,340	15,566	15,774
Removal									
1.Forests: Annual Growth	-202	-208	-214	-219	-224	-229	-233	-237	-243
2.Abandonment of Managed Lands	-1,909	-3,080	-3,590	-4,543	-5,675	-6,193	-6,802	-6,802	-6,802
Total removal	-2,111	-3,288	-3,804	-4,762	-5,899	-6,422	-7,035	-7,040	-7,045
Net total	19,136	15,705	13,511	11,990	9,064	7,853	8,305	8,527	8,729

4 Methodology, Good Practices, and Capacity

The Mongolian inventory follows the methodologies recommended by the IPCC (IPCC, 1996). In most instances the main obstacle was the lack of reliable data for the calculations. In most cases, specialized data such as emission factors and country-specific emission ratios of gases have not been worked out for Mongolia. Therefore, the IPCC recommended default values were typically used in the GHG Inventory calculations. In particular, it was difficult to gather information for the sectors of Forestry, Land Use Change and Waste due to the absence of statistics or disparity in available and necessary data. Mongolia does not possess the necessary resources for developing methods for estimating emissions from these sources. Available and necessary emission factors, activity data and methodology used for national GHG inventory are given in Table 3.8.

For estimating the emissions of GHGs and sinks, as well as the uncertainties associated with them, the IPCC top-down method according to the IPCC Guidelines was used. The Mongolian inventory also includes carbon monoxide (CO) and nitrogen oxides (NOx). The purpose of all recalculations was to improve the accuracy and completeness. Currently, the inventory of all years is re-estimated using the same methodology, adjusted statistical data and emission factors selected for Mongolia.

Table 3.8 Methodology, activity data and emission factor sources used for National GHG inventory

IPCC category	Methodology (1)	Emission factor (1)	Activity data
1. Energy	Revised 1996 IPCC methodology	Revised 1996 IPCC methodology	Energy balances provided by the Statistical Office of Mongolia
A. Fuel Combustion	D (T1)	D (T1), CS	Energy balances
B. Fugitive Emissions	D (T1)	D (T1)	Statistical Year Book
2. Industrial Processes	Revised 1996 IPCC methodology	Revised 1996 IPCC methodology	Statistical Year Book
A. Mineral Products	Not indicated	Not indicated	
4. Agriculture	Revised 1996 IPCC methodology	Revised 1996 IPCC methodology	Statistical Year Book, Mongolia
A. Enteric Fermentation	D (T1)	D (T1)	Statistical Year Book, Mongolia
B. Manure Management	D (T1)	D (T1)	Statistical Year Book, Mongolia
D. Agricultural Soils	Not indicated	Not indicated	Statistical Year Book
5. LUCF	Revised 1996 IPCC methodology	Revised 1996 IPCC methodology	Environmental Year Book
A. Changes in Forest and Other Woody Biomass Stocks	IPCC 1994, D (T1) IPCC 1996	IPCC 1994, D (T1) IPCC 1996	Environmental Year Book
B. Forest and Grassland Conversion	CS	CS	Environmental year book
C. Abandonment of Managed Lands	D	D	Environmental year book
D. CO_2 Emissions and Removals from Soil	D	D	Environmental year book
6. Waste	Revised 1996 IPCC methodology	Revised 1996 IPCC methodology	Statistical Year Book, Mongolia
A. Solid Waste Disposal on Land	D (T1)	D (T1)	Statistical Year Book
B. Wastewater Handling	D (T1)	D (T1)	Water balance report

(1) Notation keys: D (IPCC default), T1 (IPCC, Tier 1), CS (Country Specific).

5 Problems and Constrains and Future Plans

Mongolia faces a few problems in improving national inventory:

1) Availability of information:
   (1) No standard data for inventory and mitigation study except statistical data
2) Human resources:
   (1) No systems for retaining trained national experts
   (2) No permanent coordination that could provide the continuity of the study on climate change issues
3) Methodologies and tools:
   (1) Could not develop country specific emission factors for necessary sectors of the inventory
4) Financial constraints:
   (1) No financial support other than GEF to improve national inventory quality

6 Recommendations

Mongolian experts offer the following concrete recommendations:

1) Provide more training for national experts at the international level
2) Provide possibility to involve experts that have participated in previous NC
3) Establish regional or sub-regional center for GHG inventory and database
4) Establish information exchange network on climate change issues
5) Improve mechanism to fulfill specific needs identified in the NCs

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Chapter 4

ENERGY SECTOR

4.1 Introduction of the Energy Working Group

The Energy Working Group of the 3rd WGIA consisted of the following participants:

- Mr. Tomoyuki Aizawa (Chair; Japan)
- Ms. Aree Wattana Tummakird (Reporter; Thailand)
- Mr. Huaqing Xu (China)
- Dr. Sumana Bhattacharya (India)
- Mr. Dadang Hilman (Indonesia)
- Ms. Siti Indati Mustapa (Malaysia)
- Mr. Hoang Manh Hoa (Viet Nam)

The programme of the Energy Working Group Session was divided into three parts and is shown in the table below:

Part A	***Introduction of Good Practices***
	・ *"The Development of GHG Inventory for Energy Sector and Industrial Processes - Malaysia"* (Ms. Siti Indati Mustapa, Malaysia) ・ *"Japan's country-specific emission factors for the CO_2 emissions from fuel combustion"* (Mr. Tomoyuki Aizawa, Japan) ・ *"GHG emission factors developed for the energy sector in India"* (Dr. Sumana Bhattacharya, India)
	- Discussion and questions -
Part B	***Roundtable Discussion on "Challenges to be tackled and possible solutions"***
Part C	***Summary of the Working Group Discussion***

4.2 Good Practices

4.2.1 Summary

The objective of this session was to specify the features of Energy GHG inventory development in Asia by creating a list of individual countries' good practices and challenges. The working group included three presentations on the experiences of individual countries.

Dr. Sumana Bhattacharya presented the following four issues of India: (1) establishment of a national inventory management system; (2) data collection from three important sectors (power plants, transport, iron and steel); (3) adoption of the tier 2 methodology; and (4) plant specific emission factors.

Ms. Siti Indati Mustapa presented Malaysia's experiences in preparing the second national communication. She discussed Malaysia's experience with data collection and presented a variety of techniques for obtaining the data from various organisations and agencies. Information on institutionalizing the GHG program was also provided.

Mr. Tomoyuki Aizawa shared Japan's experience on development of GHG inventories. Collaboration between the Energy Agency and the Ministry of the Environment, which is an inventory agency, and application of a balance approach (Mass Balance, Energy Balance, Carbon Balance) during establishment of country-specific emissions factors were introduced.

CO_2 emissions from fuel combustion are the largest source in most countries. Therefore, sharing information on each country's experience in this area is one of the most interesting issues for someone working on GHG inventory. During the discussions, participants were given a chance to ask other participants how to solve their own issues on inventories.

4.2.2 Development of the Greenhouse Gas (GHG) Inventory for the Energy Sector in Malaysia

Azman ZAINAL ABIDIN, Siti Indati MUSTAPA, Radin Diana RADINAHMAD, and Komathi MARIYAPPAN
Policy Analysis and Research Management, Pusat Tenaga Malaysia
Level 8, Bangunan Sapura @ MINES, 7 Jalan Tasik,
The Mines Resort City, 43300 Seri Kembangan, Selangor, Malaysia

Abstract:

The preparation of a national inventory of greenhouse gas (GHG) emissions forms a part of Malaysia's obligation under Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), which Malaysia signed on 9 June 1993 and ratified on 17 July 1994. The first national GHG inventory was established during the preparation of the Initial National Communication to the UNFCCC, in which the base-year was 1994. However, the inventory has not been updated since. As Malaysia is currently preparing its Second National Communication, a concerted effort has been made to improve the estimation of greenhouse gas emissions from the Energy sector. The base-year chosen for this second inventory was 2000. While the 1994 inventory used the 1995 IPCC Guidelines, the 2000 inventory was based on the much-improved Revised 1996 IPCC Guidelines. Several knowledge gaps and challenges for estimating GHG emissions, in particular emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), were identified in preparing the inventory. An extensive effort to successfully compile and update the inventory accurately is currently underway.

This paper will describe the country's experience in preparing the inventory for the Energy Sector under the Second National Communication, as well as measures taken to ensure that the GHG inventory would be in line with the IPCC Good Practice Guidance.

1 Background

The energy sector in Malaysia is a major source of anthropogenic greenhouse gas (GHG) emissions, accounting for about 68% of the total GHG emissions in 1994. This situation is a result of the energy sector's high dependency on fossil fuels.

Although Malaysia, as a non-Annex 1 country, has no obligation to reduce its GHG emissions, it is nevertheless important that information on GHG emissions be maintained and updated to provide scenarios for future planning. Regular updates on the GHG inventory are essential to support sound national policies from the perspective of reducing GHG emissions and avoiding the adverse impacts of climate change.

Reliable estimates of GHG emissions can be used to compare the relative contribution of different emission sources and different GHGs to climate change, and to ascertain the portion of emissions attributable to individual countries and different regions of the world. They are also necessary for assessing emission differences among different technologies in order to evaluate the cost-effectiveness of alternative control technologies.

Emission estimates can also be used to evaluate the effectiveness of mitigation strategies. Unfortunately, there can be issues with the availability and certainty levels of international and national emission estimates. It is hoped that this study will be a starting point in using the Intergovernmental Panel on Climate Change (IPCC) guidelines to prepare a reliable national inventory on GHG emissions in Malaysia. From the study, it is anticipated that one could assess the country's contribution of GHG emissions to the global total, and to identify the processes, activities and sectors of the economy which contribute to the enhanced greenhouse effect.

This paper aims to describe the development of the GHG inventory for the Energy sector with highlights on good practice and issues that need to be rectified.

2 First and Second National Communications: Malaysia Experience

Malaysia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in July 1994. Subsequent to that, the National Steering Committee on Climate Change (NSCCC) was established in 1994 to formulate and implement policies to address and adapt to climate change. The committee consists of representatives from relevant government ministries/agencies and NGOs.

Under the stewardship of the NSCCC, Malaysia submitted its Initial National Communication (INC) in 2000 to the UNFCCC, in compliance with Article 12 of the Convention. The INC was an output of the UNDP/GEF Project "Enhancement of Technical Capacity to Develop National Response Strategies to Climate Change". The INC (base year 1994), prepared in accordance to the guidelines adopted in Decision 10/CP.2, was a first step towards the implementation of the UNFCCC in the country. The task gathered together scientists, experts and individuals from various government agencies, universities, research organizations, NGOs and private entities. The topics covered pertained to climate change scenarios, inventories of GHGs, assessment of impacts of climate change, public awareness and education, and abatement measures. It facilitated the development of expertise in each sector involved in the preparation of the national communication, enhanced the institutional capacity in these fields, and increased the awareness of the public and institutions concerning the UNFCCC and global warming issues.

The project for the preparation of the Second National Communication (NC2) is a continual step towards further implementation of the UNFCCC at the national level. The analysis conducted within the INC will be upgraded and extended, which will result in preparation of an advanced national report in the form of NC2. The NC2 will be prepared in accordance with "Decision 17/CP.8: Guidelines for the Preparation of National Communications from Parties not included in Annex I to the Convention".

For the preparation of NC2, the government appointed various agencies and institutions to carry out estimation for relevant emission sources. Likewise, the inventory for the Energy Sector focused on the most relevant activity data based on the IPCC guidelines. The initial inventory has been a significant benchmark for the current preparation of NC2 and has contributed towards establishing a more comprehensive GHG inventory.

3 Development of GHG Inventory

3.1 Estimation Approach

The GHG Inventory will be prepared and reported in NC2 (base year 2000) as required in the guidelines adopted in Decision 17/CP.8. Sectors of the GHG inventory cover energy, industrial processes, agriculture, land-use change and forestry, and waste.

The greenhouse gases in the inventory are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The estimations will be performed in accordance with the "Revised 1996 IPCC Guidelines for National Greenhouses Inventories" and "IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)".

Activities which are not covered in INC, as well as the constraints leading to such deficiencies, were identified and reported in NC2. The inventory used data from the annual publication of the National Energy Balance. Where data were not available for the years in question, estimations were derived by using parameters such as efficiency, load factor and average availability factor.

3.2 Development of Methodology

The energy sector inventory prepared in INC for the year 1994 demonstrated top-down and bottom-up methodologies based on the 1995 IPCC Guidelines. Within the INC, an inventory of GHG emissions by sources and removals by sinks was prepared. The data gaps, uncertainty regarding some of the data, and lack of related local emission factors were the main problems encountered in the GHG Inventory.

As for the NC2 Inventory, the Tier 1 method was used because the required data was more readily available than for the other Tiers. In the Reference Method, the Tier 1 approach is used to develop national totals by applying it in a "top down" way, meaning that national fuel combustion statistics are used. The Tier 1 approach is also used for the "bottom up" method, referred to as the Sectoral Approach (i.e. individual facilities can estimate CO_2 emissions from fuel consumption data without considering the type of combustion units being used).

As for the emission factors, the "Good Practice Guidance and Uncertainty Management" is referred to when addressing the uncertainties in estimating the inventory.

3.3 Data Sources

Data from National Energy Balance 2000 and other published documents were used in the GHG estimation. Despite the fact that NEB data are collected solely from energy suppliers, the data quality is comparable to that of other published documents. However, there are still gaps in the types of data needed under the new guidelines that require assumptions to be made. This can contribute to uncertainty in the estimation of GHG emissions. In addition, default emission factors used in the estimation may poorly reflect hourly fluctuations in the generation fuel mix corresponding to the load profile. Moreover, there are also uncertainties in the consumption data, carbon content of fuels and products, and carbon oxidation efficiencies.

3.4 Preliminary Results of Energy Sector

The Reference Approach resulted in an emission of CO_2 at 140,110 Gg whereas the Sectoral Approach resulted in an emission of 130,747 Gg CO_2. The difference was around 6.7%. The discrepancy could be due to some of the data for the Sectoral Approach being based on certain assumptions since the fuel consumption was not available (e.g. for the Navigation Sector, estimation was based on the average available factor, load factor and engine efficiency).

The GHG emissions from the energy sector are from fuel combustion, fugitive emissions from coal mining, fugitive emissions from oil and gas systems and the burning of biomass fuels. Fuel combustion released mainly CO_2, which totaled 130,747 Gg. The other sub-sectors released CH_4, with the highest contributions coming from the fugitive emissions from oil and gas systems i.e. 1,197 Gg. A small amount of N_2O was also released through the burning of biomass fuels i.e. 1.09 Gg.

Table 4.1 and 4.2 provide a summary of the nation's emission of the three main greenhouse gases in 1994 and 2000 on a sectoral basis. A comparison in CO_2 emissions between the first and second inventory was made based on the reference and sectoral approach.

Table 4.1 Comparison of CO_2 Emission between 1994 and 2000

	CO_2 Emission (Gg)		
Approach	**1994**	**2000**	**CO_2 Emission & Percentage Increase**
Reference Approach	84,415	140,110	55,695 (66%)
Sectoral Approach	43,768	130,747 93,621*	49,853 (53%)

Notes: * Excluding Energy Industries

Table 4.2 Comparison of CO_2 ,CH_4 and N_2O Emission based on energy use (Gg)

Sectoral Approach	1994	2000	Emission & Percentage Increase
Carbon dioxide (**CO_2**)			
• Transportation	21,375	41,008	19,633 (48%)
• Energy Industries		37,126	
• Industrial	18,083	28,855	10,772 (37%)
• Residential & Commercial	3,014	3,947	933 (24%)
• Agriculture	1,296	917	-379 (-41%)
• Others (transformation)		18,893	
Methane (**CH_4**)			
• Coal Mining Handling	0.13	0.34	0.21 (62%)
• Oil and Natural Gas	593	1,197	604 (50%)
Nitrous Oxide (**N_2O**)			
• Biomass		1.09	

3.5 Reference Approach

As indicated in Table 4.1, there was a significant increase in CO_2 emissions compared to the first inventory, from 84,415 gigagrams (Gg) in 1994 to 140,110 Gg in 2000. The CO_2 emission increase was about 66%. The increase in CO_2 emission could be explained by the steady annual growth of 8% in primary energy demand.

Transportation activities caused the highest emissions of CO_2 with 41,008 Gg, followed by the energy industries with 37,126 Gg, and manufacturing industries with 28,855 Gg. The remaining contributors were from other sectors (Commercial, Residential, and Agriculture) and Transformation sectors with 23,757 Gg.

3.6 Sectoral Approach

Based on the sectoral approach results, the total CO_2 emissions were 130,747 Gg. The breakdown of CO_2 emissions based on the final energy use by various activities of economy is as follows: transportation (31%), energy industries (28%), manufacturing industries (22%), other sectors (15%) (i.e. commercial, residential and agriculture/forestry/fishing) and others (4%) (i.e. losses during transformation).

The 1994 inventory excluded final electricity use from the CO_2 emission calculation; hence, direct comparison of the sectoral approach between those years could not be made. If we were to compare those years, we would also need to exclude energy industries from the 2000 inventory.

The comparison between the 1994 inventory and 2000 inventory (excluding energy industries) has shown a significant increase of 53% in CO_2 emissions. From 1994 to 2000, CO_2 emission had increased from 43,768 Gg to 93,621Gg. It should be noted that sub-sectors for energy use in various activities (e.g. transport, industries, residential, commercial, etc) under the 1996 IPCC Guidelines have been refined. Hence a direct comparison between those two years is rather complicated.

4 Issues and Knowledge Gaps

The current inventory benefited from the Revised 1996 IPCC Guidelines, which replaced the older 1995 IPCC Guidelines used in the first inventory. Data collection, both in terms of quality and quantity, has also improved. More sectors and activities, which were previously not accounted for, have been included in the current inventory.

Nevertheless, there are shortcomings in the overall implementation of the inventory. For instance, there are still gaps in the types of data required under the new guidelines, as these data are not readily available. Moreover, some of the data required were deemed confidential by the data providers, and as such could not be disclosed to the study team. Also, most of the emission factors were default factors from the IPCC Guidelines. This contributed to uncertainties in the estimation of GHG emissions as default emission factors may not be able to accurately reflect the actual conditions of country specific activities.

More accurate GHG inventories will enable Malaysia not only to identify major sources and sinks of GHGs with greater confidence, but also to make more up-to-date policy decisions with respect to appropriate mitigation measures.

5 Conclusions

Despite the fact that much improvement has been made since the last inventory, there is still a need to strengthen the institutional capacity for the collection and collation of GHG data. A focal point needs to be established to maintain and update the national registry on GHG emissions. The type of data collected and the format in which they are collected should be maintained, and improved over time. The data, to be collected on a timely basis, should be consistent with the requirements of the IPCC Guidelines, such that calculations on the GHG emissions could be carried out routinely and accurately.

In preparing the inventory, uncertainties pertaining to activity data and emission factors have always been the part that reduced data accuracy. Research to establish local emission factors such as for specific modes of transport, should also be encouraged and undertaken to further improve the accuracy and precision of the inventory. At this moment, most of the emission factors are default factors from the IPCC Guidelines. This can contribute to uncertainties in the estimation of GHG emissions as default emission factors may not be able to accurately reflect the actual condition of the country specific activities. Notwithstanding the various uncertainties and limitations encountered under the second communication, efforts are currently underway to minimize the discrepancies in estimating emissions in the Energy Sector.

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Intergovernmental Panel on Climate Change (IPCC) (1997) Revised 1996 Guidelines for National Greenhouse Gas Inventories.

4.3 Challenges and Possible Solutions

1 Activity Data

Experiences on data collection focused on 3 issues; (1) Transportation (traveling distance), (2) Power Plants, (3) Heavy Industry (e.g. Iron & Steel, Chemical, Cement etc.).

Regarding transportation data, it is quite difficult to obtain comprehensive surveyed data; therefore, these kinds of data are always based on a sampling survey. However, total fuel consumption data could be obtained by statistics related to taxation or other issues. In this case, a cross check technique among fuel consumption, energy efficiency (mileage) and cumulative traveling distance is useful.

Power plants and heavy industry plants such as for iron and steel are one of the most important large point sources. If statistical data could not provide information on such factories, direct questionnaires would be a possible solution, along with the establishment and maintenance of a network for the inventory agency and possible data-providers.

2 Emission Factors

Making a table of values of EF with basic assumptions for country-specific EFs could be a possible solution. IPCC-NGGIP's EFDB (emission factor database) is a very good resource for inventory agencies. Currently, there are fewer EFs for the Asia region. We should provide our country-specific or region-specific (Asian-specific) EF in the near future. Requirements for the explanation of EFs submitted to IPCC-NGGIP's EFDB are quite involved, so if we would like to eventually provide that information to the EFDB, we must implement research on country-specific EF in such a way that it could be used to fulfill those requirements.

Indian GHG inventory for NC2 was developed with a lot of plant-specific data. It is a very good example for us to follow in obtaining detailed data for estimating GHG emissions.

3 QA/QC

Making different databases and comparing them is an effective tool for QA/QC. These databases may be not only for GHGs but also for other statistics e.g. air pollutants, economic indexes etc.

Describing routine process and assignment to implementing agencies is also good tools for QA/QC.

4 Uncertainty Assessment

The concept of uncertainty assessment is simple: give priority to improve inventory. However, the procedure of this assessment is very complex. Guidance for uncertainty assessment included in Japan's NIR may be useful for countries other than Japan.

4.4 Other Points Discussed

All participants recognized the importance of maintaining a network to share our experiences on development of GHG inventories. In next meeting, this energy group would like to collect information on the collection of activity data focused on specific area.

Chapter 5

AGRICULTURE SECTOR

5.1 Introduction of the Agriculture Working Group

The Agriculture Working Group of the 3rd WGIA consisted of the following participants:

・Dr. Batimaa Punsalmaa (Chair; Mongolia)
・Mr. Syamphone Sengchandala (Reporter; Lao P.D.R.)
・Mr. Chan Thou Chea (Cambodia)
・Dr. Shuzo Nishioka (Japan)
・Dr. Takashi Osada (Japan)
・Dr. Damasa Magcale Macandog (Philippines)
・Dr. Amnat Chidthaisong (Thailand)

The programme of the Agriculture Working Group Session was divided into three parts as shown in the table below:

Part A	***Introduction of Good Practices***
	・*"Methane emission from Thai paddy fields by using the sensor technique"* (Dr. Amnat Chidthaisong, Thailand) ・*"Nitrous oxide and methane emissions and nitrogen dynamics in hedgerow systems in the uplands of Southern Philippines"* (Dr. Damasa Magcale Macandog, Philippines) ・*"Better evaluation system for N_2O and CH_4 emissions from composting (and wastewater purification) of livestock waste"* (Dr. Takashi Osada, Japan)
	- Discussion and questions -
Part B	***Roundtable Discussion on "Challenges to be tackled and possible solutions"***
Part C	***Summary of the Working Group Discussion***

5.2 Good Practices

5.2.1 Summary

The objective of this session was **to specify the features of the agriculture GHG inventory development in Asia by creating a list of good practices and challenges.** The working group heard three presentations.

Dr. Amnat Chidthaisong shared information on using a sensor technique to measure CH_4 emissions from paddy fields in Thailand. The good practice found in this presentation was the use of well-designed experiments for the measurement of CH_4 and N_2O emissions from paddy fields.

Dr. Damasa Magcale Macandog presented the results of field experiments and made measurements on tree and crop growth and biomass, tree litterfall, crop harvest and crop residues, and litterfall and crop residue decomposition from agroforestry systems in upland areas in the Philippines.

Dr. Takashi Osada presented experiments to measure the amount of GHG generation from pile type composting processes (and wastewater purification) of livestock.

Even though the presentations have dealt with CH_4 and N_2O emissions from three different sources, namely, from paddy fields in Thailand, agroforestry in the Philippines, and livestock in Japan, the common issue was the use of well-designed experiments to measure CH_4, N_2O, and NH_3 emissions from agricultural systems. From the discussions on these points, the following have been identified as good practices that improve the national GHG inventories of a country:

(1) the use of simple, portable equipment for measurement of CH_4, N_2O, NH_3 emissions;
(2) very comprehensive measurements; and;
(3) detailed data collection from measurements

When discussing how **the practice could be applied to other countries**, the group felt that in Asia it would be worthwhile to establish a network to conduct experiments for measuring CH_4 and N_2O emissions from all sources in the agriculture sector.

5.2.2 Nitrous Oxide and Methane Emissions in Hedgerow Systems in the Uplands of Southern Philippines

Damasa B. MAGCALE-MACANDOG [1], Edwin R. ABUCAY [1], Robert G. VISCO [2], Rogaciano N. MIOLE [3], Esmael L. ABAS [4], Gene M. COMAJIG [5] and Arsenio D. CALUB [5]
[1]Institute of Biological Science, University of the Philippines Los Baños College, Laguna 4031, Philippines
[2]Institute of Renewable and Natural Resources, University of the Philippines Los Baños College, Laguna 4031, Philippines
[3] College of Forestry and Environmental Studies, Mindanao State University, Marawi City, Lanao del Sur, Philippines
[4]Cotabato Foundation College of Science and Technology, Sub-Office Kidapawan City, South Cotabato, Philippines
[5]University of the Philippines Los Banos Foundation, Inc. College, Laguna 4031, Philippines

Abstract:

Nitrous oxide and methane are major greenhouse gases associated with agroforestry systems. Agroforestry is a natural resource management system that integrates trees and livestock in smallholder farms. This results in higher crop and tree diversity with sustainable production for increased social, economic, and environmental benefits. Hedgerow is an agroforestry system designed to control soil erosion and water run-off and restore or maintain soil fertility in sloping upland areas.

Experimental plots were established in *Eucalyptus deglupta*- and *Gmelina arborea*- based hedgerow systems to measure nitrous oxide emissions from fertilization, tree litterfall and litter decomposition, maize residue incorporation and livestock manure.

Results showed that fertilizer application, tree litter fall and crop residue incorporation are the major sources of nitrogen inputs in these hedgerow systems. Synthetic fertilizer and tree leaf litter are the major sources of direct nitrous oxide emissions in the agroforestry systems studied.

The major source of N_2O emissions from the agroforestry systems studied is the direct N_2O emissions from soil. Indirect sources of N_2O emissions in hedgerow systems are much lower compared with the direct N_2O emissions. Maize monocropping systems had higher N_2O emissions than hedgerow systems. In the agroforestry system, tree leaf litter fall and litter decomposition make a great contribution to the N input and emissions from the systems. Enteric fermentation is the major source of methane emissions from domestic livestock in Claveria.

A number of factors identified in this study that need further research to improve estimates of N_2O emissions were the N excretion factor per animal type, residue to grain (residue to crop) ratio, fraction leaching, and fraction volatilization.

Keywords: Large-eddy simulation, Chemical reaction, Liquid turbulence, Thermal stratifications

1 Introduction

Nitrous oxide (N_2O) is one of the major greenhouse gases and it plays a role in the radiative balance of the earth and in the destruction of the stratospheric ozone molecules. The concern with N_2O is due to its long atmospheric life-time of 166 +/- 16 years and higher global warming potential (310 times that of CO_2) (Bhatia et al., 2004).

Annual emission of N_2O-N from agricultural systems amounts to 6.3 Tg, which includes direct emission from agricultural soil and animal systems and indirect emission from agricultural soil through loss of nitrogen to aquatic systems and the atmosphere (Bhatia et al., 2004). Soil is considered to be one of the major sources, contributing 65% to global nitrous oxide emissions.

The formation of nitrous oxide in agricultural soils is a biogenic process and primarily results from nitrification and denitirification (Mosier, 1998). Nitrification is the biological oxidation of soil ammonium to soil nitrite and nitrate while denitirification is the stepwise biological reduction of soil nitrate to gaseous nitrogen products (de Klein et al., 2001). Nitrous oxide is an intermediate in the reaction sequences of both processes which leaks from microbial cells into the soil atmosphere (Firestone and Davidson 1989 as cited in Mosier 1998).

Both nitrification and denitrification processes are affected by a number of primary factors such as soil oxygen content, temperature, mineral N content, and pH. However, these proximal factors are in turn affected by various more distal factors, which makes the regulation of the two processes rather complex (de Klein et al., 2001).

Agroforestry is a dynamic, ecologically-based, natural resource management system that, through the integration of trees and livestock in farms, diversifies and sustains smallholder production for increased social, economic, and environmental benefits. Improved fallow systems that aim to restore soil fertility, fodder plantations, windbreaks, and riparian forest management are all examples of agroforestry (Verchot et al., 2004). It is a sustainable alternative agricultural system for degraded lands that can best meet smallholder farm household food needs as well as provide environmental services. Agroforestry systems may serve as both a source and sink of nitrogen oxides, depending on the management practices and component trees and crops of the system.

Agroforestry systems are widely adopted in the uplands of Claveria, Mindanao, Philippines. Hedgerows are widely adopted in sloping areas, as the system is effective in addressing soil erosion problems as well as conserving the topsoil. *Gmelina arborea* and *Eucalyptus deglupta* are two fast-growing timber species that are planted in hedgerow systems while maize is planted in the alley areas in between the hedgerows.

A long-term experiment on nitrous oxide and methane fluxes in six different land use systems was established in 1985 in the Peruvian Amazon (Palm et al., 2002). The high and low input agriculture systems were greater N_2O sources than the agroforestry systems, and the fallow control was an even lower source. Tsuruta et al. (2000) reported a transient increase in N_2O emissions associated with increased N availability in tree-based agricultural systems in Indonesia. Fertilizer application increases the N-oxide flux from soils because it stimulates the microbial processes of nitrification and denitrification, which results in increased gas fluxes. More so, heavy rainfall soon after the application of fertilizer to wet soils stimulates N_2O emissions (Verchot et al., 2004).

In agroforestry systems designed to restore or maintain soil fertility, trees are often grown in the fields, or nearby, and tree litter is used as a green manure. N_2O flux is very much dependent on the quality of the plant litter that is produced and incorporated into the soil (Millar et al., 2004). Incorporation of residues containing high N and low lignin such as *Sesbania* resulted to higher total N_2O emissions than *Macroptilium atropurpureum* and natural fallow residues in improved fallow systems in Kenya (Verchot et al., 2004).

Biological generation of methane in anaerobic environments, including enteric fermentation in ruminants, flooded rice fields, and anaerobic animal waste processing, is the principal source of methane from agriculture (Bhatia et al., 2004). Livestock holding is widespread in Claveria, with 74% of the households having livestock. Cattle and carabao are the most common livestock in smallholder farms in Claveria. They provide animal labor for land preparation and transportation. Animal manure is another source of nitrogen emissions from these agroforestry systems.

Methanotrophy (microbial consumption) is a process which involves the oxidation of CH_4 by bacteria; CH_4 is the C source, or the electron donor in the respiration reaction. Methanotrophs and methytrophs are all obligate aerobes; the biochemical process requires a monooxygenase enzyme, and therefore, requires molecular oxygen (O_2). Methanotrophy is the dominant process in upland soils. In these soils, oxidation generally exceeds production and there is a net uptake by the soil of CH_4 from the atmosphere (Verchot et al., 2004).

This study aims to estimate nitrous oxide emissions through fertilization, tree litterfall and decomposition, maize residue incorporation and livestock manure; and the methane emissions from livestock holdings in *G. arborea* and *E. deglupta* hedgerow systems.

2 Methodology

2.1 Description of the Study Area

Claveria is a municipality of Misamis Oriental, Mindanao with an area of about 82,500 hectares. The municipality sits on a volcanic plateau ascending abruptly from the west from about 350 m above sea level (m asl) to about 1,200 m asl in the east. Its topography is generally rugged, characterized by gently rolling hills and mountains with cliffs and escarpments. The area is divided into two topographic regimes: upper Claveria with range of elevation of 650-915 m asl and lower Claveria with range of elevation of 390–650 m asl. Upper Claveria is located along the north and northeast areas of the town while lower Claveria lies on the west and northwest section of the municipality. More than 68% of the total land area of Claveria has slopes greater than 18%.

Soils from Claveria are derived from pyroclastic materials and classified as acidic-upland (fine mixed, isohyperthermic, Ultic Haplorthox) with a depth of more than 1 m (Garrity and Agustin, 1995). Generally, the soils are characterized by high organic matter content, low pH (4.2–5.2), low CEC and anion activity (Hafner 1996, CCLUP 2000).

The climate in the area has pronounced a dry season from January to May (< 100 mm/mo) and a wet season from June to December (> 200 mm/mo), with an average annual rainfall of 2000 mm. However, rainfall patterns throughout the municipality vary with elevation, with the upper areas of Claveria having relatively greater amount of rainfall than the lower areas (CCLUP, 2000). The rainfall pattern is one factor that determines cropping patterns and land use across the landscape.

The cultivated land area in Claveria is estimated at 26,055 ha. The dominant crop is maize, with 51% of the arable land devoted to its production. In high elevation areas, 1,837 hectares are planted with tomatoes. Cassava is widely grown root crop in lower Claveria. The Department of Environment and Natural Resources (DENR) introduced *Gmelina arborea* in the 1980s to encourage tree growing as part of its reforestation program. With the establishment of the International Centre for Research in Agroforestry (ICRAF) in 1993, agroforestry practices were introduced to the farmers. ICRAF initiated the planting of *Acacia mangium* and *Eucalyptus deglupta* as agroforestry species. To date, tree planting and reforestation are popular among farmers. Tree-based agricultural systems are widely adopted by the farmers in the area. Most frequent timber tree species planted are *G. arborea*, *E. deglupta* and *Paraserianthes falcata*. Banana is commonly planted in most farms. Other fruit trees found in the area are *Cocos nucifera*, *Durio zibenthinus*, *Mangifera indica*, *Nephelium lappaceum*, and *Lansium domesticum.*

2.2 Experimental Treatments and Management

One- and seven-year old *E. deglupta* and *G. arborea* hedgerow systems were established in Patrocenio, Claveria. The treatments are different combinations of tree species (*Eucalyptus deglupta*, *Gmelina arboea*), tree age (1 and 7 year old), and tree spacing (1m x 3m and 1m x 9 m) (Table 5.1). *Eucalyptus deglupta* and *G. arborea* were planted along the hedgerows and maize was planted in the alley areas. Erosion plots and litter traps were set up in the experimental plots. Size of the experimental plots was 10m x 18m for the 1-year old treatments while plots for the 7 year-old trees were 16m x 20m.

Seeds of maize (Pioneer hybrid 3014) were planted in the alley areas at 1 seed per hill. The planting distance between furrows was 60 cm and 25-30 cm between rows. Weeding of the alleys and inter row cultivation of maize plants were done 30 days after planting. Nitrogen fertilizer (Urea, 46-0-0) and P fertilizer (Solophos, 0-18-0) were applied at the rate of 195.65 kg ha^{-1} and 166.67 kg ha^{-1}, respectively. The first half of the N fertilizer was applied during planting and the other half was applied 30 days after planting. Phosphorus fertilizer, on the other hand was applied during planting. Hand weeding was also done as needed, 2-3 weeks after the second inter-row cultivation. Two crops of maize were planted: the first crop from February to May and the second crop from July to October.

Table 5.1 The experimental treatments (tree species, tree age, spacing) and number of replicates employed in the study

Experiment No. 1 (7 year-old trees, 2 replicates per treatment)			Experiment No. 2 (1 year-old trees, 3 replicates per treatment)		
Species	Spacing (m x m)	Plot size (ha)	Species	Spacing (m x m)	Plot size (ha)
G. arborea + Z. mays	1x3	0.032	Pure G. arborea	1x1	0.018
G. arborea + Z. mays	1x9	0.032	*G. arborea + Z. mays*	1x3	0.018
E. deglupta + Z. mays	1x3	0.032	*G. arborea + Z. mays*	1x9	0.018
E. deglupta + Z. mays	1x9	0.032	Pure *E. deglupta*	1x1	0.018
Pure *Z. mays*		0.018	*E. deglupta + Z. mays*	1x3	0.018
			E. deglupta + Z. mays	1x9	0.018
			Pure *Z. mays*		0.018

2.3 Harvesting and Biomass Determination of Maize

When maize ears reached maturity (dry leaves and husk) at 105-110 days after planting, harvesting of maize cobs was done manually. Destructive sampling of 16 sample plants per plot was done to determine plant biomass. Root, stalk, leaf and cob were segregated and the fresh weight was taken. One hundred fifty grams (150g) fresh weight of the sub-sample for each plant component was taken for oven drying at 70 °C for 48 hours. The dry weight of each crop component was determined.

2.4 Nutrient Analysis of Plant Tissues

Plant tissue samples of each plant part were analyzed for total nitrogen (Kjeldahl) and phosphorus (Vanadomolybdate) contents.

2.5 Litterfall

To estimate the litter input of the trees from 7-yr old *E. deglupta* and *G. arborea* hedgerows, 4 litter traps ($1m^2$) were installed randomly inside each plot. Litter fall was collected monthly. The fresh weight of collected litter was taken and dry weight was determined after oven drying at 70 ºC for 48 hours.

2.6 Leaf Litter Decomposition

Fifty-gram leaf litter samples (collected inside the plot) were placed in net bags (12 x 12 in) for the decomposition study in the 7-year old *G. arborea* and *E.deglupta* plots. A total of 8 net bags were randomly placed inside each plot. Two bags per plot were retrieved every 21 days. The fresh weight and oven-dried weight of the retrieved leaf litter samples were determined. Decomposition rate was computed from the percent loss in weight.

2.7 Livestock Survey in Claveria

To have a statistically representative sample of the whole population of farmers in Claveria, a stratified random sampling technique was employed in selecting the respondents for the household interview. Based from the combined elevation and agroforestry system classes, 300 farmers were sampled as respondents for the household interview. A component of the survey instrument was a set of questions related to livestock holdings and feed requirements.

3 Results

3.1 Maize Biomass and Crop Residue

Sixteen plants were randomly sampled and harvested from each experimental plot. The different parts of each plant were segregated into leaves, stalks, roots, ears and cobs. The fresh and oven-dry weights of each plant part were determined. Plant residue was computed by summing up the dry weights of the different plant parts except the cob portion, which is taken out of the system. The rest of the crop remained in the field as crop residue and was incorporated back into the soil during cultivation for the next cropping. The average individual plant residue was computed based on the biomass of the 16 plant samples per plot. The approximate number of maize plants per plot was computed based on the distance between hills in a row and total number of rows in the treatment plots (Table 5.2).

Results show that biomass of maize grown under full sunlight was greater than biomass of maize grown along the alley areas in between hedgerows (Table 5.2). Growth and biomass of maize plants were higher during the first crop than second crop (Table 5.2). During the first crop, maize growth and biomass did not vary greatly with hedgerow spacing under 7-year old hedgerows. The effect of hedgerow spacing under 7-year old trees was evident during the second crop wherein maize biomass was higher in the wider spacing treatment (1x9) than in the closer spacing treatment (1x3) (Table 5.2).

When grown with 1 year old trees, maize biomass grown in closer hedgerow spacing (1x3) was reduced to almost half of the maize biomass grown in wider hedgerow spacing (1x9) in both cropping seasons. This growth performance can be attributed to light competition between the trees and crops. Both the maize crop and the 1-year old trees had almost the same height during the experiment.

Comparing the performance of maize plants under *E. deglupta* and *G. arborea*, under both the 1-yr and 7-yr old trees, maize plants grown under *E. deglupta* have relatively higher biomass under similar tree spacings. The shape of the tree canopy, root architecture and tree leaf litter composition contribute to the dynamic interaction between trees and crops in agroforestry systems.

Table 5.2 Total maize plant residue of 7 and 1-year old hedgerow agroforestry systems

Tree species	Tree age (year)	Tree spacing (m x m)	Maize plant residue biomass ($kg\ ha^{-1}\ yr^{-1}$)		Total crop residue biomass ($kg\ ha^{-1}\ yr^{-1}$)
			First cropping	Second cropping	
E. deglupta	7	1x3	7,786	2,610	10,396
E. deglupta	7	1x9	7,486	3,605	11,091
G. arborea	7	1x3	6,215	1,914	8,129
G. arborea	7	1x9	6,054	3,465	9,519
Z. mays			13,156	6,354	19,510
E. deglupta	1	1x3	4,840	2,771	7,611
E. deglupta	1	1x9	9,204	5,555	14,759
G. arborea	1	1x3	2,797	766	3,564
G. arborea	1	1x9	7,678	2,876	10,555
Z. mays			11,844	4,534	16,379

3.2 N Inputs from Litter Fall (F_{LI})

Litter fall under 7-yr old trees was collected from March 2004 to January 2005 using 1 m^2 litter traps. Litter was segregated into leaves and other components composed of branches and twigs. For both tree species, litter fall was higher under wider spacing of tree hedgerows (Table 5.3) than closer hedgerow spacing. Leaf litter from *E. deglupta* hedgerows was higher than in *G. arborea* hedgerows in both spacing treatments (Table 5.3 and Fig. 5.1). The proportion of leaf litter in the total litter fall under *E. deglupta* hedgerows ranged from 78 - 84% while leaf litter of *G. arborea* ranged from 80 - 84% of the total litter, under both tree spacing treatments (Fig. 5.1). The N input from litter fall was computed by multiplying the amount of leaf litter fall with the N fraction of the leaf litter. Results of the analysis have shown that the N content of *G. arborea* leaf litter is relatively higher than *E. deglupta* leaf litter (Table 5.3).

Table 5.3 N inputs from leaf litterfall from 7 year old *G. arborea* and *E. deglupta trees*

Tree Species	Spacing (m x m)	Leaf litter fall ($kg\ ha^{-1}\ yr^{-1}$)	N fraction	N input from litterfall (F_{LI}, $kg\ N\ ha^{-1}\ yr^{-1}$)
G. arborea	1x3	6033	0.0147	88.69
G. arborea	1x9	7231	0.0147	106.29
E. deglupta	1x3	7712	0.0102	78.66
E. deglupta	1x9	9107	0.0107	97.45

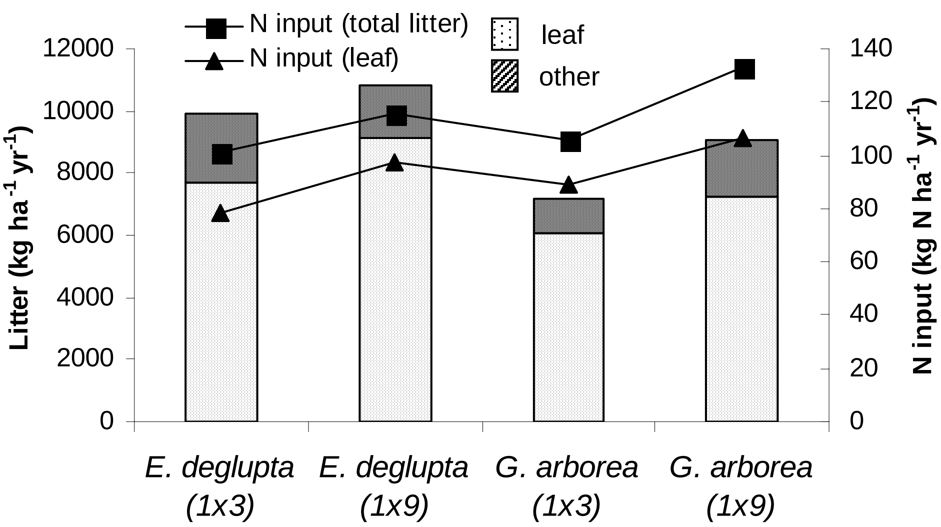
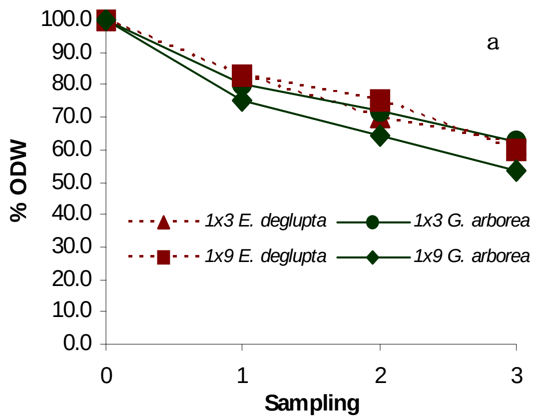


Fig. 5.1 Leaf and total (leaf, twigs, branches) litter from 7-yr old *E. deglupta* and *G. arborea.*

3.3 Leaf Litter Decomposition

Leaf litter decomposition was generally faster during the second crop (July - October), which was during the wet season (Fig. 5.2). It is evident, particularly during the second crop, that decomposition of leaf litter was faster under closer spacing treatment than wider spacing.

Results showed that during the decomposition experiment of 45 days, about 50% and 60% of Gmelina leaf litter was lost during the first cropping and second cropping seasons, respectively (Fig. 5.2). Magcale-Macandog and Rocamora (1997) reported complete decomposition of *G. arborea* leaf litter takes place within four months. Examining the leaves of the two tree species, *G. aborea* leaves are thinner and wider while *E. deglupta* leaves are thicker and narrower. The N content of *G. arborea* leaves is 1.47% while *E. deglupta* leaf litter has 1.0 – 1.07% N (Table 5.3).



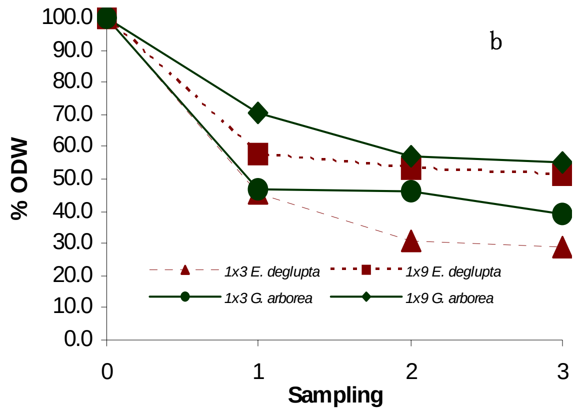


Fig. 5.2 Decomposition of *E. deglupta* and *G. arborea* leaf litter: (a) first cropping and (b) second cropping.

3.4 N Inputs from Inorganic Fertilizer (F_{SN})

F_{SN}, synthetic fertilizer N applied to soil corrected for NOx and NH_3 emissions, for the different treatments are shown in Table 5.4. Basal application of urea (46-0-0) was done in the alley areas in between tree hedgerows during planting and at 30 days after planting of maize seeds. Urea was applied at the rate of 195 kg ha^{-1} based on soil fertility analysis and fertilizer recommendation. Maize was planted for two cropping seasons in one year. Higher amounts of nitrogen were applied in bigger plots (Table 5.4). The default value for $Frac_{GASF}$ (the fraction of fertilizer nitrogen applied emitted as NOx and NH_3) is 0.1 as specified by IPCC (1997).

Table 5.4 Fertilizer nitrogen applied (total of 2 cropping season) in the different plots

Tree Species	Tree Age (yr)	Tree spacing (m x m)	Plot size (ha)	N applied (kg N ha^{-1} yr^{-1})	1-$Frac_{GASF}$	F_{SN} (kg N ha^{-1} yr^{-1})
E. deglupta	7	1 x 3	0.032	110.6	0.9	99.54
E. deglupta	7	1 x 9	0.032	172.8	0.9	155.52
G. arborea	7	1 x 3	0.032	110.6	0.9	99.54
G. arborea	7	1 x 9	0.032	172.8	0.9	155.52
Z. mays			0.018	100.4	0.9	90.396
E. deglupta	1	1 x 3	0.018	55.28	0.9	49.752
E. deglupta	1	1 x 9	0.018	94.06	0.9	84.654
G. arborea	1	1 x 3	0.018	55.28	0.9	49.752
G. arborea	1	1 x 9	0.018	94.06	0.9	84.654
Z. mays			0.018	100.44	0.9	90.396

3.5 N Inputs from Maize Crop Residues

In Claveria, incorporating maize crop residues during land preparation is common practice. Farmers do not burn crop residues. The results of plant tissue analysis of maize leaves under the different treatments are shown in Table 5.5. Zea mays grown under full sunlight has higher crop biomass, thus N inputs from maize residues were higher. Comparing maize crop residues when grown along the alley areas, maize biomass production was higher under wider spacing treatment than closer spacing, thus the amount of nitrogen coming from incorporation of crop residues will be higher in wider hedgerow spacing compared with the plots with closer spacing under both 1- and 7-year old trees (Table 5.5). Between *E. deglupta* and *G. arborea* hedgerow systems, nitrogen inputs from maize crop residues were higher under *E. deglupta* hedgerows than *G. arborea* hedgerows. This is due to the higher maize crop biomass production under *E. deglupta* hedgerows than *G. arborea* hedgerows.

Table 5.5 Nitrogen input from maize crop residues

Tree species	Tree age (year)	Tree spacing (m x m)	Total crop residue (kg ha^{-1} yr^{-1})	N fraction of maize residues	N input from residues (F_{CR}) (kg N ha^{-1} yr^{-1})
E. deglupta	7	1x3	10,396	0.0040	41.58
E. deglupta	7	1x9	11,091	0.0045	49.91
G. arborea	7	1x3	8,129	0.0040	32.52
G. arborea	7	1x9	9,519	0.0056	53.31
Z. mays			19,510	0.0048	93.65
E. deglupta	1	1x3	7,611	0.0051	38.82
E. deglupta	1	1x9	14,759	0.0045	66.42
G. arborea	1	1x3	3,564	0.0056	19.96
G. arborea	1	1x9	10,555	0.0040	42.22
Z. mays			16,379	0.0045	73.71

3.6 Direct N_2O Emissions from Soil

The direct N_2O emissions from agricultural soils (N_2O_{DIR}) are computed using the following formula:

$$N_2O_{DIR} = \left[(F_{SN} + F_{AW} + F_{BN} + F_{CR}) x EF_1 + F_{OS} x EF_2\right] x \frac{44}{28}$$

Where:

F_{SN} = synthetic nitrogen fertilizer applied, corrected for NH_3 and NO_x emissions (t N/yr)

F_{AW} = amount of manure nitrogen used as fertilizer, excluding manure produced during grazing and corrected for NH_3 and NO_x emissions

F_{BN} = amount of nitrogen fixed by N-fixing crops (t N/yr)

F_{CR} = amount of nitrogen in crop residues returned to soils (t N/yr)

EF_1 = emission factor for direct emissions (t N_2O-N/t N input)

F_{OS} = area (ha) of cultivated organic oils (histosols)

EF_2 = emission factor for organic soil mineralization due to cultivation (kg N_2O-N/ha/yr)

44/28 = molecular conversion ratio

In this study, leaf litter is another source of N input and N_2O emissions and will be designated as F_{LI}. In Claveria, animal manure is left in the field where the animals dropped it, thus the value of F_{AW} is zero. In the hedgerow system studied, there are no nitrogen-fixing plants or trees, hence F_{BN} is also equal to zero. The soil type in the study area is not histosol.

Synthetic fertilizer and tree leaf litter are the major sources of direct nitrous oxide emissions in the agroforestry systems studied (Table 5.6). Maize crop residue is another source of direct nitrous oxide emissions. Due to leaf litter, the total direct N_2O emissions from 7-year old hedgerow systems were higher compared with the open maize cropping system and 1-year old hedgerow systems (Table 5.6).

Table 5.6 Direct nitrous oxide emissions from soils

Tree species	Tree age (year)	Tree spacing (m x m)	F_{SN} (kg N ha^{-1} yr^{-1})	F_{CR} (kg N yr^{-1})	F_{LI} (kg N yr^{-1})	EF_1 (kg N_2O-N/kg N input	N_2O_{DIR} (kg N_2O ha^{-1} yr^{-1})
E. deglupta	7	1x3	99.54	41.58	78.66	0.0125	4.32
E. deglupta	7	1x9	155.52	49.91	97.45	0.0125	5.95
G. arborea	7	1x3	99.54	32.52	88.69	0.0125	4.34
G. arborea	7	1x9	155.52	53.31	106.29	0.0125	6.19
Z. mays			90.396	93.65	-	0.0125	3.62
E. deglupta	1	1x3	49.752	38.82	-	0.0125	1.74
E. deglupta	1	1x9	84.654	66.42	-	0.0125	2.97
G. arborea	1	1x3	49.752	19.96	-	0.0125	1.37
G. arborea	1	1x9	84.654	42.22	-	0.0125	2.49
Z. mays			90.396	73.71	-	0.0125	3.22

3.7 Domestic Livestock

Most (74%) of the households surveyed in Claveria have animal holdings. Cattle and carabao are very useful as draught animals for land preparation and daily hauling of water and other field supplies. Methane emissions from livestock come from enteric fermentation and manure management.

3.8 Methane Emissions from Enteric Fermentation

Methane emissions from enteric fermentation are computed using the following equation:

$$M_a = P_a \times EF_a$$

Where:

M_a = methane emissions for animal type "a"
P_a = population of animal type "a"
EF_a = methane emission factor for animal "a"

Non-dairy cattle are the major source of methane from enteric fermentation in Claveria (Table 5.7).

Table 5.7 Methane emissions from enteric fermentation

Animal type	Population	Emission factor (kg CH_4 $head^{-1}$ yr^{-1})	Methane emissions (kg CH_4 yr^{-1})
Non-dairy cattle	258	44	11,352
Carabao	62	55	3,410
Goat	46	5	230
Swine	398	1.5	597
Poultry	1252	-	-
Total			15,589

3.9 Methane Emissions from Manure Management

Methane emissions from manure management were computed using the following equation:

$$M_a = P_a \times EF_a$$

Where:

M_a = methane emissions for animal type "a"

P_a = population of animal type "a"

EF_a = methane emission factor for manure management for animal "a"

Swine are the major source of methane from manure management (Table 5.8) in the study area.

Table 5.8 Methane emissions from manure management

Animal type	Population	Emission factor (kg CH_4 $head^{-1}$ yr^{-1})	Methane emissions (kg CH_4 yr^{-1})
Non-dairy cattle	258	2	516
Carabao	62	3	186
Goat	46	0.22	10.1
Swine	398	7	2,786
Poultry	1252	0.023	28.8
Total			3,526.9

Based on local surveys and laboratory analyses of animal manure, the local values for daily manure production are presented in Table 5.9. The N emissions from different animal types are much lower than the default values given by IPCC (1997). Local values for total N excretion for cattle and carabao were 12.3 and 14.2 kg, respectively (Table 5.9). IPCC (1997) default values were 40 kg for both non-dairy cattle and carabao.

Table 5.9 Local values for nitrogen input from animal waste based on average animal live weight

Animal	Average animal live weight (kg)	Daily manure production (% of LW)	Daily manure production (FW, kg)	Dry matter (%)	Daily manure production (ODW, kg)	Nitrogen content (%)	Total N animal^{-1} yr^{-1} (kg N yr^{-1})
Cattle	300	5	15	15	2.25	1.5	12.3
Carabao	350	5	17.5	15	2.6	1.5	14.2
Goat	15	3	0.45	25	0.11	1.5	0.6
Pig	80	5	4	20	0.80	2	5.84
Chicken	1.2	3	0.04	20	0.01	3	0.11

3.10 Nitrous Oxide Emissions from Grazing Animals

Nitrous oxide emissions from grazing animals were computed using the following equation:

$$N_2O_{GRAZING} = (N_{EXPR} \text{ x } EF_3 \text{ x } \frac{44}{23})$$

Where:
$N_2O_{GRAZING}$ = N_2O emissions from grazing animals (kg N_2O yr^{-1})
N_{EXPR} = nitrogen excretion value for pasture range and paddock (kg N yr^{-1})
EF_3 = N_2O emission factor for pasture range and paddock (kg N_2O-N kg N^{-1})

Non-dairy cattle and swine are the major sources of nitrous oxide emission from livestock (Table 5.10).

Table 5.10 Nitrous oxide emissions from grazing animals (N_{EXPR}) using local values for N excretion per animal type

Livestock Type	Number of animals	N excretion per animal type (local, kg head^{-1} yr^{-1})	Total annual N excretion (kg N)	Fraction pasture range and paddock	N_{EXPR} (kg N yr^{-1})	EF_3 (kg N_2O-N kg N^{-1})	$N_2O_{GRAZING}$ (kg N_2O yr^{-1})
Non-dairy cattle	258	12.3	3173.4	1	3173.4	0.02	99.74
Carabao	62	14.2	880.4	1	880.4	0.02	27.67
Goat	46	0.6	27.6	1	27.6	0.02	0.87
Swine	398	5.8	2308.4	1	2308.4	0.02	72.55
Poultry	1252	0.1	125.2	1	125.2	0.02	3.94
Total			6515				204.77

Using the IPCC values for N excretion per animal type, the computed N_2O emissions from grazing animals is 3 times the computed value using local N excretion values (Tables 5.10 and 5.11).

Table 5.11 Nitrous oxide emissions from grazing animals (N_{EXPR}) using IPCC (1997) default values for N excretion per animal type

Livestock Type	Number of animals	N excretion per animal type (IPCC, kg head^{-1} yr^{-1})	Total annual N excretion (kg N)	Fraction pasture range and paddock	N_{EXPR} (kg N yr^{-1})	EF_3 (kg N_2O-N/kg N)	$N_2O_{GRAZING}$ (kg N_2O/yr)
Non-dairy cattle	258	40	10320	1	10320	0.02	324.34
Carabao	62	40	2480	1	2480	0.02	77.94
Goat	46	12	552	1	552	0.02	17.35
Swine	398	16	6368	1	6368	0.02	200.14
Poultry	1252	0.6	751.2	1	751.2	0.02	23.61
Total			20471.2				643.38

3.11 Indirect Nitrous Oxide Emissions

A portion of nitrogen in manure and synthetic fertilizers applied to soils may escape to the atmosphere in the form of NH_3 or NOx, or they may enter water courses by leaching and runoff. In any case, indirect emissions of N_2O can occur as a result of the conversion of this 'displaced' nitrogen into N_2O. To estimate indirect emissions of N_2O as a result of atmospheric deposition and leaching of nitrogen, the only activity data needed are total livestock nitrogen excretion (F_{AW}) and synthetic nitrogen fertilizer consumption (N_{FERT}).

3.12 Indirect Nitrous Oxide Emissions from Volatilization

Following the IPCC guidelines, the amount of N_2O emissions from volatilization from synthetic fertilizer applied and animal manure is minimal for all the experimental plots (Table 5.12). The total N excretion by livestock was obtained by dividing the total N excretion using local values (6515 kg N/yr) by the number of households surveyed (300) to yield an average of 21.72 kg N excreted by livestock for each of the plots.

3.13 Indirect Nitrous Oxide Emission from Leaching

The indirect nitrous oxide emissions from leaching ranged from 0.58 – 1.46 kg N_2O yr-1 (Table 5.13). Higher indirect nitrous oxide emissions from leaching were observed in wider hedgerow spacing due to larger alley areas planted to maize and fertilized with inorganic fertilizer.

3.14 Total N_2O Emissions

The major source of N_2O emissions from the agroforestry systems studied is the direct N_2O emissions from soil. Indirect N_2O emissions from leaching were greater than N_2O emissions from grazing animals and volatilization (Table 5.14). N_20 emissions were higher in hedgerow system for both *G. arborea* and *E. deglupta* having 1x9 m spacing than maize monocropping and 1x3 m hedgerow spacing. Total N_2O emissions were higher in the 7-year old hedgerow system than 1-yr old hedgerow system.

3.15 Total Methane Emissions

Enteric fermentation is the major source of methane emissions from domestic livestock in Claveria (Table 5.15). Non-dairy cattle were the major contributor of methane from enteric fermentation. Methane emissions from manure management were much smaller compared with emissions from enteric fermentation. Swine are the major contributor of methane from manure management.

4 Issues regarding GHG inventory

4.1 Crop Residue to Grain Ratio

The ratio of crop to grain that is used in the computations is a critical factor. In the case of the Philippines GHG inventory, the crop to grain ratio used for maize was 1. Based on the actual experimental biomass partitioning data, the residue (including corn cob) to grain ratio ranged from 2.68 to 4.08. If the corn cob is included in the grain yield, the residue to grain + cob ratio ranged from 2.11 to 3.18 (Table 5.16).

4.2 N Excretion Factor for Animal Types

The local values for N excretion for the different animal types were computed based on local data on animal live weight, daily manure production and laboratory analysis of the dry matter content and N content of animal manure. The N content of animal manure varies with the composition of animal feed given to animals. The local values for N excretion were much lower compared with the IPCC default values for all animal types studied in this paper (Table 5.17).

4.3 Fraction Leaching

The fraction of synthetic fertilizer nitrogen applied that is lost through leaching will vary with the season of the year (rainy season and dry season), frequency and intensity of rainfall, timing of fertilizer application with respect to rain events, soil type and topography of the land.

4.4 Fraction Volatilization

The fraction of synthetic fertilizer nitrogen applied that is lost through volatilization will vary with mode of fertilizer application (broadcast, basal), type of fertilizer (slow-release, coated), and season of the year (temperature and moisture).

Table 5.12 Indirect nitrous oxide emissions from atmospheric deposition of NH_3 and NOx

Tree Species	Tree Age (yr)	Tree spacing (m x m)	N applied (kg N ha^{-1} yr^{-1})	Fraction of synthetic fertilizer N applied that volatilizes $Frac_{GASF}$	Amount of Synthetic N applied to soil that volatilizes (kg N)	Total N excretion by livestock N_{EX} (kg N yr^{-1}) (local)	Fraction of total manure N excreted that volatilizes $FRAC_{GASM}$	Total N excretion by livestock that volatilizes (kg N)	EF_4 (kg N2O-N kg N^{-1})	N_2O emissions from atmospheric deposition (kg N_2O-N yr^{-1})
E. deglupta	7	1 x 3	110.6	0.1	11.06	21.72	0.2	4.34	0.01	0.35
E. deglupta	7	1 x 9	172.8	0.1	17.28	21.72	0.2	4.34	0.01	0.35
G. arborea	7	1 x 3	110.6	0.1	11.06	21.72	0.2	4.34	0.01	0.35
G. arborea	7	1 x 9	172.8	0.1	17.28	21.72	0.2	4.34	0.01	0.35
Z. mays			100.4	0.1	10.04	21.72	0.2	4.34	0.01	0.35
E. deglupta	1	1 x 3	55.28	0.1	5.53	21.72	0.2	4.34	0.01	0.24
E. deglupta	1	1 x 9	94.06	0.1	9.41	21.72	0.2	4.34	0.01	0.22
G. arborea	1	1 x 3	55.28	0.1	5.53	21.72	0.2	4.34	0.01	0.24
G. arborea	1	1 x 9	94.06	0.1	9.41	21.72	0.2	4.34	0.01	0.22
Z. mays			100.44	0.1	10.04	21.72	0.2	4.34	0.01	0.22

Table 5.13 Indirect nitrous oxide emission from leaching

Tree Species	Tree Age (yr)	Tree spacing (m x m)	N applied (kg N ha^{-1} yr^{-1})	Total N excretion by livestock N_{EX} (kg N yr^{-1}) (local)	Fraction of N that leaches $FRAC_{LEACH}$ (kg N kg N^{-1})	EF_5 (kg N_2O-N/ kg N)	N_2O emissions from leaching (kg N_2O-N yr^{-1})
E. deglupta	7	1 x 3	110.6	21.72	0.3	0.025	0.99
E. deglupta	7	1 x 9	172.8	21.72	0.3	0.025	1.46
G. arborea	7	1 x 3	110.6	21.72	0.3	0.025	0.99
G. arborea	7	1 x 9	172.8	21.72	0.3	0.025	1.46
Z. mays			100.4	21.72	0.3	0.025	0.92
E. deglupta	1	1 x 3	55.28	21.72	0.3	0.025	0.58
E. deglupta	1	1 x 9	94.06	21.72	0.3	0.025	0.87
G. arborea	1	1 x 3	55.28	21.72	0.3	0.025	0.58
G. arborea	1	1 x 9	94.06	21.72	0.3	0.025	0.87
Z. mays			100.44	21.72	0.3	0.025	0.92

Table 5.14 Direct and indirect soil N_2O emissions in *E. deglupta* and *G. arborea* hedgerow systems

Tree species	Tree age (yr)	Tree spacing (m x m)	N_2O_{DIR} (kg N_2O yr^{-1})	N_2O emissions from grazing animals	Indirect N_2O emissions from atmospheric deposition (kg N_2O-N yr^{-1})	Indirect N_2O emissions from leaching (kg N_2O-N yr^{-1})	Total N_2O emissions (kg N_2O-N yr^{-1})
E. deglupta	7	1x3	4.32	0.68	0.35	0.99	6.34
E. deglupta	7	1x9	5.95	0.68	0.35	1.46	8.44
G. arborea	7	1x3	4.34	0.68	0.35	0.99	6.36
G. arborea	7	1x9	6.19	0.68	0.35	1.46	8.68
Z. mays			3.62	0.68	0.35	0.92	5.57
E. deglupta	1	1x3	1.74	0.68	0.24	0.58	3.24
E. deglupta	1	1x9	2.97	0.68	0.22	0.87	4.74
G. arborea	1	1x3	1.37	0.68	0.24	0.58	2.87
G. arborea	1	1x9	2.49	0.68	0.22	0.87	4.26
Z. mays			3.22	0.68	0.22	0.92	5.04

Table 5.15 Total methane emissions from domestic livestock in Claveria

Animal type	Enteric fermentation ($kg\ CH_4/yr$)	Manure management ($kg\ CH_4/yr$)	**Total methane emissions** ($kg\ CH_4/yr$)
Non-dairy cattle	11,352	516	11,868
Carabao	3,410	186	3,596
Goat	230	10.1	240.1
Swine	597	2,786	3,383
Poultry	-	28.8	28.8
Total	15,589	3,526.9	19,115.9

Table 5.16 Ratios of crop residue: grain and residue: grain+cob

Tree Species	Tree age (year)	Spacing (m x m)	Maize residue*	Grain yield*	Grain + cob*	Ratio (residue: grain)	Ratio (residue: grain+cob)
E. deglupta	7	1x3	195.11	58.83	72.41	3.32	2.69
E. deglupta	7	1x9	307.23	86.27	103.88	3.56	2.96
G. arborea	7	1x3	122.11	29.96	40.30	4.08	3.03
G. arborea	7	1x9	272.59	75.31	89.95	3.62	3.03
Z. mays	7	-	439.93	110.37	138.42	3.99	3.18
E. deglupta	1	1x3	220.75	81.74	101.72	2.70	2.17
E. deglupta	1	1x9	287.12	111.07	135.78	2.59	2.11
G. arbroea	1	1x3	176.07	60.71	74.99	2.90	2.35
G. arbroea	1	1x9	203.13	74.45	90.88	2.73	2.24
Z. mays	1	-	308.26	115.23	138.14	2.68	2.23

*values in grams per plant

Table 5.17 Local and IPCC default values for the N excretion values for the different animal types

Livestock Type	N excretion per animal type (IPCC, $kg\ head^{-1}\ yr^{-1}$)	N excretion per animal type (local, $kg\ head^{-1}\ yr^{-1}$)
Non-dairy cattle	40	12.3
Carabao	40	14.2
Goat	12	0.6
Swine	16	5.8
Poultry	0.6	0.1

5 Discussion

The higher maize biomass production under full sunlight (pure maize) and wider hedgerow spacing (1x9) is largely due to light availability. Higher competition for light between the trees along the hedgerows and maize crop in the alley areas occurs at closer hedgerow spacing treatment, thus maize crop biomass is lower. Maize crop biomass was higher when grown with *E. deglupta* than those grown with *G. arbore*a. The shape of the tree canopy, root architecture and tree leaf litter composition contribute to the dynamic interaction between trees and crops in agroforestry systems.

Leaf litter of hedgerow trees is a major source of N inputs in these hedgerow systems. The high rate of litterfall in the study area and the relatively high N fraction of the leaf litter contribute to the high N inputs to these hedgerow systems. *Gmelina arborea* leaves have higher N content (1.47%) and decomposes completely within four months. This will make a great contribution to the N dynamics in the system. In agroforestry systems where leaf litter is used as a green manure, N_2O flux is very much dependent on the quality of the plant litter that is produced and incorporated into the soil. Greater emissions have been recorded following incorporation of residues with low C:N ratios, such as those of legumes (Verchot et al., 2004).

Synthetic fertilizer applied to the different plots was another major source of direct N_2O emissions from the hedgerow systems. It was reported that agricultural soils have higher nitrous oxide emissions than soils under native vegetation primarily due to fertilizer application. Fertilizer application stimulates the microbial processes of nitrification and denitrification, which results in increased N_2O fluxes (Verchot et al., 2004). Velthof et al. (1997) and Thornton et al. (1996, 1998) found that N_2O emissions from urea were substantially lower than nitrate-based fertilizers.

In general, when soil conditions favored denitrification, nitrate fertilizers caused higher emissions, whereas in warm, dry conditions emissions following applications of urea or ammonium-based fertilizers were higher. Lower rainfall and subsequent lower WFPS (water-filled pore spaces) (42-58%) limit denitrifier activity suggesting that N_2O emissions at this time may have been predominantly produced during nitrification, with soil conditions too aerobic for significant denitrification, resulting in the low emissions. Moreso, heavy rainfall soon after the application of fertilizer to wet soils stimulates N_2O emissions. As a result, peak N_2O emission or denitrification rates are often found following rainfall or irrigation events. The IPCC methodology does not account for variations in climatic and physical conditions, which are known to affect N_2O emissions.

Incorporation of maize crop residue to the soil is another source of direct N_2O emissions from agricultural soils. The amount of N_2O emissions is based on the quantity and N content of the residue. Verchot et al. (2002) reported that nitrous oxide emissions were increased after residue incorporation and were greater from improved-fallow treatments than from the natural-fallow and maize treatments. Most of this N_2O was emitted during the first 4 weeks after incorporation. This is due to the increased C supply and substrate for nitrification and denitrification stimulating microbial decomposition (Millar et al. 2004, Shen et al. 1989).

Study has shown that enteric fermentation is the major source of methane emissions from domestic livestock in Claveria. In the global CH_4 budget, upland tropical soils are a net sink. In fact, soils worldwide are the largest biotic sink for atmospheric CH_4, consuming 15-45 Tg annually (Verchot et al., 2004).

6 Conclusion

The major source of N_2O emissions from the agroforestry systems studied is the direct N_2O emissions from soil. In tree-based hedgerow systems, synthetic fertilizer application, tree leaf litter and crop residue incorporation are the major sources of direct N_2O emissions from the soil. Indirect sources of N_2O emissions in hedgerow systems are much lower compared with the direct N_2O emissions. Maize monocropping system had higher N_2O emissions than hedgerow systems. In agroforestry systems, tree leaf litter fall and litter decomposition make a great contribution to the N input and emissions from the systems. Enteric fermentation is the major source of methane emissions from domestic livestock in Claveria.

The factors identified in this study that need further research to improve estimates of N_2O emissions were the N excretion factor per animal type, residue to grain (residue to crop) ratio, fraction leaching and fraction volatilization.

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5.2.3 Better Evaluation System for N_2O and CH_4 Emission from Composting (and Wastewater Purification) of Livestock Waste

Takashi OSADA
Research Team for Waste Recycling System,
National Agricultural Research Center for Hokkaido Region,
National Agriculture and Food Research Organization,
1 Hitsujigaoka, Sapporo, Hokkaido 062-8555, Japan

Abstract:
In order to measure the amount of greenhouse gas generated from actual manure treatment processes more exactly, and to analyze the variation factors, we developed a quantitative measurement system using a large-sized dynamic chamber. The measurement system we developed consisted of a dynamic chamber device which carried out the collection of exhaust gas from treatment materials and a measurement device. The system was evaluated with standard gas of CH_4 and N_2O. High recoveries of 96.6% (CH_4, SD 4.03), and 99.5% (N_2O, SD2.68) were obtained for each gas emission in the chamber in 17-20 min. The measured values of those gases obtained by the IPD method and conventional method during a composting examination of swine waste were measured, and the differences were only a few percent of the total emissions. According to the results of our experiment with this measurement system, the composting-manure emission factors of CH_4 and N_2O varied significantly between livestock types, moisture contents of the pile materials and ambient temperature. Those factors should also depend on manure treatment type. This can be important information not only for inventory data, but also for the development of greenhouse gas regulations and technologies.

1 Why Do We Focus on N_2O and CH_4 Emission from Livestock Waste Treatment?

Wherever intensive livestock farming is performed, the environmental load caused by the high-level use of nutrient salts and the concentrated generation of large quantities of livestock waste must be considered. In recent years, the global warming phenomenon has begun to attract attention. According to IPCC (1994), agriculture accounts for one-fifth of the annual increase in anthropogenic greenhouse warming. Most of this is due to methane (CH_4) and nitrous oxide (N_2O); agriculture produces about 50% and 70%, respectively, of their anthropogenic emissions. Although there are many unknown portions, the source of about 5% of anthropogenic CH_4 and about 30% of anthropogenic N_2O is presumed to be livestock excrement, and mandatory curtailment of this figure is desired in the future (Moiser et al., 1998a, Moiser et al., 1998b).

About 94 million tons of livestock waste is excreted annually in Japan. This livestock waste contains 737 Gg of nitrogen. According to recent data estimates, around 10,999 Gg CO_2 eq. of N_2O and 933 Gg CO_2 eq. of CH_4 might be emitted from composting and other livestock waste treatment processes (Ministry of the Environment, Japan, 2002). These amounts account for about 0.9% of the annual greenhouse gas (GHG) emission in Japan. For this reason, the regulation of GHGs from livestock waste treatment processes is likely to be implemented in Japan in the future. Proper recycling of nutritive salts from livestock compost cannot be completed only by circulation in an area where the livestock density per unit area is especially high. Thus, livestock excrement can be made more manageable through the composting process, and the resulting product can be distributed over a wide area. Since a large amount of livestock waste is processed, GHG generation is recognized to be substantial. However, few experiments to quantitatively measure the amount of GHG generation from the pile type composting process, which is the most widely used composting system, have been carried out.

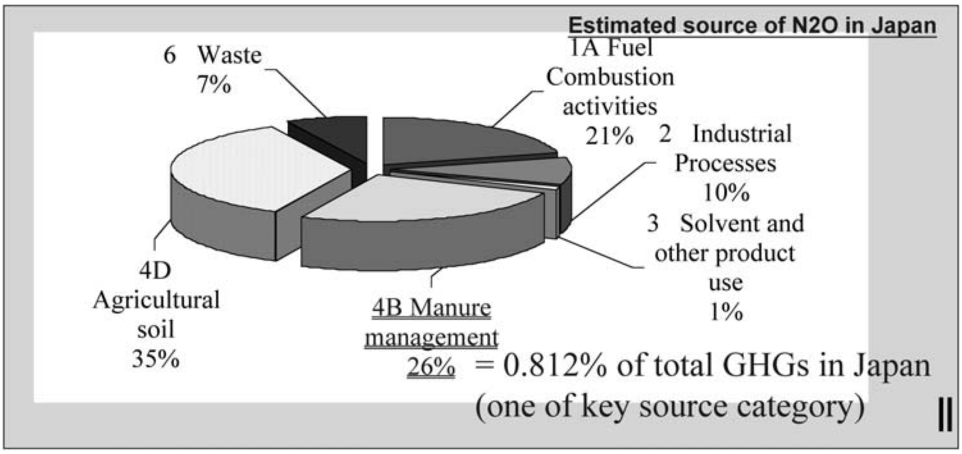

Fig. 5.3 N_2O estimated source in Japan.

We investigated composting on a small scale, and examined the gas discharge produced by the composting process (Osada et al., 2000). Our results showed that CH_4 and N_2O emissions from the composting of one cubic meter of swine dung varied from 0.6 to 385 g CH_4 m^{-3} and from 1.9 to 71.9g N_2O-N m^{-3}, respectively. Large variations in measured values were also seen in the discharges from actual processing institutions (Husted, 1993; Czepiel et al., 1996).

For this reason, we previously developed an experimental quantitative measurement system to evaluate the emission materials produced by composting using a large chamber (Osada et al., 2001). In the present report, I would like to introduce our measurement system, and some measurement results with this system.

2 How to Evaluate? Measurement System and Experimental Design

The measurement system consists of a dynamic chamber device to collect the exhaust gas from composting materials, and a measurement device (Fig. 5.4).

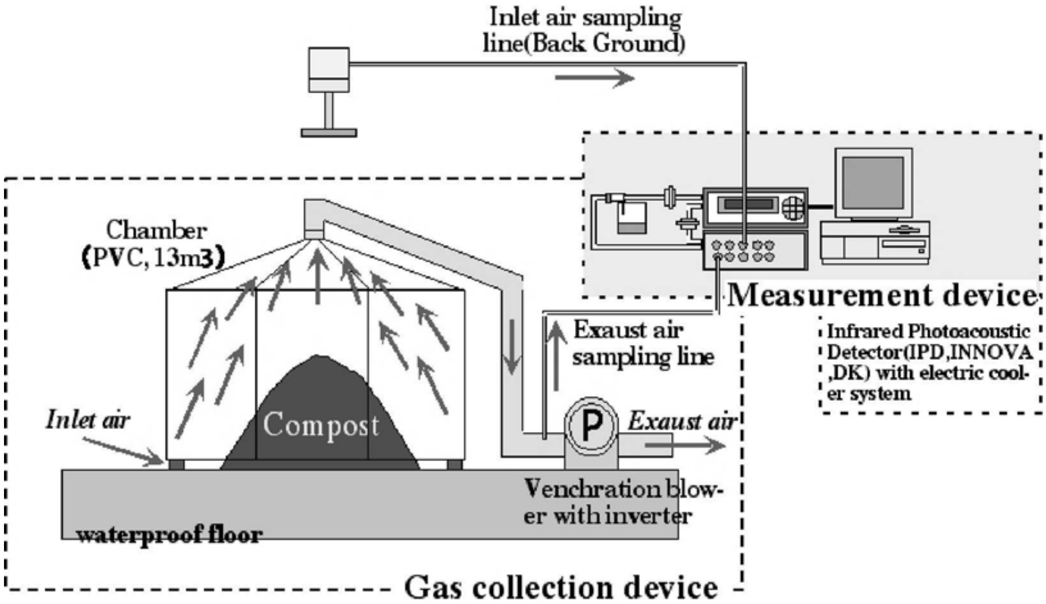

Fig. 5.4 System for measuring the emissions from composting.

2.1 Gas Collection Device

The cylindrical dynamic chamber was made as an experiment, and installed in a waterproof concrete floor. The dynamic chamber was a chamber made from polyvinyl chloride (3 m diameter, 2.2 m height, 13 m^3 volume). Fresh air is introduced through a space between the floor and the lower edge of the chamber, and exhaust gas is sucked from the middle of the ceiling by an inverter-controlled blower. The air flow rate analysis was conducted with an inclined manometer (Okano Factory) in exhaust pipe (100 mm in diameter) according to the method of JIS B 8330. By this suction, air in the chamber was exchanged 10 times per hour so that it can be very stabilized (S.D 0.13). The chamber can accommodate about 1 m^3 of livestock waste from the barn at a fixed amount of ventilation rate (130 m^3/h).

2.2 Measurement Device

A field laboratory, located close to the chamber, provided the electricity and conducted the measurements. Samples of inlet air (fresh air) were extracted from the height of 30 cm beside the chamber, and outlet air (exhaust air) was extracted just before going into the ventilation blower (Fig. 5.4). Gas from each sampling point was automatically carried to the analysis apparatus through a Teflon tube (4 mm in diameter). NH_3, CH_4 and N_2O concentrations in exhaust air from the chamber were measured by Infrared Photoacoustic Detector (IPD, multi gas monitor type 1312, INNOVA, Copenhagen DK) at 5-min. intervals. Gas dried by electric cooler was used for measurement of methane and nitrous oxide to improve accuracy. According to the technical data of IPD, the detection limits of CH_4 and N_2O were 0.39 and 0.03 ppm at a pressure of 1 atm and temperature of 25^oC. For NH_3 and CO_2 the detection limits were 0.2 ppm and 1.5 ppm, respectively, at a pressure of 1 atm and temperature of 25^oC.

2.3 Method of Calculating the Emissions from Each Substance

The emission rate (E) of each substance (CH_4 and N_2O) was computed based on the amount of ventilation and the differences in concentration of each substance between the inlet and the outlet air samples.

E (mg/hour) = (Conc. of outlet air (mg/m^3) - Conc. of inlet air (mg/m^3)) x Ventilation rate (m^3/hour)

3 N_2O and CH_4 Emission from Livestock Waste Composting

Several cubic meters (around 300 - 1000kg) of mixtures of animal-specific livestock waste and moisture amendment were piled in a specially devised chamber, and the amounts of CH_4 and N_2O generated from them were evaluated throughout the composting periods in two different cycles, warm- and cool-weather. The measurement system we devised consisted of a cylindrical chamber (3 m in diameter, 2.2 m in height, 13 m^3 in volume), which collected the exhaust gas produced by composting materials, and a measurement device.

Manure of the four major livestock—dairy cattle, beef cattle, fattening pig and poultry—were mixed well with wheat straw or sawdust as a moisture conditioner. The compost piles were thereby adjusted to the standard initial moisture contents of piled manure on Japanese farms for each kind of livestock (Osada, et.al, 2004).

According to the results of this experiment, the composting-manure emission factors of CH_4 (g per one kilogram organic materials) and N_2O (g per one kilogram nitrogen in composting materials) varied significantly between livestock types. This should be important information not only for inventory data but for the development of greenhouse gas regulations and technologies (Fig. 5.5).

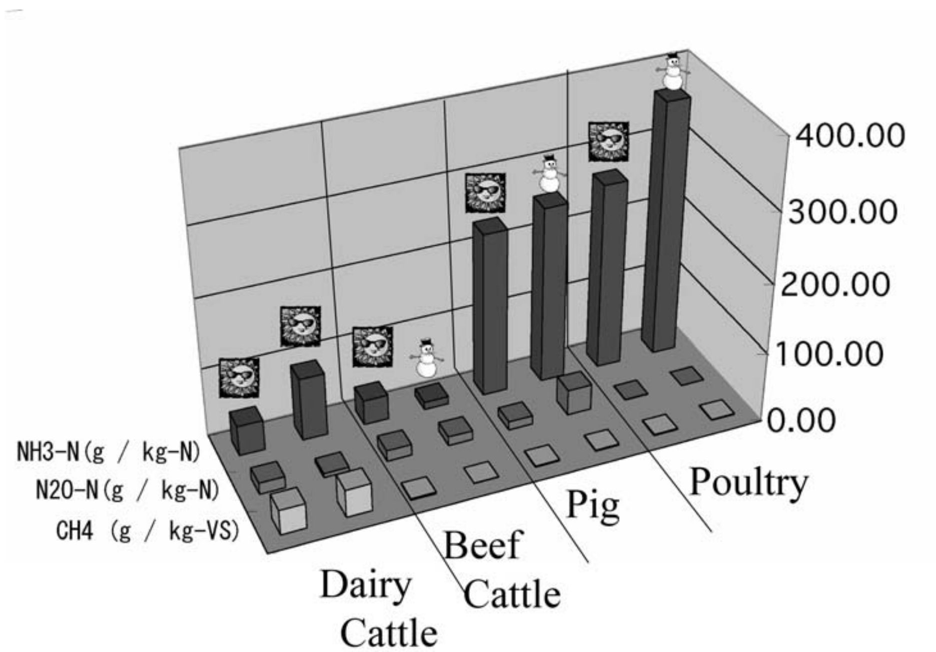

Fig. 5.5 NH_3, N_2O and CH_4 emission during plied type composting of each livestock manure.

4 Conclusions

We developed a system for the quantitative measurement of emissions from composting using a large dynamic chamber in an experiment. According to the results of this experiment, the composting-manure emission factors of CH_4 and N_2O varied significantly according to livestock types, moisture contents of the pile materials and ambient temperature. Those factors should also depend on manure treatment type. This can be important information not only for inventory data but for the development of greenhouse gas regulations and technologies. In Asian countries, the compost process is widely used for the treatment of livestock waste. However, the exact amount of greenhouse gases generated from actual composting is not known. Not only the compost, but the emission factor of each treatment system should be evaluated according to each country's procedure and general conditions, because those factors might widely vary. It is important that each country has a measurement technique for GHG emissions, not only for inventory data but for the development of greenhouse gas regulations and technologies.

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5.3 Challenges and Possible Solutions

The agriculture sector is significant in Asia, as it is one of the main contributors to GHG sources (CH_4 and N_2O) in this region. To improve GHG inventories in this sector, we need to do a lot of things. One of them is to collect more viable data by increasing the number of experiments for measuring emissions. This could allow us to develop region-specific emission factors. For example paddy field agriculture is unique to Asian countries, thus it may be worth developing region-specific emission factors for paddy fields. Developing region-specific emission factors certainly will not only cost much less than developing country-specific emission factors but also improve the quality of the inventory over the use the IPCC default values. Agroforestry in Asia also has some special characteristics compared to other regions.

Establishing a network of monitoring stations for GHG emissions and arranging for collaboration among experts in this region could be very beneficial for sharing experiences regarding data collection, methodologies and good practices.

Major barriers that face the countries are the lack of financing and the skilled personnel to improve GHG inventories and conduct experiments to measure emissions.

Therefore, some solutions to overcome the challenges could include:

- obtaining funding for research and capacity building in the region;
- developing and implementing a regional research project;
- collaborating with experts; and
- sharing databases and expertise.

5.4 Other Points Discussed

During the discussion, some additional points were raised. For example, it was discussed whether it would be worthwhile to develop country-specific emission factors in country specific areas (for example livestock sector) in order to improve the quality of inventories that use the tier 1 method. In this regard, some experts pointed out that if livestock is a key source of GHG emissions in a country, it is especially important to improve emission factors and data collection.

Chapter 6

LAND USE, LAND-USE CHANGE, AND FORESTRY (LULUCF) SECTOR

6.1 Introduction of the LULUCF Working Group

The LULUCF Working Group of the 3rd WGIA consisted of the following participants:

- Dr. Rizaldi Boer (Chair; Indonesia)
- Ms. Chisa Umemiya (Reporter; Japan)
- Mr. Heng Chan Thoeun (Cambodia)
- Mr. Atsushi Sato (Japan)
- Mr. Lip Khoon Kho (Malaysia)
- Ms. Joyceline A. Goco (Philippines)

The programme of the LULUCF Working Group Session was divided into three parts:

Part A	***Introduction of Good Practices***
	・ "*Development inventory of the country-specific activity data and estimation methods for forests ecosystems and land-use change in Malaysia*" (Mr. Lip Khoon Kho, Malaysia) ・ "*Development of the LULUCF's GHG Inventory of Cambodia*" (Mr. Heng Chan Thoeun, Cambodia) ・ "*Experience learned by using IPCC's Good Practice Guidance on Land Use, Land-Use Change and Forestry in developing Japan's GHG inventory*" (Mr. Atsushi Sato, Japan)
	- Discussion and questions -
Part B	***Roundtable Discussion on "Challenges to be tackled and possible solutions"***
Part C	***Summary of the Working Group Discussion***

6.2 Good Practices

6.2.1 Summary

The objective of this session was **to specify the features of LULUCF GHG inventory development in Asia by creating lists of good practices and challenges.** There were three presentations for sharing experiences.

Mr. Heng Chan Thoeun discussed Cambodia's experiences in developing local emission/removal factors (E/RF) and activity data (AD) and conversion of measured biomass values into carbon pools under the GPG-LULUCF.

Mr. Lip Khoon Kho presented Malaysia's experiences in conducting verification of reported activity data used in the development of the national GHG inventory, uncertainty analysis, and main gaps and challenges in development of the inventory.

Mr. Atsushi Sato shared Japan's experiences in developing the national GHG inventory for LULUCF sectors, in particular the main changes necessary when changing from IPCC1996GL to LULUCF-GPG methodologies.

The main challenges in the development of national GHG inventory on LULUCF sector are the availability of national E/RF and AD and their development and institutionalizing the process of inventory development. Most countries, particularly developing countries stated that the LULUCF sector has high uncertainty in their estimates, while improvement of the inventory through the development of local E/RF is quite expensive. In addition, the people who are in charge of the development of the inventory change quite often and no stable institutional arrangement has been established. The members of the group discussed how the countries handle these issues and proposed a number of approaches to handle the problems. It was stated that a large improvement has been made by the countries during the preparation of the LULUCF GHG inventory for their second national communication.

6.2.2 Development and Issues on Greenhouse Gas (GHG) Inventories for the Land Use Change & Forestry (LUCF) Sector in Malaysia

*KHO Lip Khoon, Elizabeth PHILIP and Abdul Rahim, N.
Forest Research Institute Malaysia (FRIM),
52109 Kepong, Selangor Darul Ehsan, Malaysia

Abstract:

Non-annex I (NAI) parties are required to report national sectoral greenhouse gas (GHG) inventory to the United Nations Framework Convention on Climate Change (UNFCCC). GHG inventory guidelines have been progressively updated to minimize uncertainties in estimation and reporting. The guidelines provided by the Intergovernmental Panel on Climate Change (IPCC) – IPCC 1996GL – aim to assist all parties in preparing the sectoral inventory and reports. The Land Use Change and Forestry (LUCF) sector is supported by Good Practice Guidance – Land Use, Land-Use Change and Forestry (GPG-LULUCF 2003), an additional tool to further enhance the consistency of estimation and reduce limitations. As Malaysia is currently preparing its Second National Communication, extensive efforts on the LULUCF sector were initiated to improve the estimation of GHGs. Several knowledge gaps and challenges were identified in preparing the inventory and implementing the GPG-LULUCF 2003. An extensive attempt is currently underway to compile the inventory as accurately and consistently as possible. In addition, the LULUCF sectoral working group aims to progress into higher tier levels in the inventory as acknowledged in the guidelines. This paper aims to provide an overview of the Malaysian experience in preparing the inventory of the LULUCF sector for the Second National Communication.

1 Background

The United Nations Framework Convention on Climate Change (UNFCCC) requires that non-Annex I (NAI) Parties report to the Conference of Parties (COP) information pertaining to emissions by sources and removals by sinks of all greenhouse gases (GHGs), which are not controlled by the Montreal Protocol. This should serve as a component in the preparation of National Communications based on the reporting of inventory sectoral tables and worksheets. The preparation of National Communications is based on the guidelines adopted at the second session of COP, by decision 10/CP.2. To date, more than 100 NAI Parties who have committed to report national GHG inventories have adopted the Intergovernmental Panel on Climate Change (IPCC) guidelines.

The guidelines have progressively improved in order to enable the provision of quality reports, and to further reduce uncertainties and constraints faced by NAI Parties. The guidelines were revised based on decision 17/CP.8 to further assist NAI Parties in the preparation of their GHG inventories. However, synthesis of NAI inventories still addressed several difficulties and limitations in using the Revised 1996 IPCC Guidelines (IPCC 1996GL) (FCCC/SBSTA/2003/INF.10).

Constant adaptation and improvement of the guidelines has resulted in the inclusion of new additional tools to enhance the inventory process. GPG2000[1] and GPG-LULUCF[2] 2003 were developed to resolve some of the limitations and reduce difficulties and uncertainties to a certain extent. The GPG-LULUCF 2003 approach is comprehensive, consistent, and

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* Principal author
[1] Good Practice Guidance (GPG)
[2] Good Practice Guidance – Land Use, Land-Use Change and Forestry (GPG-LULUCF)

transparent (IPCC, 2003). The capacity of such tools and methods has yet been rigorously assessed due to several technical and capacity building issues. In addition, the recent new improved software developed by the UNFCCC could give valuable flexibility and improved methodology processes. However, such assessment requires framework assessment within regions (e.g. the Asia region) to evaluate technicalities, methodologies and uncertainties that may be faced by users.

Development of GHG inventories, particularly in Malaysia, involves several issues such as capacity building, uncertainties dealing with estimation and assumption, activity data reporting, and scientific capacity. Such difficulties were encountered as the preparation of the inventory progressed to a higher methodological approach and comprehensive reporting. Having requirements for explicit reporting and inventories contributes to the development of comprehensive National Communications; however, certain issues such as the lack of capacity building and committed cooperation could have a negative impact on the efficient preparation of the report. Climate change issues in Malaysia are generally less crucial; therefore, collection of relevant robust data from which to extrapolate GHG emissions is relatively arduous.

This paper aims to explain the development of a second national inventory and highlight key issues that need to be rectified in the LUCF[3] sector in particular. The second national inventory used the initial inventory as a guideline or benchmark to improve on data accounting and estimation. The approach adopted was established at higher tier levels based on data availability and to obtain estimation of reduced uncertainties.

2 National Communication: Malaysia Experience

The National Initial Communication was prepared in 1994 and submitted to the COP on August 22, 2000. The report and inventory served the purpose of reporting on GHG emissions and removals for various sectors in Malaysia. Various agencies, institutions, and departments were commissioned to carry out estimations for the GHG inventory. Likewise, the LUCF sector was prepared with the most relevant activity data based on categories outlined according to the guidelines. The initial GHG inventory was used as a benchmark for the current second national inventory, particularly in the LUCF sector.

The LUCF sector functions based on two key assumptions: a) the flux of CO_2 to/from the atmosphere is in an equilibrium state to the changes in biomass stocks of existing biomass and soils, and b) the rate of changes in land use and its practices shall determine the changes of carbon stocks (IPCC, 1997). The LUCF inventory is estimated by quantifying CO_2 emissions/ removals from four key categories (changes in forest and other woody biomass stocks; forest and grassland conversion; abandonment of croplands, pastures, plantation forests, or other managed lands; and CO_2 emissions and removals from soils) and immediate release of non-CO_2 trace gases from open burning of biomass.

2.1 Carbon Emissions/ Removals in the LUCF Sector

The reported total annual CO_2 removal in LUCF sector for the national initial inventory was 61,080 Gg and CO_2 emission amounted to 7,637 Gg due to forest conversion (MOSTE, 2001). Hence, the projected carbon stocks in existing forests and other woody biomass was

[3] Land Use Change and Forestry (LUCF)

estimated at 68,717 Gg. The CO_2 removal estimation suggested that the LUCF sector in Malaysia is accumulating a considerable amount of carbon stocks. This is primarily projected from plantation forests and agricultural perennial crops. However, IPCC 1996GL requires estimation of carbon stocks in key categories regardless of whether the land use has undergone change (IPCC, 1997). Thus, it is predicted that the LUCF sector in Malaysia could generate higher values compared to the initial inventory by adopting comprehensive and consistent estimation (FCCC/KP/CMP/2005/3).

The initial National Communication reported several uncertainties and limitations in preparing the inventory. The report highlighted the main issues pertaining to activity data and defining key categories (MOSTE, 2001). Recent review of the initial inventory suggested additional uncertainties, which could possibly affect the low CO_2 removal figures. The forest resources or categories reported are limited only to plantation forest and perennial crops (e.g. oil palm and rubber). In addition, plantation forest accounts only for *Acacia mangium* whereas significant biomass stands of other species were quantified collectively on the same average growth data. Accurately allocating annual biomass growth for specific forest types or planted species and following consistent adopted classifications or categories in the inventory may improve the carbon uptake estimation.

2.2 Estimation Approach

The initial inventory adopted a Tier I approach by using default data according to IPCC 1996GL. This approach provides the most fundamental calculation for GHG inventory estimation. However, NAI Parties are encouraged to apply higher tier levels in order to reflect more national or country-specific results. The guidelines introduced three levels of approach with different levels of complexity and geographic scales, which can be adopted depending on availability of data, capabilities, and importance of estimations (IPCC, 1997).

Tier structures allow flexibility in estimations from the use of simple default values or equations to country-specific values and more complex national default data. Tier I is the most fundamental approach that employs basic default conversion data and method as suggested by the IPCC 1996GL. Data provided could be of high uncertainty due to the interpretation from global or regional sources. Tier III is the most complex and highest order of methods that provides more certainty and country-specific values of estimations. Higher tiers involve complex and comprehensive national scale modeling, forest inventories that are repeated over time, and extrapolation of activity data at different sub-levels and categories. In addition, Tier III methodology and data generation requires additional verification for quality checks, audits and validations.

3 Development Framework of Methodology & Assessment

The preparation of the second national inventory is more complex and rigorous in terms of methodology and approach to establish higher levels of accounting. Recommendations and improvements on LUCF were adopted from the initial inventory to increase the accuracy of reporting. However, the levels of execution are dependent on the availability of activity data and the extensiveness of data collection. Higher levels of uncertainties may transpire through such specific modeling or inventory due mainly to data quality and quantity, and aggregation of data to the national level and standards.

The second national inventory adopted a combination of tiers for the LUCF sector. Tier I and II are used for different categories, the land use category, and carbon pool for activity data and emission factors. Calculated data reflected country-defined estimations, which could capture important geographic variations in key categories and subcategories (IPCC, 1997).

3.1 The Extent of Data

The forestry sector in Malaysia is well managed in accordance with the principles of Sustainable Forest Management (SFM) in order to achieve a balance between development and conservation. Comprehensive forest inventories are conducted every 10 years to plan, manage, develop, and conserve forest resources in Peninsular Malaysia. In addition, forestry statistics are produced and compiled at regional and national levels to improve monitoring and data management in every state.

Consequently, the current technology used to improve forest inventory and monitoring has further reduced errors in data reporting. Satellite imagery is the most common and accurate, which ensures the most comprehensive and extensive data collection.

Plantation logs for commercial harvest reported in the initial inventory were estimated at about 50% more than the current second inventory. However, commercial harvest was accounted for in the second inventory based on three categories as reported in the forest inventory and statistics, mainly heavy, medium and light hardwood. This variation in terms of carbon removal and categories may influence the amount of carbon released. Intensive harvesting of plantation logs and other sources of roundwoods reduced the biomass stocks through the increase of wood removals from the forest. Harvested woody biomass stocks are assumed to be oxidized in the removal year and release carbon at certain rates based on production. This is not an accurate assumption, but serves as a conservative assumption of default estimation for initial calculation (IPCC, 1997).

Conversion of forest is reported at 1 kha annually in the initial inventory and it is described as tropical forest. The basis of such assumptions and conversion categories is not stipulated in the initial report. This module shall include forest or grassland being converted to other land uses, including agriculture, pasture or development and resulting in CO_2 emission. Annually converted areas are estimated based on a 10-year average loss of forested area in the second national inventory. The lost forested area is assumed to have been converted to agriculture, pasture or to have been developed. As expected, stateland forest recorded the largest annual conversion due to the land being reserved mainly for development.

Conversely, the second national inventory gave the most complete data on restoration or forest plantation according to species. Growth and yield measurement data were estimated based on plantation plots and forest experimental plots for country-specific default values. However, more modeling of extensive data is needed to obtain accurate interpreted default values.

3.2 Preliminary Second National Inventory – LUCF Sector

Preliminary estimation of carbon uptake and emissions was based on Peninsular Malaysia and the Sarawak region. The current total of LUCF CO_2 removals for these two regions is estimated at 273,763 Gg CO_2 more than the initial inventory. This is more than 4 times the total of LUCF CO_2 removal reported in the initial inventory. Thus, the LUCF sector in Malaysia has great potential to act as carbon sinks. The summary estimation of LUCF sector is shown in Table 6.1.

Table 6.1 The preliminary summary comparison of carbon removals and emissions in LUCF sector for initial and second national inventory

	Total land-use change & forestry (Gg CO_2 removals)	Changes in forest and other woody biomass stocks (Gg CO_2 removals)	Forest & grassland conversion (Gg CO_2 emissions)	Abandonment of managed lands (Gg CO_2 removals)
Initial Inventory (1994 as base year)	-61,080	-68,717	7,637	N/A
[α]Second Inventory (2000 as base year)	-334,843[*]	-281,312	10,550	-64,082[*] (Sarawak only)

[*] Signs for uptake are always (-) and for emissions (+)

[α] Current inventory includes Peninsular Malaysia and Sarawak only.

4 Issues & Knowledge Gaps

The main issue and challenge in GHG inventory estimation is accuracy. The accuracy of assumptions, estimations, and calculations are based on consistency in interpretation and data representation. Integration and aggregation of data should be constructive to ensure consistency in data management. However, standards and frameworks need to be established to determine the level of accuracy within each country. The inventory and data analysis can be substantially comprehensive; however, inconsistency in the data representation of key categories and classifications could prevent accurate estimation. The growth and yield data of various forest plots may be extrapolated to obtain mean growth rates. However, the variation of the calculated mean may differ significantly due to species composition and age classes. Such inconsistency of representation calls for more complex data analysis. Inconsistency and uncertainty contribute to variability in the estimation of carbon emissions (Houghton, 2005).

The lack of baseline data causes difficulties in establishing national default data. The extrapolated data could not be compared and verified by obtaining consistent values. Thus, long-term monitoring and measurement are required to determine these values. However, such efforts require ample time for consistent representation of data, and standard guidelines or procedures, within the framework of key categories, age classes, climatic conditions, and species composition, for data modeling. Thus, ground measurement is challenging and time-consuming (Houghton, 2005).

Soil carbon is the least studied field for activity data or emission factors. It should be reiterated that soil classifications and groups vary nationally and regionally. The guidelines provided in the IPCC 1996GL on soil classification, which is based on Food and Agriculture Organization (FAO) and United States Department of Agriculture (USDA) systems, may not be relevant to the classification as reported in Malaysia. Soil activity data based on land use management systems (IPCC, 1997) over the past 20 years may not be available.

Another issue that needs to be clarified includes the inclusion of totally protected areas (TPA), protection forests, and/or wildlife reserves. Natural, unmanaged, or undisturbed forests are not to be considered in the calculations (IPCC, 1997). However, several studies suggest that existing undisturbed and natural forest could act as potential carbon sinks (Chan, 1982; Lugo and Brown, 1992; Grace et al., 1995; Houghton, 2002). The IPCC guidelines suggested that accounting of undisturbed forest be excluded unless it is being used as a source of fuelwood, or being affected in any way by human activities (IPCC, 1997). The issue that remains unresolved is the policy and responsibility of each country for reporting undisturbed or protected areas as being affected by human intervention. This applies to the forest conversion modules in reporting conversion of forested area for agriculture, pasture or development purposes.

Intensive efforts shall be channeled to capacity building and technical training to keep national experts aware of matters related to the inventory. This shall increase the knowledge and hands-on experience with additional software, particularly GPG-LULUCF 2003 and Emission Factor Database (EFDB). The regional working group shall serve as the main platform for comprehensive discussions related to inventory and the current development of the National Communication. However, such efforts should be targeted at the relevant authority and personnel involved directly in the preparation of inventory and reports.

The knowledge gained shall be extended to members of the working group and their co-workers to ensure better cooperation and awareness. Although Malaysia is functionally involved in the international convention on climate change, the intensity of development in technical and scientific segments is still inadequate. Consequently, relevant authorities are putting great efforts into enhancing the preparation of the national inventory.

5 Conclusion

The process of GHG inventory requires a specific and detailed approach to forest inventories and methodologies to acquire accurate and consistent estimation. The methodological approaches in the guidelines provided a basis for estimations. Uncertainties pertaining to activity data and emission factors of the inventory are acknowledged limitations that reduced the accuracy. Therefore, the GHG inventory is updated, improved and supported by additional tools to enhance the consistency of reporting and reduce the uncertainties in estimations. The Malaysian inventory process experienced several issues and challenges in producing reliable estimation due to various uncertainties and limitations encountered. However, efforts are currently underway to minimize the discrepancies in estimation under the second national inventory. Technical and capacity building is imperative in guiding NAI Parties towards the same objective and preparing reliable National Communications.

Acknowledgements

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6.2.3 Development of the LULUCF's GHG Inventories of Cambodia

Heng Chan THOEUN
Ministry of Environment
#48, Samdach Preah Sihanouk, Tonle Bassac, Chamkarmon, Phnom Penh, Cambodia

Abstract:

Cambodia ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 18 December 1995. The Convention entered into force for Cambodia on 17 March 1996, thus making the country eligible under the financial mechanism of the UNFCCC. The Royal Government of Cambodia signed the instrument of accession to the Kyoto Protocol on 4 July 2002. The National GHG Inventory for base year 1994 was prepared under the Climate Change Enabling Activity Project phase1 (CCEAP-1) for the Initial National Communication to the UNFCCC. The GHG inventory improvement for the LULUCF sector was prepared through developing local emission factors and increasing accuracy of activity data estimation under the (CCEAP-phase2).

The Capacity Building for Greenhouse Gases Inventory Development in Asia-Pacific Developing Countries is a three-year project, funded by APN and executed by the National Institute for Environmental Studies (NIES) of Japan. The field survey focused on the main forest types which play an important role as the key source/sink categories: (Evergreen forest, Deciduous forest; and Secondary forest). The measurement consists of two parts: (i) non-destructive sampling for the trees, including diameter and height of living tress and necromass; (ii) destructive sampling for the understorey and litter. The Development of the LULUCF's GHG Inventories of Cambodia is focused on the direct measurement of biomass of the major forest types; conversion of measured biomass values into values in carbon pools under the GPG-LULUCF; development of activity data for 2000 including assumptions made to estimate land areas which went through land use conversion.

1 Introduction

Cambodia ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 18 December 1995. The Convention entered into force for Cambodia on 17 March 1996, thus making the country eligible under the financial mechanism of the UNFCCC. In August 1998, the Government of Cambodia and the United Nations Development Programme (UNDP)/Global Environment Facility (GEF) signed the project document *Enabling Cambodia to Prepare its First National Communication in response to the UNFCCC* (Cambodia's Climate Change Enabling Activity Project: CCEAP). This 3-year project started in January 1999 with the objective of preparing the First National Communication in response to the UNFCCC. This is seen as the first step taken by the government in the actual implementation of the UNFCCC in Cambodia (MoE, 2002).

The Royal Government of Cambodia signed the instrument of accession to the Kyoto Protocol on 4 July 2002, indicating its commitments to the global efforts in addressing climate change issues. This makes Cambodia eligible for hosting emission reduction projects under the Clean Development Mechanism (Ponlok, 2005). The Ministry of Environment (MoE) is the National Focal Point for the UNFCCC and the Kyoto Protocol.

The National GHG Inventory for base year 1994 was prepared under the Climate Change Enabling Activity Project phase1 (CCEAP-1) for the Initial National Communication to the UNFCCC. The inventory was based on the Revised 1996 IPCC Guidelines. The results indicated that Cambodian Land Use Change and Forestry sector contributed to about 97% of total national CO_2 emissions. Because of inadequate activity data, biomass regrowth on abandoned lands and soil carbon were not taken into account in the inventory of GHG emissions or uptake. Therefore, GHG sources and sinks for the LUCF sector accounted mainly for net annual biomass growth land use/forest conversion practices which involved decay and biomass burning. The majority of the emission factors used were the default values of the Revised 1996 IPCC Guidelines and some activity data needed to be estimated from available activity data (MoE, 2001).

1.1 The Improvement of Activity Data and Emission Factors for the Forestry Sector with Methodologies Based on the Revised 1996 IPCC Guidelines

The GHG inventory improvement for the LULUCF sector was prepared through developing local emission factors and increasing accuracy of activity data estimation under the CCEAP-phase2. Data required for developing the GHG inventory were converted area per forest type, mean annual increment of trees, aboveground biomass of natural forests, biomass expansion factors, biomass density, fraction biomass burnt on site/off site and decay. The parameters of the significant data included converted forest area, mean annual increment, wood harvest and biomass density of each forest type. Limited accurate estimates of these data would lead to underestimation or overestimation of the GHG uptake/or emission. The improvement of activity data and emission factors of forest focused on Semi-evergreen, Coniferous, Secondary, Inundated, Mangrove, and Forest Plantation (MoE, 2003).

The Capacity Building for Greenhouse Gases Inventory Development in Asia-Pacific Developing Countries is a three-year project, funded by APN and executed by the National Institute for Environmental Studies (NIES) of Japan. Cambodia is one of the project partners and conducts a study and surveys for the improvement of GHG inventories of the LULUCF sector. In Fiscal Year 2004, the project activities in Cambodia were: determining the overall work plans for Year 2 and 3; planning and preparing for the field training in Koh Kong province; organizing and conducting measurement in CAPaBLE plots; analyzing data and evaluating the measurement; and writing an activity report (Sum Thy, 2005).

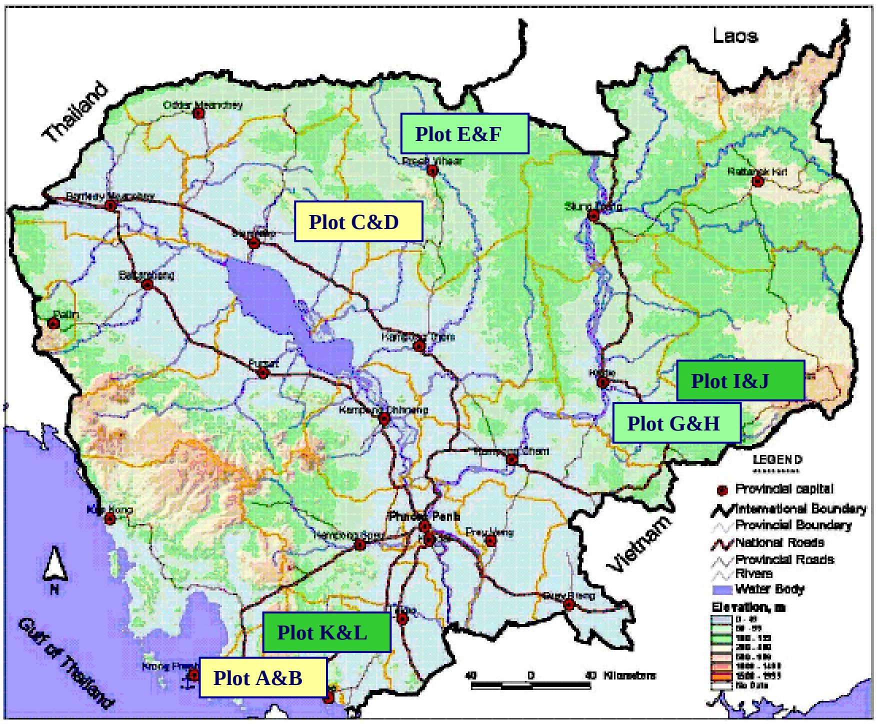
For 2004-2006, the CAPaBLE project in Cambodia focused on these activities:

- Determination of the overall work plans
- Planning and preparation for the training in Dec. 2004
- Organizing a three-day field training (Koh Kong province)
- Planning and preparation for the measurement in CAPaBLE plots
- Implementation of the first time measurement (Mar. 2005)
- APN CAPaBLE-NIES: Meeting with MoE-Cambodia (October 4-7, 2005): Preparing the Excel table format for the application of collected and analyzed data to an inventory by using the IPCC's GPG-LULUCF; Comparing the estimation methodologies used in the previous and new inventories; Evaluating the overall methodology used; Discussing the items to be included in the final activity report
- The second time measurement (Jan-Feb. 2006)
- Data analysis, evaluation of the measurement, and report.

2 Direct Measurement of Biomass of the Major Forest Type

The field survey focused on the main forest types which play an important role as the key source/sink categories: (evergreen forest, deciduous forest; and secondary forest). Two different locations of field measurements were selected for each forest type. The objectives of field surveys were to: (i) identify type, species, and number of trees in three selected forest types; (ii) estimate the aboveground biomass of trees in these selected forest types; and (iii) estimate the annual biomass increment of the selected forest types.

The field surveys started on 28 February 2005 and finished by 3 April 2005 for the measurement in time 1. Time 2 measurement went from January to February 2006 in the same province as the first time measurement, including (i) Sihanoukville (Ream NP); (ii) Siem Reap (Kulen Prumtep NP); (iii) Preah Vihear (Wildlife sanctuary); (iv) Kratie -Snoul (Wildlife sanctuary); and (v) Kampot (Bokor NP), *See on Figure 6.1 and Table6.2.*



Note:
- Secondary: A,B,C,D
- Deciduous: E,F,G,H

Fig. 6.1 Map of Cambodia.

Table 6.2 Locations and schedule of survey

Plot	Forest type	Location	Measurement Time 1	Measurement Time 2
A	Secondary forest	Sihanoukville (Ream NP)	28 Feb-3 March 05	January 06
B				
C		Siem Reap (Kulen Prumtep NP)	6 -9 March 05	February 06
D				
E	Deciduous	Preah Vihear (Wildlife sanctuary)	19-23 March 05	February 06
F				
G		Kratie -Snoul (Wildlife sanctuary)	27-31 March 05	January 06
H				
I	Evergreen	Kratie -Snoul (Wildlife sanctuary)	2-5 April 05	January 06
J				
K		Kampot (Bokor NP)	6-9 April 05	January 06
L				

The methodology for field survey followed *Hairiah K. et al. (2001)*: *Methods for sampling carbon stocks above and below ground* and the final report of the Cambodia Climate Change Enabling Activity Project's Phase 2 (2003). The measurement consisted of two parts: (i) non-destructive sampling for the trees, including diameter and height of living tress and necromass; (ii) destructive sampling for understorey and litter. The tree biomass and tree necromass were measured using non-destructive sampling while understorey biomass was measured using destructive sampling. In addition, measurement of diameter and height of trees was conducted at two times with a time interval of about 12 months. This is to estimate the annual increment of the tree diameter as well as height of the trees. The sampling protocol for each activity is described below:

Sampling protocol for living tree biomass and tree necromass (Diameter >30 cm): Sample area: 20m x 100 m = 2000 m^2 (*See in Figure 6.2*).

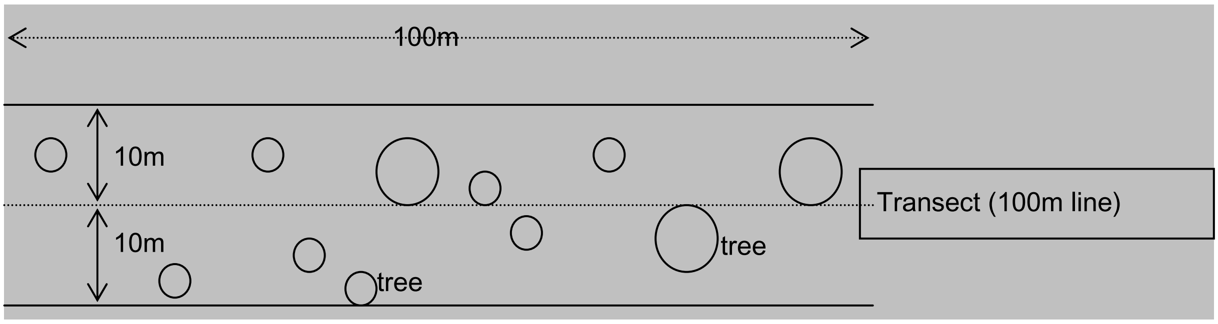


Fig. 6.2 Sampling protocol for living tree biomass and tree necromass (D >30 cm).

Sampling protocol for living tree biomass and tree necromass (Diameter from 5-30 cm): Sample area: 5m x 40 m = 200 m^2 (*See in Figure 6.3*).

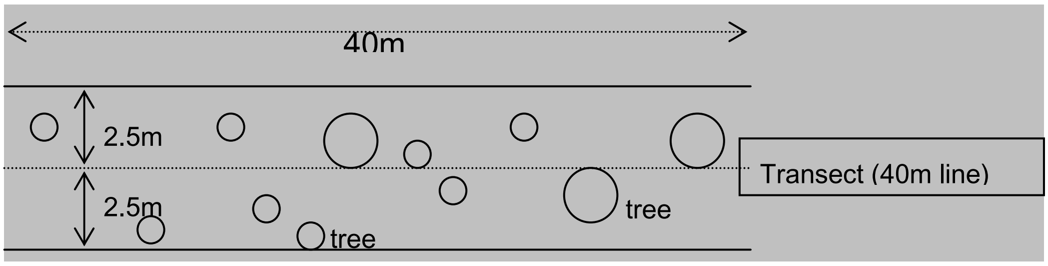


Fig. 6.3 Sampling protocol for living tree biomass and tree necromass (D: 5-30 cm).

- For each tree, the species is recorded and the diameter at 1.3m above the soil surface is measured using a diameter tape (diameter at breast height: DBH) for the first and second time;
- Height of trees, selected within a plot, is also measured and recorded for the first and second time;

Sampling protocol for tree necromass: Sample area: 5m x 40 m = 200 m^2 (*See in Figure 6.4*).

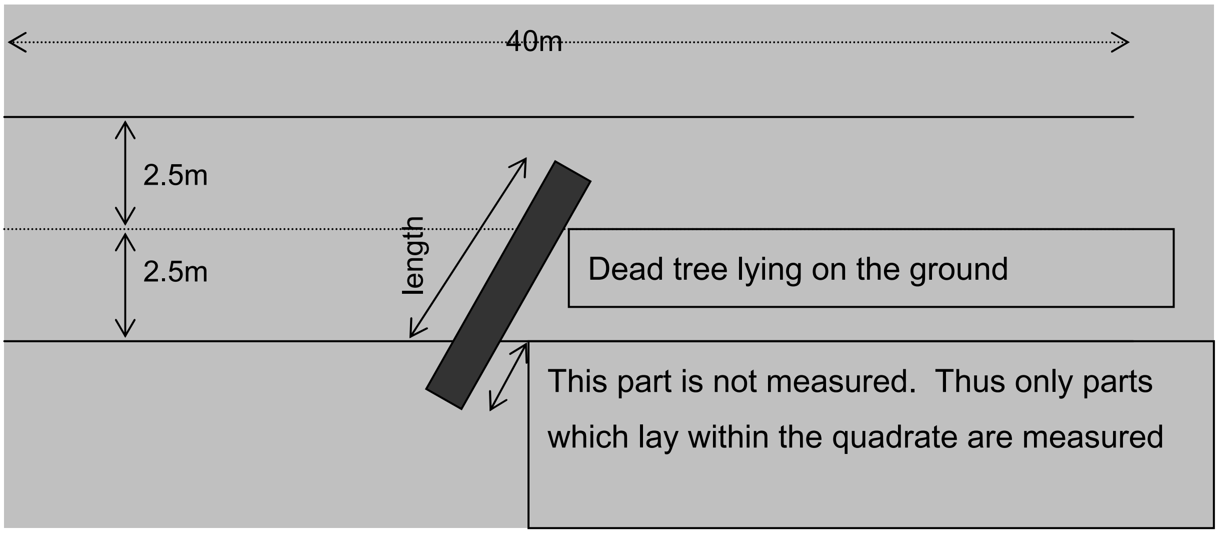


Fig. 6.4 Sampling protocol for tree necromass.

Sampling protocol for destructive sampling in 1.25 m^2: Sample area: 5m x 40 m = 200 m^2 (*See in Figure 6.5*).

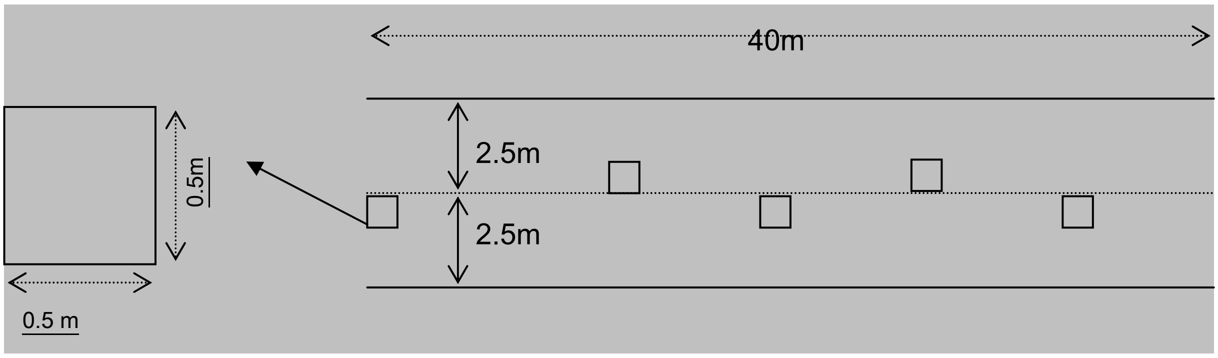


Fig. 6.5 Sampling protocol for destructive sampling.

- *Living tree biomass:* set up randomly a sampling frame of 0.5m x 0.5m in each quadrate with trees less than 5 cm DBH, i.e. seedling or saplings, are harvested within the 1m x 1m quadrate;
- *Coarse litter:* crop residues, all unburned leaves and branches;
- *Fine litter:* dark litter, including all woody roots which partly decomposed;
- *Sun dry:* living tree biomass, coarse litter and fine litter are dried using sun-light.

3 Conversion of Measured Biomass Values into Values in Carbon Pools under the GPG-LULUCF

The definitions of carbon pools are described in the IPCC's Good Practice Guidance for Land Use, Land-Use Change, and Forestry (GPG-LULUCF). For the purposes of UNFCCC inventory reporting of GPG-LULUCF, the pools are categorized into three groups: changes in (i) living biomass (aboveground biomass and belowground biomass), (ii) dead organic matter (dead wood and litter) and (iii) soils (soil organic matter) (IPCC, 2003). Greenhouse gas inventories for land use categories involve the estimation of changes in carbon stock from five carbon pools such as *aboveground biomass, belowground biomass, dead wood, litter*, and *soil organic matter* as well as emissions of non-CO_2 gases from such pools. The translation of carbon pools from CAPaBLE to GPG-LULUCF is shown in Table 6.3.

Aboveground biomass: All living biomass above the soil including stem, stump (the part of something such as tree, tooth, arm or leg which is left after most of it has been removed), branches, bark, seeds, and foliage. In cases where forest understorey is a relatively small component of the aboveground biomass carbon pool, it is acceptable for the methodologies and associated data used in some tiers to exclude it, provided that the tiers are used in a consistent manner throughout the inventory (IPCC, 2003).

Belowground biomass: All living biomass of live roots. Fine roots of less than (suggested) 2 mm diameter are often excluded because these often cannot be distinguished empirically from organic matter or litter (IPCC, 2003).

Dead wood: Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10cm in diameter or any other diameter used by the country (IPCC, 2003).

Litter: Includes all non-living biomass with a diameter less than a minimum diameter chosen by the country for lying dead (for example 10 cm), in various states of decomposition above the mineral or organic soil. This includes the litter, fumic, and humic layers. Live fine roots (of less than the suggested diameter limit for below-ground biomass) are included in litter where they cannot be distinguished from it empirically (IPCC, 2003).

Soil organic matter: Includes organic carbon in mineral and organic soils (including peat) to a specified depth chosen by the country and applied consistently through the time series. Live fine roots (of less than the suggested diameter limit for below-ground biomass) are included soil organic matter where they cannot be distinguished from it empirically (IPCC, 2003).

Table 6.3 Translation of carbon pools from CAPaBLE to GPG-LULUCF

CAPaBLE	**Symbol**	**Definition**	**Sampling method**	**IPCC Pool**
Carbon pools				**Carbon pools**
Live trees	BT	With a stem diameter of 30 cm in standard sample plot (20*100 m)	Non-destructive	Aboveground biomass
	LT	With a stem diameter of 5<…<30 cm in large area (5*40 m)		
Understorey	L+S	Includes trees less <5cm in diameter	Destructive	Aboveground biomass
Litter	CLit	Coarse/standing litter: tree necromass <5cm in diameter and/or <50 cm length	Destructive	Litter
	FLit	Fine litter: dark litter, including all woody roots which partly decomposed		Litter
		Surface roots		
Dead felled trees	DFT	Dead trees on the ground with a diameter >5cm and >50cm length	Non-destructive	Dead wood
Stump (trunk) remains in forest	DST	Dead standing trees with a diameter >5cm and >50cm length	Non-destructive	Dead wood

4 Development of Activity Data for 2000 Including Assumptions Made to Estimate Land Areas Which Went Through Land Use Conversion

Based on IPCC GPG-LULUCF, to estimate the land areas which went through the conversion of land uses in 2000, a number of assumptions were proposed. Specifically, it was assumed if the area of the land assigned to a specific land use category changed between the initial and final point in time, land conversion was assumed to have taken place. For example, in Cambodia, it was estimated that forest land area decreased by around 55,000 hectares in 2000. In this case, we assumed that 55,000 hectares of forest land area went through land use conversion and the remaining forest land area was unchanged (Umemiya, 2005).

Measurements were taken at the beginning and end of 2000 to determine the difference in area of land that belonged to each category. If there was an increase in one category, it was assumed that there was a corresponding decrease in another category. Decisions about the resulting land conversion were based on the assumptions that were deemed "most realistic". For example, if there was an increase in grassland and a decrease in forest land, it was assumed that the forest land was converted to grassland. (*See Table 6.4 and Figure 6.6*).

Table 6.4 Assumptions made to estimate the areas of land use conversion

Assumption No.	Land conversion concerned (Area in Ha)		Description of assumption
	Before	**After**	
1	Grassland (2,529.5)	Forestland (2,529.5)	It is difficult to predict whether forest planting was conducted after destroying existing forests. Considering ecological reasons, it is also difficult to plant trees in wetlands. Hence, it is assumed that all plantations were established in grasslands.
2	Forestland (3,336.3)	Grassland (3,336.3)	It is the most realistic to assume that grassland was established by converting forestland.
3	Grassland (247.5)	Settlements (247.5)	It is the most realistic to assume that settlements were established by converting grassland.
4	Forestland (54,565.3)	Cropland (83,785.3)	The remaining area of forestland that went through conversion was reported here.
5	Grassland (29,220)		It is assumed that the rest of the area of cropland converted from different land uses was area converted from grassland.
6	Grassland (4,196.5)	Other land (6505.5)	The remaining area of grassland that went through conversion was reported here.
7	Wetlands (2309.0)		It is assumed that the rest of area of other land converted from different land uses was area converted from wetlands.

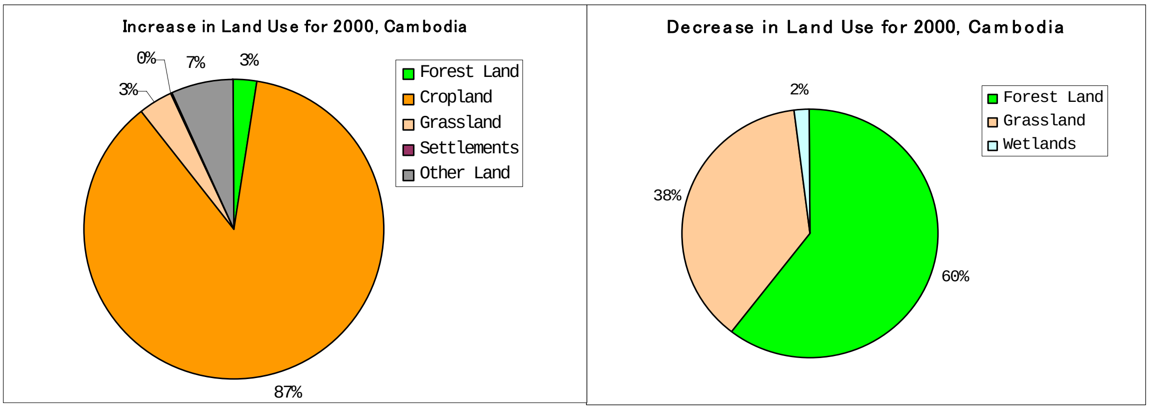


Fig. 6.6 Land area went through conversion in 2000.

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6.2.4 Experience Learned from Using IPCC's GPG for LULUCF in Developing Japan's Inventories

Atsushi SATO
Center for Global Environmental Research, National Institute for Environmental Studies
(Environmental Policy Consulting Department, Mitsubishi UFJ Research and Consulting)
16-2, Onogawa, Tsukuba, Ibaraki 305-8506 Japan

Abstract:

Japan developed the LULUCF sector's GHG inventory in 2005 by using the IPCC's Good Practice Guidance on Land Use, Land-Use Change and Forestry. New estimation methods and new data will be required and much more attention will be necessary for land classification consistency and time series consistency for LULUCF inventory preparation compared to LUCF inventory. One of the most difficult points Japan faced in 2005 for frequent transmission from LUCF inventory to LULUCF inventory was land category classification. This report introduces Japan's experience of LULUCF inventory preparation particularly focusing on the comparison with the previous inventories that were developed following the Revised 1996 IPCC Guidelines. Japan's experience might be useful for countries in Asia which could employ the GPG-LULUCF in the future.

Keywords: LULUCF-GPG, Comparison between LULUCF inventory and LUCF inventory, Statistic based method, GIS based method

1 Overview of Japan's GHG Inventory

1.1 GHG Emissions and Removals in Japan

Total greenhouse gas emissions in fiscal 2004 (the sum of emissions of CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6 converted to CO_2 equivalents) was 1,355 million tons (in CO_2 equivalents). Removals of carbon dioxide by sinks in FY1995 were 88.0 million tons. Removals by the land use, land-use change and forestry sector after 1995 have not been estimated (NE).

1.2 Japan's GHG Inventory and Inventory Preparation System

Japan has developed and submitted to UNFCCC the national GHG inventory every year since 1996. NIR (National Inventory Report) has been prepared since 2003. Emission calculation is conducted by using Excel based calculation files and is reported in CRF (Common Reporting Format). Japan used a CRF reporter for submitting the report to UNFCCC in 2006 according to SBSTA requirements.

The national entity responsible for national GHG inventory is the Ministry of the Environment, Japan (MOE). GIO (Greenhouse Gas Inventory Office in Japan) and some private-sector consulting firms work together with MOE to prepare the inventory. Other Ministries are involved in the inventory preparation system by providing data, confirming data from a technical viewpoint, etc. External experts review calculation methods, EF, activity data, and the entire inventory and provide advice. Japan has been developing its national inventory system to satisfy the UNFCCC and Kyoto Protocol requirements.

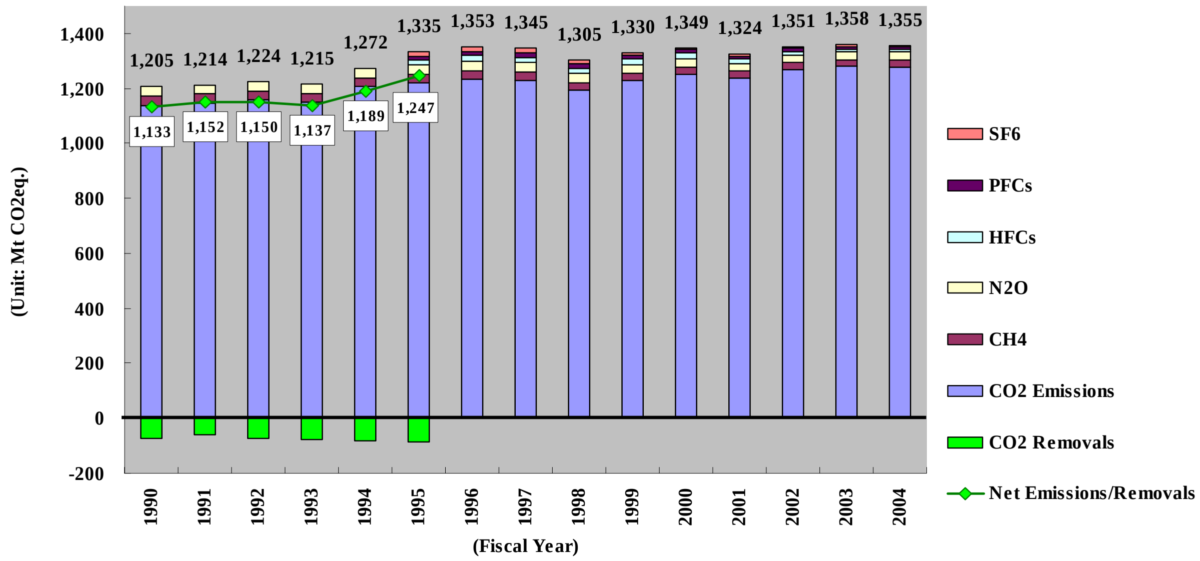

Fig. 6.7 Trends in emission and removals of greenhouse gases in Japan (2006).

2 Overview of LULUCF Sector

2.1 Japan's LULUCF Inventory and LULUCF Inventory Preparation System

Japan has been reporting GHG inventory related to the land use and forestry sector since the first submission to UNFCCC in 1996. Inventories were developed based on the 1996 revised IPCC guidelines (1996GL) until 2004. In 2005, inventory related to land use and forestry sector was widely revised based on LULUCF-GPG. The development and revision of the inventory is still ongoing. Japan has also been working on the development of an inventory for Kyoto Protocol article 3.3 and 3.4.

MOE coordinates and is responsible for the inventories, and the Forest Agency (FA), the Ministry of Agriculture Forestry and Fisheries (MAFF) and the Ministry of Land Infrastructure and Transport (MLIT) also play important roles in the LULUCF inventory preparation from a technical perspective. Expert review is conducted as appropriate for improving LULUCF inventory quality.

2.2 Features of Land Use in Japan

Features of land use are one of the main factors which control GHG emissions and CO_2 removals. A brief summary of Japan's land use:

- ➢ Area of forest cover is large
    - ・ Two-thirds of the national land
    - ・ This ratio has not changed for the last 100 years
- ➢ Most agricultural land use is crop land
    - ・ Grassland is not significant in Japan
- ➢ The ratio of settlements has been increasing
    - ・ Urban greening has also been undertaken

Table 6.5 Emissions & Removals in the LULUCF sector in 1995

$GgCO_2eq$

Land Use Categories		CO_2	CH_4	N_2O
5A. Forest Land	-93,149			
1. Forest Land remaining Forest Land		-91,637	22.45	2.28
2. Land converted to Forest Land		-1,537	IE	IE
5B. Cropland	2,298			
1. Cropland remaining Cropland		0	0.00	0.00
2. Land converted to Cropland		2,085	6.17	207.26
5C. Grassland	1,636			
1. Grassland remaining Grassland		0	NE	NE
2. Land converted to Grassland		1,635	0.93	0.09
5D. Wetlands	231			
1. Wetlands remaining Wetlands		NO,NE	NE	NE
2. Land converted to Wetlands		225	5.52	0.56
5E. Settlements	4,548			
1. Settlements remaining Settlements		-332	NE	NE
2. Land converted to Settlements		4,759	109.29	11.09
5F. Other Land	1,127			
1. Other Land remaining Other Land			NE	NE
2. Land converted to Other Land		1,114	11.82	1.20
Total Land-Use Categories	-83,309	-83,688	156	222

(+) emission, (-) removal (Source: LULUCF CRF of Japan, 2005)

Table 6.6 Area of Land Use in Japan

Land Use Category		1990	1995	2003
Forest	[10^4ha]	2,524	2,514	2,509
Agricultural land use	[10^4ha]	534	513	482
Wilderness	[10^4ha]	27	26	26
Water surface and river	[10^4ha]	132	132	134
Road and Residential land	[10^4ha]	275	291	313
Other land use	[10^4ha]	285	303	316
Total	[10^4ha]	3,777	3,779	3,780

(Source: Land White Book, MLIT Japan, 2005)

3 Comparison between LULUCF Inventory and LUCF Inventory

3.1 Changes to LULUCF-GPG from 1996GL-LUCF

There are relatively large differences between inventories based on 1996 GL (LUCF Inventory) and inventories based on LULUCF-GPG (LULUCF Inventory). The major differences are:

- Reclassification of calculation categories
  - Land based categorization
  - All national land and the entire land use change between categories are covered
  - Past land use information (ex. 20 years) is required
- Clarification of five carbon pools for calculation
  - Above-ground Biomass, Below-ground Biomass, Dead wood, Litter, Soil Organic Matter
  - Reporting conducted under three categories (Living Biomass, Dead Organic Matter, Soil)

- Annex (necessary information) and Appendix (extra information)

3.2 Transformation from LUCF to LULUCF inventory

For LULUCF inventory preparation, new estimations will be generally required, more data are necessary to develop complete inventory, category classification becomes complex, and much more attention is necessary for land classification consistency and time series consistency, compared to the LUCF inventory.

4 Profile of Japan's LULUCF Inventory

Japan's LULUCF inventory consists of an Excel-based calculation system as a part of its national inventory system. Japan uses statistics-based land classification system for obtainment of land use area activity data. The area of land and land use change is derived from several statistics. One of the advantages of these systems is that the person who compiles the inventory does not need special training.

Many parameters are country specific. Improvement for parameter usage and data collection is ongoing.

Table 6.7 shows Japan's work on LULUCF inventory preparation in 2005. Some methods were newly developed; other methods were used in LUCF inventory.

Table 6.8 and 6.9 show the summary of reporting categories in LUCF inventory CRF and LULUCF inventory CRF.

Table 6.7 Status of LULUCF inventory compared to LUCF inventory of Japan

Carbon pool	Main points
Living Biomass	• Some methodologies are used for forest removals and emissions. • Carbon loss from forest disturbance and forest fire are newly estimated. • Emissions from land use change concerning non forest lands are newly estimated.
Dead Organic Matter	• Dead Organic Matters are reported as NE.
Soil	• Emissions and removals from carbon stock changes caused by land use changes are newly estimated under "conversion" categories. • Using Tier.1 (no change) for "remaining" categories.
Non CO_2 Gas	• Non CO_2 gas emissions from "disturbance associated with land-use conversion to cropland" and "biomass burning" are newly estimated.

Table 6.8 The Categories Japan reported under LUCF-CRF based on 1996GL

LUCF Category		Status	LULUCF Inventory
5A	2.Temperate Forests	○	→5A1
	5.Other (Park and Green space conservation zone)	○	→5E1
5B	2.Temperate Forests conversion	○	→5B2, 5C2, 5D2, 5E2, 5F2
	4.Grassland conversion	NE	Newly estimated
5C	2.Abandonment of managed temperate forests	NE	-
	4.Abandonment of managed grassland	NE	-
5D	CO_2 emissions and removals from Soil	NE	Newly estimated

1) ○: Reported

2) Other Categories are reported as NO

Table 6.9 The Categories in Japan's LULUCF-CRF based on LULUCF-GPG

From \ To	Forest	Cropland	Grassland	Wetlands	Settlements	Other land
Forest	○	○	○	○	○	○
Cropland	○	○	○	○	○	○
Grassland	○	○	○	○	○	○
Wetlands	○	○	○	○	○	IE
Settlements	○	○	○	○	○	IE
Other land	○	○	○	IE	IE	○

5(I)	5(II)	5(III)	5(IV)	5(V)
IE	NO (Organic Soil) NE (Mineral Soil)	○ (Organic Soil) NO (Mineral Soil)	NE	○(controlled fire) NE (wild fire)

1) ○: Reported

5 Special Considerations for LULUCF Inventory Preparation

5.1 Difficulties Faced in 2005

Setting consistent land use categories between "Remaining" and "Conversion" categories was one of the difficult issues. We need two data of land use change area for estimation. One is area of simple annual land use change for estimation of living biomass C-stock change. The other is land use change data over 20 years for estimation of soil C-stock change. How can we obtain information on land use and land use change from the last 20 years, and what is the most appropriate estimation method for land use change? We used a combination of several statistical data and estimated all land use change by using them. However, the method was complicated and inconsistency was found in some parts. We are discussing the estimation methods and planning improvements continually. To investigate appropriate estimation and interpolation methods was also an important issue for Japan, because the data acquisition interval was different from data to data (e.g. Some is annual, others have a 5 year interval) and this difference caused inconsistency in estimations. Inspections have been conducted and improvements have been put in place.

Lack of country specific parameters is another issue. Relevant research is being performed in Japan.

5.2 Potential Advantages and Disadvantages of Two Land Classification Methodologies

There are two approaches for land classification: a statistical based approach and a GIS based approach. Table 6.10 shows the potential advantages and disadvantages that were found at a discussion held in Japan. This table may prove useful for other countries when they prepare their inventories using LULUCF-GPG or IPCC 2006 Guidelines. However, this table may not cover all pros and cons.

Table 6.10 Potential advantages and disadvantages of two land classification methodologies

	Statistical Base (Approach1,2)	GIS Base (Approach3)
Advantage	• Existing forest inventory, land statistics or agricultural census can be used. • Consistent to agriculture sector. • Periodic updating is relatively easy. • Categorization is easy if single statistic is used for preparation.	• Existing GIS data can be used if available. • Consistent land categorization can be performed.
Disadvantage	• Consistent land categorization may be difficult if several data are used together.	• Georeference is essential • Periodic updating might involve high cost and labor.

5.3 Considerations for LULUCF Inventory Preparation

The important points which should be considered for LULUCF inventory preparation are listed below.

- Analysis of data acquisition and applicability are necessary.
- Objectives and the precision level should be clarified.
- Cooperative framework between the inventory compiler and the data providers, experts, etc., may be important.

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National Inventory Report of Japan (2006) http://www-gio.nies.go.jp/aboutghg/nir/2006/NIR_JPN_2006_E.pdf

6.3 Challenges and Possible Solutions

The LULUCF sector is one of the main contributors to GHG sources (CO_2, CH_4, N_2O, CO and NOx). However, the estimates of the GHGs emission and removal from this sector have high uncertainty levels. The main sources of uncertainty are the inaccuracy of E/RF, and lack of some activity data. Improvement of the reliability of the GHG inventory in this sector cannot be done only by improving the accuracy of the E/RF and activity data, but also must include the establishment of stable institutional arrangements, continued data and information sharing among countries in the region, regular regional training workshops for the national inventory team on new tolls, models and methods for generating E/RF and AD, and sharing good practices. Therefore, establishing a network of collaboration and communication among experts in this region would be very beneficial for sharing experiences regarding data collection, methodologies and good practices.

6.4 Other Points Discussed

During the discussion, the members of the working group proposed a number of approaches that can be implemented by countries to improve their local EF/R factors and activity data. These include (i) enhancement of national level and local coordination and sector-to-sector coordination, (ii) increasing official support from national governments for the GHG inventory works, (iii) increasing the engagement of local universities and research agencies in the GHG inventory, particularly in the area of E/RF development, and cost-effective methods for AD collection and generation.

Chapter 7

WASTE SECTOR

7.1 Introduction of the Waste Working Group

The Waste Working Group of the 3rd WGIA consisted of the following participants:

- Dr. Sirintornthep Towprayoon (Chair; Thailand)
- Dr. Gao Qingxian (Reporter; China)
- Mr. Yasuhiro Baba (Japan)
- Dr. Masato Yamada (Japan)
- Dr. Kyoung-sik Choi (Korea)
- Ms. Bujidmaa Borkhuu (Mongolia)
- Ms. Ma. Gerarda Asuncion D. Merilo (Philippines)
- Ms. Raquel Ferraz Villanueva (Philippines)

The programme of the Waste Working Group Session was divided into three parts.

Part A	***Introduction of Good Practices***
	・ *"The estimate model of MSW generation in China"* (Dr. Qingxian Gao, China) ・ *"Estimation and uncertainty analysis of CH_4 emissions from landfills"* (Dr. Kyoungsik Choi, Republic of Korea) ・ *"Organic and fossil carbon flow analysis of waste streams: A good practice for the solid waste sector"* (Dr. Masato Yamada, Japan)
	- Discussion and questions -
Part B	***Roundtable Discussion on "Challenges to be tackled and possible solutions">***
Part C	***Summary of the Working Group Discussion***

7.2 Good Practices

7.2.1 Summary

Three voluntary presentations were made in this session. Discussion was based on these presentations which mainly focused on solid waste management. Discussion regarding the flow of waste from sources to disposal by means of activity data and emission factors was also conducted. The group agreed that, in accordance with Dr. Gao's presentation and with respect to the variation of country activity data, major concerns for good practice are:

1. Population data: improved level of data desegregation, data such as urban and urban non-agricultural population as well as migrated population is necessary.
2. Database: to maintain time series consistency, a database of activity data including historical data needs to be established. This database can be shared among Asian countries for information and experience exchange.

Discussion on waste stream and composition analysis continued after Dr. Masato Yamada's presentation. We concluded that waste stream investigation supported the decision tree in the Good Practice Guideline and waste composition analysis helped in identifying organic carbon content in the waste. Many countries in Asia promote waste recycling which is an important factor influencing waste composition and leads to variation in waste treatment. The group also discussed the importance of site measurements to obtain the most accurate k value in the landfill treatment.

Dr. Kyoung-sik Choi's presentation showed an example of the advanced methodology for emission factors in tier 2. The group believed that a country with advanced knowledge enables it to use a higher tier and conduct uncertainty analysis. However, to achieve the normal standard of data within the same region, a standard operation procedure based on the same guidance should be set up and shared among member countries in the region. This activity could help raise the quality of inventory in Asia.

7.2.2 The Estimate Model of MSW Production in China

GAO Qingxian[1], DU Wupeng[2], ZHANG Enchen[3]
[1]Chinese Research Academy of Environmental Science
No. 8 Dayangfang, Anwai, Beijing, 100012
[2]Nanjing University of Information Science & Technology
Pukou Lulou, Nanjing, Jiangsu Province, 210044
[3]Shenyang Environmental Engineer Designing Institutes
Donglin District, Shenyang, Liaoning Province, 110013

Abstract:

In this paper, the status of the treatment of municipal solid waste (MSW) in China is reviewed based on the statistical year books and survey data for typical cities. Waste composition and its regional distribution are also examined. The driving forces (such as GDP, urban population and GDP per capita, etc.) of MSW generation are analyzed, and the results show that MSW generation has very good relationship with these driving forces. Estimate models of MSW generation were developed according to the analysis results. Finally the models are used to estimate future MSW generation amounts for different scenarios.

Methane (CH_4) is a very strong greenhouse gas (GHG), of which a large proportion is emitted from waste treatment, such as municipal solid waste landfill or open dumps, and wastewater handling systems. Estimates of global methane emissions from solid waste disposal sites (SWDS) range from less than 20 to 70 Tg/yr, or about 5 to 20 per cent of the total estimated emissions of 375 Tg/yr (IPCC, 1996) from anthropogenic sources globally. The methane emission inventory is one of the main components of the Greenhouse Gas Inventory for each member country of UNFCCC. It has caught the attention of the government and policy makers.

With gradual improvements in the standard of living, waste generation (especially municipal solid waste, MSW) has been increasing in recent years. This phenomenon is more obvious in developing countries. The annual output of global municipal solid waste has exceeded 450Mt; the average annual rate of increase is 8.42%. The annual MSW generation amount has reached 1 Mt in China. The annual MSW generation amount intensity in China is 440kg/per capita, the daily production per person is 0.89kg, and the annual increase rate ranges from 8 percent to 10 percent. The accumulated MSW amount exceeds 6 billion tons in China, and there are more than 200 cities surrounded by solid waste treatment facilities or dumping grounds. At the same time, the composition of solid waste has become more and more complex due to the use of macromolecule materials, plastic materials and others. So the damage from municipal solid waste, especially to the atmosphere and groundwater, is becoming more and more serious. The methane emitted from municipal solid waste treatment has become increasingly important to GHG inventories. Although the generation amount of MSW increases ceaselessly, the methods of disposal are very limited and need to be studied further.

In developing countries, a large proportion of municipal solid waste is food waste from kitchens and sweeping waste, which include mainly soil and water. However, in developed countries, the main component of municipal solid waste is wastepaper that contains more carbon (more than 40% in mass) than that of foods (only 15% in mass). Incinerators for managing municipal solid waste can reduce methane emissions, and they are widely used in most developed countries, but in developing countries, open dumps and landfills are commonly used to manage municipal solid waste, so solutions for mitigating methane emissions are still elusive for most developing countries. The recycling of MSW and converting it to useful resources are the best possibilities for the future.

In this paper, the status of municipal solid waste and its treatment in China is reviewed based on statistical data, and the MSW composition is also examined. Several driving forces for MSW generation amounts are analyzed and an estimate model is developed and used to calculate further MSW generation amounts according to different scenarios.

The data used in this paper are from “Statistic Annals of Chinese Municipal Construction”, “Chinese Statistic Yearbook” and “Annual Statistic Communiqué of China”, which are published by the National Statistics Bureau, as well as the research report entitled “The Greenhouse Gases Emission from Chinese Municipal Solid Waste”. The data and research reports from other research groups are also used in this paper.

1 The Status of MSW in China

1.1 Generation Amount and Carrying Amount of MSW

Municipal solid waste refers to any garbage from human activities. It includes household garbage, sweeping waste, commercial refuse, institutional and community waste, etc. Municipal solid waste generation amounts are the amounts generated by human life and social activities in a given area, and the carrying amount of solid waste refers to the waste transported out of city to landfill or other treatment facilities.

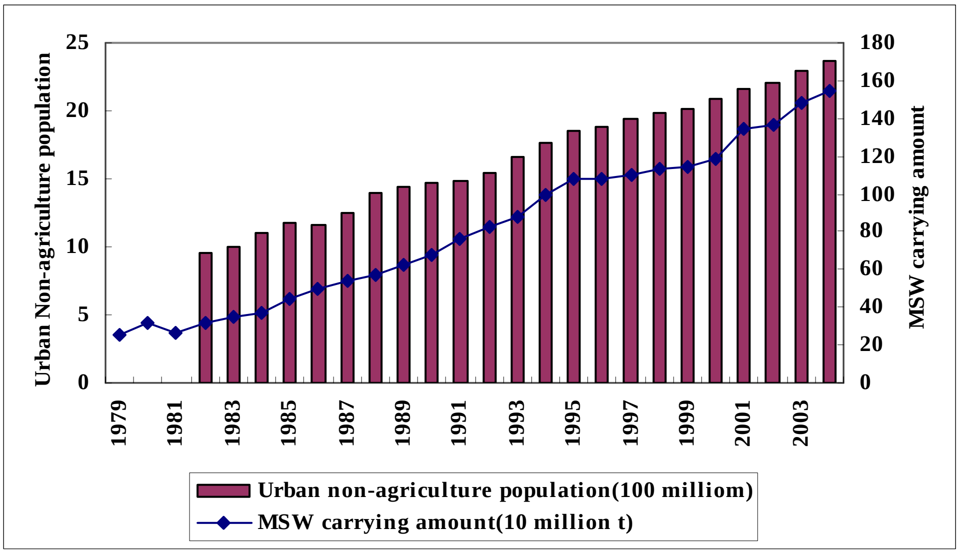

Fig. 7.1 Trends in carrying amounts of MSW and non-agriculture population.

Municipal solid waste generation amounts and carrying amounts have a very close relationship with urban population, city scale, number of cities, income of the residents, consumption level of the residents, gas utilization rate of the residents, etc. Since 1979, the number of cities in China has increased steadily, the city scale has expanded very rapidly, urban population and areas increased quickly, standards of living improved significantly, and at the same time, municipal solid waste in China went through a sharp stage of increase.

Figure 7.1 gives the trends in carrying amounts of municipal solid waste and urban non-agriculture population increases from 1990 to 2004 in China, and it shows that both the carrying amount of municipal solid waste and the urban non-agriculture population show a distinct increasing trend. In particular, the carrying amount of MSW increased very quickly before the middle of the 1990s. From the middle of the 1990s to 2000, the increasing trend is obvious, and then it tended to decrease. It should be noted that after 2000 the carrying amount of MSW increased again. In the decade from 1985 to 1995, the rate of increase in the carrying amount is much higher than the urban non-agriculture population, and the major reason is that with the development of the economy, urbanization and expansion of city areas, and with increased openness to the international community, more and more agriculture populations moved to urban areas. The actual population living in urban areas is much higher than the statistical data, so the MSW generation increase rate is higher than that of the non-agriculture population. The MSW carrying amount in 1982 was about 3.13 million tons and it increased almost 5 times to 15.51 million tons in 2004. During the same period, the non-agriculture population increases only 2.5 times, from 95.9 million in 1982 to 236.4 million in 2004.

1.2 Waste Treatment in China

Municipal solid waste treatment began from the beginning of the 1980s in China. The treatment rate before 1990 was about 10 percent, and after that it increased rapidly. There have been three stages in MSW carrying amount trends in China: before 1992 it was gradually increasing, from 1992 to 2000 it was stable, and after 2001 it increased rapidly again. The treatment rate increased quickly from 1990, and it was almost stable at around 60% from 1995 to 1999. After 1999 the treatment rate decreased. The reason for this was that with the steady economic development of China, the standard of living was enhanced and as a result, the generation amount of MSW increased dramatically. At the same time the local government paid more attention to MSW treatment and the treatment rate increased gradually. But in recent years, due to rapid increases in the MSW carrying amount and slow improvements in treatment facilities and abilities, the treatment rate is showing a decrease. According to the Chinese Municipal Construction Statistic Annals, there were 609 solid waste treatment facilities in 2000, and the treatment rate was about 48 percent, with a total MSW carrying amount of 995.2 million tons. In 2004, the treatment rate increased to 52.16 percent with 559 solid waste treatment facilities, and an MSW carrying amount of about 1550.9 million tons. Compared to developed countries, the treatment rate in China is low, and the treatment abilities should be enhanced in order to match the fast increase in MSW.

Figure 7.2 compares MSW treated amounts in each province of China for 2000, 2002 and 2004. It is clear that the treatment of MSW was generally steady over these years in most of the provinces and that there was more treatment in the eastern and central regions than in the western region.

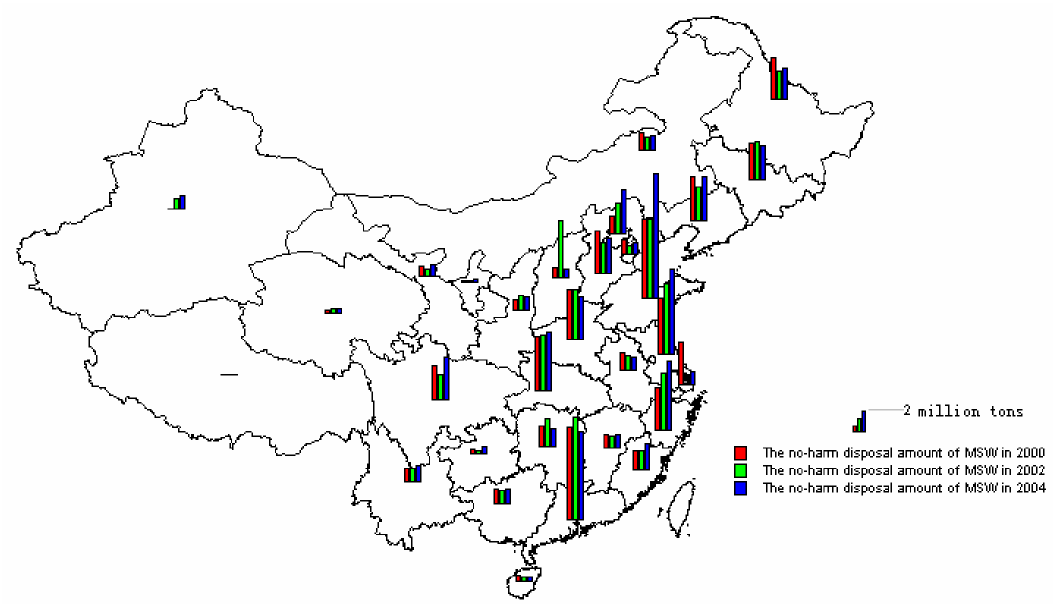

Fig. 7.2 Comparing MSW treated amounts in each provinces of China (2000, 2002 and 2004).

China is a huge country and there are imbalances in levels of economic development. In addition, the city scales are different and the customs of residents in different region are different, so there is huge terrain diversity in MSW treatment abilities. Table 7.1 gives the MSW treatment abilities of different regions in 2004. The general result is that treatment ability in the eastern area is much higher than that in the western region, and the treatment ability of super and big cities is much higher than that of medium-sized and small cities.

Table 7.1 The sub-region MSW treatment situation in 2004

2004	MSW treatment Ratio (%)	MSW carrying amount (10000 t)	MSW treatment ability (t/d)	MSW treatment amount (10000 t)
Whole country	52.15	15509.3	238519	8088.71
Eastern Region	63.85	7502.0	133581	4790.16
Central Region	39.04	5011.1	60272	1956.45
Western Region	44.79	2996.2	44666	1342.10
Mega Cities	68.00	3444.9	67074	2342.59
Super Cities	73.95	1972.2	41505	1458.48
Big Cities	48.08	2618.7	39601	1259.18
Medium-sized Cities	43.28	3490.6	40088	1510.81
Small Cities	38.1	3982.9	50251	1517.65

2 MSW Composition in China

2.1 Main Composition of Solid Waste in Cities

Table 7.2 lists the main municipal solid waste catalogues and composition in China. This data is from the comprehensive survey and sample analysis for typical cities, and the results show that resident solid waste accounts for about 60 percent of total MSW. The composition of resident solid waste is more complex than other kinds of waste, and the composition changes according to the weather and the season in the city. Sweeping solid waste accounts for 10 percent of total MSW. Its average water containment is low but the heat value is much higher than for resident solid waste. Institutional and community waste accounts for about 30 percent of total MSW, the composition of this kind of solid waste varies clearly due to the different sources. Its water containment is low and there is more tinder with high heat values in it.

Table 7.2 The sources and composition of MSW

Cataloguers	Composition
Resident MSW	Food, wastepaper, cloth, timber, metal, glass, plastic, rubber, pottery and china, fuel ash, brickbat, sundry goods, etc.
Sweeping MSW	Waste from public, including mud, dust, deadwood and leaves, commodity packaging materials, etc.
Institutional and community MSW	Waste from business, industry, institutions and transporting departments. The diversity is huge due to the different sources.

2.2 Regional Variability of MSW Composition in China

China is a huge country with far-flung terrain, and differences in temperature are great due to the different climate zones from south to north. Economic development is uneven between the eastern and western region, and the fuel structure and customs of residents are clearly different. MSW composition changes with the terrain. For example, in regions where gas dominates energy consumption, the organic waste in MSW accounts for 72.12 percent, which is higher than inorganic waste (16.84 percent) and other waste (12.04 percent). However, in the region where coal dominates energy consumption, the organic waste in MSW is only 25.09 percent; moreover inorganic waste accounts for 70.76 percent, which is much higher than the gas-based regions. Other waste accounted for 4.52 percent of the total. In developed regions, the percentage of wastepaper in MSW is higher than the others. Food waste is the main MSW component in developing regions.

Based on a survey of 73 cities in 2000, the MSW composition in Southern and Northern of China is listed in Table 7.3. It shows that the organic waste and recycle waste in MSW of southern cities (especially plants) are far higher than that of northern cities. In addition, the percentage of rubber waste in MSW of southern cities is higher than that of northern cities, but the inorganic waste composition (such as dust and ash) in southern cities is lower than that of northern cities. The major reason is that in northern cities, during the winter season (heating season) coal consumption is high, and the coal ash form heating facilities becomes municipal solid waste, so the composition is obviously different from that of southern cities.

Table 7.3 The composition of MSW in different zone cities in 2000

Region	Number of Cities	Recycle waste (%)						Organic waste (%)		Inorganic Waste (%)		Others (%)
		Wastepaper	Plastic and rubber	Cloth	Glass	Metal	Wood	Plant	Animals	Ash	Brickbat	
Southern	41	6.88	13.76	2.13	2.37	0.8	3.01	48.15	2.29	12.73	3.42	4.39
Northern	32	6.22	7.40	2.38	2.25	1.50	2.62	28.25	3.08	28.51	7.19	10．05

The MSW composition in various scale cities is different. The standard of living and consumption level in big cities is higher than that in medium-sized and small cities. The geography and environment are different, so there are some differences in MSW composition in different scale cities.

Table 7.4 gives the composition of MSW in different scale cities in 2000. It is obvious that inorganic waste, such as residue, dust, ash, etc. in big cities is lower than that in medium-sized and small cities. The percentage is only one third of that in medium-sized and small cities (Figure 7.3). Organic waste and recycle waste, especially combustible waste (wastepaper and rubber etc.) are lower than in medium-sized and small cities. For example, the percentage of recycle waste in big cities is about 30 percent, which is higher than in medium-sized and small cities (21 percent).

Table 7.4 The composition of MSW in different size cities

City scale	Number of cities	Recycle waste (%)						Organic waste (%)		Inorganic waste (%)		Others(%)
		Wastepaper	Plastic and rubber	Cloth	Glass	Metal	Wood	Plant	Animal	Ash	Brickbat	
Big cities	13	7.87	12.07	1.99	3.29	0.83	3.19	53.17	1.51	11.42	2.65	1.82
Medium -sized and small cities	54	4.29	7.88	2.33	2.40	1.46	2.11	33.40	4.14	28.86	8.62	6.32

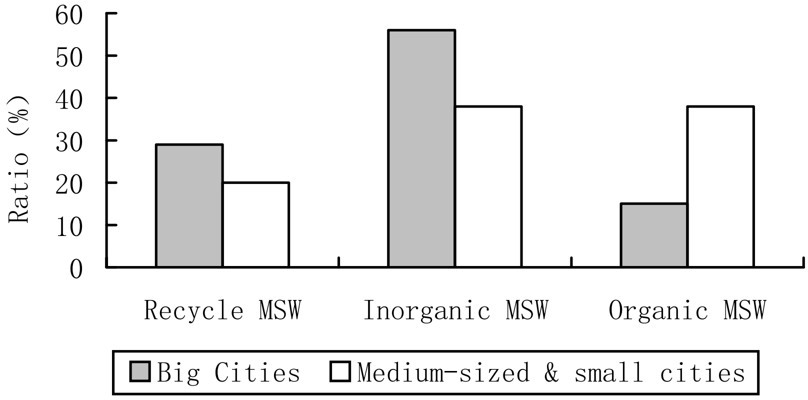

Fig. 7.3 Comparing the composition of MSW in different size cities.

2.3 Long Term Trends in MSW Composition in China

Based on a survey of some cities and research on GHG emissions from municipal solid waste treatment in China, the long term trends in MSW composition have been listed in Table 7.5.

Table 7.5 Investigation and statistics on MSW composition in China

Number of cities	Year	Fresh waste composition (%)									Moisture %
		Food	Wastepaper	Plastic	Cloth	Wood	Metal	Glass	Brickbat	Others	
57	1985—1990	27.54	2.02	0.68	0.70		0.54	0.78	67.76		
68	1991	59.86	2.85	2.77	1.43	2.10	0.95	1.60	25.03	3.41	41.06
72	1992	57.94	3.04	3.30	1.71	1.90	1.13	1.79	25.90	3.28	40.68
67	1993	54.25	3.58	3.78	1.71	1.83	1.08	1.69	27.76	4.32	41.61
75	1994	55.39	3.75	4.16	1.90	2.05	1.16	1.89	25.69	4.00	40.71
69	1995	55.78	3.56	4.62	1.98	2.58	1.22	1.91	23.71	4.64	39.05
82	1996	57.15	3.71	5.06	1.89	2.24	1.28	2.07	22.31	4.27	40.75
67	1999	49.17	6.72	10.73	2.10	2.84	1.03	3.00	21.58	3.26	48.15
73	2000	43.60	6.64	11.49	2.22	2.87	1.07	2.33	23.14	6.42	47.77

It may be concluded from this table that the average content of organic waste in MSW (mostly kitchen waste) was about 27.54 percent from 1985 to 1990. The maximum was 57.15 percent in 1996. In recent years, this has been gradually increasing. The inorganic waste content (mostly brickbat and ash etc.) has been gradually decreasing. The recycle waste in MSW increased rapidly: the average increased from 11.7 percent in 1991 to 26.6 percent in 2000. The combustible waste content in MSW increased dramatically, and the heat value of solid waste also increased. Plastic went up more than 3 times, from 2.77 percent in 1991 to 11.49 percent in 2000. Wastepaper also went up, from 2.85 percent in 1991 to 6.64 percent in 2000. The cloth and wood content in MSW showed small changes.

3 Driving Forces Analysis of MSW in China

3.1 Driving Forces of MSW Generation Amounts

There are plenty of driving forces of MSW generation amounts, such as urban population, city scale, consumption level of residents, income of residents, gas ratio used in city, etc. In this paper we focus on 6 driving forces: urban non-agriculture population, gross domestic product (GDP), urban population, constructed areas of city, numbers of cities and, GDP per capita.

3.1.1 Urban Non-Agriculture Population

With the rapid development of urbanization, rural populations migrate into urban areas to live and work. The MSW generation amount and urban non-agriculture population increase if the average MSW generation rate stays constant. Figure 7.4 shows the relationship between the urban non-agriculture population and the MSW generation amount. It shows that there is very close relationship, with a correlation coefficient of about 0.965. It also shows that with the increase in urban non-agriculture population, the increase rate of MSW generation amount tends to slow down.

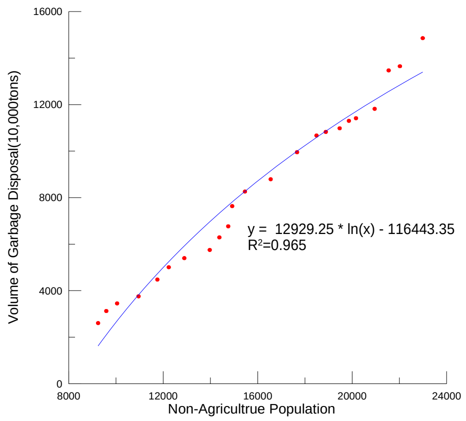

Fig. 7.4 Relationship between non-agriculture population and the carrying amount of MSW.

3.1.2 Gross Domestic Product (GDP)

Economic development and the enhancement and improvement of living standards boost the increase of MSW to a certain extent. Figure 7.5 shows the mutuality graph of GDP with MSW generation amount, with a correlation coefficient of 0.978. The first part of the curve increases rapidly. It represents the real situation in which, during the developing stages of a city, the MSW increases rapidly, and at same time its treatment and carrying ability is low. With quick economic development and enhancement of public environmental awareness, as well as the use of clean energy the reinforcement measures for recycling MSW, etc., the MSW generation amount starts to slow. The second part of curve shows a slow increasing trend.

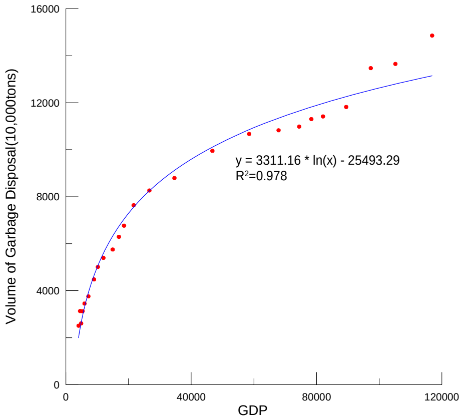

Fig. 7.5 Relationship between GDP and the carrying amount of MSW.

3.1.3 Constructed Areas of City

The constructed areas of cities indicate the areas of the region in which MSW is generated to some extent. Normally, the MSW generation amount has a positive relationship with the constructed areas of cities under the assumption that the living standards of residents and population density are closely related in all cities. So the larger the city areas, the more people live and work there and the more MSW generated there. Figure 7.6 shows the correlation curve of constructed areas of cities and MSW generated in China since 1981. There is a linear relationship with correlation coefficient of 0.989.

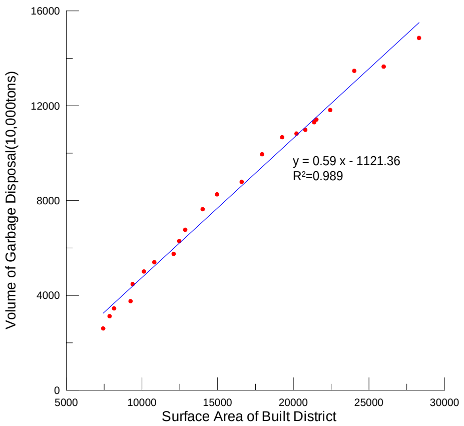

Fig. 7.6 Relationship between areas of built-up districts and the carrying amount of MSW.

3.1.4 Urban Populations

The MSW generation amount has quite a close relationship with urban population, and the correlation coefficient is as high as 0.906. Figure 7.7 gives the correlation curve. It was found that there are several points apart from the curve, which means that, in recent years, the urban population has increased slowly but rural population migrated to urban areas and caused an increase in the MSW generation.

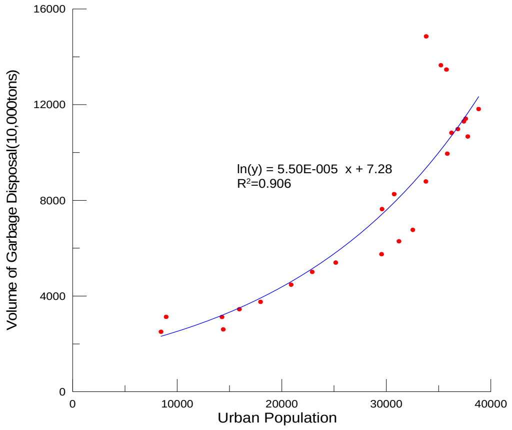

Fig. 7.7 Relationship between urban population and the carrying amount of MSW.

3.1.5 The Number of Cities

The statistic of MSW carrying amount is the total MSW generation amount from all constructed cities. From 1979 to 2004, the numbers of cities in China increased from 206 cities in 1979 to 661 cities in 2004. Figure 7.8 gives the correlation curve of numbers of cities and MSW generation amount, with a correlation coefficient 0.930. The curve shows that before the 1990s, the reason for increasing MSW was not only that the cities were getting bigger, but that their numbers were increasing. In recent years, due to merging and expansion of cities, the number of cities has stayed steady, so the relationship between the MSW generation amount and the number of cities gradually decreases with time.

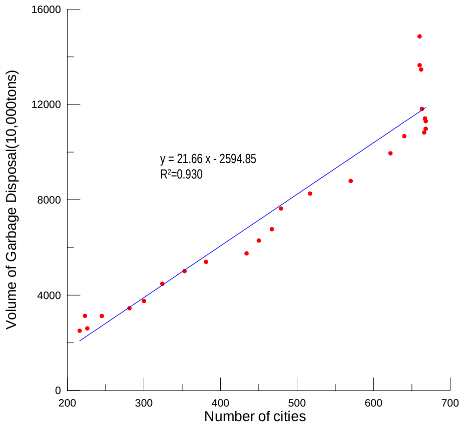

Fig. 7.8 Relationship between number of cities and the carrying amount of MSW.

3.1.6 GDP Per Capita

The GDP per capita is a very important index for assessing the standard of living in a country, and improvements in the standard of living will impact on MSW generation. It is clear that the MSW generation amount increases with the GDP per capita as a logarithmic form, with a correlation coefficient of 0.977. From Figure 7.9, we can conclude that after the GDP per capita increases to a certain value, the MSW generation rate will gradually decrease.

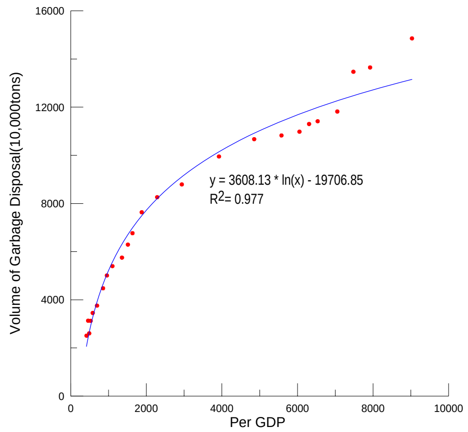

Fig. 7.9 The relation of per GDP and the carrying amount of MSW.

3.2 The Estimate Model for MSW Generation in China

According to the analysis of these six driving forces of MSW, and based on the real situation of Chinese municipal solid waste treatment and statistic data, three estimate models were developed for estimating future MSW generation amounts. The models are as follows.

1. **Urban non-agriculture population model**

$$W_g = f(NAP) = 12929.25\ln(NAP) - 116443.35$$

Where, *Wg* means the MSW generation amount (10000 t), NAP means urban non-agriculture population (10000 people). The coefficient of determination, R-squared, is 0.965 and it passes 99% confidence interval test.

2. **GDP model**

$$W_g = f(GDP) = 3311.16\ln(GDP) - 25493.29$$

Where, *GDP* means Gross Domestic Product (100 million Yuan RMB). The coefficient of determination, R-squared is 0.978 and it passes 99% confidence interval test.

3. **GDP per capita model**

$$W_g = f(GDPperC) = 36.8013\ln(GDPperCNAP) - 19706.85$$

Where *GDPperC* means the GDP per capita, the unit is Yuan RMB. The coefficient of determination, R-squared is 0.977 and it passes 99% confidence interval test.

4 Future MSW Generation Amount Estimation and Trend Analysis

Estimating the future MSW generation amount is very important for urban development, and it is also a fundamental work for waste management. At the same time, it can provide basic data for estimating future greenhouse gases emissions in order to set up suitable mitigation and adaptation measure. There are several methods for estimating the MSW generation amount, including the gray system model, analogy model, regression analysis models, etc. The single variable statistic model is widely used and its results are reasonable because of its pretreatment of raw data, although it fails to consider all effecting factors.

4.1 GDP Scenarios Estimation of MSW

Due to the uncertainty of economic development and its unpredictable factors, three GDP scenarios were designed for this paper. Scenario 1 (S1) is a sublimate increase model and in this scenario, the economy develops steadily in China. Scenario 2 (S2) is based on economic development orderliness and combines with the assumption that the economic development rate will gradually slow down and stabilize. This can be treated as the real increase scenario. In scenario 3 (S3), a good many disadvantageous factors and difficulties are considered and it can be treated as a scenario of slow increase. Table 7.6 gives the GDP forecast for the three scenarios and it is based on the complex analysis of economic development actualities, GDP growth rate, change rate, etc.

Table 7.6 Three future GDP scenarios for China Unit : 10^8 yuan RMB

Year	2010	2020	2030	2040	2050
S1	229750	455537	1024068	2093019	3885585
S2	217390	411624	836146	1544204	2590390
S3	205589	346130	591246	928190	1295195

The future MSW generation amount in China was calculated based on the scenarios and using the GDP estimation model. Figure 7.10 gives the estimation results. The maximum value for 2030 is 2033.08 million tons, the minimum value is 1851.2 million tons, for a difference of about 1818.8 million tons. In 2050, the maximum value is 2474.62 million tons, the minimum value is 2110.85 million tons, and the difference is about 3637.7 million tons.

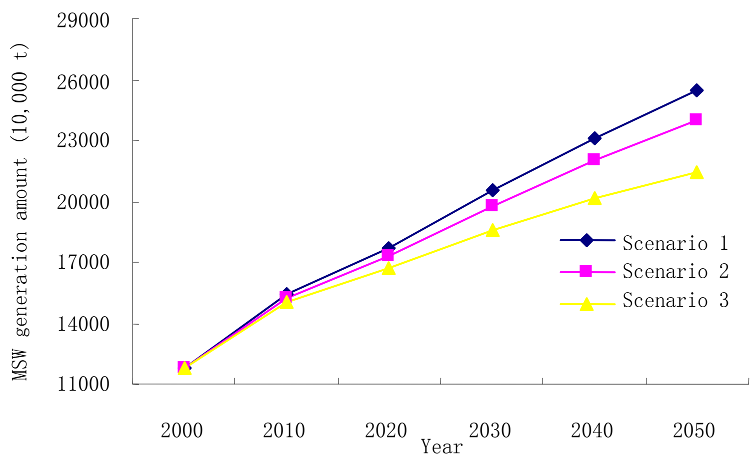

Fig. 7.10 MSW generation amount predicted by GDP model.

4.2 GDP Per Capita Scenarios Estimation of MSW

GDP per capita is a very important index to weigh the standard of living for a country, and the MSW generation amount will increase with improvements to the standard of living. Based on future population estimates from the National Statistics Bureau (Table 7.7) and the GDP scenarios, the three GDP per capita scenarios are listed in Table 7.8. Using the GDP per capita model, the MSW generation amount is calculated for different scenarios. Figure 7.11 gives the estimation results. The results are similar to those obtained with the GDP model.

Table 7.7 Chinese population estimation in the future Unit : 10^8 persons

Year	2010	2020	2030	2040	2050
Population	13.5926	14.3498	14.6956	14.6864	14.3229

Table 7.8 Three future per capita GDP scenarios in China Unit : yuan RMB

Year	2010	2020	2030	2040	2050
Scenario 1	16902.58	31744.29	69685.01	142517.9	271284.4
Scenario 2	15993.26	28687.49	56894.51	105148.8	180856.3
Scenario 3	15125.07	24123.01	40235.39	62519.35	90428.14

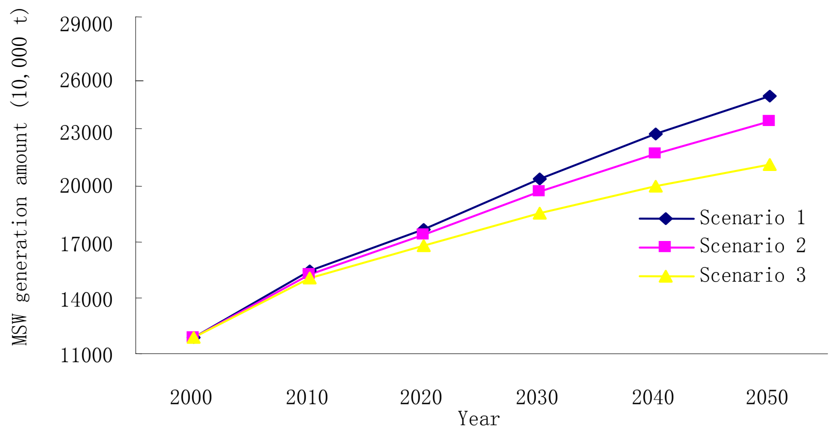

Fig. 7.11 The MSW generation amount predicted by GDP per capita model.

4.3 Urban Non-Agriculture Population Scenarios Estimation of MSW

The urban non-agriculture population annual rate of increase was about 3.34 per cent from 1993 to 2003, and it will reach its peak at 2030 at this rate. Based on the forecast from National Statistics Bureau, the rate of increase from 2030 to 2040 will be 2 percent, and 1 percent for 2040 to 2050. The urban non-agriculture population in the future is shown in Table 7.9. Figure 7.12 gives the estimate results. The MSW generation amount in 2030 will reach 2494.57 million tons and it will be 2879.26 million tons in 2050. The results are slightly higher than that of the GDP model and GDP per capita model. The main reason is that GDP and GDP per capita represent whole cities, and municipal solid waste collection and treatment facilities are only available in cities and big towns and villages in China. So the estimation of urban non-population model is closer to the real situation.

Table 7.9 The urban non-agriculture population of China in the future Unit : 10^4 persons

Year	2000	2010	2020	2030	2040	2050
Urban non-agriculture population	20952.5	29101.4	40419.6	56139.6	68433.9	75593.6

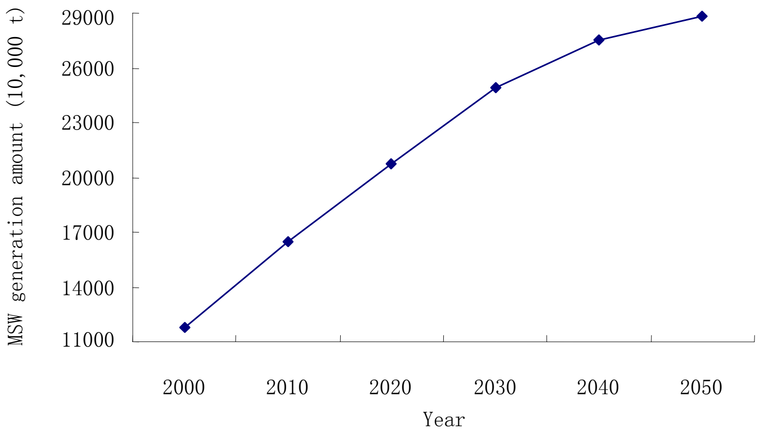

Fig. 7.12 The MSW generation amount predicted by non-agriculture population model.

5 Conclusions and Discussion

From the analysis above it is concluded that:

1. MSW generation in the future was calculated based on different models and scenarios. The GDP model gives the result that the MSW generation amount in 2030 will range from 1851.2 million tons to 2033.0 million tons for different scenarios, and from 2110.85 million tons to 2474.62 million tons for 2050. The GDP per capita model results are 1854.84 million tons to 2053.01 million tons for 2030, and 2147.03 million tons to 2543.42 million tons for 2050. The urban non-agriculture model result is 2494.57 million tons for 2030 and 2879.26 million tons for 2050.
2. The estimate results from the GDP model and GDP per capita model are similar, although the assumptions and their relationship are different. The difference between these two models in different scenarios gradually increases with time, but their results are slightly higher than that from the urban non-agriculture population model. On the one hand, with the progress of technology, the recycle rate of MSW increases quickly, so the increase rate of MSW generation amount per capita gradually slows down. On the other hand, the urban non-agriculture model only represents the solid waste generated in cities. The whole country average status was considered in the GDP and GDP per capita models, so they include both city and country.
3. The major MSW treatment method in China is landfill. More than 95 percent of MSW are treated in landfill, although there are huge differences in technique, management, and manner levels. Compost and incineration are secondary methods in China. In addition to the relatively low treatment ability of MSW throughout China, there are distinct regional differences, with some cities being even less able to treat the MSW than the national average.
4. MSW composition changes with terrain region and economic development levels. Organic and recycle waste in the southern region of China are much higher than that of the northern region. The content of plastic in MSW is almost double that in northern cities, but the inorganic waste, such as soil and ash, is less than half of that in northern cities.
5. The proportion of inorganic waste, such as soil and ash, in big cities is less than that of medium-sized and small cities, and it is only one third of that, but the proportion of organic waste and recycles waste, especially the combustible waste, is much higher than that of medium-sized and small cities. The proportion of recycle waste in big cities is

about 30 percent.

6. Organic waste increases gradually with time in China, but inorganic waste decreases with time. The average content of organic and inorganic waste stabilizes and the composition changes slightly. The recycle rate in MSW increases rapidly and combustible waste and its heat value increase to some extent.

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7.3 Challenges and Possible Solutions

Solid waste management varies widely in Asian countries. In China, a wide range of variation can be found within the country. Understanding waste flow in communities is very important. The group suggested underlining waste flow analysis and following the GPG decision tree with specific modifications according to the circumstances in each country. A high degree of use of disaggregated activity data was also recommended.

Gaps between countries with advanced technology and countries with conventional technology can be narrowed by setting up a network among member countries to share experiences and transfer knowledge. Such activities could include workshops and training, data base formation and joint research.

7.4 Other Points Discussed

Issues regarding co-benefits between waste treatment and energy and between waste treatment and the promotion of recycling were discussed within the working group. It was agreed that co-benefits need to be clarified and quantified along with solid waste treatment.

Since no voluntary presentation on wastewater handling and incineration was given, discussion on these matters was not focused.

Chapter 8

NEXT STEPS

The various efforts that countries in Asia have made demonstrate the progress that has been made in inventory compilation in Asia in terms of its technical and institutional aspects. However, countries identified a number of constraints and problems that they have experienced in developing and improving inventories. Therefore, further efforts to overcome the issues are necessary. Common issues are summarised as follows.

- Activity Data: Availability, accessibility, compatibility, and reliability of necessary activity data should be improved.
- Emission Factors: The number of country-specific emission factors is very limited. More research is required to develop country-specific emission factors.
- Capacity Building: Capabilities of experts responsible for inventory development should be enhanced.
- Institutional Arrangements: Institutional arrangements need to be improved, particularly at the national level, to ensure greater efficiency and sustainability in preparing inventories.

To support the countries in Asia to address the issues above, the participants of WGIA have identified the following action items to implement in the future.

1. *Continuing the current style of information exchange and sharing experiences*

The current style of information exchange regarding country practices is beneficial for regional inventory experts to increase their body of knowledge. Experts can learn how others cope with the issues that they face during the process of inventory development and can come up with the solutions they can implement in their own countries. Moreover, via such information exchange, experts can review some of the important UNFCCC reporting requirements. Also, information exchange can generate ideas for supporting inventory development that certain countries might not have otherwise recognized (e.g. activity based on a bilateral or regional framework).

2. *Conducting joint activities by groups of regional experts to conduct more practical information exchange*

More technical information exchange can be done using tools other than the current style of information exchange. For example, regional tables or databases can be created for experts to share information regarding refinement of emission factors. If possible, such tables and database can be put on the Internet so that experts can freely access and update necessary information. Since the information is specialized, a group of experts needs to act as a working group for this activity.

3. *Implementing regional research projects to develop region-specific emission factors, a region's standard measurement manual, etc.*

Regional collaborative research projects are desirable to estimate region-specific emission factors where development of country-specific emission factors is not possible. In the case of the agriculture sector, many of the agricultural practices, such as rice cultivation and agroforestry, are unique to Asia thus estimated region-specific emission factors would be valuable for many countries in the region. In the case of the waste sector, a region's standard measurement manual for collecting data could be developed because the measurement procedures are common to most of countries in the region.

4. *Distributing the information of WGIA's experiences and results constantly to share with others*

Transmitting the information of WGIA to others through WGIA's website and publications is essential. The information of WGIA is useful not only to inventory experts within and outside the Asia region but also to policy makers and researchers in other fields of climate change (e.g. mitigation, adaptation and CDM). The submission of locally-developed emission factors to the IPCC's Emission Factor Database is encouraged, when possible.

5. *Seeking for opportunities to financially support national efforts at the domestic and regional levels*

Additional financial support would be highly desirable, particularly for item 3 above and other national efforts requiring financial assistance. The network of WGIA will collect relevant information to identify such opportunities.

Appendix 1: List of Contact Persons

Chapter 1-2:

Ms. Chisa Umemiya
Assistant Fellow
Greenhouse Gas Inventory Office of Japan
Center for Global Environmental Research
National Institute for Environmental Studies
16-2, Onogawa, Tsukuba, Ibaraki 305-8506
JAPAN

Chapter 3:

Mr. Chan Thou Chea **(3.1)**
Deputy Director of Department
Department of Planning and Legal Affairs
Ministry of Environment
#48, Preah Sihanouk Blvd, Phnom Penh,
CAMBODIA

Dr. Sumana Bhattacharya **(3.2)**
National Expert Consultant
National Communications
Ministry of Environment and Forestry
Government of India
Natcom Project Management Cell
Winrock International India
1, Navjeenvan Vihar, New Delhi 110017
INDIA

Ms. Siti Indati Mustapa **(3.3)**
Program Manager
Pusat Tenaga Malaysia
Level 8, Bangunan Sapura@Mines, 7, Jalan
Tasik, The Mines Resort City, 43300 Seri
Kembangan, Selangor Darul Ehsan,
MALAYSIA

Ms. Bujidmaa Borkhuu **(3.4)**
Researcher
Institute of Meteorology and Hydrology
Juulchny Gudamj-5, 210646, Ulaanbaatar
MONGOLIA

Dr. Dagvadorj Damdin **(3.4)**
Director
Information, Evaluation and Monitoring
Division
Ministry of Nature and Environment of
Mongolia
Government Building 3, Room 410,
Ulaanbaatar 21A
MONGOLIA

Chapter 4:

Mr. Tomoyuki Aizawa **(4.2.1, 4.3, 4.4)**
Researcher
Greenhouse Gas Inventory Office of Japan
Center for Global Environmental Research
National Institute for Environmental Studies
16-2, Onogawa, Tsukuba, Ibaraki 305-8506
JAPAN

Ms. Siti Indati Mustapa **(4.2.2)**
Program Manager
Pusat Tenaga Malaysia
Level 8, Bangunan Sapura@Mines, 7, Jalan
Tasik, The Mines Resort City, 43300 Seri
Kembangan, Selangor Darul Ehsan,
MALAYSIA

Chapter 5:

Dr. Batimaa Punsalmaa **(5.2.1, 5.3, 5.4)**
Senior Researcher
Institute of Meteorology and Hydrology
PO Box 664, Ulaanbaatar-24,
MONGOLIA

Dr. Damasa Magcale Macandog **(5.2.2)**
University of the Philippines Los Banos
Associate Professor
Institute of Biological Science, University of
the Philippines Los Banos, College, Laguna
4031,
PHILIPPINES

Dr. Takashi Osada **(5.2.3)**
Team Leader
Research Team for Waste Recycling System
National Agricultural Research Center for Hokkaido Region
National Agriculture and Food Research Organization
1 Hitsujigaoka, Sapporo, Hokkaido, 062-8555
JAPAN

Chapter 6:

Dr. Rizaldi Boer **(6.2.1, 6.3, 6.4)**
Head of Laboratory of Climatology
Department of Geophysics and Meteorology
Faculty of Mathematics and Natural Sciences
Bogor Agricultural University
Kampus IPB Darmaga, Bogor 16680, West Java,
INDONESIA

Mr. Lip Khoon Kho **(6.2.2)**
Urban Forestry and Forest Recreation
Division of Forestry and Conservation
Forest Research Institute Malaysia (FRIM)
52109 Kepong, Selangor Darul Ehsan,
MALAYSIA

Mr. Heng Chan Thoeun **(6.2.3)**
Chief Office for Environmental Inspection
Ministry of Environment
#48, Samdach Preah Sihanouk, Tonle Bassac, Chamkarmon, Phnom Penh,
CAMBODIA

Mr. Atsushi Sato **(6.2.4)**
Collaborating Researcher
Greenhouse Gas Inventory Office of Japan
(Analyst, Climate Change Mitigation Policy Group, Environmental Policy Consulting Department, Mitsubishi UFJ Research and Consulting)
Center for Global Environmental Research
National Institute for Environmental Studies
16-2, Onogawa, Tsukuba, Ibaraki 305-8506
JAPAN

Chapter 7:

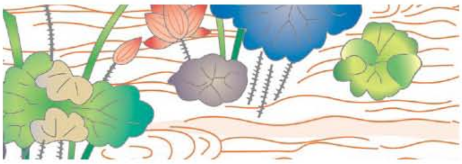
Dr. Sirintornthep Towprayoon **(7.2.1, 7.3, 7.4)**
Associate Professor
Joint Graduate School of Energy and Environment
King Mongkut's University of Technology Thonburi
Bangmod, Bangkok 10140,
THAILAND

Dr. Gao Qingxian **(7.2.2)**
Center for Climate Impact Research, SEPA
Chinese Research Academy of Environmental Science
8 Da Yangfang, An Wai, Beijing 100012,
CHINA

Chapter 8:

Ms. Chisa Umemiya
Assistant Fellow
Greenhouse Gas Inventory Office of Japan
Center for Global Environmental Research
National Institute for Environmental Studies
16-2, Onogawa, Tsukuba, Ibaraki 305-8506
JAPAN

Appendix 2: WGIA Leaflet



WGIA:

"Workshop on GHG Inventories in Asia Region"

Activities Overview

The Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are required to develop and publish a national inventory of greenhouse gases (GHG) not controlled by the Montreal Protocol. Reporting requirements for GHG inventories differ between industrialized (Annex I to UNFCCC) and developing countries (Non Annex I). GHG inventories are compiled following the guidelines of the Intergovernmental Panel on Climate Change (IPCC).

WGIA ("Workshop on GHG Inventories in Asia Region") aims at assisting the countries in the Asia region in developing and improving their GHG inventories by creating the opportunities to exchange information and share their own experience on an annual basis. The major players of WGIA are government officials and researchers who are involved in preparing GHG inventories. WGIA has also been benefited from the participation of relevant international organisations, such as the UNFCCC Secretariat and the Technical Support Unit of the IPCC National Greenhouse Gas Inventories Programme.

WGIA has achieved to:

- Identify common issues and possible solutions to improve the quality of inventories, by sector
- Share countries efforts and practices that can be learnt by others
- Update each other on the national status of inventory development regularly

http://www-gio.nies.go.jp/wwd/wgia/wgiaindex-e.html

"Workshop on GHG Inventories in Asia Region"

WGIA:

WGIA is sponsored by the Ministry of the Environment, Japan. The National Institute for Environmental Studies in Japan coordinates the workshops.

- Contact-
Greenhouse Gas Inventory Office of Japan
Center for Global Environmental Research,
National Institute for Environmental Studies
16-2 Onogawa Tsukuba, Ibaraki, 305-0051 Japan
www-gio@nies.go.jp
Phone: +81-29-850-2169
Fax: +81-29-858-2645