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COMPARATIVE ANALYSIS OF EMISSION FACTORS AND ACTIVITY DATA USED FOR THE ESTIMATION OF GREENHOUSE GAS EMISSIONS IN THE ENERGY AND LAND-USE CHANGE AND FORESTRY SECTORS FOR SOME DEVELOPING COUNTRIES

Technical Paper

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I. INTRODUCTION

A. Mandate

1. The Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), by decision 10/CP.2, requested the UNFCCC secretariat "to facilitate assistance ... through the organization of workshops at the regional level [and] to provide a forum for the exchange of experience in the development of emission factors and activity data for the estimation of the inventory".

2. In response to this request, the UNFCCC secretariat convened two workshops on greenhouse gas (GHG) emission factors and activity data. The first was held from 16 to 18 September 1998 in Havana, Cuba; the second was held from 4 to 6 August 1999 in Accra, Ghana. The workshops provided an opportunity for developing country Parties to exchange experience in the development and use of emission factors and activity data for the estimation of their GHG emissions by sources and removal by sinks.

3. This paper is divided into two parts. The first part focuses on the energy sector and the second part on land-use change and forestry. It was prepared to facilitate discussions on the energy and the land-use change and forestry sectors at the Havana and Accra workshops. However, it has been revised based on the comments and recommendations made by the participants in the two workshops. Moreover, the paper incorporates comments made by participants at the first and second forums for the exchange of experience in the development and use of GHG emission factors and activity data, held in Buenos Aires, Argentina and Bonn, Germany, during the ninth and tenth sessions of the subsidiary bodies of the Conference of the Parties, respectively. The present version is intended to provide a basis for further discussion at a third forum on the same issue to be held in Bonn during the eleventh sessions of the subsidiary bodies.

B. Scope

4. This paper reviews existing emission factors and activity data used in the energy sector (Part One) and the land-use change and forestry sector (Part Two) based on the available literature, including the initial national communications submitted by non-Annex I Parties and various GHG inventory reports. It describes the methodology used, assesses the reliability and accuracy of the collected data and highlights the major problems encountered by non-Annex I Parties during the preparation of the GHG inventories in these two sectors. Based on the analysis, a number of conclusions are drawn and recommendations made on how to improve the reliability and comparability of emission factors and activity data, with a view to enhancing the quality of national GHG inventories. The complete bibliographical references of the reviewed documents are listed at the end of the paper.

C. Methodology used for emission estimates

5. The Intergovernmental Panel on Climate Change (IPCC) 1995 Guidelines, which were revised to become the IPCC Revised 1996 Guidelines,[1] are the recommended methodology for estimating the GHG emissions for various sectors, including the energy and land-use change and forestry sectors.

6. The emission can be estimated by the following equation:

$$\text{Emission} = \text{activity data} (\pm x\%) \times \text{emission factor} (\pm y\%)$$
$$= \text{activity data} \times \text{emission factor} (\pm \{x+y\}\%),$$

where x% and y% are the percentage errors of activity data and emission factor, respectively.

PART ONE: ENERGY SECTOR

II. LITERATURE REVIEWED

7. Emission factors and activity data used in 42 GHG inventory reports from 36 non-Annex I Parties were reviewed. These include:

(a) Eight initial national communications submitted by non-Annex I Parties, namely: Argentina, the Federated States of Micronesia, Jordan, Mexico, the Republic of Korea, Senegal, Uruguay and Zimbabwe;

(b) United Nations Environment Programme (UNEP) Country Case Studies on Sources and Sinks of GHGs in Costa Rica, the Gambia, Mexico, Morocco, Senegal, Uganda, the United Republic of Tanzania and Venezuela;

(c) United States Country Studies Programs in Bangladesh, Bolivia, Chile, China, Costa Rica, Côte d'Ivoire, Ecuador, Ethiopia, Fiji, the Gambia, Kazakhstan, Kiribati, Malawi, Mauritius, Nepal, Nigeria, Pakistan, Peru, the Philippines, Sri Lanka, Venezuela, Zambia and Zimbabwe;

(d) Preliminary reports from the United Nations Development Programme (UNDP) BRA/95/G31 project in Brazil (PPE/COPPE/UFRJ, 1998);

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[1] The IPCC Revised 1996 Guidelines include revised methodologies and default data for fuel combustion, industrial processes, agricultural soils, land-use change and forestry, waste and methane from rice fields. In addition, several additional sources and sinks are identified in the Revised 1996 Guidelines, for 'new' gases: hydrofluorocarbons (HFCs), perfluorinated hydrocarbons (PFCs), sulphur hexafluoride (SF_6), ozone and aerosol precursors, and the direct GHGs, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

(e) GHG inventories prepared by Indonesia and the Seychelles;

(f) Report of the UNFCCC workshop on emission factors and activity data held in Accra (FCCC/SBI/1999/INF.6);

(g) Summary of methodological issues identified while processing greenhouse gas inventories of the second national communications by Annex I Parties relevant to the workshop on emission factors and activity data (FCCC/SBSTA/1998/7);

(h) Draft background paper to the expert group meeting on national feedback on the Revised 1996 IPCC Guidelines (IPCC/OECD/IEA, 1998);

(i) Review of the country- and region-specific emission factors in national greenhouse gas inventories (Lammers, Feenstra and Olstroorn, 1997).

III. EMISSION ESTIMATES

8. All the above reports used the IPCC 1995 Guidelines to estimate the GHG emissions in the energy sector, while the IPCC Revised 1996 Guidelines were used for only a few specific cases. The activity data (which are quantitative data representing economic activities, such as the total quantity of fuel consumed), aggregated emission factors (each of which often consists of a combination of several parameters and/or a weighted average of more specific emission factors) and the resulting GHG emission estimates were reported.

9. The emissions from various energy systems are divided into two main categories: fuel combustion and fugitive emissions. Most of the reports presented GHG inventories of energy-related emissions for a single year, usually 1990. In five countries, namely Argentina, Brazil (1990 to 1995), Ethiopia, the Republic of Korea (1990 to 1995) and Senegal (1994), at least partial estimates were presented for more recent years, hence permitting the analysis of recent trends in GHG emissions.

A. <u>CO_2 emissions from fuel combustion</u>

10. Emissions of CO_2 from fuel combustion generally account for the largest share of GHG emissions and can be calculated accurately at a highly aggregated level since they are primarily dependent on the carbon content of the fuel. Accordingly, all studies calculated the emission using the 1995 IPCC reference approach. This is a simple “top-down” method based on energy supply data (detailed only by fuels), with a few adjustments accounting for the carbon stored in non-energy uses and the fraction of carbon not oxidized due to incomplete combustion.

11. Eleven studies reported CO_2 emissions from fuel combustion using the IPCC “bottom-up” technology-based approach. The basic calculations are applied at a very detailed level, considering specific end-uses of different fuel types and covering up to 20 subsectors, depending on the disaggregation level of available data. Being data-intensive, detailed results

from this method certainly present a higher level of uncertainty if data are not available or unreliable. Otherwise, the emission estimates thus obtained are clearly more reliable than those obtained using the "top-down" reference approach.

12. Table 1 shows the differences between CO_2 emissions from fuel combustion calculated by the reference approach and the detailed technology-based approach in 11 countries.

Table 1: Comparison of CO_2 emissions from fuel combustion in 1990 using the reference approach and the detailed technology-based approach

Country	CO_2 emissions (Tg)[a]		Difference [(B-A) / A] (%)
	Reference approach (A)	Detailed technology-based approach (B)	
Bolivia	6.25	5.92	-5.0
Indonesia	149.36	140.40	-6.0
Jordan [b]	11.97	13.39	12.0
Kazakhstan [c]	93.16	93.57	0.4
Mexico	310.32	275.02	-11.0
Nigeria	94.04	99.51[d]	6.0
Peru	19.60	19.73	0.7
Philippines	38.25	35.67	-7.0
Seychelles	0.19	0.18	-8.0
Tanzania	1.94	2.02	4.0
Venezuela	105.90	84.45	-20.0

Notes:
a 1 teragram (Tg) = 10^{12}g
b Data for the year 1994
c CO_2 emissions from fuel combustion in power generation only
d Includes 56.83 Tg of fugitive emissions

13. In six out of 11 countries, the amount estimated using the detailed technology-based approach is lower than that estimated using the reference approach. However, within the limits of uncertainty, only the discrepancies for Mexico (-11%) and Venezuela (-20%) seem to be significant. It is not possible to disaggregate the total amount of energy consumption by subsectors or end-uses due to the lack of data or statistical adjustments. The difference is thus partly explained by the lower total of fuel consumption considered in the bottom-up method (e.g. -25% energy and -20% emissions in Venezuela). Similarly, of the five cases which show a

higher estimate of CO_2 emission using the bottom-up approach, perhaps only the case for Jordan (+12%) is significant. No explanation of the numerical differences was provided in these five reports. Thus it may be concluded, based on the above limited number of cases, that the CO_2 emission estimates using the reference approach and the bottom-up approach are mostly comparable. Some countries, namely Indonesia and Mexico employing the bottom-up method, and Jordan and the United Republic of Tanzania using the top-down method, have chosen the lower figures as their best estimates.

14. It is generally considered that the top-down method produces reasonably reliable estimates because energy supply data are usually available from national statistics. On the other hand, a disaggregated bottom-up approach requires the use of reliable data on emission factors and activity levels in all fuel combustion subsectors which are usually not available in developing countries. Additionally, a number of complex accounting problems which can be ignored when using the top-down approach would have to be addressed if the bottom-up method is used. The GHG emissions during the transformation of energy from one form to another are an issue of particular interest to developing countries. Examples of this include oil refining and the manufacture of solid fuels. As recognized by the IPCC, "the IPCC Guidelines do not yet provide detailed guidance for dealing with these complexities" (IPCC 1995 Guidelines, page I.47).

B. Non-CO_2 emissions from fuel combustion

15. Unlike CO_2, emissions of CH_4, N_2O, nitrogen oxides (NO_x), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs) from fuel combustion must be estimated at a detailed activity/technology level, as they depend on the fuel type used, the combustion technology, operating conditions, control technology, maintenance and the age of the equipment. Accordingly, the IPCC 1995 Guidelines provide a bottom-up method to estimate these emissions from stationary and mobile sources, as well as from the burning of traditional biomass fuels. Road transport accounts essentially for the vast majority of fuel consumed by mobile sources. Primary emphasis is placed on motor vehicles, for which emission estimation methods A (the most detailed method) to D (the simplest method) exist in the Guidelines.

16. The IPCC Guidelines divide the methods for estimating these emissions into three "tiers" encompassing different levels of activity and technology detail. Simple methods are tier 1 and detailed methods constitute tiers 2 and 3. The new tier 1 methodology included in the Revised 1996 Guidelines enables rough estimates of non-CO_2 greenhouse gas and sulphur dioxide (SO_2) emissions to be made by applying emission factors to fuel statistics which are organized by the above-mentioned subsectors. Tier 2 applies a bottom-up method and tier 3 is the CORINAIR 94 methodology available from the European Environment Agency. A new tier 2 method for estimating emissions from aircraft, the second most important subsector, was made available based on aircraft types and fuel consumption averages for cruising, landing and take-off.

17. As most of the reviewed studies were carried out before the release of the IPCC Revised 1996 Guidelines, researchers faced many difficulties in using the bottom-up method. The

majority of the studies used the default assumptions provided by the IPCC 1995 Guidelines, even if the national context was very different in terms of combustion technology, operating conditions, maintenance and age of the equipment. Despite these efforts, several countries were unable to report estimates of the indirect GHG emissions, particularly of NMVOCs, due to the lack of appropriate emission factors.

18. A few countries, including Uganda, benefited from the availability of the new tier 1 methodology included in the Revised 1996 Guidelines and from the new tier 2 method for estimating emissions from aircraft. However, estimates of SO_2 emissions were only reported in the recent Chilean study.

C. Fugitive emissions from the production and handling of fossil fuels

19. Fugitive emissions are intentional or unintentional releases of gases (mostly methane) during the production, processing, transmission, storage and use of coal, oil and natural gas. The methodologies for the estimation of methane fugitive emissions are separated in the IPCC Guidelines by sources, as follows:

(a) From coal mining and handling, further disaggregated by underground and surface mines and by mining and post-mining activities;

(b) From oil and gas activities, split into oil (exploration, production, transport, refining and storage); natural gas (production, processing, transmission, distribution, other leakage); and venting and flaring from oil and gas production.

20. Three different levels of detail are proposed for coal mining and handling and for oil and gas activities by the IPCC Guidelines, as follows:

(a) Tier 1, based on global average emission factors; tier 2, based on national average emission factors developed by the country on its own; and tier 3, based on mine-specific measurement of emissions;

(b) Tier 1, using a production-based average emission factor approach; tier 2, a mass balance approach (for oil activities only); and tier 3, a rigorous source-specific approach.

21. Emissions of other GHGs may arise as fugitive or by-product emissions from energy systems. These include CO_2 emissions from the flaring of natural gas at oil and gas production facilities; CO_2 emissions from burning coal deposits and waste piles; CO_2 emissions from SO_2 scrubbing technology used in conjunction with coal combustion; and NMVOC fugitive emissions. Fugitive emissions of GHGs other than methane are not very well covered by the IPCC 1995 Guidelines.

22. Most of the reviewed inventories, with the exception of a few large oil, gas and coal producers (e.g. China, Kazakhstan and Mexico), adopted the simplified tier 1 method to calculate

fugitive emissions of methane. The major problems reported regarding this issue which concern activity data and emission factors are discussed in the following sections.

IV. ACTIVITY DATA

A. Completeness and disaggregation

23. The degree of completeness of activity data and their disaggregation in the energy sector as reported by the reviewed studies is given in tables 2 and 3. All studies provided aggregate estimates of CO_2 emissions from fuel combustion. The number of studies providing estimates for non-CO_2 greenhouse gases was considerably lower, with fewer countries reporting inventories of CH_4, CO, NO_x, N_2O and NMVOCs, the last mentioned being covered in less than half of the countries (table 3).

24. In the estimate of CO_2 emissions from fuel combustion, all countries were able to use activity data from their own national sources (especially energy balances when available) and did not need default activity data from international sources. Most reports could disaggregate these emissions into four subsectors: energy industries and transformation (19 countries); manufacturing industries and construction (18 countries); transport (20 countries); and small-scale combustion (18 countries).

25. Further disaggregation of data from these subsectors was available in some studies:

(a) Energy: generally split into power generation (17 countries), oil refining (9 countries) and others (7 countries);

(b) Industry: sometimes split into selected industrial branches of particular relevance in the national contexts (9 countries);

(c) Transport: generally split into domestic aviation (15 countries), railways, national navigation (14 countries each) and roads (15 countries, and in 13 of them divided by three or more vehicle and fuel types using more often cars, light and heavy trucks driven by gasoline, diesel oil or natural gas);

(d) Small combustion: generally split into residential (14 countries), commercial/institutional (13 countries) and agriculture, forestry and fisheries (11 countries).

Table 2: CO_2, CH_4, N_2O: completeness of reporting and disaggregation of activity data in GHG inventories

	CO_2		CH_4		N_2O	
Subsector	**Number of countries**	**Percentage of countries**	**Number of countries**	**Percentage of countries**	**Number of countries**	**Percentage of countries**
Fuel combustion	36	100	25	69	19	53
Energy	19	53	14	39	10	28
Power plants	17	47	13	36	8	22
Refineries	9	25	3	8	4	11
Other	7	19	5	14	3	8
Industry	18	50	12	33	8	22
Different branches*	9	25	5	14	4	11
Transport	20	56	16	44	15	42
Air	15	42	12	33	7	19
Road	15	42	12	33	11	31
Vehicles	13	36	12	33	11	31
Rail	14	39	10	28	9	25
Navigation	14	39	7	19	6	17
Small combustion	18	50	14	39	11	31
Residential/institutional.	14	39	12	33	4	11
Commercial	13	36	8	22	4	11
Agriculture, forestry, fisheries	11	31	10	28	8	22
Biomass burning	26	72	24	67	23	64
Wood	21	58	23	64	19	53
Charcoal	13	36	11	31	10	28
Others	12	33	16	44	14	39
Fugitive emissions (coal)	-	-	15	42	-	-
Fug. emissions (oil/gas)	2	6	19	53	-	-

*Number of industrial branches disaggregated: 3 (Seychelles); 4 (Bolivia); 5 (Kazakhstan); 6 (Chile, United Republic of Tanzania); 9 (Peru, Venezuela); 11 (Brazil); 17 (Philippines)

Table 3: CO, NO_x and NMVOCs: completeness of reporting and disaggregation of activity data in GHG inventories

	CO		NO_x		NMVOCs	
Subsector	**Number of countries**	**Percentage of countries**	**Number of countries**	**Percentage of countries**	**Number of countries**	**Percentage of countries**
Fuel combustion	23	64	20	56	17	47
Energy	15	42	15	42	7	19
Power plants	12	33	13	36	4	11
Refineries	5	14	6	17	3	8
Other	3	8	4	11	2	6
Industry	12	33	15	42	6	17
Different branches*	6	17	6	17	1	3
Transport	16	44	16	44	16	44
Air	12	33	12	33	11	31
Road	13	36	13	36	12	33
Vehicles	13	36	13	36	12	33
Rail	12	33	12	33	11	31
Navigation	11	31	12	33	6	17
Small combustion	13	36	14	39	7	19
Residential/institutional	12	33	11	31	4	11
Commercial	9	25	8	22	3	8
Agriculture, forestry, fisheries	10	28	10	28	7	19
Biomass burning	18	50	23	64	1	3
Wood	17	47	22	61	1	3
Charcoal	9	25	12	33	-	-
Others	12	33	12	33	1	3
Fugitive emissions (coal)	-	-	-	-	-	-
Fugitive emissions (oil/gas)	-	-	-	-	1	3

*Number of industrial branches disaggregated: 3 (Seychelles); 4 (Bolivia); 5 (Kazakhstan); 6 (Chile, United Republic of Tanzania); 9 (Peru, Venezuela); 11 (Brazil); 17 (Philippines)

26. Although disaggregated data for the estimation of the non-CO_2 greenhouse gases are often difficult to obtain, a significant number of countries (16) estimated the emissions of these gases in the transport subsector. Better data are still needed in this subsector, especially in road transportation, as vehicle statistics are poorly recorded in many countries. It is also worth mentioning that at least one study (Chile) was able to provide data on all of the direct and indirect GHGs (and also SO_2) at a fairly disaggregated level (20 subsectors), hence allowing for the application of the bottom-up method to estimate the emissions.

B. International bunkers

27. The estimation of emissions from international bunkers presented difficulties for more than half of the countries (table 4). According to the IPCC 1995 Guidelines, these emissions have to be calculated separately and excluded from the total amount of national GHG emissions. Only 15 Parties were able to separate the amount of fuels used in international bunkers from national data and some of them quantified the corresponding CO_2 emissions. Other countries faced insurmountable difficulties in the separation of domestic aviation and/or navigation fuel consumption data from the overall bunkers total. One study (Nigeria) included data from international sources.

Table 4: CO_2 emissions from international bunkers, 1990 (Gg)

Country	Gasoline	Jet kerosene	Gas / diesel oil	Residual fuel oil	Lubricants	Other bituminous coal	Other kerosene
Chile			240.0	688.8			
Costa Rica		123.4					
Côte d'Ivoire		73.8	109.6	89.4			
Fiji	0.20	27.2	43.6	35.7	0.18	0.28	122.9
Mexico	122.30	5 384.0		1 671.0		538.00	
Nigeria			266.9	788.0			
Philippines		1 078.0	62.0	140.0			
Seychelles		13 1036.0	225.6	8.4			
Tanzania		60.5	27.3	25.5			
Venezuela		1 145.0	373.0	2 278.0			
Zambia	1.17	170.7					

C. Fugitive emissions

28. Another major problem encountered in the calculation of fugitive emissions from oil and gas activities was the estimation of the total amount of vented and flared natural gas, which is usually the difference between gross and net production. However, most countries do not keep separate records of methane fugitive emissions due to venting and CO_2 emissions from the flaring of natural gas at oil and gas production facilities. Two studies (Bolivia and Venezuela) were able to report on them separately. This is important for the accuracy of total GHG emissions, given the large differences in the global warming potential of these two gases and the fact that 19 countries reported fugitive methane emissions from oil and gas activities.

D. Power generation from autoproducers

29. Some problems were encountered in the collection of data on power generation by autoproducers. Their identification is very difficult due to the large number of small-scale autoproducers within different sectors using various fuels. Reliable data available from power companies generally do not include autoproducers.

E. Biomass burning

30. Most countries estimated GHG emissions from biomass burning, including CO_2 emissions (to be accounted for under land-use change and forestry emission totals to avoid double counting, according to the IPCC Guidelines). The reported estimates reflect the importance of biomass fuels in the energy balance of developing countries and in the emission of non-CO_2 greenhouse gases (tables 5 and 6). The exception is the case of NMVOC emissions from biomass burning, which were only reported in one study (Chile). The quality of the activity data used for these estimates, however, is generally much lower than those for fossil fuel. Even if the use of biomass fuels plays an important role in the industrial sector of a few countries (e.g. Brazil), the bulk of fuelwood is consumed by the residential sector in the large majority of developing countries. Moreover, a significant share of biomass fuel use is channelled through non-commercial circuits, with correspondingly poor data records. In most cases, data on the consumption of biomass fuels are simple estimates based upon an average household consumption. Many difficulties are also encountered with the estimation of biofuels consumed in the small-scale industries and commercial activities within the so-called “informal sector”. Among the successful initiatives to improve GHG inventories in this respect is the Tanzanian effort to incorporate the results of specific surveys of biomass fuel consumption patterns in urban households, cottage industries and the informal sector.

Table 5: Non-CO_2 emissions from charcoal production, 1990 (Gg)

Country	Total carbon (C) released	Emissions			
		CH_4	CO	N_2O	NO_X
Costa Rica	13.3	1.12	1.90	0.0022	0.080
Côte d’Ivoire	1 790.0	119.40	1 119.40	1.7900	7.900
Malawi	2 699.0	226.80	377.90	0.3000	10.700
Mexico	180.0	15.10	25.20	0.0200	0.470
Philippines	1 213.0	101.90	169.80	0.0500	1.930
Senegal	144.6	12.10	20.20	0.0160	0.380
Zambia	640.0	53.80			
Zimbabwe	7.0	0.60	0.98	0.0008	0.018

Table 6: Non-CO_2 GHG emission from biomass burning, 1990 (Gg)

Country	Wood					
	Total carbon (C) released	Emissions				
		CH_4	N_2O	NO_x	CO	NMVOC
Brazil		38.6	0.18	114.2	9 219	
Chile		26.7	0.45	11.25		53.08
Costa Rica	136.4	2.2	0.022	0.81	19.9	
Côte d'Ivoire	1 941.4	5.4	0.143	2.59	214.3	
Fiji	76.7	1.2	0.008	0.3	10.7	
Gambia	156.2	2.5	0.017	0.62	21.87	
Kazakhstan	63	1.1	0.007	0.25	8.82	
Kiribati	4.2E-05	0	5E-09	0	6E-06	
Malawi	2 872					
Morocco	2 885	38.5	0.31	7.48	404	
Nepal		64.8	0.45	16.1		
Nigeria		360.5[a]	2.6[a]	93[a]	3 274.8[a]	
Pakistan	11 419	182.7	1.26	45.4	1 599	
Philippines	6 668	106.7	0.29	10.6	933.5	
Senegal	700	11.2	0.077	1.82	98	
Uganda	4 603	73.65	0.506	11.936	644.4	
Zambia	2 792	44.7	0.43		547.2	
Zimbabwe	3 881	62.1	0.43	10.06	543.4	

a Total, not only from wood

Table 6 (continued)

Country	Charcoal					
	Total carbon (C) released	Emissions				
		CH_4	N_2O	NO_x	CO	NMVOC
Brazil		0.232	0.006	125.8	114.3	
Costa Rica	4.96	0.009	0.0008	0.029	0.7	
Côte d'Ivoire	399.90	1.6	0.034	0.62	112.9	
Malawi	587.20					
Morocco	184.00	0.35	0.02	0.47	25.7	
Pakistan	132.00	2.99	0.015	0.612	18.5	
Philippines	1 009.00	1.88			141.2	
Senegal	235.50	0.44	-	-	32.96	
Uganda	215.00	0.401			30.1	
Zambia	475.90	0.9				
Zimbabwe	0.77	0.001			0.11	

Table 6 (continued)

Country	Other[b]					
	Total carbon (C) released	Emissions				
		CH_4	N_2O	NO_x	CO	NMVOC
Brazil		24.7		55.143	306.2	61.2
Pakistan	3 952	89.57	0.65	27.49	553.3	
Senegal	49.229	0.328	0.008	0.191	6.892	

b For Brazil, ethanol = 291.4 Gg CO; 24.5 Gg CH_4 ; 6.5 Gg NO_x; 61.2 Gg NMVOC; for Pakistan figures refer to dung; for Senegal figures refer to peanut coke.

Table 6 (continued)

Country	Total carbon (C) released	Bagasse and agricultural wastes				
		Emissions				
		CH_4	N_2O	NO_x	CO	NMVOC
Brazil		0.426		45.7	964	
Chile		1.06	0.14	3.53		1.767
Costa Rica	149.8	1	0.025	0.89	21	
Côte d'Ivoire	304.3	0.93	31.96	0.78	3.69	
Fiji[c]	178	1.9	0.02	0.71	24.9	
Kazakhstan	804	5.36	0.09	3.2	112.6	
Malawi	240.7	1.6	0.05	1.81	33.7	
Nepal		20.1	0.15	5.37		
Pakistan	5 619	76.8	0.79	33.4	786.7	
Philippines	669	4.46	0.1	3.46	93.7	
Senegal	119.7	0.8	0.02	0.47	16.8	

c Figures refer to bagasse and agriculture wastes (copra)

F. Uncertainties

31. It was not possible for countries to estimate uncertainties according to the IPCC Guidelines. However, some studies provided useful indications of the margins of uncertainty of GHG emission estimates for different subsectors. Uncertainties reported, which were generally lower for CO_2 emissions from fuel combustion, were as follows:

(a) In the Seychelles, 1 to 3% in the power generation, roads and aviation subsectors, compared to 50% in the fishing, industry and commercial/institutional subsectors;

(b) From -0.5% to + 2% in China's overall emissions;

(c) Less than 5% in Zimbabwe's overall emissions;

(d) 9 to 12% in Mexico's overall emissions;

(e) 20% in the Fiji and Uganda overall emissions;

(f) In Kazakhstan, 5%, 17% and 20% in the power generation, transport and industry subsectors, respectively.

Higher figures were reported for the uncertainty margins in the estimate of non-CO_2 emissions:

(a) From -25% to +19% for methane emissions in China;

(b) 60% for methane emissions in Mexico;

(c) In Kazakhstan, 41% for NO_x emissions and 66% for CO emissions.

V. EMISSION FACTORS

32. Besides uncertainties in activity data, many studies indicated that the use of IPCC default emission factors was another main source of uncertainty in national GHG emission estimates. Twenty of the GHG reports considered in this part of the paper were also included in a review of specific emission factors which provided some recommendations on potential application of these emission factors developed by country study teams in other countries, regions and ecosystems (Lammers et al., 1997). The following brief discussion highlights some key issues about GHG emission factors relevant to the developing countries.

A. Use of gross calorific values

33. Most of the studies reviewed used energy data from national sources expressed in terms of gross calorific value (GCV). However, the IPCC default emission factors are expressed in kilograms or tons of GHG per unit of energy in terms of the net calorific value (NCV) of the fuels. The difference between the NCV and the GCV of a fuel is the heat of condensation of moisture in the fuel during combustion, which is excluded in the calculation of the NCV. The IPCC Revised 1996 Guidelines provide default NCVs for many countries. When NCVs are not available for a given country, it is suggested that the NCV of another country that uses similar fuels could be adopted. For example, the Gambia used the NCV of heavy fuel available in Senegal. In most cases, however, the studies used the suggested approximation procedure proposed in the IPCC 1995 Guidelines: to correct data based on GCV by a factor of 0.90 for gaseous fuels and 0.95 for solid and liquid fuels. Both procedures are unsatisfactory and may cause inaccuracies as the relationship between GCV and NCV is heavily dependent on the water and hydrogen contents of the fuels, which vary with different national conditions. A few countries (e.g. Argentina, China, Kazakhstan and Morocco) were able to use the NCV from national data sources. It is desirable that other countries embarking on these studies should adopt this procedure.

B. Need for specific emission factors

34. The IPCC default values of GHG emission factors for various fuel types were extensively used by developing countries, since there were no suitable regional or local emission factors (see table 7). However there were several fuels with different end-uses in developing countries for which the default values of GHG emission factors provided in the IPCC 1995 Guidelines were found to be inappropriate. The absence or inadequacy of IPCC default emission factors for the following energy sector activities were highlighted in the reviewed studies:

(a) Kerosene and other fuels used for lighting;

(b) Tars from charcoal production;

(c) Cars running on ethanol or gasohol (blend of gasoline with up to 25% of ethanol);

(d) City gas produced from a mix of different sources (coal, naphtha, natural gas);

(e) Biomass fuels: wood and charcoal, but also agricultural wastes, rice hulls, coconut shells, sugarcane bagasse, among others;

(f) Black liquor and other residues from pulp and paper production;

(g) Different coal types with high ash and sulphur contents;

(h) Power generation plants, given the specific design, maintenance, operating conditions and different fuels used in developing countries, and especially in the case of autoproducers;

(i) Hydropower plants with large reservoirs (CO_2 emissions have to be accounted for in the land-use change and forestry sector, but methane emissions are particularly relevant).

35. The absence of appropriate emission factors is more problematic for non-CO_2 greenhouse gases, especially N_2O and NMVOCs, and particularly for biomass fuels. In the case of methane fugitive emissions from oil and gas activities, the range of emission factors used in developing countries (categories “other oil-exporting countries” and “the rest of the world” in the IPCC Guidelines) is extremely wide. Thus any studies to estimate local emission factors could be very useful in establishing the kind of situations associated with low, medium and high values. The same applies in the case of coal waste piles from underground and surface mines.

Table 7: Emission factors of various fuel types used by countries for the estimation of CO_2 emissions in the energy sector (tonnes of carbon/terajoule)

Country	Crude oil	Natural gas liquids	Gasoline	Jet kerosene	Other kerosene	Gas / diesel oil	Residual fuel oil	LPG	Ethane
IPCC default (d)	20.0	17.2	18.9	19.5	19.6	20.2	21.1	17.2	16.8
Bangladesh		20		d	d	d		d	
Bolivia	d	15.2	d	d		d		d	
Brazil	d	d	d	d	d	d	d	d	
Chile	d		d	d	d	d	d	d	
China									
Costa Rica	d		d	d	d	d	d	d	
Côte d'Ivoire	d	17.35	19.55, 19.61	19.6	d		20.59 - 21.43	18.55	
Ecuador	d	d	d	d	d	d	d	d	
Fiji			d	d	d	d	d	d	
Gambia			d	19.6	d	d	d	d	
Kazakhstan			d	d	d	d	d	d	
Kiribati			d	d	d	d		d	
Malawi			d	d	d	d			
Mexico	d	d	d		d	d	d	20.2	
Morocco	d	d	d	d		d	d		
Nigeria		d	d	d	d	d	d		
Pakistan	20.36	d	18.956	20.02	20.02	21.21	d		
Peru	d		d		d	d	d	d	
Philippines	d		d	d	d	d	d	d	d
Senegal	d		d	d	d	d	d	d	
Seychelles			d	d	d	d	d	d	
Uganda			d	d	d	d	d	d	
Tanzania	d		d	d	d	d	d	d	
Venezuela	d	16.2	d	d	d	d	d	d	
Zambia	d		d	d	d	d	d	d	
Zimbabwe			d	d	d	d		d	

Table 7 (continued)

Country	Naphtha	Bitumen	Lubricants	Petroleum coke	Refinery feedstocks	Other oil	Anthracite	Coking coal	Other bit. coal
IPCC default	20.0	22.0	20.0	27.5	20.0	20.0	26.8	25.8	25.8
Bangladesh		d	d			d	d	d	
Bolivia		d	d			d	d		d
Brazil	d	d	d	d		d		d	d
Chile	d				d			d	d
China							26.35		24.26
Costa Rica	d	d				d			
Côte d'Ivoire		d			20, 21.09	21.43			
Ecuador		d	d						
Fiji		d	d			d			d
Gambia									
Kazakhstan									
Kiribati		d	d						
Malawi									
Mexico								d	
Morocco	d	d	d			d			
Nigeria	d	d	d		d	d		27.21	
Pakistan	d	d	d			d		d	
Peru			d					d	
Philippines	d	d	d			d			
Senegal									
Seychelles									
Uganda						d			
Tanzania		d	d						
Venezuela	d	d	d	27.6		d		26.8	
Zambia		d							
Zimbabwe		d						d	d

Table 7 (continued)

Country	Sub-bit. coal	Lignite	Peat	Coke oven/ gas coke	Solid biomass	Liquid biomass	Gas biomass	Other
IPCC default	26.2	27.6	28.9	29.5	29.9	20.0	30.6	
Bangladesh				d				
Bolivia		d	d	d	d			
Brazil				27.5	d	d		Tar 25.8, refinery gas 15.3
Chile	d			d	d		d	City gas 26.8, blast furnace gas 66
China		24.08		24.26				
Costa Rica	d			d	d	d		
Côte d'Ivoire								
Ecuador								
Fiji					d			
Gambia					d			
Kazakhstan		27.1		d				
Kiribati								
Malawi	d				d			
Mexico					d			Solid secondary fossil fuels 29.5
Morocco					25.8	d		Paraffin 20
Nigeria	d				d			
Pakistan		24.97						
Peru				d				Refinery gas 18.2
Philippines	d				d			
Senegal					d			
Seychelles								
Uganda								
Tanzania	d				d			Animal dung 30.0, agricultural waste 30.0
Venezuela				d	d			
Zambia	d							LSG 20.0
Zimbabwe				d				Avgas 20.3

C. Emission factors for charcoal production

36. In addition to the shortcomings of the IPCC 1995 Guidelines mentioned above, another issue of utmost importance for developing countries is the mass balance of charcoal production from wood and other feedstocks. This heavily influences GHG emission factors (CO_2 emissions are accounted for in the land-use change and forestry sector, but methane emissions are particularly relevant). Several studies reviewed supplied specific transformation ratios different from the default value of 6:1 suggested by the IPCC 1995 Guidelines. A wide range of values was also recorded in different national estimates: Costa Rica (4:1); Zambia (4:1); Brazil (4.1:1); Peru (4.5:1); Sri Lanka (5.2:1; 2.8:1 for charcoal from coconut shells); Uganda (6.6:1); Malawi (7:1); the United Republic of Tanzania (10:1). In terms of energy efficiency of the transformation: Morocco (18%); Côte d'Ivoire (19.3 to 27.6%).

D. Specific approaches

37. Specific field surveys are required to reduce the uncertainty margins of such estimates. A number of studies on the determination of country-specific emission factors were reported by several countries, as follows:

(a) Burning of wood, bagasse, rice hulls, coconut shells (the Philippines);

(b) Wood, charcoal, residues (Côte d'Ivoire);

(c) Charcoal production from coconut shells (Sri Lanka);

(d) Combustion processes in the copper and pulp and paper industry, and sulphur dioxide emissions from the burning of black liquor (Chile);

(e) Non-energy uses: 21 different products (China);

(f) Carbon equilibrium of coal combustion facilities to determine carbon oxidized fractions and emission factors for four coal types (China);

(g) Fugitive emissions, burning of coal waste piles and sulphur emissions from different coal types (Brazil);

(h) Hydropower dams (Brazil);

(i) Mass balances of charcoal and tar production from wood in different types of kilns (Brazil);

(j) Ethanol and gasohol fuelled cars (Brazil).

38. Table 8 summarizes the specific approaches identified in different countries to improve GHG inventories, including the methods used, the collection of activity data and the use of emission factors.

Table 8: Specific approaches to improving national GHG inventories

Approach reported	**Reporting country**
Methods	
Explanation of differences between results from bottom-up and top-down methods	Bolivia, Venezuela
Tiers 2 and 3 methods to calculate fugitive emissions of methane	China, Kazakhstan, Mexico, Tanzania
Calculation of SO_2 emissions	Chile
Activity data	
All GHGs inventoried at detailed data level (20 subsectors)	Chile
CO_2 emissions from the flaring of natural gas	Bolivia, Venezuela
Surveys of biomass fuel consumption in urban households, cottage industries and the informal sector	Tanzania
Emission factors	
Net calorific values from national data sources	Argentina, Morocco, China, Kazakhstan
Burning of wood, bagasse, rice hulls, coconut shells	Philippines
Wood, charcoal, residues	Côte d’Ivoire
Charcoal production from coconut shells	Sri Lanka
Combustion processes: copper and pulp and paper industries	Chile
Sulphur dioxide emissions from the burning of black liquor	Chile
Non-energy uses: 21 different products	China
Carbon oxidized fractions/emission factors - four coal types	China
Fugitive emissions, burning of coal waste piles and sulphur emissions from different coal types	Brazil
Field measurements to determine GHG emission factors from hydropower dams	Brazil
Mass balances of charcoal and tar production from wood in different types of kilns	Brazil
Experimental measurements of GHG emission factors for ethanol- and gasohol-fuelled cars	Brazil

VI. CONCLUSIONS

39. There is a need to improve the completeness, accuracy and comparability of GHG inventories in the energy sector, as reported by some developing countries. The review of 42 reports prepared by 36 countries revealed that significant difficulties were encountered in the use of the IPCC Guidelines due to the lack of appropriate and reliable activity data and emission factors. However, a number of successful approaches to improving the quality of GHG inventories were also described. In order to encourage the application of these approaches, targeted efforts aimed at strengthening existing capacities and capabilities in developing countries are recommended. The exchange of experience between developing countries will certainly enhance the quality and comparability of national GHG inventories and also enrich the scope of the IPCC Guidelines.

40. The results of a number of initiatives in compiling GHG inventories for the energy sector being undertaken by various developing countries could be shared with others with similar problems. There is still a great need to improve national GHG inventories in many countries, and this can be met by initiating new studies at the regional and subregional levels. It is, however, suggested that a limited number of carefully chosen countries participate in each study. The choice of the group of countries to be involved in any study would depend on the issue to be covered in each case. Regional or subregional groups of countries with similar sectoral characteristics may like to propose studies to improve the availability of activity data and the development of specific emission factors.

41. Some key issues identified for further studies on activity data include:

(a) Methodological development and data surveys to extend national energy statistics allowing for the detailing of energy end-uses and efficiencies by subsectors, technology, equipment vintage and operating conditions, particularly in the residential, transport and industry sectors. This would allow for the application of the bottom-up method which is supposed to give more accurate results. Regional groups of countries could be formed to participate in such a study, drawing upon the experience of the Latin American Energy Organization (OLADE) in the preparation of energy balances in Latin America;

(b) Studies to collate reliable activity data and determine appropriate emission factors for road transport, including fleet age and operating characteristics. The strategic importance of the transport subsector for GHG inventories, the lack of data and the lack of appropriate emission factors justify such studies. Regional projects with participation of a number of countries may be proposed, building on the experience of the recent Brazilian initiative;

(c) Survey of energy consumption in the residential sector, particularly of biofuels used in rural areas. Given the widespread use of biomass throughout developing countries, this important initiative could be undertaken jointly by regional groups of countries, based on the experience of the recent Tanzanian study in urban households, cottage industries and the informal sector.

42. Key issues identified for further study on the estimate of specific emission factors include:

(a) Determination of carbon oxidized fractions and emission factors (including fugitive and sulphur emissions) for different coal types. The high carbon content of coal deserves special attention. A group of important coal-producing countries could jointly undertake this initiative based on the experience of the recent Chinese study;

(b) Methodological development and determination of appropriate emission factors for the calculation of fugitive emissions of methane and CO_2 from oil and gas activities. The strategic importance of the oil and gas subsector and the high global warming potential of methane justify a sustained effort in this regard. A group of important oil and gas-producing countries could collectively undertake this initiative based on the experience reported by Bolivia and Venezuela;

(c) Calculation of GHG emission factors in the use of biofuels and particularly of mass balances in charcoal production from different biomass feedstocks (wood and agricultural wastes) for several types of kilns and operating conditions. The key role of charcoal in the residential, commercial and industrial subsectors and the widely different conditions of its production deserve careful examination by a group of developing countries with significant consumption levels.

VII. RECOMMENDATIONS

43. Some targeted actions to address the key issues listed above can be undertaken by developing country institutions supported by existing international programmes, including the following activities as short-term priorities:

(a) Dissemination of information (compilation and provision of access to existing data and documentation, through the establishment of web sites and databases);

(b) Critical review of published and unpublished data (collection and study of the background documentation of GHG inventories, and the organization of technical workshops to discuss the results of these reviews);

(c) Establishing the need for further research efforts and launching of studies to meet these needs. The results of the research can be disseminated through the training courses and workshops.

PART TWO: LAND-USE CHANGE AND FORESTRY SECTOR

I. LITERATURE REVIEWED

44. The GHG inventories, in particular the activity data and emission factors used in the land-use change and forestry sector, of the following reports were reviewed:

(a) Eleven national communications of non-Annex I Parties, namely Armenia, Egypt, Georgia, Jordan, Kazakhstan, Mauritius, Mexico, the Republic of Korea, Senegal, Uruguay and Zimbabwe;[2]

(b) United Nations Environment Programme (UNEP) country case studies on sources and sinks of GHGs in Costa Rica, the Gambia, Mexico, Morocco, Uganda, the United Republic of Tanzania and Venezuela;

(c) United States Country Studies Programs in Bangladesh, Bolivia, Fiji, Malawi, Nigeria, Peru and Zambia;

(d) GHG inventories prepared by Indonesia, Pakistan and the Seychelles.

II. EMISSION ESTIMATES

45. Except Jordan, which used the IPCC Revised 1996 Guidelines, all other initial national communications reviewed used the IPCC 1995 Guidelines to estimate emissions from the land-use change and forestry sector. The only major difference between the two guidelines is with respect to worksheet 5.5 dealing with CO_2 emissions from soils.

A. Changes in forest and other woody biomass stock

46. The activity data for this worksheet relate to changes in carbon stock in the existing plantations and managed forests due to commercial management, harvest and establishment of plantations. The changes in biomass stocks due to these activities, without involving land-use change, are estimated. The key activity data include: area of forests and plantations, annual growth rate, commercial harvest, fuelwood consumed and other wood use. Carbon emission or removal is estimated by multiplying these changes in biomass stock by the emission factor (carbon fraction of biomass), as given in the methodology described in paragraph 6 above. The results from the reviewed national communications and country studies are summarized in table 9.

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[2] The Federated States of Micronesia are not included as the forest sector GHG inventory is not given. Argentina is also not included, as the English version of the communication is not available.

Table 9: CO_2 emissions in the land-use change and forestry sector (Mt)

Country	Changes in forest and other woody biomass (WS 5.1)	Forest and grassland conversion (WS 5.2)	Trace gases (CO_2 equiv.) (WS 5.3)	Abandonment of managed lands (WS 5.4)	Agriculturally impacted soils	Net CO_2 emissions
NATIONAL COMMUNICATIONS						
Armenia	-0.62	n.d.	n.d.	n.d.	n.d.	-0.62
Egypt	-9.90	n.d.	n.d.	n.d.	n.d.	-9.90
Georgia						0.033
Jordan	-0.28	0.37	2.45	0.83	2.84	6.22
Kazakhstan	-4.62	0.61	27.70		n.d.	23.69
Mauritius	0.22	n.d.	n.d.	n.d.	n.d.	0.22
Mexico	-31.55	217.73	6224.50	-50.32	n.d.	6360.36
Republic of Korea	-26.23	0.00	n.d.	n.d.	n.d.	-26.23
Senegal	-25.82	19.24	667.80	n.d.	n.d.	661.22
Uruguay						1.97
Zimbabwe	-64.76	2.50	0.02	n.d.	n.d.	-62.24
OTHER STUDIES						
Bangladesh	-25.15	n.d.	n.d.	n.d.	n.d.	-25.15
Bolivia	-0.46	0.05	55.68	3.06	n.d.	58.33
Costa Rica	-0.88	3.31	0.27	0.31	n.d.	3.01
Fiji	-0.51	1.35	0.88	0.05	n.d.	1.77
Gambia	-0.09	1.63	0.45	0.03	n.d.	2.02
Indonesia	-548.54	312.60	255.11	14.01	n.d.	33.18
Malawi	13.88	7.32	0.42	1.36	n.d.	22.98
Morocco	3.88	2.30	0.14	1.44	n.d.	7.76
Nigeria	55.38	53.12	9.00	0.52	n.d.	118.02
Pakistan	36.29	n.d.	n.d.	n.d.	n.d.	36.29
Peru	-0.33	130.00	10.19	11.77	n.d.	151.63
Philippines	-48.65	120.03	16.59	0.91	n.d.	88.88
Seychelles	-0.83	n.d.	n.d.	n.d.	n.d.	-0.83
Tanzania	54.12	0.73	0.64	0.09	n.d.	55.58
Uganda	4.96	10.39	0.88	0.05	n.d.	16.28
Venezuela	-5.50	85.99	76.41	4.46	n.d.	161.36
Zambia	4.34	141.87	75.79	6.34	n.d.	228.34

Notes:
The CO_2 equivalent of trace gases are calculated based on GWP for methane = 24.5 and nitrous oxide = 320.
n.d. = not determined
For Georgia and Uruguay, only the net emissions are given

B. Carbon emissions due to forest grassland conversion

47. The carbon emissions due to conversion of forests and grasslands to pasture, crop land or other managed uses are also estimated. The key activity data include: area converted annually, biomass before and after conversion, fraction of biomass burned *on-site* and *off-site*. In particular, carbon emission from decay is calculated using the activity data on average area converted and fraction of biomass left for decay and multiplying by the emission factor (carbon fraction of biomass). Of the 11 national communications and the17 country studies reviewed, only 5 and 14, respectively, estimated the emissions due to forest and grassland conversion (see table 9). Those which failed to do so cited as reasons:

(a) Forest conversion has not been assumed, due to the government ban on deforestation;

(b) Non-availability of data on the rate of conversion; and

(c) Forest and grassland conversion is insignificant.

C. Emissions of non-CO_2 trace gases from *on-site* burning of forests

48. Burning of biomass is a significant source of CH_4, N_2O, CO and NO_x. CH_4 and CO emissions are estimated as ratios to carbon fluxes emitted during biomass burning. Total nitrogen is estimated based on the nitrogen-carbon ratio. N_2O and NO_x are estimated as ratios to total nitrogen. The non-CO_2 gases are estimated based on the carbon emission estimated from biomass burning using several emission factors such as the ratios of N to C, C to CH_4, C to CO, total N to N_2O and total N to NO_x. Only five national communications presented non-CO_2 gas estimates. Among the country study reports, Bangladesh, Pakistan and the Seychelles did not estimate non-CO_2 trace gas emissions from *on-site* biomass burning.

D. Carbon uptake from abandonment of managed lands

49. If managed lands (e.g., crop lands and pastures) are abandoned, carbon will re-accumulate in the vegetation and soil. The carbon uptake from abandoned land over more than 20 years can be estimated by multiplying the activity data of the total area abandoned, the activity data of the annual above-ground biomass growth rate and the carbon fraction in biomass. Except for the national communications from Jordan and Mexico, others did not report the carbon uptake from abandoned land, while only three country studies failed to do so. The reasons include the absence of activity data. In some countries, abandonment of land is not a common practice due to government policy or due to high land-use pressure.

III. ACTIVITY DATA

50. Activity data, including their sources, the methods and assumptions used to derive them, are reviewed based on the available data in the literature (one national communication and 15 country studies), as summarized in tables 10 to 13.

A. Sources of data, methods and assumptions used

51. **Use of country-specific data:** The main sources of the activity data used in emission inventories are: published and unpublished literature, forest inventories, field measurements, satellite assessments, and the default values from the IPCC Guidelines (table 10). Where data are not available, expert judgement has been used. Some experts have used multiple sources of information for the same activity data, such as the annual growth rate.

(a) **Area under forests and plantations and forest and grassland area converted annually:** Table 11 lists the methods adopted and assumptions made in estimating the area under vegetation types and area converted annually. Of all the national communications reviewed, only that of Zimbabwe provided the source of data on forest types and area, which was the Forestry Commission. The inventory experts utilized the data on area of plantations and managed forests currently available from state authorities such as the Ministry of Natural Resources or the environment or forest departments. The forestry sector master plan and forest action plan initiated by the Forest Department is the source of data for Bangladesh and Zambia. The United Republic of Tanzania, Costa Rica and Morocco inventories relied on published data. Nigeria used the IPCC default values. Malawi and Uganda used multiple sources of data. All the developing countries (except Malawi and Nigeria) considered more elaborate vegetation types than the standard forest or plantation categories given in the default tables of the IPCC Guidelines. The Gambia, Peru and Venezuela used data obtained from the forest inventory and satellite assessments.

The data on areas under vegetation types according to plantation species, such as eucalyptus and teak, and forest types such as moist, seasonal and dry forests, are required for the IPCC methodology. The related activity data concern the forest area converted according to the forest type. Of the country reports reviewed, 15 sought national or regional forest-specific data. Experts adopted different approaches and made differing assumptions for different vegetation types.

(b) **Annual growth rate of biomass:** The sources, methods and assumptions used for obtaining the annual growth rate of biomass from the literature reviewed are summarized in table 12. Zimbabwe largely relied on the published literature.

(i) **Default values:** Default values were used by Costa Rica, Nigeria, the Philippines (for natural forests), Uganda and Zambia. The Philippines used the IPCC default value for hardwoods and softwoods for the dipterocarp (managed) forest category. Nigeria and the Seychelles used the default values for growth rate in abandoned land for regenerating forests.

(ii) **Expert judgement:** This approach was adopted by Bangladesh, Costa Rica and the Philippines.

(iii) **Literature data:** Country experts from Costa Rica, Malawi, Pakistan, Peru, the United Republic of Tanzania and Venezuela obtained data on growth rates of biomass from published and unpublished literature for some of the forest and plantation categories.

(iv) **Other methods:** The Gambia used values from the GHG inventory of Senegal. Growth rates for some categories were estimated using the commercial harvest data by some experts.

(c) **Biomass fraction burned *on-site:*** This fraction is needed to calculate the immediate carbon release from biomass burning. The national communication of Zimbabwe reports that 80% of biomass is assumed to be left for *on-site* burning during conversion to crop land. In the absence of measured data, 7 out of 17 countries used expert judgement (table 13). The fraction burned *on-site* is assumed to be 20% in the United Republic of Tanzania (assuming 75% is collected as fuelwood). In Costa Rica, the fraction is back-calculated after deducting the commercial harvest, biomass left for decay and *off-site* burning. Malawi assumed 10% of biomass burned *on-site* (reasons not given). In the Philippines, the fraction is derived after consultation with the Forest Department. In Fiji and Nigeria, the estimated fraction of biomass burned *on-site* varies from region to region depending on forest type. For inventory purposes, Fiji took the average for different regions.

(d) **Fraction of biomass burned *off-site*:** Estimates of the fraction of biomass burned *off-site* are also largely based on expert judgement (table 13). In the United Republic of Tanzania, only broadleaf-logged forests are assumed to be converted to agriculture and 75% of the cleared wood is assumed to be removed and burned *off-site* as fuel. In Fiji, the estimates are assumed to vary with forest types and forest-dependent communities, but for inventory purposes, the average of different regions is considered. In the Philippines, the fraction is derived after consultation with forestry experts. In the United Republic of Tanzania and Malawi, the estimated biomass burned *off-site* is based on fuelwood use coming from forest clearings. Uganda based the data on per capita consumption of fuelwood, obtained from a national survey. The Gambia derived the fraction after accounting for other end-uses.

(e) **Fraction of biomass left to decay:** This is required in order to estimate delayed emissions, occurring over a longer period (of 10 years), from debris left behind on the forest floor. Expert judgement is used in deciding the fraction of above-ground biomass left behind (table 13). The United Republic of Tanzania and Costa Rica assumed the extent of non-commercial biomass (foliage, twigs and branches) left on the forest floor to decay. Fiji based its estimate on the forest category and community practices in the different forest types. Experts making the emissions inventory in Malawi, Nigeria and the Philippines based their estimates either on consultations with forest experts, or on their own judgement.

(f) **Commercial harvests:** Commercial harvest from plantations and managed forests is used to estimate carbon emissions from changes in forest biomass stock. Forest departments and the FAO report the production and use of different categories of wood (sawnwood, industrial wood and fuelwood). The IPCC Guidelines refer to the FAO data source. Costa Rica supplemented the Forest Department data (for authorized felling) by expert judgement on unauthorized felling. Data on commercial felling given by the Forest Department or the FAO could be an underestimate, as they do not account for unrecorded logging. Fiji, Peru, the Seychelles, and Zambia used the data from Forest Department or ministry sources (table 13). Other sources of data are household surveys (Bangladesh); extrapolations from per capita wood use (Pakistan and Uganda); commercial harvest data for poles in plantations, charcoal and fuelwood from woodlands (Zambia); national inventories (Venezuela); and published data (the United Republic of Tanzania). Data used by the Philippines were obtained from the FAO and UNDP studies. Nigeria considered only fuelwood in its estimation.

(g) **Above-ground biomass (biomass before conversion):** Zimbabwe took the mean above-ground biomass density of woodlands and shrub lands in southern Africa. The IPCC gives default values for different forest types for 30 countries. These were used by Fiji, Malawi, Nigeria and the Philippines, while the Gambia used forest inventory data (table 10). Country studies used published and unpublished data. The assumptions vary for forest types, both within a country and among the countries. Countries such as Peru and Zambia did not explain the source or the method of obtaining the data. The vegetation categories used in the IPCC default values table are different from the vegetation categories used by the countries except for the Gambia and the Philippines. This indicates that experts attempted to use their own national data.

(h) **Biomass after conversion:** Data on biomass left on the field after conversion to permanent agriculture and pasture is rarely measured and reported in the literature. The IPCC default value of 10 t/ha is used in seven country reports. Costa Rica used a value of 20 t/ha assuming that 15-20 trees are left in the field to provide shade for grazing animals. The United Republic of Tanzania used a value according to vegetation type and its end-use after conversion (based on the literature).

(i) **Soil carbon density:** Emissions or removals of carbon from soils are considered differently in the IPCC 1995 and the Revised 1996 Guidelines. According to the IPCC 1995 Guidelines, soil carbon density and the fraction of carbon released is required for estimating the total carbon released due to forest and grassland conversion. Of all national communications, only that from Jordan analysed carbon emissions from agriculturally impacted soils, though the details of data are not given in the report. Of the country studies reviewed, ten estimated soil carbon emissions due to forest and grassland conversion. Five countries used the IPCC default values. Published data are extrapolated and used by Fiji, Malawi, the Philippines and the United Republic of Tanzania. Uganda extrapolated the average soil carbon content for different forest types, based on laboratory experiments conducted on six soil samples. However, all the countries take the fraction of C released over 25 years uniformly as 0.5. The annual carbon (C) uptake used is in the range of 0.4 to 1.3 t/ha/year. Many countries may not have estimated the carbon release or uptake from soil due to lack of data.

B. Use of IPCC defaults for activity data

52. The IPCC Guidelines give a set of default values to assist countries in making a tier 1 or initial estimate of the GHG emissions, if the forest type or region or country-specific activity data or emission factors are not available or accessible. The focus of the present review is on the approaches, methods and assumptions used for activity data and emission factors and not directly on the actual data and their accuracy or reliability. However, some preliminary observations on the actual values used in the worksheets for making the emissions inventory are summarized in this section.

(a) *Area of forest and rate of forest conversion according to forest type:* The activity data required include rate of forest conversion for the reference year and the average for the previous 10 years. Experts in the majority of countries did not entirely rely on the default values given in the guidelines based on FAO data.

(b) *Annual growth rate*: The mean growth rates over the expected lifetimes are given in the IPCC Guidelines for the dominant tropical plantation species, mixed hardwoods and softwoods. Experts in 10 countries relied on the IPCC default values. The majority of countries used default values in the range of 6.8 to 14.5 t/ha/year.

(c) *Biomass before conversion (dry matter in above-ground biomass):* The IPCC 1995 Guidelines give above-ground biomass, according to major forest types, for 30 tropical countries. A range of values is given only for Myanmar, Panama, the Philippines and Sri Lanka. Above-ground biomass default values were used by experts in four countries. In the other countries, experts used different vegetation classifications and more detailed categories than given by the IPCC. This means that a more detailed country-specific categorization of forest and plantation types is often available at the national level.

(d) *Above-ground biomass growth:* Default values are given for broad forest types at the continental level for periods of both less than and more than 20 years. Experts assumed that the forests are subjected to management (extraction) and thus are under succession and accumulating biomass (or carbon). Five national communications and nine country studies did not estimate the carbon uptake in abandoned land.

53. The values for different activity data vary for different vegetation (forest and plantation) types and are likely to be different within and between countries. However, many countries, probably due to lack of data or access to data, used only one value. Some countries did not estimate the emissions in some worksheets (such as worksheets 5.2 and 5.4) probably due to lack of data.

Table 10: Sources of some activity data used for the GHG inventory in the land-use change and forestry sector

Country	Area of forest/plantations	Area converted	Growth rates	Standing biomass
NATIONAL COMMUNICATIONS				
Zimbabwe	Forestry Commission estimates	WWF	PL	PL
OTHER STUDIES				
Bangladesh	FSMP, Forest Research Institute	Not considered	USCSP (IPCC)	Not considered
Costa Rica	FD, PL	Ministry	IPCC, PL, EJ	PL
Fiji	FD	PL	IPCC	IPCC
Gambia	Forest inventory	EJ, forest inventory, PL	From GHG inventory of Senegal	Forest inventory data
Malawi	FD, PL	PL based on forest inventory, aerial photography, and land-based surveys	Report from agriculture sector	IPCC
Morocco	PL	PL	PL	PL
Nigeria	IPCC	FAO, IPCC	FAO, IPCC	IPCC
Pakistan	FSMP	Not considered	Based on growth formula, PL	Not considered
Peru	FD	Satellite imagery, PL, graphical estimates	PL	Source not given
Philippines	FD	Source not given	IPCC, EJ	IPCC, EJ
Seychelles	EJ	PL	IPCC	Not considered
Tanzania	PL	PL	Ministry, PL, FAP	Ministry, PL
Uganda	PL, Atlas, FD, FAO,	EJ, PL, FAO, Ministry	IPCC	National biomass study, FD
Venezuela	FD	Satellite image, Ministry	Vegetation maps, national forest inventory, PL	Vegetation map, national forest inventory
Zambia	FAP	Forestry management	IPCC	Not given

Notes:
PL = published literature, FD = forest department, FAP = forestry action plan, FSMP = forestry sector master plan, EJ = expert judgement, WWF = World Wide Fund for Nature
English language information not available - Bolivia, Mexico, Senegal and Uruguay
Source of data not available - Armenia, Egypt, Georgia, Jordan, Kazakhstan, Mauritius and the Republic of Korea
Inventory not done - Federated States of Micronesia

Table 11: Sources and features of activity data used in the preparation of GHG inventories of the land-use change and forestry sector

Country	Forest type and conversion rate	Forest area converted	Plantation area	Area of regrowth after abandonment
NATIONAL COMMUNICATIONS				
Zimbabwe	Forestry Commission estimates of national woody cover. Based on local level studies conducted by WWF (1997). Latest figures applied to 1994 (base year).		Forestry Commission estimates of national woody cover.	Not considered.
Egypt	Non-forest trees	Not considered	Non-forest trees	Not considered
OTHER STUDIES				
Bangladesh	Not considered; assumed that due to the Forest Act, forest conversion does not take place	Not considered; assumed that due to the Forest Act, forest conversion does not take place	From forestry master plan 1995, and for non-forest trees from Forest Research Institute, questionnaire survey, 1995	Not considered, as traditional slash-and-burn cultivation is limited
Costa Rica	Only tropical rain forest considered; annual deforestation rate of 1990-1993 considered for base year 1990 (Ministry of Natural Resources).	Only tropical rain forest considered (as deforestation in 1980s and 1990s only in this forest type), (Ministry of Natural Resources).	From Ministry of Natural Resources and published report for the period 1980-1990.	Taken from the land-use change during 1979 and 1990-1991 based on maps of land-use, interpretation of Land-Sat satellite images from 1979 and Land-Sat TM for 1990-1992. Verified with field trips.
Fiji	From annual reports and communication from the Conservator of Forests.	From annual reports and communication from the Conservator of Forests.	Annual report of the Forest Department	No data available.
Gambia	Forest inventory carried out in 1982, based on sampling with prestratification carried out according to stand density based on aerial photography; the number of samples based on hectare-volume and total area of land class use.	Based on expert judgement (2% deforestation) from the Department of Forestry. Only two forest types taken for forest clearing calculations.	Based on forest inventory of 1982.	Not considered - no reasons stated.

Table 11 (continued)

Country	Forest type and conversion rate	Forest area converted	Plantation area	Area of regrowth after abandonment
Malawi	From published reports on land-use inventory and change detection analysis based on satellite images, aerial photography and land-based surveys.	From published reports on land-use inventory and change detection analysis based on satellite images, aerial photography and land-based surveys.	From Forest Department (1993) based on national inventory.	From published literature, based on shifting cultivation practices
Morocco	Data obtained from Direction des Eaux et Forets et de la Conservation des Sols, Ministry of Agriculture	Data obtained from Direction des Eaux et Forets et de la Conservation des Sols, Ministry of Agriculture	The worksheet (changes in woody biomass stock) is modified.	Worksheet abandonment of lands - not considered.
Nigeria	FAO (1993).	FAO (1993).	FAO (1993)	The assumption is that 1% of pasture land in the forest area is regrowing.
Pakistan	Not considered, as forest area is not converted to agriculture or rangelands.	Not considered, as forest area is not converted to agriculture or rangelands.	From Government of Pakistan reports (1992).	Not considered; as per government policy, no forest area abandoned.
Peru	From the satellite assessment for 1985 and 1990.	10 years deforestation - published literature; 25 years deforestation - graphical estimate.	Plantation up to 1990 from forest department statistical analysis	Published data.
Philippines	Source not given; land categorization taken from Philippines forestry sector.	Source not given.	Source not given.	Source not given.
Seychelles	Area vegetated assumed as 90% of the geographic area.	Due to government policies with regard to environmental protection, housing and other developmental priorities, insignificant conversion of forests.	Area vegetated assumed as 90% of the geographic area.	Not considered, as land allocated to agriculture is limited, there is high pressure on land and abandonment of land not a common practice.

Table 11 (continued)

Country	Forest type and conversion rate	Forest area converted	Plantation area	Area of regrowth after abandonment
Tanzania	Based on study of Land-Sat MSS satellite data and forest inventory.	Based on study of atlas maps and the Land-Sat MSS satellite data and forest inventory; also using this information, projections were made as a function of time, population, climate change, land tenure policies, by-laws and other factors. Forest conversion to agriculture is based on a number of assumptions.	From Dept. of Water, Energy and Minerals and Ministry of Lands, Natural Resources and Tourism; biofuel plantations not considered as their harvesting is sustainable	Based on published reports, the cashew farms and sisal estates were abandoned and left to regrow in 1960s and early 1970s.
Uganda	FAO 1990 Forest Assessment.	Annual rate of deforestation (10-year period) - UNEP study, 1988 and FAO 1990 Forest Assessment.	From Forestry Department for plantations and IUCN report for managed forest.	Not considered, as shifting cultivation limited due to high population pressure, and also no data available.
Venezuela	Based on regions; for north-east, north-west - based on multi-temporal analysis of satellite images between 1973 and 1988. No data for the south region and hence not considered.	10- year period - based on agricultural statistics for the area change in open savannas; new cultivated land on savanna based on satellite imagery and geographical information system to estimate savanna burning.	From Venezuelan Forest Service, the area managed by private industries between 1970 and 1990.	Not calculated due to lack of data
Zambia	Zambia Forestry Action Plan (ZFAP) report.	Areas converted to shifting cultivation and permanent cultivation considered and details obtained from ZFAP. Production of charcoal and commercial firewood cutting does not lead to forest clearing as it is done selectively.	Zambia Forestry Action Plan report.	According to forestry experts, no significant land is abandoned.

Notes:
English language version not available - Bolivia, Mexico, Senegal and Uruguay
Source of data not available - Armenia, Egypt, Georgia, Jordan, Kazakhstan, Mauritius and the Republic of Korea
Inventory not done - Federated States of Micronesia

Table 12: Sources and features of annual growth rate of biomass

Country	Sources and features
NATIONAL COMMUNICATIONS	
Zimbabwe	From published literature.
OTHER STUDIES	
Bangladesh	Data not available for the forest types; based on dominant species of the forest, the growth rates assumed uniformly for all trees. For non-forest trees, assumed as 5.5 t/1000 trees. Bamboos not considered due to lack of data.
Costa Rica	Plantations - from IPCC. Tropical rain forest - literature. Natural regeneration - derived by assuming that tropical forest regrows to 70% of its undisturbed biomass in the first 20 years.
Fiji	Plantations considered as mixed hardwoods and IPCC default used.
Gambia	Plantations - from greenhouse gas inventory report of Senegal.
Malawi	Annual growth rates obtained from a study in the agriculture sector.
Morocco	Average taken as 0.63 t dm/ha/yr (derived from published literature and conforming with another study).
Nigeria	Tropical forests, tropical plantations, tropical rain forest, moist deciduous, dry deciduous, very dry, hill and montane; based on FAO (1993) for Nigeria. Estimates of non-forest trees - IPCC default values. For abandoned land regrowth - IPCC default values.
Pakistan	Calculated as twice the growing stock per hectare, divided by rotation of years (using Von Mantel's formula) assuming equal representation of all age classes. The growth in the stock data of different forest types and their growth/ increment figures derived from UNDP/EW/WB (1993).
Peru	Different species are planted, which are largely hardwoods; the annual growth rate of mixed hardwoods taken from published reports of the forest department.
Philippines	For dipterocarp (old growth) - no net uptake or emission. Dipterocarp (residual) - IPCC default for mixed hardwood and softwood. Pine (close and open) - IPCC default and half of closed pine forest. Sub-marginal, mossy, mangrove, bushland, forest plantations, non-forest trees - expert judgement.
Seychelles	Mixed fast growing hardwood - IPCC default values. For 20 abandoned area regrowing - IPCC default of seasonal forest.
Tanzania	For mixed softwoods and mixed fast growing hardwoods plantations - published report. For non-forest trees - eucalyptus is the representative tree. 4.9t/ha/yr considered - Forestry Action Plan 1990/91.
Uganda	Plantations – IPCC default values.
Venezuela	For managed forest - published literature.
Zambia	IPCC default values for eucalyptus and pinus. Other forests - source not given.

Notes:
English language version not available- Bolivia, Mexico, Senegal and Uruguay
Source of data not available - Armenia, Egypt, Georgia, Jordan, Kazakhstan, Mauritius and the Republic of Korea
Inventory not done - Federated States of Micronesia

Table 13: Methodology adopted and assumptions made for some of the activity data by the reporting countries in the preparation of GHG inventories in the land-use change and forestry sector

Country	Features of activity data
	Biomass burned on-site
1. Expert judgement	
Costa Rica	Back-calculated after deducting the commercial harvest, biomass left to decay and *off-site* burning.
Fiji	Based on forest type and community practices.
Malawi	10% assumed.
Nigeria	Varies according to forest type - dry forests - 50% burned and tropical grasslands - 80% burned *on-site*.
Philippines	Forestry experts were consulted.
Seychelles	No *on-site* burning - the waste from forest (either from commercial or forest maintenance activity) is left to rot in the forest.
Tanzania	After fuelwood collection (75%), the remaining biomass is assumed to be burned in fields while 10% of the carbon remains on the ground as charcoal.
Zimbabwe (initial communication)	80% is *on-site* burning and the remainder left on the boundaries of the cleared area during conversion to cultivated area.
	Biomass burned off-site
1. Expert judgement	
Costa Rica	10%; not due to fuelwood, but due to industrial use.
Fiji	Based on forest type and community practices. Dry forests (indigenous people - 35%; Indo-Fijians - 7-%); wet forests (indigenous people - 50% and Indo-Fijians - 40%); mangroves - 90%; in spite of these assumptions, the fraction is adjusted to tally the total biomass from *on-site* burning, *off-site* burning and decay.
Gambia	Back-calculated to arrive at *off-site* burning, while accounting for the total biomass harvested.
Malawi	90%
Nigeria	Dry forests - 50% burned *off-site*, tropical grassland - 20% burned *off-site*
Philippines	Consulted forestry experts.
Tanzania	About 75% of the total cleared biomass is collected as fuelwood; conifer forests not susceptible to conversion to agricultural land; 88% of clearing in broadleaf forests and 12% in unproductive forests.
2. Estimate based on per capita consumption of fuelwood based on a survey	
Uganda	Fuelwood consumption - 0.66 kt dm/1000 persons

Table 13 (continued)

Biomass left to decay	
1. Expert judgement	
Costa Rica	4% of the total biomass as trunks and branches left to decay.
Fiji	Based on forest type and community practices.
Malawi	No reasons specified.
Nigeria	No reasons specified.
Philippines	No reasons specified.
Tanzania	5% of above-ground biomass such as foliage, twigs and humus decay in the field over an average of 10 years.
2. IPCC default	
Zimbabwe (initial communication)	50% of biomass.
Commercial harvest	
1. Forest department	
Bangladesh	Roundwood, fuelwood and other wood harvest data obtained from a questionnaire survey conducted in 1995.
Pakistan	Roundwood is 56% of the total biomass having a minimum diameter of 5 cm over bark. Corrected to account for 44% of the biomass in the form of lops, tops, twigs and branches consumed. Based on per capita consumption of wood and population projections for the period 1993-2018, fuelwood consumption calculated. Is is assumed that 50% is attributed to felling of mature trees and the rest comprises branch wood, twigs, shrubs, lops and tops, etc.
Seychelles	Forest Department of the Division of the Environment.
Uganda	The annual harvest from forest and for fuelwood - per capita consumption x population. The annual harvest is taken only from open forests and assumed to be mainly fuelwoods.
Venezuela	Based on national forestry inventory (literature). Various expansion factors applied for different forest types to account for non-commercial harvest.
Zambia	Commercial harvest for poles in plantations, and charcoal and fuelwood harvest from miombo woodlands.
Biomass burned off-site	
1. Expert judgement	
Costa Rica	Commercial timber extracted only from natural forests and fuelwood from seasonal pruning of shade trees, coffee bushes or garden hedges. Accounted for harvest from timber extraction with Forest Department permit + unauthorized fellings as opined by the experts from timber trade. To avoid double counting, firewood from forest conversion included in forestry sector.
Peru	From yearly report of sawnwood; traditional wood consumption based on national statistics.

Table 13 (continued)

2. Published data	
Fiji	Assumptions of commercial harvest based on data from Department of Energy. Assumptions made regarding the extent of fuelwood gathered, posts and poles from the plantations and natural forest.
Malawi	Amount of wood harvested for fuel calculated from traditional fuelwood consumption estimates from energy sub-module.
Philippines	Data provided by the FAO 1993 and UNDP 1992 for timber, lumber and fuelwood.
Tanzania	Timber harvest from a report (1994). Conversion factor applied to account for non-commercial harvest.
3. Source not given	
Nigeria	No net biomass loss from harvesting of forest products in 1990 (harvest of poles, sawnwood, veneerwood, pulpwood, etc.) has taken place. Reason not specified. Has taken into account only the fuelwood - for *off-site* burning. Spreadsheet not done for commercial harvest.
Standing biomass (before conversion)	
1. Published data	
Costa Rica	Only tropical rainforest considered - published literature.
Pakistan	Growth in the stock data of different forest types derived from UNDP/EW/WB (1993).
Zimbabwe (initial communication)	Took the mean ground biomass density of woodlands and shrublands in southern Africa.
2. From Ministry	
Uganda	Source from national biomass study, forest department (method not given).
Tanzania	From Ministry of Natural Resources and also published literature.
3. Source not given	
Peru	
Senegal	
Zambia	
4. Worksheet not done	
Bangladesh	Due to Forestry Act, which forbids encroachment of forest lands; very little slash-and-burn cultivation; suggests that no significant emissions take place from forest conversion; hence worksheet on forest conversion not considered.
Seychelles	Due to Forestry Act, which forbids encroachment of forest lands; very little slash-and-burn cultivation; suggests that no significant emissions take place from forest conversion; hence worksheet on forest conversion not considered.
5. Multiple source	
Morocco	Based on a study (published literature 1995). From the average annual productivity valued multiplied by 50 (assuming that in the first 50 years, growth takes place), standing biomass calculated. This calculation is comparable with another study (published literature).

Table 13 (continued)

6. IPCC defaults	
Fiji	Default values from Asia, moist forests from the IPCC Guidelines.
Malawi	IPCC defaults.
Nigeria	From tropical forests in Africa.
Philippines	The mid-value of the range for the given forest type as give by the IPCC taken for computation.
7. Forest inventory	
Gambia	Based on inventory data (1982). Prestratification carried out according to stand density, i.e., the forests have been classified according to stock density (published literature). Prestratification carried out with the help of aerial photography.
Venezuela	Two sources: (i) the Venezuelan vegetation map (1980), which subdivides the country's forest area on the basis of height and density characteristics. This information was used to subdivide the annual cleared land proportionally to the area converted by the different forest types by the map; (ii) the national forest inventory provides information on commercial biomass for different types of forest. Various expansion factors were applied to these values (published literature) to account for non-commercial biomass and converted to mass as dry matter.

Notes:
English language versions not available - Bolivia, Mexico, Senegal and Uruguay
Source of data not available - Armenia, Egypt, Georgia, Jordan, Kazakhstan, Mauritius and the Republic of Korea
Inventory not done - Federated States of Micronesia

IV. EMISSION FACTORS

54. In the land-use change and forestry sector, there are very few emission factors compared to the energy and agriculture sectors. The emission factors used in the inventory are carbon fraction of dry matter, biomass conversion/expansion ratio, fraction of biomass oxidized *on-site* and *off-site*, nitrogen-carbon ratio and trace gas emission conversion ratios. Soil carbon related emission factors are base factors, tillage factor, input factor, and annual soil carbon loss rate. In the land-use change and forestry sector, the distinction between activity data and emission factors is not very clear as in the case of the energy and agriculture sectors. The IPCC Guidelines give default values for all the emission factors. Most countries relied largely on the default values for emission factors in estimating the GHG emissions. Emission factors like carbon fraction of biomass, trace gas conversion ratio and nitrogen-carbon ratio for forest categories are unlikely to vary from location to location for a given forest type or a plantation species. Information is not yet available on the extent of use of default values for soil carbon related emissions in the national communications. The default values given in the IPCC Guidelines need to be improved to make them forest type-specific. The emission factors need not be developed for each country. Emission factors could be developed at regional level for each of the dominant tree species and forest and plantation types.

V. STRATEGY FOR IMPROVING ACTIVITY DATA AND EMISSION FACTORS

55. Accurate and reliable activity data and emission factors are a prerequisite for the preparation of good quality national GHG inventories, which are needed for national planning, including the promotion of national forest conservation and sustainable development. In addition, reporting of activities under Articles 3.3, 3.4, and 6, and potentially Article 12 of the Kyoto Protocol may require full carbon accounting and verifiable changes of carbon stocks during the commitment periods.

56. The short and long-term strategies and activities required to improve the quality of activity data and emission factors and their dissemination, with indicative spatial and time scales are contained in boxes 1 to 5, which are briefly discussed below.

57. The short-term strategy to address these issues includes the generation of forest or plantation type activity data and emission factors within a country and region. Emission factors such as carbon fraction of biomass, nitrogen-carbon ratio, fraction of biomass oxidized *on-site* and *off-site* are unlikely to vary for a given forest type within a country or even a region. Thus, a regional programme could be launched to generate emission factors and these could be evaluated and disseminated through regional workshops.

58. The main goals of the long-term strategy are: (i) to increase the scientific and technical capacity and infrastructure in the countries to undertake research and monitoring for generating vegetation- and location-specific activity data and emission factors; (ii) to build institutions and to enhance the capacity and infrastructure of the existing institutions; and (iii) to internalize the GHG inventory through the process of data collection, validation, publication and use by establishing long-term programmes.

59. The critical programmes necessary for improving the reliability and accuracy of activity data in the long-term include:

(a) ***Monitoring land-use change and forest area through satellite assessments:*** This should involve national and regional level assessment of land cover and deforestation rates, and be accompanied by very detailed ground-based data and the validation of regional satellite data interpretation. It is important to use the forest categories currently recognized in different countries while interpreting, analysing and reporting forest area and changes therein;

(b) ***Forest inventory studies:*** The most reliable activity data, such as annual growth rate of plantations and managed forests, biomass before and after conversion, biomass burned *on-site*, *off-site* and left to decay, annual rate of above-ground biomass growth and soil carbon density, are likely to come from properly sampled and vigorously monitored forest inventory studies;

(c) ***Studies on biomass consumption and extraction from forests:*** Currently, the FAO data on the production and consumption of biomass (fuelwood, sawnwood and industrial wood) are based on statistics supplied largely by the government agencies. Even the nationally available data are often from government sources. As mentioned in some reports, government sources may record only authorized logging or officially recorded extraction. Unauthorized removal of biomass is not included. It may be necessary to conduct national studies on the consumption and demand for commercial wood, fuelwood and other wood, so as to improve the reliability of the estimates of emissions. The ideal approach would be to monitor extraction from different forest and plantation types;

(d) ***Institutional arrangements and capacity enhancement:*** Many developing countries may not have adequate institutional and technical capacity to generate reliable activity data and to produce complete emission inventories. Thus it is necessary to develop appropriate institutions and enhance capacity. Multilateral institutions could supplement national and regional efforts through financial support, coordination, promotion of information sharing, training and capacity enhancement;

(e) ***Networking and information-sharing activities:*** National and regional networking of institutions and experts involved in activity data generation and inventory is needed to share and validate the information generated;

(f) ***Role of multilateral institutions:*** Multilateral institutions such as the GEF, FAO, UNDP, UNEP and the World Bank can play a role in the following:

(i) Facilitating institutional infrastructure development and human technical capacity enhancement for the improvement of activity data and emission factors;
(ii) Organizing training programmes on methodologies for forest inventory and wood consumption surveys, and on the interpretation of satellite imagery;
(iii) Organizing national and regional workshops for the assessment and dissemination of national and regional activity data and emission factors;
(iv) Supporting studies for the development of region-specific default values for activity data and emission factors.

Box 1: Suggested strategy and activities for improving the quality of activity data and emission factors along with spatial and time scales: land-use change

Activity data	Timescale	Level at which data are required	Suggested strategy	Activities for multilateral agencies
1. Forest and plantation area 2. Forest area converted	Annual 10 years average Past 25 years average	Vegetation types within a country	SHORT TERM Compile and provide access to available satellite data and past land-use records LONG TERM Initiate periodic satellite assessment	Training for validation, interpretation and use of satellite data Institutional capacity-building at national and regional level
Total area abandoned and regrowing	Past 20 years > 20 years (past)	Vegetation type within a country level	SHORT TERM Compilation and access to past satellite and land-use data LONG TERM Initiate periodic satellite assessment	Training workshops on interpretation and use of past satellite data Training in methods of compilation of past records Infrastructure and capacity-building

Box 2: Suggested strategy and activities for improving the quality of activity data and emission factors along with spatial and time scales: biomass and growth rates

Activity data	Timescale	Level at which data are required	Suggested strategy	Activities for multilateral agencies
1. Biomass (above-ground) growth rates 2. Biomass before conversion 3. Biomass after conversion	Annual	Vegetation type At regional level in short term	SHORT TERM Compilation of literature and existing forest inventory data by vegetation type Preparing regional default values LONG TERM Initiate forest inventory studies Compilation, review and dissemination	Identify national and regional institutions Support compilation Regional workshop for assessing and sharing data Institutional capacity-building Training on forestry inventory methods Training in analysis Workshop for disseminating data at regional level
4. Annual rate of biomass growth: - in forests and plantations - in abandoned land	Annual < 20 years > 20 years (past)	Different land categories • within country • regional level	SHORT TERM Compilation of existing data Report preparation LONG TERM Forest inventory	Assist in compilation and report preparation Regional workshop for sharing data Institution and capacity-building

Box 3: Suggested strategy and activities for improving the quality of activity data and emission factors along with spatial and time scales: soil carbon

Activity data/ emission factor/ data	Timescale	Level at which data are required	Suggested strategy	Activities for multilateral agencies
Carbon density in soil	Annual	Different land categories: • within country • regional level	SHORT TERM Compilation of existing data Report preparation LONG TERM Include soil C in forest inventory and monitor periodically	Assist in compilation and report preparation Regional workshop for sharing data Institution and capacity-building

Box 4: Suggested strategy and activities for improving the quality of activity data and emission factors along with spatial and time scales: wood use

Activity data	Timescale	Level at which data are required	Suggested strategy	Activities for multilateral agencies
Fraction of biomass burned on-site Fraction of biomass burned off-site Fraction of biomass left to decay Fuelwood use	Annual	Vegetation type: • within country • regional level	SHORT TERM Compilation of literature Report preparation LONG TERM Initiate field studies	Regional workshop to disseminate regional level data on biomass burning and decay Training
Commercial harvest Other wood use	Annual	Country level Rural and urban and province level	SHORT TERM Review and compilation of studies and data LONG TERM Initiate provincial level wood production, extraction and consumption studies	Regional and national workshops to validate, evaluate and share compiled data Training programme on methodologies Institutional capacity-building Periodic workshops

Box 5: Suggested strategy and activities for improving the quality of activity data and emission factors along with spatial and time scales: emission factor

Activity data	Timescale	Level at which data are required	Suggested strategy	Activities for multilateral agencies
Carbon fraction of biomass Nitrogen: carbon ratio Fraction of biomass oxidized	No timescale	Forest types at regional level Country level	SHORT TERM Development of emission factors Compilation and sharing of emission factors	Regional workshop to disseminate emission factors

VI. CONCLUSIONS

60. Based on the above review, it can be concluded that:

(a) The lack of activity data and the lack of or limited access to currently available data in both published and unpublished form (e.g. forest inventory and satellite data assessments at the national, regional or global level) are the two main barriers to making reliable and comparable emissions inventories. Because of these barriers, expert judgement has been used for activity data such as fraction of biomass burned *on-site* and *off-site* and that left for decay, and even for parameters such as growth rates, above-ground biomass and biomass after conversion. Even though national emission inventories in the national communications are supposed to be prepared for 1990 or 1994, activity data pertaining to an earlier period are often extrapolated. Further, activity data are extrapolated from one location or from one forest type or plantation type to another (e.g. for estimating fuelwood use or above-ground biomass or annual growth rates);

(b) Given the limitations of global, continental or biome level default values, only a few countries relied on them. The national experts used IPCC default values only for a few parameters. It is important to note that the national experts preferred to obtain the activity data locally or nationally rather than using the default values. One of the reasons for the low dependence on default values could be the differences between the vegetation types (or forest categories) given in the IPCC Guidelines tables and the actual vegetation categories traditionally used in the countries;

(c) The assumptions made in obtaining activity data vary within a country and between countries for different vegetation types. Thus caution must be exercised while making inter-country comparisons, since the confidence level regarding the activity data is not given in the reports.

61. The uncertainties involved in making GHG emission inventories in the land-use change and forestry sector of some developing countries are not given in their national communications.

Only a few countries annexed the IPCC worksheets to their national communications, so it is difficult to comment on the accuracy of the activity data. Even the information given in the worksheets provided by several country studies is not adequate to assess the accuracy of the data. The main uncertainties are caused by:

(a) Lack of activity data, and lack of or limited access to existing data;

(b) Lack of forest type or region-specific emission factors;

(c) Very broad global, biome or country level default values, often a single value;

(d) Lack of clarity on activity data required (such as fraction of biomass for *on-site* and *off-site* burning, area abandoned for less than and more than 20 years, etc.);

(e) Enormous flexibility in making assumptions (area regenerating for more than 20 years or fraction of biomass for *on-site* or *off-site* burning); and

(f) Ambiguity regarding the definitions of managed and natural forests and lack of data on the status of forest.

VII. RECOMMENDATIONS

62. In order to improve the comprehensiveness of national GHG inventories in developing countries, particularly in the land-use change and forestry sector, there is a need to develop short-term and long-term strategies to improve the quality of activity data and emission factors as described in section XII. These include human resources and institutional capacity-building or strengthening for accessing, interpreting and using satellite imagery, conducting forest inventories, adopting consistent procedures for data collection, conducting national-level studies on biomass consumption or demand, and training in methods of preparing GHG emission inventories based on good practice.

63. National and regional networking of institutions and experts in the same field, and regular forums such as those organized by the UNFCCC secretariat for exchanging experience in the development of emission factors and activity data, are essential activities which will greatly enhance the quality of national GHG inventories.

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