Country Case Study on Sources and Sinks of Greenhouse Gases in Mexico

Final Report

Global Environment Facility

UNEP

SECRETARIA DE MEDIO AMBIENTE, RECURSOS NATURALES Y PESCA

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PREFACE

In accordance with Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC), all Parties are required to develop, periodically update, publish and make available to the Conference of the Parties, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol using comparable methodologies to be agreed upon by the Conference of the Parties.

A methodology for conducting such inventories was developed by the OECD Environment Directorate, the International Energy Agency (IEA), and the IPCC Working Group I Technical Support Unit and was proposed as the standard methodology as required under the Convention.

In order to test and further refine the method, the UNEP Atmosphere Unit, working in collaboration with the UNEP Global Environment Facility (GEF), implemented a series of nine complementary national studies using these "IPCC Guidelines for National Greenhouse Gas Inventories".

This report is one of the nine technical reports resulting from this effort. Based partly on this study and on a series of regional workshops sponsored by UNEP under the GEF funded programme and with the assistance of experts from a number of countries, an improved version of the IPCC Guidelines was prepared and approved at the Tenth Plenary Session of the IPCC in Nairobi (November 1994).

The First Conference of the Parties to the UNFCCC (Berlin, April 1995) also adopted the IPCC methodology as the recommended standard to be employed by all Parties in making their inventories in accordance with Article 4.

It is hoped that this report will assist other country study teams in the development and updating of future inventories of greenhouse gases.

E. Dowdeswell

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Executive Director
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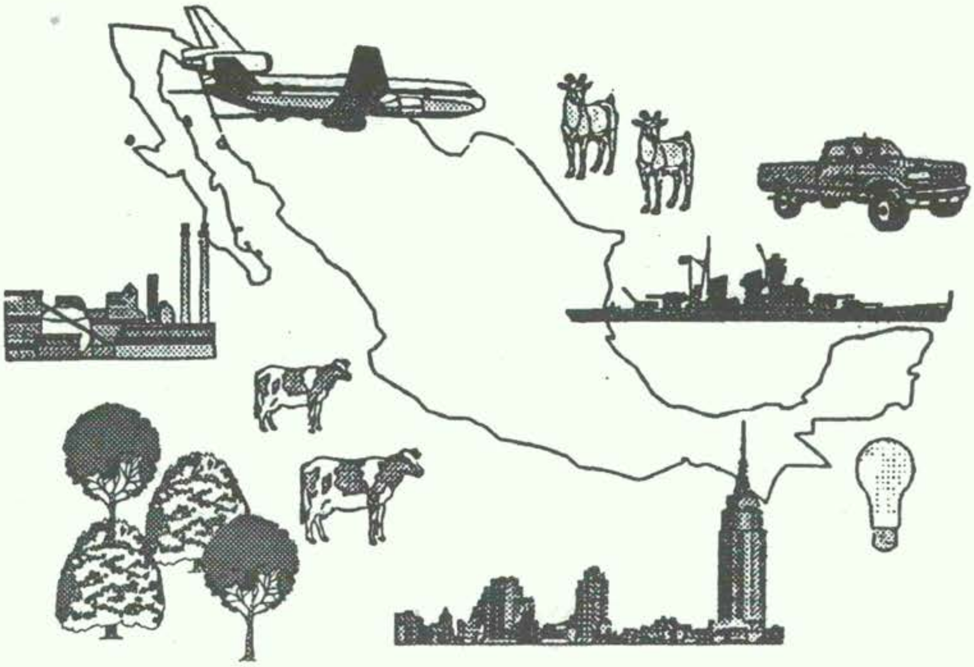
Preliminary National Inventory of Greenhouse Gas: Mexico



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PREFACE

This report is the first comprehensive national green house gas emissions inventory produced in Mexico. It enables the country to rank itself among other nations regarding anthropogenic green house gas emissions. This inventory has been made to fulfill part of Mexico's commitments, among the nations, to mitigate the possible global warming.

In relation to data quality and quality of results, they are the only available today. These calculations are being cross checked by numerous experts, some of them from abroad during project supervision. Also, a preliminary version of this report was circulated among national experts belonging to public, private and academic institutions. Comments, observations and even some errors were pointed. We have welcomed these observations, most of them have been included in this version of the inventory. When needed, replies from the authors of the different sections have been forwarded to whom originated the comment. Therefore, this version is a product upon which there is consensus and can be presented as the National 1990 Inventory of Greehouse Gas Emissions, preliminary version.

The making of the inventory has also involved the participation of graduate students on the different areas relating the different sources. Its natural links to planing of mitigation options and integral environmental management are evident. All this, enables us to state that the benefits of the inventory are far more reaching that the sole fulfillment of an international agreement to report these inventories.

It also represents one success of international cooperation between friendly nations and the support of the United Nations to member countries to build the capabilities needed to face the challenges that a potential global warming pose to humanity.

September 1995.

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Executive Summary

I. Introduction

The mexican effort to produce a Greenhouse Gases Emissions Inventory within the Mexico Country Study is being supported by the United Nations Environmental Programme (UNEP) and the US Country Studies Support Program (CSSP). It is well acknowledged by the Mexican Government, through the National Institute of Ecology (INE), that good and detailed greenhouse gases inventories are an excellent tool for an integral environmental management. The richness of the data collected and organized for the inventories has a potential for utilization that goes well beyond the immediate satisfaction of the commitment assumed by Mexico with the Framework Convention on Climate Change, to produce a National Inventory for the base year of 1990.

The preliminary Greenhouse Gas Inventory within the Country Study has been built trough the cooperative effort of several research institutions under the coordination of INE with the collaboration of the Center for Atmospheric Sciences of the National University (CCA, UNAM). The interest of INE, the other participant national institutions and the National University for producing a detailed inventory was initially supported by the US CSSP and later by UNEP. It was understood that the additional UNEP funding would boost the mexican effort within the Country Study, a major effort funded by the USCSSP involving the development of emission scenarios and vulnerability studies, besides the National Inventory of GHG. It was agreed that UNEP funds would be used to produce an Inventory to Tier 1 of the adopted IPCC methodology halfway the course of the Country Study in order to comply with UNEP'S funding calendar. However some teams have got enough results that have enabled them to reach Tier 2 estimates (using more detailed information, methodologies and emission factors) for some or all of their assignments.

II. Working procedure

Responsibility for coordination of the inventory work was assigned to the National Institute of Ecology with the collaboration of the Center for Atmospheric Sciences (CCA-UNAM), the inventory of emissions of CO_2 by the energy sector and other industrial processes, was in charge of the Electricity Research Institute (IIE), as well as the integration of other parts of the inventory into a mexican software and MINERG. Another group within IIE was assigned the inventory from landfills. The National Institute for Research on Forestry, Agriculture and Livestock (INIFAP) with the support of the Center of Ecology (C E-UNAM) was assigned the responsibility for the calculation of emissions from land use change. The inventory of methane and nitrous oxide from agriculture was also responsibility of CCA-UNAM. Non-energy emissions from the oil industry were resposability of the Mexican Petroleum Institute (IMP).

All teams had to report to IIE to integrate the results into the software and the coordination at CCA responsible of the final report.

III. Greenhouse gas emissions

The gases included in this inventory are Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Nitrogen Oxides (NO_x), Carbon Monoxide (CO) and Non Methane Volatile Organic Compounds (NMVOC's). Table 1 provides the summary of greenhouse gas emissions. The different sources of emissions in the energy sector (Table 2) conform the most important anthropogenic source in Mexico. Emissions come mainly from the use of energy fuel, land use, agriculture and fugitive emissions generated by oil and gas production.

Most of the emissions presented here were calculated using the IPCC Draft Guidelines for National Greenhouse Gas Inventories.

Table 1. Summary report for national greenhouse gas inventories

SOURCE CATEGORIES	CO_2 Emissions BOTTON-UP	CO_2 Emissions TOP-DOWN	(Gg) CH_4	N_2O	NO_x	CO	NMVOC
1. Total National Emissions	398425	433721	5654	9	1822	14292	1047
2. All energy (Fuel Combustion + Fugitive)	275020	310316	1286	3	1790	12588	1047
Fuel Combustion	275020	310316	247	3	1790	12588	1047
Fugitive Fuel Emission			969				
Coal mining			69				
3.Industrial Processes	11621	11621					
4. Agriculture			1889	5.5			
Domestic animals			1853				
Agricultural Soils				5.5			
Rice paddies			35				
5. Land use Ch.& Foresty	111784	111784	195	1	32	1704	
Forest clearing	188479						
Managed forest	-76690						
6. Waste			526				

IV. Carbon dioxide emissions

In 1990 total carbon dioxide emission have been calculated both in a top-down (433.721 Tg) as in a bottom-up (398.425 Tg) fashion. The most important source is the energy sector (275.02 bottom-up; 310.316 top-down).

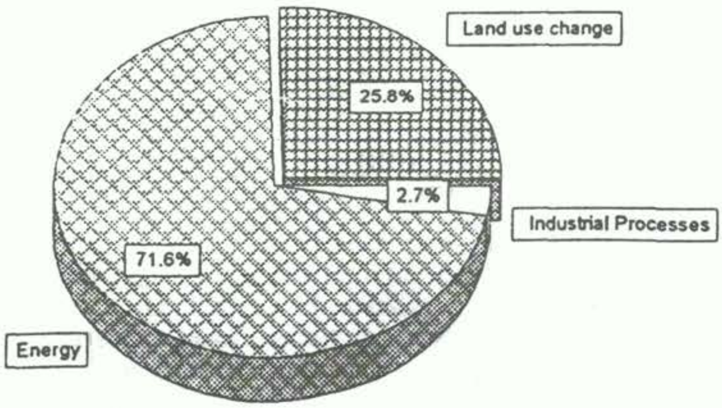

Fig. 1 Carbon dioxide sources.

Other industrial processes and sources of CO_2 such as grassland and agricultural waste burning or agricultural soils shall be included in the next update of the inventory. Nevertheless, at this stage of the national inventory, main sources are evident, therefore, mitigation analysis may be performed on better basis.

Table 2. National greenhouse gas emissions by energy sector

	Greenhouse gas Gg					
Source	CO_2	CO	CH_4	NO_x	N_2O	NMVOCs
Stationary						
-Industry	70730	164	17.1	95.6		
-Residencial/Commercial	42420	5490	22.3	76.2	1.24	
-Electricity Generation	67410	23.9	1.36	185		
Subtotal	180560	5680	25.4	356.8	1.24	
Mobile						
-Particular	48190	5060	216	271	0.620	789
-Urban	10560	270	0.768	12.5	0.132	34.3
-Goods	26160	1550	4.80	204	0.454	218
-Aviation	5600	15.81	0.320	22.0	2.50 E-3	2.88
-Railroad	1970	16.4	0.161	48.3	5.37 E-2	3.49
-Maritime	1980	0.557	6.23 E-2	14.1	1.02 E-2	
-Subtotal	94460	6910	22.3	572	1.27	1047
Total Emissions	275020	12590	24.8	929	2.51	1050

V. Energy

Emissions from the energy sector arise mainly from combustion of fossil fuels. These emissions were calculated using a Tier 1 approach using data from the National Energy Balance. The energy sector is the most important source of the greenhouse gases at a global level. Emmisions of carbon dioxide amount up to 310.316 Tg from the energy sector. Incomplete combustion also gives place to emissions of carbon monoxide, and non-methane hydrocarbons. High temperatures taking place in combustion processes also allow the oxidation of small amounts of nitrogen to nitrogen oxides.

Methane is the most important component of natural gas and consequently any emission during these operations will emit methane directly to the atmosphere. Fugitive emissions from the energy sector are the second most important source of methane in the country; 969.31 Gg were emitted in 1990.

VI. Methane

Methane is a greenhouse gas with (on molecular bases) a twentyfold warming potential larger than carbon dioxide. Agriculture is the largest source of it with a share of 48.49% (1.88 Tg), followed by fugitive emissions from oil industry and small portion from coal mining contribution with a 26.65% (0.969 Tg), waste accounts for the 13.51% (0.551 Tg), fuel contribution adds a 6.31% and finally, land use change adds a 5.00%

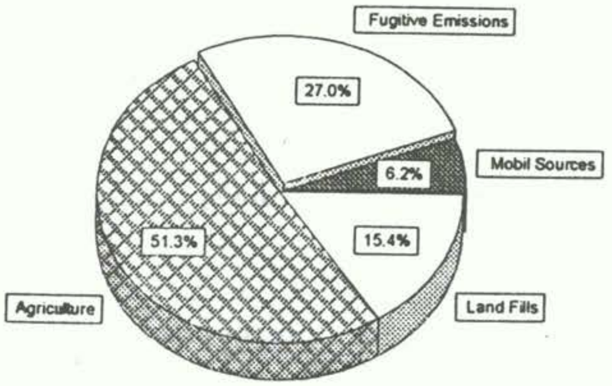

Fig.2 Methane Sources

VII. Agriculture

Greenhouse gas emissions from agriculture (not including energy use) arise mainly from manure and enteric fermentation of livestock (1.85 Tg of methane), specific crops (i.e. 35 Gg of methane from rice paddies), use of fertilizers (5.55 Gg of N_2O) and a family of greenhouse gases from prescribed burn of on site crop refuses. Only methane from livestock and rice paddies and nitrous oxide from use of fertilizers are reported, other gases and sources will be included in the next release of the inventory due in the fall of 1995.

VIII. Land use change and forestry

The study is based on a in-depth review of the existing information on forest cover deforestation rates, areas afforested or currently regrowing as well as on forests' carbon-related biological characteristics. The analysis covers tropical-evergreen forest, deciduous-temperate-coniferous forest, broadleaf-closed forests and open forests.

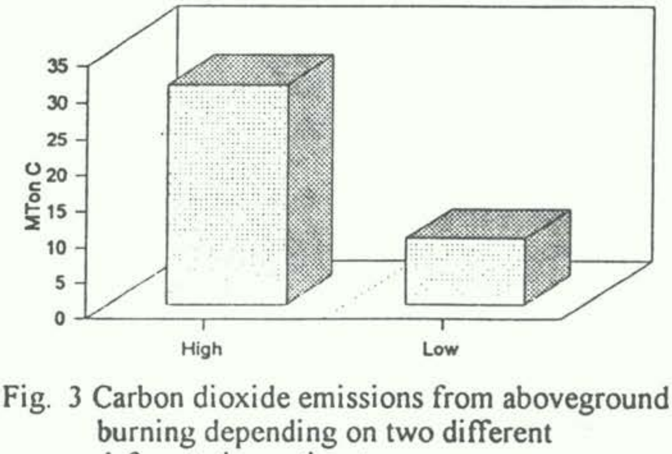

Fig. 3 Carbon dioxide emissions from aboveground burning depending on two different deforestation estimates.

Two estimates, high and low, are derived about greenhouse gas emissions from land use change. The high deforestation rate, implies that 820,000 ha were deforested and affected by forest fires in 1990. The low deforestation is estimated at 370,000 ha/yr.

The analysis indicates that net emissions from forestry and land use changes reach between 9.3 and 30.5 MtonC (figure 3)(million tons of carbon), depending on the assumed deforestation rates.

IX. Landfills

In Mexico landfills contribute with 0.468 Tg which represent the 12.34% of methane emissions in the country. Of these, 41.6% concentrate in the Federal District, the remaining 58.4% is distributed in the rest of the country but again it concentrates in the next major cities (Fig 4).

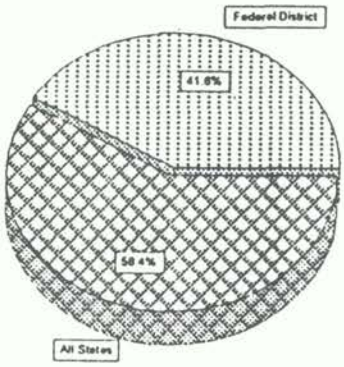

Fig. 4 Methane from landfills

X. Mexico's greenhouse gas emissions in the world context

Mexico ranks among the first 15 countries that emit antropogenic greenhouse gases (BIE, 199X). At the same time, in comparison, among FCCC non-Annex 1 countries, is only outranked by China, India, Brazil and Indonesia.

Table 3. Greenhouse index ranking and percentage share of global emissions: 1987, 1989 and 1991[a]

Country	1987		1989		1991	
	(%)	Rank	(%)	Rank	(%)	Rank
United States	17.6	1	18.4	1	19.1	1
Former Sovient Union	12.0	2	13.5	2	13.6	2
China	6.6	4	8.4	3	9.9	3
Japan	3.9	7	5.6	4	5.1	4
Brazil	10.5	3	3.8	5	4.3	5
Germany	3.9	6	3.6	7	3.8	6
India	3.9	5	3.7	6	3.7	7
United Kingdom	2.7	8	2.4	8	2.4	8
Indonesia	2.4	9	—	—	1.9	9
Italy	—	—	1.8	10	1.7	10
Mexico	—	—	2.0	9	—	—
France	2.1	10	—	—	—	—
Australia	1.1	19	1.1	17	1.1	16

Notes:– Denotes that country did not rank in the top 10 emitters in that year. [a] The greenhouse index includes

CFC emissions which are covered under the Montreal Protocol and are therefore not relevant to the Framework Convention on Climate Change.

Source: Bureau of Industry Economics, Research Report 66, Greenhouse Gas Abatement and Burden Sharing, an analysis of efficiency and equity issues for Australia, Australian Government Publishing Service, Canberra.

In 1990, Mexico contributed with about 2% of global emissions. In regard to carbon dioxide, emited 310.316 Tg (Top-down) or 275.02 (Bottom-up) from the energy sector. In a per capita CO_2 basis, it emited 3.89 tons of CO_2/person. In this category, Mexico outranked the former four countries, it emited more than China, and twice than Brazil (Figures in Table 3). In terms of energy effiency, Mexico is about half than that from industrialized countries, the same as Indonesia and much more than India and China. Brazil's use of bioenergy for transport puts it in a special case.

XI. Pending inventory tasks

Some categories in the inventory such as solvents, some industrial processes and grasslands have not been worked out, most of these shall be included in the next release of the inventory due in the fall of 1995.

1 INTRODUCTION

As part to the Rio Convention on Climate Change, Mexico is committed to report the national greenhouse gas emissions inventory. This report, The National Inventory of Green House Gas Emissions of Mexico, 1990, preliminary version, represents the initial fulfillment of that compromise. It builds up on the Preliminary Green House Gas Inventory for 1988. In doing so, it also represents the commitment of Mexico to update periodically and improve, in depth and quality, the national inventory.

The gases included in this inventory are Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Nitrogen Oxides (NO_x), Carbon Monoxide (CO) and Non Methane Volatile Organic Compounds (NMVOC's). In 1990, total carbon dioxide emissions were 433.721 Tg calculated by top-down procedure, and were 398.425 Tg when calculated by a bottom-up procedure. The differences arise in the energy sector due to changes in the emission factors used in each procedure and to differences in the activities of the different categories which still need to be conciliated. The energy sector is the most important anthropogenic source in Mexico. Its conttibution is 315.75 Tg by top–down or 275.02 by buttom-up procedures. Other important sources are: land use change, which is the second most important source of CO_2 (111.78 Tg), agriculture, which is the largest source of CH_4 (1.89 Tg), and fugitive emissions generated by oil and gas production.

The inventory shows a mixed application of Tier one and two of the IPCC methodologies, and locally developed ones. Degree of detail depended on the availability of data. In some cases such as carbon uptake by abanoned lands, or methane from leaks of natural gas system in the oil industry, great uncertainties still exist due to lack of information. In others, such as in methane from cattle growing, an extensive search of literature has lead to the building of extensive data bases with great potential for other uses. Full design of categories and novel use of data provided by the IPCC Handbooks enabled us to improve in the quality of the inventory. Participation of the National University and public research institutes also enabled us to support their research and to streamline the use of recent research results, as with methane from landfills and deforestation rates. Links between emissions processes were highlighted such as the links between carbon CO_2 from land use change and CH_4 from cattle rising. The making of a national inventory is a permanent task, currently, some categories of sources have not been included, contribution of these to the national totals will be small. In future updates, some missing categories will be integrated and in other cases a more detailed inventory will be produced.

2. ENERGY

R. Muñoz Ledo

The energy sector is the most important source of the greenhouse gases at global as well as at national level. Emissions from the energy sector arise mainly from combustion of fossil fuels and fugitive emissions due to oil and gas production, storage and transport.

Most of these emissions were calculated using a Tier 1 approach using data from the National Energy Balance, although the begining of a bottom-up inventory is also reported. Incomplete combustion also gives place to emissions of carbon monoxide, and non-methane hydrocarbons (OECD, 1991). High temperatures taking place in combustion processes also allow the oxidation of small amounts of nitrogen to give nitrogen oxides.

2A. FUEL COMBUSTION ACTIVITIES

Carbon dioxide emissions from the energy sector related to combustion processes were calculated using top/down and bottom/up procedures following 1994 IPPC methodologies. Emissions from other greenhouse gases were calculated using bottom/up procedures following the corresponding IPPC methodologies (1,3).

2A.1. Method

2A. 1. b. Top/Down

Top/down calculations for carbon dioxide are reported in Tables 2.1-2.4. Calculations were carried out based exclusively on data obtained from the BALANCE NACIONAL DE ENERGIA 1990 (BNE) (SEMIP, 1991). In Mexico there are not specific emission factors, therefore default IPCC factors were used.

2A.1.c. Top/Down Results

Table 2.4 shows CO_2 emissions as carbon and as carbon dioxide from the top/down methodology. 310.32 Tg of CO_2 are released from fosil fuels. Emissions of carbon dioxide due to traditional biomass burning are not in the totals.

2A.1.d. Bottom/Up

Other gases in Table 1.7-1.9 were calculated using the energy consumption of each energy sector reported in the BNE. All gases in the bottom/up procedure were calculated using:

$$Emissions = \sum_{i=1}^{Ss} EF_{abc} * Activity_{abc}$$

where meaning of subindexes are dependant on the activity.

2A.1.D(1) Stationary Sources

In México the greenhouse gas emissions from energy related to Stationary Sources and their combustion activities have been grouped in three sectors :

Industrial
Residential, Commercial and Public
Electric Utilities.

in this case:
EF = Emission Factor (g/GJ).
Activity = Energy (GJ).
a = Fuel Type.
b = Sector Activity.
c = Technology type

Table 2.1. CO_2 from energy fuel combution activities (apparent consumption)

Module	Energy
Submodule	CO_2 form energy source (reference approach)
Worksheet	I-1
Sheet	1 of 5

Step 1

		Fuel types	A Production	B Imports	C Exports	D International Bunkers	E Stock change	F Apparent Consuption F = A+B -C-D-E
			PETACALORIES					
Liquid Fossil	Primary Fuels	Crude oil	1401.3	0.0	703.9		3.1	694.3
		Nat. gas L.	57.3	0.0	0.0		0.0	57.3
	Secondary Fuels	Gasoline@		17.3	4.0	0.43	0.7	12.20
		Kerosene		0.0	7.5	18.08	-0.6	-25.00
		Diesel		0.0	16.6	ND	-1.3	-15.3
		Residual fuel oil		30.2	4.5		0.3	25.4
Liquid Fossil Total			1458.6	47.5	736.5	ND	2.2	748.9
Solid Fossil	Primary Fuel	Coal	35.6	1.4	0.0		1.5	35.5
	Secondary Fuels	Coke		0.8	0.0		-0.2	1.0
Solid fossil total			35.6	2.2	0.0	ND	1.3	36.5
Gaseous Fossil	Secondary Fuels	G.L.P		8.1	18.1		0.0	-10.0
	Primary Fuels							
		Gas asoc.		0.0	0.0		0.2	-0.2
		Gas	392.0		0.0		0.0	392.0
Gasseous fossil total			392.0	8.1	18.1	ND	0.2	381.8
Total			1886.2	57.8	754.6	18.51	3.7	1167.2
Biomass Total			91.6	0.0	0.0		0.0	91.6
		Solid Biomass	91.6	0.0	0.0		0.0	91.6

NOTES:
In the information is not included: Nucleoenergy, Geoenergy, Hidroenergy and Electricity
1 Calorie is equal to 4.186 Joules.
1 TeraJoule (TJ) is equal to 1×10^{12} Joules
1 Petacalorie (Pcal) is equal to 1×10^{15} Calories
@In the National Energy Balance the gasoline and naftalene are not desagregated
Accord of metodology($_4$), the production of energy for combustion of biomass is not necessary included
ND Do not have information
Condensated are liquids to natural gas

Tabla 2.2. CO_2 from energy fuel combustion activities (Carbon content)

			Module	Energy			
			Submodule	CO_2 from energy sources (reference appoach)			
			Worksheet	I-1			
			Sheet	2 of 5			
				Step 2		Step 3	
			G Conversion factor TJ/Pcal	H Apparent Consumption (10^4TJ)	I Emission factor (t C/TJ)	J Carbon content (t C)	K Carbon content (Tg C)
	Fuel Types		x 10^3	H = (FxG)		x 10^6	
Liquid fossil	Primary Fuel	Crude oil	4.1868	290.69	20.00	58.138	58.138
		Nat. gas L.	4.1868	23.99	17.20	4.126	4.126
	Secondary fuel	Gasoline	4.1868	5.11	18.90	0.996	0.996
		Kerosene	4.1868	-10.47	19.60	-2.052	-2.052
		Diesel	4.1868	-6.41	20.20	-1.295	-1.295
		Residual fuel oil	4.1868	10.63	21.10	2.244	2.244
Liquid fossil total				313.59		62.127	62.127
Solid Fossil	Primary Fuels	Coal	4.1868	14.86	25.80	3.835	3.835
	Secondary Fuels	Coke	4.1868	0.42	29.50	0.124	0.124
Solid Fossil total				15.28		3.959	3.959
Gaseous Fossil	Secondary Fuels	G.L.P.	4.1868	-4.19	20.20	-0.837	-0.837
	Primary Fuels	Gas asoc.	4.1868	-0.08	15.30	-0.013	-0.013
		Gas	4.1868	164.12	15.30	25.110	15.110
Gaseous Fossil Totals				159.85		24.260	24.260
Total						90.346	90.346
Biomass Total				38.35		11.467	11.467
		Solid Biomass	4.1868	38.35	29.90	11.467	11.467

Table 2.3. CO_2 from energy fuel combustion activities (carbon stored)

Module	Energy
Submodule	CO_2 from energy
Worksheet	Auxiliary worksheet I-1, estimating carbon stored in products
Sheet	1 of 1

	A Estim. Fuel Q. Pcal.	B Conver. Factor TJ/Pcal	C Est. Fuel 10^4TJ	D Emis. Fact. tC/TJ	E Carb. Cont. 10^3t C	F Carb. Cont. Tg C	G Frac. Carb. Sto.	H Carb. Sto. Tg C
Fuel Types		x 10^3	C = AxB		E = CxD	F = Ex10^{-3}		H = FxG
Crude oil	51.24	4.1868	21.45	20.00	4290	4.29	0.75	3.21
Gas	28.04	4.1868	11.74	15.30	1796	1.80	0.33	0.59
Gasoline	17.38	4.1868	7.28	18.90	1376	1.38	0.75	1.04
Bagasse	1.68	4.1868	0.70	29.90	209	0.21	0.75	0.16
Kerosene	0.10	4.1868	0.04	19.60	8	0.01	0.75	0.01
Coke	0.30	4.1868	0.13	29.50	38	0.04	0.75	0.03
TOTAL	98.74	4.1868	41.34		7717	7.72		5.04

Table 2.4. CO_2 from energy fuel combustion activities (CO_2 Emissions)

		Module	Energy				
		Submodule	CO_2 from energy sources (reference apporach)				
		Worksheet	I-1				
		Sheet	3 of 5				
			Step 4		Step 5		Step 6
			L Carbon Stored (Tg C)	M Net Carbon Emissions (Tg C)	N Fraction of Carbon Oxidised	O Actual Carbon Emission (Tg C)	P Actual CO_2 Emission (Tg CO_2)
	Fuel Types			M = (K-L)		O = (MxN)	P = Ox44/12
Liquid Fossil	Primary	Crude oil	3.21	54.93	0.990	54.381	199.40
		Nat Gas L.	ND	4.13	0.990	4.080	14.96
	Secondary	Gasoline	1.10	-0.134	0.990	-0.133	-0.488
		Kerosene	0.01	-2.062	0.990	-2.041	-7.484
		Diesel	ND	-1.29	0.990	-1.277	-4.68
		Residual Fuel oil	ND	2.24	0.990	2.218	8.13
Liquid fossil totals			4.32	57.814		57.190	209.84
Solid Fossil	Primary	Coal	ND	3.835	0.980	3.758	13.78
	Secondary	Coke	0.03	0.094	0.980	0.092	0.34
Solid Fossil Totals			0.03	3.929		3.850	14.12
Gaseous Fossil	Secondary	G.L.P.	ND	-0.837	0.995	-0.833	-3.05
		Gas Asoci.	ND	-0.013	0.995	-0.013	-0.05
	Primary	Gas	0.59	24.52	0.995	24.397	89.456
Gaseous Fossil Totals			0.59	23.67		23.551	86.356
TOTAL			4.94	85.413		84.541	310.316
Biomass Total			0.16	11.307		11.080	40.62
		Solid Biomass	0.16	11.307	0.980	11.080	40.62

Table 2.5. Totals of GHG's per consumption of energy in the industrial process by fuel type *(Teragrams* (1×10^{12})).

FUELS	CO_2	CO	CH_4 (Tg)	NO_x	N_2O	NMVOC's
Solid Fossil	6.20	0.138E-01	0.656E-04	0.000	0.000	0.000
Gaseous Fossil	29.30	0.884E-02	0.728E-3	0.348E-01	0.000	0.000
Liquid Fossil	27.70	0.539E-02	0.917E-03	0.583E-01	0.000	0.000
Biomass	7.53	0.136	0.000	0.700E-02	0.000	0.000
Total	70.73	0.164	0.171E-02	0.956E.01	0.000	0.000

Table 2.6 Totals of GHG's per consumption of energy in the residencial, commercial and public sectors, by fuel type

Fuel	CO_2	CO	CH_4 (Tg)	NO_x	N_2O	NMVOC's
Wood	18.68	5.49	2.19E-2	5.92E-2	7.11E-4	0.00
G. L. P.	19.73	2.76E-3	3.04E-4	1.30E-2	0.00	0.00
Kerosene	0.99	1.75E-4	6.71E-5	6.85E-4	0.00	0.00
Diesel	0.12	2.39E-5	8.95E-7	9.55E-5	2.34E-5	0.00
Oil	0.52	1.52E-4	1.43E-5	1.39E-3	4.16E-4	0.00
Natural gas	2.40	3.65E-4	4.57E-5	1.83E-3	9.13E-5	0.00
Total	42.42	5.49	2.23E-2	7.62E-2	1.24E-3	0.00

Table 2.7 Totals of GHG's per consumption of energy in the generation of electricity by fuel type

Fuel	CO_2	CO	CH_4 (Tg)	NO_X	N_2O	NMVOC's
Oil	51.00	9.89E-3	4.62E-4	1.33E-1	0.00	0.00
Natural gas	8.06	4.60E-3	8.48E-4	2.70E-2	0.00	0.00
Diesel	1.16	2.34E-4	5.00E-8	1.06E-3	0.00	0.00
Coal	7.19	9.20E-3	5.32E-5	2.48E-2	0.00	0.00
Total	67.41	2.39E-2	1.36E-3	1.85E-1	0.00	0.00

2A.1.D.(2) Mobile Sources

In Mexico the greenhouse gas source of emissions from energy related to Mobile Sources and their combustion activities is only the transport sector. The activities of Agriculture, Foresty and Fishing were not calculated because of these sectors account only for about 2% of the total energy consumption. In this case:

EF = Emission Factor (g/GJ)
Activity = amount of energy consumed
a = transport mode (road, air, rail, urban, public, etc.)
b = fuel type (gasoline, diesel, oil, electricity, etc.)
c = vehicle type (passenger, light or heavy duty, etc.)

Table 2.8 Totals of GHG's per consumption of energy in the transport* sector by fuel type

Fuel	CO_2	CO	CH_4 (Tg)	NO_x	N_2O	NMVOC's
			PARTICULAR			
Gasoline	47.73	5.05	2.16E-1	2.69E-1	6.20E-4	7.85E-1
G. L. P.	0.46	1.05E-2	2.18E-4	2.76E-3	0.00	4.65E-3
			URBAN			
Gasoline	1.94	2.48E-1	5.59E-4	9.78E-3	1.40E-5	3.13E-2
G. L. P.	0.20	4.74E-3	9.35E-5	1.12E-3	0.00	1.59E-3
Diesel	8.42	1.72E-2	1.15E-4	1.61E-3	1.18E-4	1.49E-3
			GOODS			
Gasoline	11.42	1.46	3.30E-3	5.77E-2	8.24E-5	1.85E-1
G. L. P.	0.36	8.69E-3	1.71E-4	2.06E-3	0.00	2.91E-3
Diesel (lig)	4.60	1.19E-2	0.00	1.07E-2	1.19E-4	6.27E-3
Diesel Hea)	9.72	6.76E-2	1.33E-3	1.34E-1	2.52E-4	2.39E-2
			AERIAL			
Gasoline	0.20	6.79E-3	1.70E-4	2.26E-4	2.50E-6	1.53E-3
Kerosine	5.37	9.02E-3	1.50E-4	2.18E-2	0.00	1.35E-3
			RAILROAD			
Diesel	1.97	1.64E-2	1.61E-4	4.83E-2	5.37E-5	3.49E-3
Electricity	0.00	0.00	0.00	0.00	0.00	0.00
			MARITIM			
Diesel	0.30	2.35E-4	0.00	1.07E-2	1.02E-5	0.00
Oil	1.68	3.22E-4	6.23E-5	3.46E-3	0.00	0.00
Total	94.46	6.91	2.23E-1	5.73E-1	1.37E-3	1.05

* The consumption of energy in the Transport Sector was obtained from the BNE (2), Its distribution was found in the Estadistic Manual of the Transport Sector 1992 (5) and the estadistic anuary (6) published by National Institute of Geography and Statistics of Mexico (INEGI).

Table 2.9 Emissions from energy sector

Sources	EMISSIONS (Tg)					
	CO_2 Top/down	CO	N_2O	NO_x	CH_4	NMVOC's
National emissions from Energy sector	315.75	12.588	0.002	1.790	1.215	1.047
Combustion	315.75	NC	NC	NC	NC	NC
Stationary sources	NC	5.678	0.001	1.217	0.024	0.000
Mobile sources	NC	6.910	0.001	0.573	0.223	1.047
Fugitives	NC	NC	NC	NC	0.968	NC
Oil & natural gas	NC	NC	NC	NC	0.968	NC

NC Not calculated

2.A.1.E International Bunkers

International bunkers are the fuels used by sea and air transport going in and out of the country, there are given for information only as intructed by the IPCC methodology (IPCC, 1995), these emissions are not accounted for in the national total.

In 1990 air transport (national and international) used 18.5 Pcal, on which 97.7% was Jet Kerosene (turbosene in the BNE, 1991), the other 2.3% was gasoline. Sea transport used 6.4 Pcal of which 81.4% was residual fuel oil and 18.6% was diesel.

We assumed that all the used Jet Kerosoene, gasolina, residual fuel oil, and all butuminous imported coal are part of the international bunkers. This amount to 7.72 Tg of carbon dioxide which are equivalent to a 2.5% of the total national emissions. This amount is over estimated given that fuels used in national air and sea trips are also included but the impact on the national total will be small.

Table 2.10. Emissions from CO_2 international bunkers

			Module	Energy			
			Submodule	CO_2 from energy sources (Reference approach)			
			Worksheet	I-1			
			Sheet	4 of 5 emissions from international Bunkers (International Marine and Air Transport)			
		Step 1		Step 2		Step 3	
		A Quantities Delivered Petacalories	B Conversion Factor (TJ/Pcal)	C Quantities Deliver (TJ)	D Carbon Emission Factor (t C/TJ)	E Carbon Content (t C)	F Carbon Content (Gg C)
Fuel Types		* o #		C=BxA		E=CxD	$F=Ex10^{-3}$
Solid Fossil	Other Bituminous Coal	1.38	4186.8	5773.6	25.80	148958.9	148.9
Liquid Fossil	Gasoline	0.43	4186.8	1783.6	18.90	33710.0	33.7
	Jet Kerosene	18.08	4186.8	75676.4	19.60	1483257.4	1483.3
	Residual fuel oil	5.21	4186.8	21813.2	21.10	460258.5	460.3
			Total	105046.8			

Tabla 2.11

			Module	Energy			
			Submodule	CO_2 from energy sources (Reference approach)			
			Worksheet	I-1			
			Sheet	5 of 5 emissions from international Bunkers (International Marine and Air Transport)			
		Step 4		Step 5		Step 6	
		G Fraction of carbon stored	H Carbon stored (Gg C)	I Net carbon emissions (Gg C)	J Fraction of carbon oxidized	K Actual carbon emissions (Gg C)	L Actual CO_2 emissions (Gg CO_2)
Fuel Types		H=FxG	I=F-H		K=IxJ	L=Kx44/12	
Solid Fossil	Other Bituminous Coal	0	0	148.9	0.98	146.8	538.3
Liquid Fossil	Gasoline	0	0	33.7	0.99	33.4	122.3
	Jet Kerosene	0	0	1483.3	0.99	1468.5	5384.4
	Residual fuel oil	0	0	460.3	0.99	455.7	1670.9
						Total	7715.9

2.A.1.F Coal mining

In Mexico there is a small coal production in the states of Coahuila and Michoacan, all coal from Coahuila. 5.923 Mt is underground coal. All coal from Michoacan is open sky mined.

Table 2.12. Methane emissions from coal mining and handing

			Module	Energy		
			Submodule	Methane emissions from coal mining and handing		
			Worksheet	I-4		
			Sheet	1 of 1		
		Step 1			Step 2	
		A Amount of coal produced (million t)	B Emission factor (m^3CH_4/t)	C Methane emissions (*million m^3*)	D Conversion factors ($0.67Gg\ CH_4/10^6m^3$)	E Methane emissions ($GgCH_4$)
				C=(AxB)		E=(CxD)
Underground Mines	Mining	5.923*	17.50	103.65	0.67	69.45
	Post-mining	ND	ND	ND	0.67	ND
Surface Mines	Mining	0.5370	1.15	0.62	0.67	0.41
	Post-mining	0.5370	1.15	0.62	0.67	0.41
					Total	70.27

Table 2.13. Traditional biomass burned for energy

Module	Energy
Submodule	Traditional biomass burned for energy
Worksheet	1-2 optional fuelwood consumption accounting
Sheet	1 of 1
	Not included

2.A.2. DISCUSSION

An study about climatic change is strongly dependent on emissions and its participation. Such emissions may be obtained through an inventory process that indentifies and quantifies a country sources of the greenhouse gases. The table 1.11 and figure 1.4 provide a summary of greenhouse gas emissions. The energy sector is the most important anthropogenic source in México.

Primary fuels (crude oil, natural gas and biomass) provide more than 95% of the energy used in Mexico. This allow us to identify were mitigation options may be most needed.

It needs to be pointed out that for 1990, production of Kerosene and Diesel in Mexico was smaller than the added vaules of stocks plus exports therefore a negative net contribution of these categories to the emissions.

Following the IPCC methodology (1), the carbon dioxide emissions produced by the combustion of firewood and bagasse that is fixed by regrowth should not be added to the totals. However, in regard to firewood there is not enough information. Once better knowledge from land use change is obtained, this part of the inventory shall be better known.

Carbon dioxide emissions obtained by using the default emission factors given in the workbook (1) are about ±2-3 % different that those obtained using the IPCC software (MINERG). Most likely this is due to some differences in the applied emission factors.

Emissions of CO2 by Top/Down methodology in the energy sector are 310.32 Tg (Table 2.11), in this procedure all the activities are included. In the Bottom/Up methodology emissions are 275.02 Tg which are 11.38% smaller than the former. However, in the Bottom/Up the agriculture and foresty sectors are not included and these represents about the 2.6% of all energy consumption. Further more some forms of autoconsumption are not avilable. Therefore actual differences between both methods may be smaller and this fact may be seen in next releases of the inventory.

2 A.3. CONCLUSSIONS

The main source of greenhouse gases is the energy sector given that the most used fuels are crude oil, natural gas and biomass, the other fuels have a small impact on total emissions. Sources and sinks not included (bunkers, traditional biomass burning and regrowth, methane from carbon extraction) whick may be included in future releases of the inventory will also have a small impact.

2 A.4. UNCERTAINTY

We consider that the largest source of error are the data given in the BNE, in order to estimate an uncertainty for the emissions from energy sector, an average between the minimum and maximum errors suggested by default, was considered for the activity data, error from emission factors was the given by default (5%). Error propagation leads to a 9% of unceratinty which may increase up to a 12% if maximum error in activity data is accepted.

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2B.1 FUGITIVE EMISSIONS FROM FUELS (OIL AND GAS).

D. Cuatecontzi, J. Gasca, F. Guzmán

Atmospheric fugitive emissions from the energy sector originate from three main sources:

- Disposal of associated natural gas. During the production of oil, some associated gas may be produced for which there is no commercial use within an economic transport range. Traditionally, surplus gas has been disposed by venting or flaring it. Re-injecting the gas into the producing reservoir, where suitable reservoir conditions exist, is another way to dispose of it.
- Safety/relief systems. Hydrocarbon containing systems are normally provided with means to safeguard against over pressure and for disposal of the gas inventory in an emergency. A vent or flare is installed for this purpose, the presence of which often leads to a continuos fugitive releases from processing valves and seals. An explosive atmosphere is prevented from forming in the flare system by applying a continuos purge, for which the most convenient source has been natural gas.
- Fugitive emissions in the whole natural gas system.

Methane is the most important component of natural gas and consequently any emission during these operations will emit methane directly to the atmosphere. By considering global fugitive methane emissions from oil and gas activities, these probably are 30 to 70 Tg per year. They include world wide emissions from the production, processing, transport and use of oil and natural gas besides those from non-productive combustion (EPA, 1994).

Fugitive emissions from the energy sector in Mexico are the second important source of methane in the country; 969 Gg were emitted in 1990, which represents 26.50% of the national emissions of this gas and probably 2.3% of global fugitive methane emissions. Figure IB-1 shows the distribution of methane from fugitive emissions by area, where natural gas processing, transport and distribution and oil production are the main emitters.

2B.2 METHOD

The emissions estimate were based on the IPCC Guidelines for National Greenhouse Gas Inventories. It contains simple, default methods and assumptions that cover the major sources and sinks of greenhouse gases and it discusses more detailed methods in order to provide the Countries with the option of using various methods and levels of detail depending on their own needs and capabilities. In addition, a common reporting and documentation framework for all inventories to make a consistent comparison of all the national inventories.

For the fugitive emissions from oil and natural gas activities the methodology takes into account:

- Emissions during normal operations such as those associated with venting and flaring during oil and gas production, chronic leaks or discharges from process vents.
- Emissions during repair and maintenance.
- Emissions during system upsets and accidents.

The emission estimates were obtained by following the first two levels of detail considered by the IPCC methodology, namely: Tier -2 and Tier-1. Tier 2 or mass-balance approach was principally used and when there was no way to apply it, Tier 1 or production-based average emission factors approach was the choice.

Tier-2 approach is only recommended for oil system releases of methane, and should not be used for releases from natural gas activities because no Tier 2 method exists for such activities. It employs standard, generally easy-to-obtain, oil and gas data to estimate the maximum amount of methane that could be emitted to the atmosphere by different sectors of the oil and gas industry (PEMEX, 1991). In order to reflect actual emissions, these amounts are then scaled by applying appropriate emission factors. The minimum emission factors account for the amount of gas that is disposed of by control devices, consumed by combustion equipment, conserved or re-injected. Leak emission factors account for the amounts lost through leaks from these control/utilization systems. The emissions estimates were based on the Tier-2 approach of the IPPC methodology for oil production, crude oil transportation and refining, and natural gas processing and distribution.

Tier-1, requires assembling activity data for Mexico which are obtained from the 1990 Mexican National Energy Balance (SEMIP, 1991), selecting emission factors based on information in the tables of typical regional values, and multiplying by such activity data to produce emissions estimates by major sub category. Emission factors used were the high emission factors of the Table 1-8 of the IPCC Workbook (Vol. 2, 1993) for the Rest of the World Region, in accordance to the recommendation made by the ICF consulting group. Those emission factors were applied to the exploration and drilling losses and non-associated gas production areas.

2B.3. OIL AND GAS SYSTEMS

RESULTS BY ACTIVITY

2B.3.1. Production

Almost 84% of total gas produced, 30 270 millions of standard cubic meters (MMSCM), was associated to oil production in 1990. Around 6.6% of gas produced was re-injected to the oil fields while 2.7% was flared. Additionally, 90% was processed in gas plants. Figure 2.B-2 shows the main uses of natural gas production.

The methane emissions from routine maintenance and venting and flaring for oil production were estimated with Tier-2 approach of the IPCC methodology. Additionally, the methane emissions from routine maintenance and venting and flaring for non-associated gas production were estimated with the high emission factors of the Table 2-8 of the IPCC Workbook (Vol. 2, 1993) for the Rest of the World Region.

The results obtained are summarized in Table 2B-1. As can be seen, 497.40 Gg of methane were emitted by oil and gas production operations in 1990, 83.3% of this was generated in the oil production areas.

2B.3.2. Oil production

Taken into account in this activity are all of the amounts of associated gas that are produced, to be processed or consumed later, or to be re-injected, disposed by control devices and consumed in combustion equipment, as well as their associated leaks, which are assumed to be 3% of each operation. The minimum methane emissions that are assessed in this segment amount to 368 Gg/yr, while those from leaks in the fuel, flaring and re-injected gas system are equal to 47 Gg/yr. More research most be done since the associated leaks, which are assumed to be 3% of the gas processed for this, and other operations, has a large uncertainty.

2B.3.3. Gas production

Methane emission generated by non-associated gas production area, 82.69 Gg, are only 8.53% of total methane fugitive emissions. These emissions were obtained with Tier-1 approach, applying the high emission factors of the Table 1-8 of the IPCC Workbook (IPCC, 1995b) for the Rest of the World Region.

2B.3.4. Exploration and drilling activities

Total methane emissions from the exploration and drilling activities will usually be small compared to the quantity that is emitted by other activities inside the petroleum industry. Consequently, a simple Tier 1 approach is perhaps the most appropriate for Mexico. As no datum exists for the average quantity of methane emitted per well in Mexico, it was used the same figure as that for the USA. (0.07 Mg/well). The emission estimate value for exploration and drilling, 0.33 Gg, was the lowest of the all natural gas system and represents only 0.03% of total methane fugitive emissions.

2B.3.5 Refining, transportation and storage of oil

Emissions from these activities are presented in Table 2B-2. As can be seen, these are negligible as they represent only 2.52% of total methane fugitive emissions. The estimates were based on the Tier-2 approach provided by the IPCC methodology.

Two important parameters are required in this activity in order to estimate methane emissions: the solution gas factor and the methane fraction, both associated with the type of crude oil which is managed. Table I-47 of IPCC Reference Manual (IPCC, 1995c) provides some estimated values for these two parameters at onshore and offshore facilities. Although better estimates may be determined by performing site specific process simulations. In Mexico most of the refinery facilities process crude oil mixtures with a major constituent importing characteristics very close to type medium crude oil. When the extreme default values for the solution gas factor and the mole fraction associated with the type of crude oil production are used, the resulting estimates for the transport and refining of petroleum represent the lower- and upper-limit of the range, with the true value located within it. Therefore, methane emissions which were assessed for this segment reach 15.6 and 24.4 Gg/yr as the minimum and maximum amounts respectively.

2B.3.6 Processing, transmission and distribution of gas

Methane fugitive emissions from processing, distribution and transmission were estimated to be 318.51 Gg, which represents 32.86% of total methane fugitive emissions in 1990. This value was the second most important in the natural gas system.

The emission estimate value from leakage at industrial plants and power stations and in the residential and commercial sectors was 129.03 Gg, which represents 13.31% of total methane fugitive emissions.

All these emissions estimates were based on the Tier-2 approach of the IPPC methodology, assuming that the associated leaks were 3% of the gas in each operation. Table 2B-3 shows the results.

2B.4 DISCUSSION

In the Table IB-4 the emission factors obtained with the combination of Tier-2 and Tier-1 approaches are shown. These emission factors are compared with the high emission factors of the Table 1-8 of the IPCC Workbook (IPCC, 1995b) for the Rest of the World Region.

For the oil production and the crude oil transportation and refining sectors the emission factors obtained with the Tier-2 approach are greater than those reported for the Rest of the World Region. On the other hand, for the natural gas processing, transport and distribution sector the emission factors obtained with the Tier-2 approach are lower than those reported for the Rest of the World Region (Fig. 2B-3).

The emissions estimates obtained in this work can be improved if more research work is done. In particular, the venting and flaring quantities from oil production must be estimated more carefully, as well as the leaks from natural gas processing, distribution and transmission and from the industrial plants and power stations.

2B.5 UNCERTAINTIES

Uncertainties in the calculation of the fugitive methane emissions can be estimated from the differences in the results obtained with the different levels of the IPCC methodology. With the Tier-1 approach a range from 435 to 1069 Gg is obtained. These numbers come from the application of the so-called minimum and maximum emission factors for the Rest of the World Region (Cuatecontzi, 1995a). On the other hand, if the emission estimates are obtained by combining the Tier 2 and Tier-1 approaches, as in this work, the quantity of 969 Gg results.

On other work, methane emissions for the Mexico's petroleum sector were estimated to be in a range from 1000 to 1700 Gg (EPA, 1994). However, Mexico was classified within the Other Oil Exporting Countries Region. In our opinion, that is not adequate, taken into consideration that there is a difference in the exploitation of natural gas between those countries and Mexico (Cuatecontzi, 1994). The different emissions estimates made for Mexico are shown in the Fig. IB-3.

The IPCC provides a total uncertainty of 60methane emissions coming from the petroleum sector (IPCC, 1995 Vol. 1). With this uncertainty and taking 970 Gg as a basis, the methane emissions would be between 474 and 1570 Gg. The lower value of this interval is superior than the minimum emission value (435 Gg) which was obtained with the Tier-1 for the Rest of the World Region. On the other side, the higher value of this interval (1570 Gg) is less than 1700 Gg, the maximum value estimated by the EPA (1994). In other words, the dispersion of results when Mexico is classified either in the Rest of the World Region or in the Other Oil Exporting Countries Region is also about 60.

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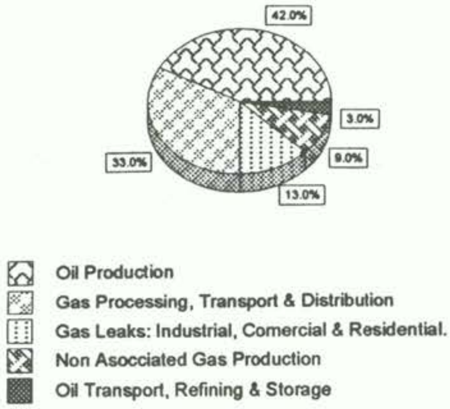

Fig. 2B1 Methane Distribution from Fugitive Emissions

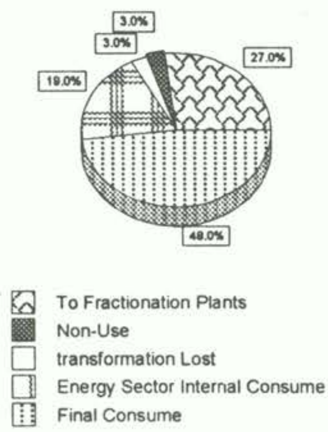

Fig. 2B2 Natural Gas Uses.

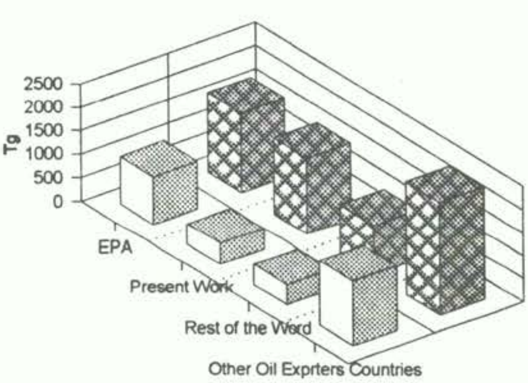

Fig. 2B3 Mexico Estimated Emissions

Table 2B1. Summary
Fugitive fuel emissions (oil and gas)

Source and Sink Categories	Activity Data Fuel Qunatitu (PJ)	Emission CH4 (Gg)	Estimates CO2 (Gf)	Aggregate CH4 (kg/PJ)	Emission Factor CO2 (kg/PJ)
2B1 a Crude Oil(Total)	5862.88	439.09		74893.14	
i Production	5862.88	414.69		70731.20	
ii Transported	2946.92	7.69		2609.80	
iii Refined	2897.84	16.71		5766.40	
2B1 b Natural Gas (Total)	1640.09	530.22		323284.97	
i Production	271.10	82.69		305000.00	
ii Consumption	1074.50	447.53		416501.58	
2B1 c Oil/Gas Joint		969.31			

Table 2B-2
1990 Emissions from oil processing

Source	CH4 Emissions Gg	%
Transportation	7.69	31.52
Refining	14.19	58.16
Storage	2.52	10.33
TOTALS	24.40	100.00

Table 2B-3
1990 emissions from gas processing

Source	CH4 emissions Gg	%
Processing distribution and transportation	318.51	71.17
Plants leakage	126.79	28.33
Residential leakage	2.24	0.50
Total	447.54	100.00

Table 2B-4
Methane fugitive emission factors

Category	B Emission Factor Tier-2 and Tier-1	B Emission Factor Tier-1 Rest of the World
Oil & Gas Production		
Exploration and Drilling	kg CH4/well drilled 70.00	kg CH4/well drilled
Fugitive and Other Routine Maintenance Emissions from Oil Production	kg CH4/PJ 6051.30	kg CH4/PJ 5000.00
Fugitive and Other Routine Maintenance Emissions from Gas Production	kg CH4/PJ 96000.00	kg CH4/PJ 96000.00
Venting and Flaring from Oil and Gas Production	kgCH4/PJ oil 64623.40	kg CH4/PH oil
	kg CH4/PJ gas 209000.00	kg CH4/PJ gas 209000.00
Crude Oil Transportation Storage and Refining		
Transportation	kg CH4/PJ 2609.80	kg CH4/PJ 745.00
Refining	kg CH4/PJ 4897.80	kg CH4/PJ 1400.00
Storage Tanks	kg CH4/PJ 868.60	kg CH4/PJ 250.00
Natural Gas Processing Transport and Distribution		
Emission from Processing Distribution and Transmition	kg CH4/PJ 194200.90	kg CH4/PJ 288000.00
Leaking at industrial plants and power stations	kg CH4/PJ 117997.20	kg CH4/PJ 175000.00
Leaking in the residential and commercial sectors	kg CH4/PJ 58826.60	kg CH4/PJ 8700.00

Module		Energy		
Sub-Module		Methane from oil and gas systems		
Worksheet		Revised 1-5		
Sheet		A		

Category	Step 1 A	B	Step 2 C	Step 3 D
	Activity	Emission Factor	CH4 Emissions (kgCH4)	Emission CH4 (Gg CH4)
Oil & Gas Production			C=(A*B)	D=(C x 10-6)
Expl. and Drilling	num. of wells drilled	kg CH4/well drilled		
	4732	70	331240	0.331
Fug. and other rout. Maint. Emissions from Oil Production	PJ oil produced	kg CH4/PJ(*)		
	5862.88	6051.30	35478046	35.478
Fug. and other rout. Maint. Emissions from gas production	PJ gas pooduced	kg CH4/Pj		
	271.10	96000.00	26025600	26.026
	PJ oil& gas produced	kg CH4/PJ		
Vent. and. Flar. from Oil and Gas Produc.	PJ oil produced	kgCH4/PJ(*)		
	5862.88	64623.40	378879239	378.879
	PJ gas produced	kg CH/PJ		
	PJ gas produced	kg CH4/PJ		
	271.10	209000.00	56659900	56.660
Total CH4 from oil and gas production				497.374
Crude Oil Transportation Storage and Refining				
Transporation	PJ oil tankered	kg CH4/PJ(*)		
	2946.92	2609.80	7690872	7.691
Refining	PJ oil refined	kg CH4PPJ(*)		
	2897.84	4897.80	14193041	14.193
Storage Tanks	PJ oil refined	kg CH4/PJ(*)		
	2897.84	868.60	2517064	2.517
Total CH4 form crude oil transporation storage, and distribution				24.401
Natural Gas Processing, Transport and Distribution				
Emission from Proces. Distr.and transmition	PJ gas produced	kg CH4/PJ(*)		
	1640.09	194200.0	318506054	318.507
Leak. at indus.plantes and powerstations	PJ non-residential gas consumed	kg CH4/PJ(*)		
	1074.5	117997.2	126787991	126.788
Leak. in the resid. and commercial sec.	PJ residential gas consumed	kg CH4/PJ(*)		
	38.01	58826.6	2235999	2.236
Total CH4 from gas processing transport and distribtuing				447.531
Total CH4 emissions from				969.306

3. INDUSTRIAL PROCESSES

R. Muñoz Ledo

Cement production is the main industrial process wich generates greenhouse gases and it is not a combustion process.

3.A METHOD

In this release, emissions for the industrial process only includes production of cement, other processes shall be included in the next release of the national inventory. The method used is the given by the IPPC methodology (3) with default emission factors.

3.B ESTIMATED EMISSIONS

In México the production of cement is aproximatly 23 312 000 tons (1,2), if the factor emission is 0.4985 ton CO_2 per ton Cement (3) then 11.612 Tg of carbon dioxide are emitted to the atmosphere (Table 3.1). Although cement production is the main source, its contribution is the 2.35% of total emissions of carbon dioxide.

Table 3.1 Industrial processes (cement production)

Module	Industrial Processes		
Submodule	CO_2 from cement production		
Worksheet	2-1		
Sheet	1 of 1		
	Step 1		Step 2
A Cement Produced (t)	B Emissions factor (t CO_2/t cement)	C CO_2 emitted (t)	D CO_2 emitted (Gg)
		C=(A×B)	D=C/1000
23,312,000	0.4985	11,621,032	11,621.03

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4. AGRICULTURE

E. González, L. G. Ruiz

Greenhouse gas emissions from agriculture (not including energy use) arise mainly from livestock (1.85 Tg of methane), specific crops (i.e. 35 Gg of methane from rice paddies), use of fertilizers (5.51 Gg of N_2O) and a family of greenhouse gases from prescribed burn of on site crop refuses. In this report only methane from livestock and rice paddies and nitrous oxide from use of fertilizers are reported, other gases and sources will be included in the next release of the inventory due in the fall of 1995.

IPCC methodologies (IPCC, 1994, a – c) for methane emissions inventories from livestock require data on cattle population by climate (cold, temperate and warm), average weight, energy intake (food intake), mean temperature, kind of herd (diary, beef, range, or young, mature, etc). All this information in not readily available as needed for the inventory calculation, particularly in developing countries. Therefore, broad assumptions (Tier 1 of IPCC methodology) or models regarding these set of data are applied (Tier 2). In both cases, Mexico is classified as a developing country and assumptions about values of the needed data set are made.

In this section, procedures to extract or estimate the needed information from diverse and scattered economic, geographic and agricultural data are described. Part of the needed information was obtained from data bases of the Undersecretary for Cattle Rising of the Secretary of Agriculture and Hydraulic Resources (SARH, 1994) and the National Institute of Statistics, Geography and Information (INEGI). Procedures to improve on default IPCC values are commented. These are based on a better knowledge of herd numbers, structure, management systems and climate distribution. Variational analysis on methane emissions have shown these to be linearly dependant on the values of most of the variables involved in the used formulae (Anastasi and Simpson, 1993; González Avalos, 1994). A comparison of results from a straight forward application of Tier 1 and advances on application of Tier 2 show that results from the former should be considered an upper limit to emissions.

Table 4.1. Age structure of the herd (%) from national agricultural census from 1950-1990

Class	1950	1960	1970	1981	Mean
Breeding	42.06	43.15	37.83	39.41	40.62
+3	6.57	8.33	9.85	11.63	9.10
2-3	14.83	15.44	22.97	14.71	16.99
1-2	15.26	12.97	16.23	11.78	14.06
0-1	21.28	20.11	13.11	22.46	19.24

4.A.1. Method

Data on energy intake by cattle is needed for methane emissions from enteric fermentation and for emissions from manure. Currently, this kind of data is not available in Mexico. However, an analysis of tables given in the Reference Manual (Table B-1 in the Reference Manual) allows us to obtain a linear relationship between energy intake (EI) and typical animal mass (TAM) which is available for dairy cattle (Fig 4.2 and eq. 4.1) and for non dairy cattle (Fig 4.2 and eq. 4.1), the former is based on a smaller data set.

$$EI = 32.42 + 0.26 * TAM_i \quad (4.1)$$

$$EI\ (dairy) = 52.37 + 0.24 * TAM_i \quad (4.2)$$

Where EI is energy intake in MJ and TAM*i* is typical animal mass. Use of these linear relationships allow us to use a more detailed description of herd structure already available and to approach a Tier 2 procedure for manure.

4.B. RESULTS FOR ENTERIC FERMENTATION

Methane emissions from enteric fermentation from all livestock species were calculated using a Tier 1 approach to give 1.80 Tg and account for 97.37% of emissions from livestock.

4.B.1. Cattle and other species

Methane emissions from cattle due to enteric fermentation are 1.62 Tg, which represent the 90.00% of all emissions of this kind. Of these, 21.05% are from dairy and 68.95% are from beef cattle. Contribution of other non-cattle domestic species to methane emissions due to enteric fermentation is small, 180.3 Gg, representing only the 9.99%

4.B.2 Discussion for enteric fermentation from cattle

Food intake is directly related to the animal weight and a classification by age is needed in order to use average weights. Census data provide some information although questionnaires vary from one census to another, even the names of age categories reflect the idiosyncratic preferences of designers. Nevertheless, it was possible to reduce all this categories into a standard age classification. Analysis of census data from 1950 to 1980 (Fig. 4.1, Table 4.1) allows us to state that, within each of the main regions, herd structure remains constant. This statement stands on the fact that herd structure is regulated by purpose of the herd, management systems, health of the herd, reproduction rate. Impact of these factors seem to be able to remain unchanged along several census. In any case trends in herd structure may be observed by analysis of census data. Figures 4.3, 4.1 and table 4.2 also show that about 50% of the herd have a typical animal mass (TAM) less than the average default weight (Tier 1) given for developing countries in the newest IPCC methodologies. This knowledge may, when applied, lead to smaller emissions from enteric fermentation. That is if full information for a Tier 2 approach is not available, Tier 1 may be applied to assignments of the herd leading to a better estimate of methane emissions.

Table 4.2

Class	Typical Animal Mass (TAM) [kg]	
	Dairy	Non Dairy
Crow	433.69	396.40
+ 3 years old	530.37	446.66
2-3 years old	350.90	358.16
1-2 years old	267.30	267.30
0-1 years old	154.04	155.20

4.C. RESULTS FOR MANURE

Methane emissions from manure are 48.802 Gg, which represent the 2.63% of methane emissions from livestock. Of these 24.798 Gg (1.34% of the total) are from cattle and the remaining 1.29% of the total from all other species.

4.C.1. Cattle and other species

Use of 1994 methodology for methane emissions from manure represent a significant drop in emissions from this source. This is due to a reduced climatic classification, lower emission coefficients and a slightly different formulae. Former methodology was based on Safley *et al.* (1992), current methodology is based on Steed and Hashimoto (1993). The former relayed heavily on expert opinion, whereas the later is the result of experimental work. However, cautionary notes in Steed and Hashimoto report state that the given emission factors may not hold for humid environments. If that is so, and Safley's approach classification and formulae proves to be better suited for warm-humid climates, methane emissions from manure in those climates in Mexico may rise by a factor of 5, at least.

4.C.2. Discussion for manure from cattle and other species

Total herd population is available, as well as desegregated by federal state without great difficulty on a yearly basis. However Mexico is a country with a wide climatic variability (IG, 1990), spanning from tropical rain forest to high mountains with perpetual snow and glaciers, including large deserts, some of these climates within the same federal state. Simple climatic classification such as that used on IPCC methodology (warm, temperate, cool) may lead to a oversimplified picture of the country. This climatic variability has lead to the use of a particular climatic classification (Table 1, Fig 4.4).

Cattle population data by state do not distinguish on climate. Applying gross average classification may lead to gross miscalculation of methane emissions. (González-Avalos *et al.*, 1994). Extensive agricultural census are carried out every decade in the country with detail down to municipal level. By performing a correlation analysis between climate and herd population of 313 municipalities, which include those with the larger cattle population, from all the 31 federal states, a basic working hypothesis has been put forward. This states that **to a given percent of a climate in any federal state corresponds the same percent of the herd in the sate** (González-Avalos, 1994). It seem to say that herd distribution is climate independent (with a 9.6% error). However it needs to be pointed out that this statement holds better for the

the central region of the country and poorly in the states with the most extreme climates. Also it has to be applied within each state and not nation wide. The most extreme climates been truly inhospitable for both, humans and cattle. This finding makes it possible to map statistic data on cattle population by federal state on to climate maps and therefore to apply the correct emission factor. Within this high climatic variability, it is possible to divide the country in four regions based on the dominant climate, most abundant cattle races and feeding practices.

Data were available for performing a Tier 2 approach. In order to calculate the emission factors from manure for it, is necessary to have information of the volatile solids excreted daily for each type of animal, between other variables that intervene in the methodology. On their turn, volatile solids are dependant on of the energy (energy intake) ingested by the animal. Correlation given in eqs. 4.1 and 4.2 were used.

Methane emissions from cattle by regions are 5.45 Gg (21.98%) from cool and arid regions, representing the 55.23% of the national land surface, 7.85 Gg (31.65%) from temperate representing the 20.10% of the surface and 11.50 Gg (46.37%) from warm climates, representing the 24.67% of the national land surface (Fig. 4.5).

For the other species the hypothesis about climatic distribution of the cattle herd was applied without demonstration. All together they produce 24 Gg (see tables) from manure fermentation.

4.D. RICE

In Mexico, currently available information related to rice cultivation provided by INEGI and SARH is reduced to the area cultivated under the watering regime (in this work equivalent to flooded cultivation) and under the rainfall regime (equivalent to dry cultivation). This assumption agrees with the default values given by the IPPC methodology for Mexico. It needs to be pointed out that 1) in this report only data for 1990 were considered, and 2) a mean annual temperature of 24°C was considered for all regions. The total methane emissions from this sources are 35 Gg of methane.

4.E. NITROUS OXIDE

IPCC methodologies relative to nitrous oxide emissions from agricultural soils require data on applied nitrogen through; industrial fertilizer, manure and biologic fixation (Tier 1). Data on agricultural soils were obtained from FAO (1993). Data on industrial fertilizer were obtained from INEGI (1994). Nitrogen in applied manure was obtained from the methane calculation assuming that only manure from intensive cattle rising is collected and applied on to farming fields. Nitrogen content in manure was obtained from local literature (Flores 1983, Castrejón 1993). Following the Reference Manual, biological fixed nitrogen was taken to be 25 kg/ha/year. Procedures given in the 1991 IPPC methodologies were used in order to obtain emission coefficients from different fertilizers. Total emissions of nitrous oxide from this source were 5.51 Gg.

4.F. UNCERTAINTY

4.F.1. Livestock

Uncertainty on herd structure has been considered to be ±6% (González-Avalos, 1994), whereas uncertainty on climate distribution is about ±10% (González-Avalos, 1994), therefore uncertainty on activity data for animal population with climate resolution has been considered to be ±12%.

Default uncertainty on emission factors for enteric fermentation and mature fermentaion are given as 25% and 20% respectively, therefore overall uncertainty on these emissions are ±28% and ±23%. However it should be pointed out that emission factors given by IPPC are based on experimental work carried out in a dry climate, cautionary notes given by the authors (Steed and Hashimoto, 1993) indicate that these factors may not hold for human climates. If this is so and former values are better suited for these climates then an underestimation of a factor of 5 may be produced for emissions from manure in warm-humid climates (about 25% of herd population).

4.F.2. Rice

The advised three years period needs to be calculated, current estimates are based on 1990 data, more resolution on temperatures needs to be introduced. However as this ource accounts only for 1.85% of the total, therefore this is not a pressing demand. Default uncertainties shoud be considered.

4.F.3. N_2O

The advised three years period needs to be calculated, current estimates are based on 1990 data. Default uncertainties should be considered.

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Fig. 4.1

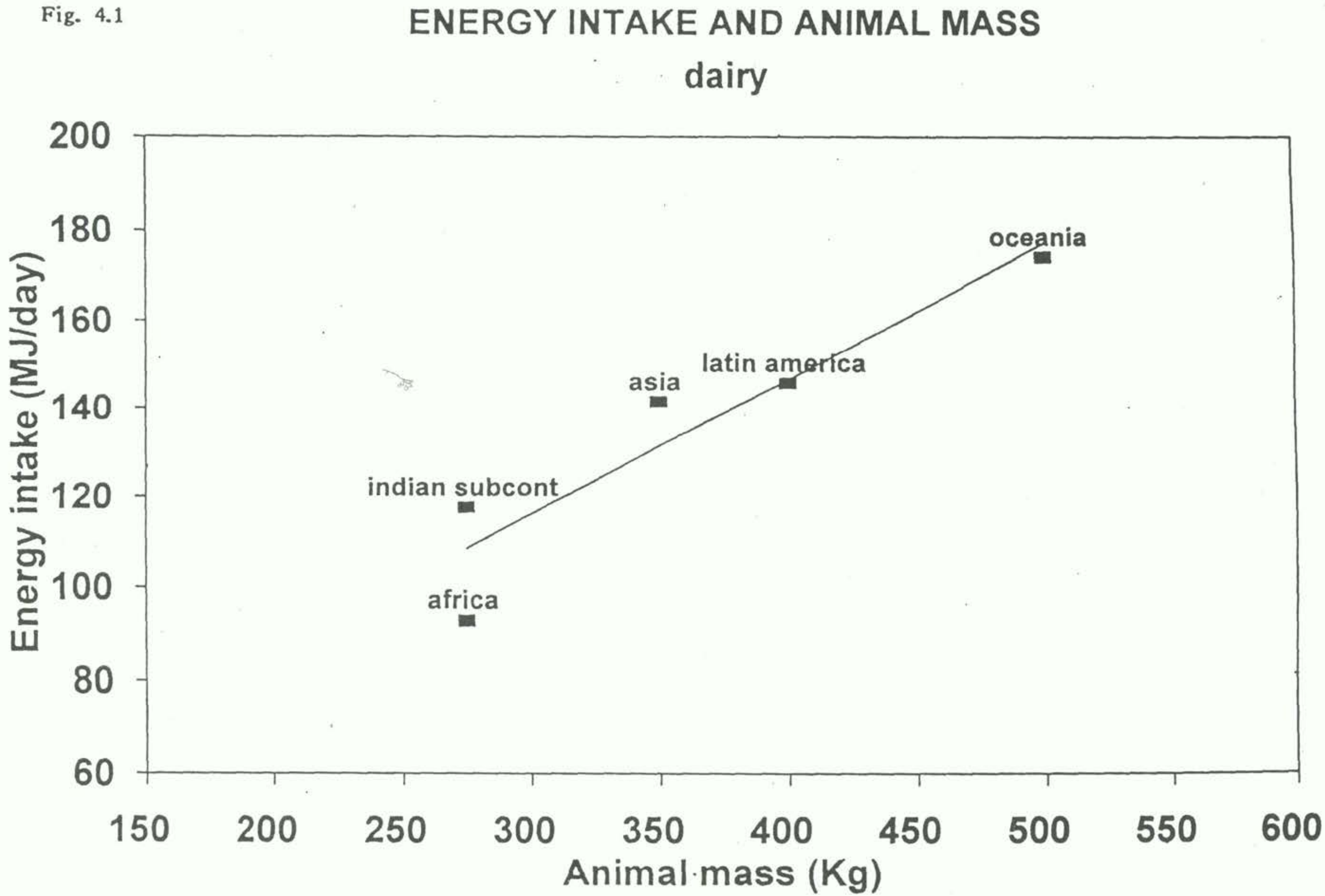

ENERGY INTAKE AND ANIMAL MASS
dairy
Energy intake (MJ/day)
200
180
160
140
120
100
80
60
Animal mass (Kg)
150
200
250
300
350
400
450
500
550
600
oceania
latin america
asia
indian subcont
africa

Fig. 4.2

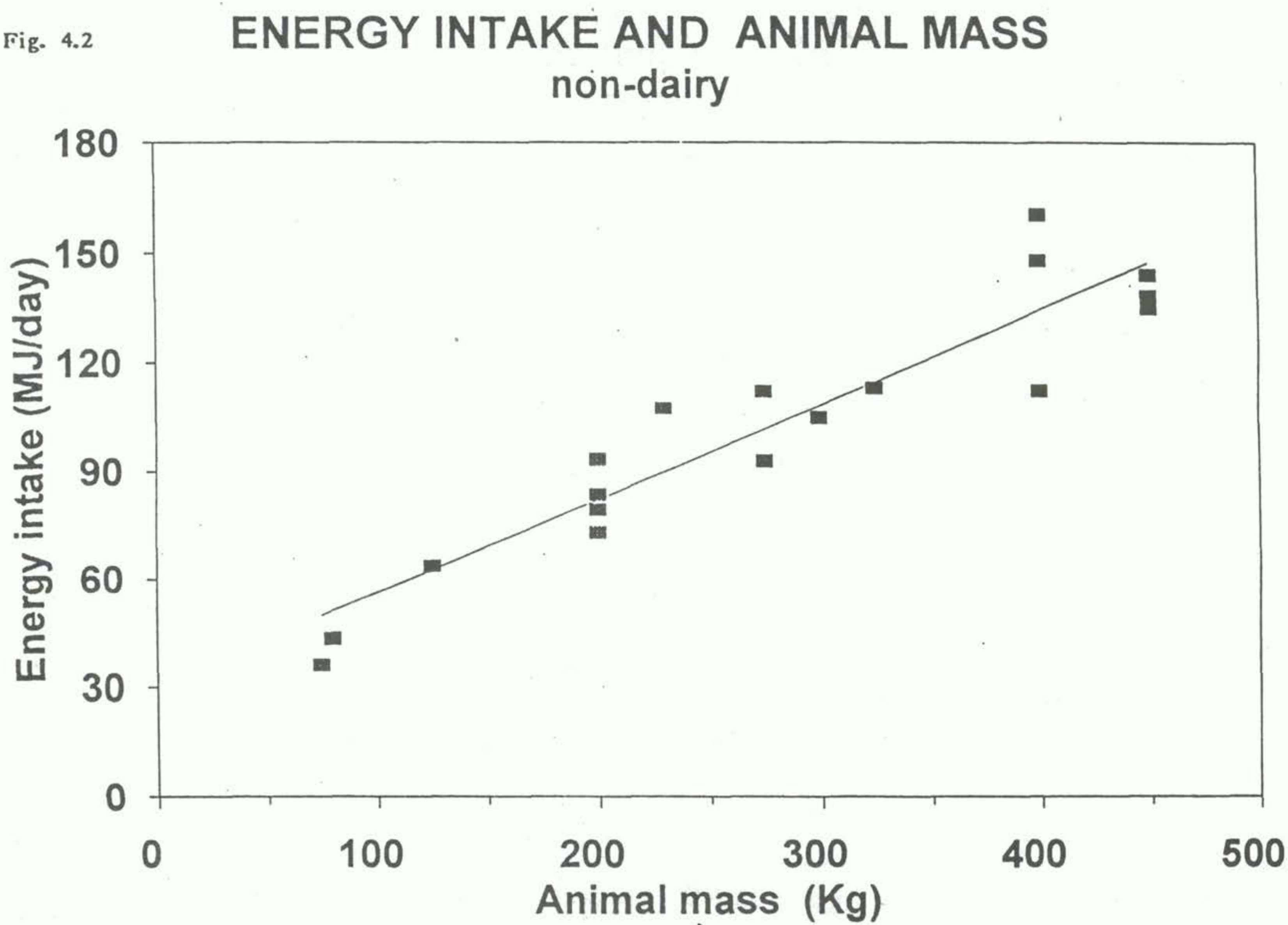

ENERGY INTAKE AND ANIMAL MASS
non-dairy
Energy intake (MJ/day)
180
150
120
90
60
30
0
0
100
200
300
400
500
Animal mass (Kg)

Fig. 4.3

HERD STRUCTURE BY AGE

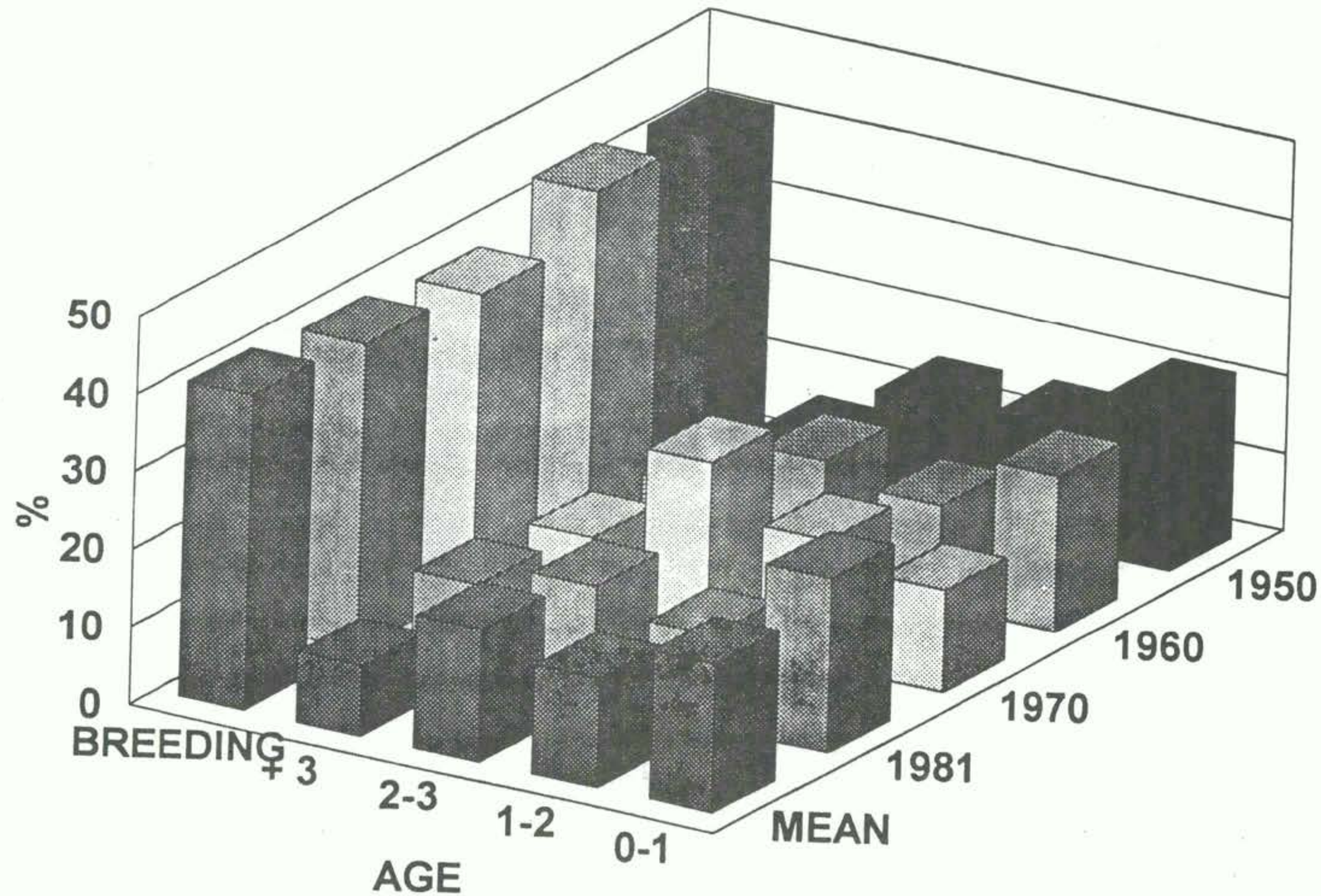
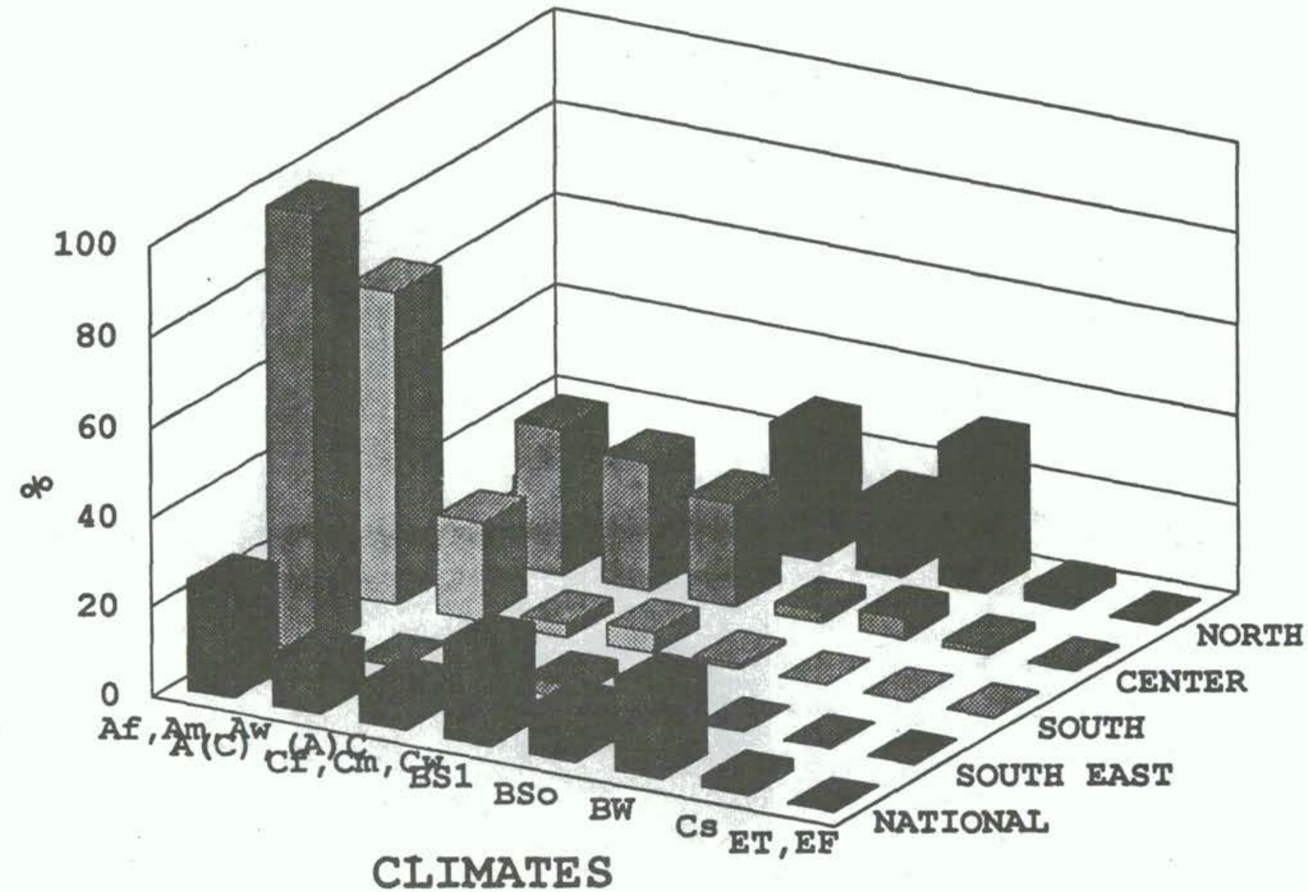


Fig. 4.4

CLIMATE DISTRIBUTION BY REGION



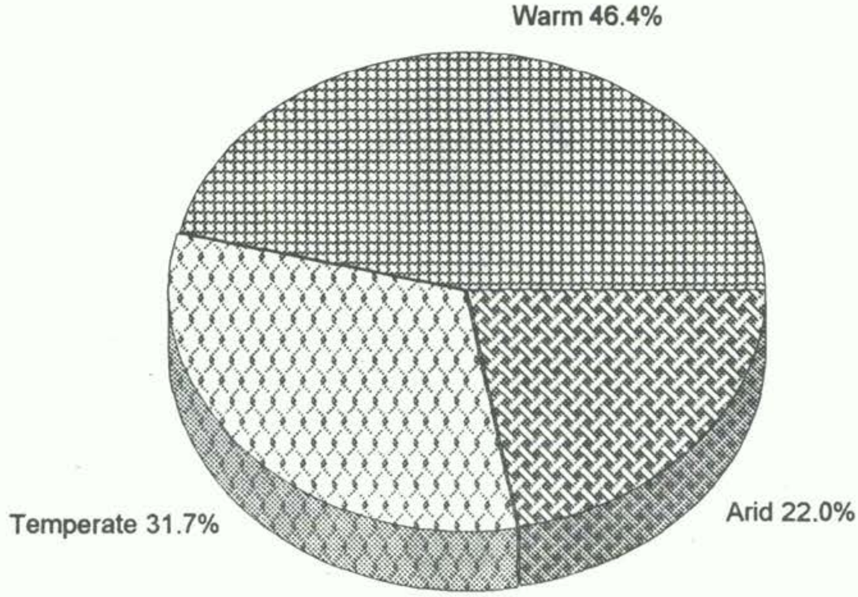


Fig. 4.5 Methane Emissions from Cattle Manure by Climate Distribution.

Standard Data Table 4
Agriculture: 4 A and B Enteric Fementation and Manure Management
National

Source and sink Categories	Activity Data	Emission Estimates	Factor	Aggregate Emission	
	A		B		C
	Number of Animals (1000	Enteric fermentation (Cg CH_4)	Animal Manure	Enteric fermentation (KG CH_4 per animal) C=(B/A)x 1000	Animal manuere
Cattle	32.055.417	1.624.041	24.798	ND	*
a Dary	6.665.702	379.945	5.386	57	8
b Non-Dairy	25.389.715	1.244.096	19.412	49	*
2 Buffalo	NE	NE	NE	NE	NE
3 Sheep	5,744.676	28.723	0.800	5	0.139
4 Goats	10.433.343	52.167	1.554	5	0.149
5 Camels and Llamas	NE	NE	NE	NE	NE
6 Horses	3.322.223	59.800	4.882	18	1.469
7 Mules/Asses	2.403.777	24.038	1.938	10	0.806
8 Swine	15.566.159	15.567	10.809	1	0.694
9 Poultry	252.561.152	NC	4.021	ND	0.016
10 Other	NE	NE	NE	NE	NE
Total	- - -	1.804.336	38.802	- - -	- - -

* = Emission factors obtained by use of equations 4.1 and 4.2 were used for each one of the age categories given in tables 4.1 and 4.2
NC = Non calculated
ND = Non data
NE = Non exist

Standard Data Table 4
Agriculture: 4 A and B Enteric Fermentation and Manure Management
Cool/ardi regions

Source and sink Categories	Activity Data	Emission estimates		Aggregate emission factor	
	A	B		C	
	Number of Animals	Enteric fermentation	Animal manure	Enteric fermentation	animal manure
	(1000)	($GgCH_4$)		(KG CH_4 per animal) C=(B/A) x 1000	
1 Cattle	11.941.133	605.531	5.449	ND	*
a Dairy	2.558.140	145.814	1.129	57	*
b Non-Dairy	9.382.993	459.767	4.320	49	*
2 Buffalo	NE	NE	NE	NE	NE
3 Sheep	3.172.785	15.864	0.317	5	0.100
4 Goats	5.732.335	28.812	0.631	5	0.110
5 Camels and Llamas	NE	NE	NE	NE	NE
6 Horses	1.823.863	33,027	2.000	18	1.090
7 Mules/Asses	1.327.606	13.276	0.797	10	0.600
8 Swine	8.597.521	8.597	0.000	1	0.000
9 Poultry	139.489.524	NE	1.674	ND	0.012
10 Other	NE	NE	NE	NE	NE
Total	- -	805.160	10.868	- -	- -

* = Emission factors obtained by use of equation 4.1 y 4.2
were used for each one of the age categories given in table 4.1 and 4.2
NC = Non calculated
ND = Non data
NE = Non exist

Standard Data Table 4
Agriculture: 4 A and B Enteric Fermentation and Manure Management
Temperate regions

Source and sink Categories	Activity Data	Emission estimates		Aggregate emission factor	
	A	B		C	
	Number of Animals	Enteric fermentation	Animal manure	Enteric fermentation	Animal manure
	(1000)	($GgCH_4$)		(KG CH_4 per animal) $C=(B/A) \times 1000$	
1 Cattle	9.620.515	495.777	7.849	ND	*
a Dairy	2.046.514	173.651	2.797	57	*
b Non-Dairy	6.574.001	322.126	5.052	49	*
2 Buffalo	NE	NE	NE	NE	NE
3 Sheep	1.154.680	5.773	0.185	5	0.160
4 Goats	2.097.102	10.485	0.357	5	0.170
5 Camels and Llamas	NE	NE	NE	NE	NE
6 Horses	667.767	12.020	1.095	18	1.640
7 Mules/Asses	483.159	4.832	0.435	10	0.900
8 Swine	3.128.919	3.129	3.129	1	1.000
9 Poultry	50.764.791	NC	0.914	ND	0.018
10 Other	NE	NE	NE	NE	NE
Total	- -	532.02	13.96	- -	- -

* = Emission factors obtained by use of equation 4.1 y 4.2
were used for each one of the age categories given in table 4.1 and 4.2
NC = Non calculated
ND = Non data
NE = Non exist

Standard Data Table 4
Agriculture: 4 A and B Enteric Fermentation and Manure Management
Warm regions

Source and sink Categories	Activity Data	Emission estimates		Aggregate emission factor	
	A	B		C	
	Number of Animals	Enteric fermentation	Animal manure	Enteric fermentation	Animal manure
	(1000)	($GgCH_4$)		(KG CH_4 per animal) C=(B/A) x 1000	
1 Cattle	10.493.769	522.683	11.499	ND	*
a Dairy	1.061.048	60.480	1.460	57	*
b Non-Dairy	9.432.721	462.203	10.039	49	*
2 Buffalo	NE	NE	NE	NE	NE
3 Sheep	1.417.212	7.086	0.298	5	0.210
4 Goats	2.573.906	12.869	0.566	5	0.220
5 Camels and Llamas	NE	NE	NE	NE	NE
6 Horses	819.592	14.753	1.787	18	2.180
7 Mules/Asses	593.012	5.930	0.706	10	1.190
8 Swine	3.840.319	3.840	7.680	1	2.000
9 Poultry	62.306.836	NC	1.433	ND	0.023
10 Other	NE	NE	NE	NE	NE
Total	- -	567.16	23.97	- -	- -

* = Emission factors obtained by use of equation 4.1 y 4.2 were used for each one of the age categories given in table 4.1 and 4.2
NC = Non calculated
ND = Non data
NE = Non exist

Standard Data Table 4
Agriculture: 4 B Manure management
National

Source and sink categories		Activity data	Emission estimates	Aggregate emission factor
		A Number of Animals (1000)	B Animal manure ($GgCH_4$)	C Animal manure (KG CH_4 per animal) C=(B/A) x 1000
1 Cattle		32.054.300	24.798	*
	a Dairy	6.665.702	5.386	*
	b Non-Dairy	25.388.598	19.412	*
a Dairy	0-1 years old	1.508.723	0.794	0.526
	1-2 years old	723.752	0.544	0.752
	2-4 years old	793.142	0.711	0.896
	+3 years old	307.388	0.379	1.233
	Cows	3.332.697	2.958	0.888
Non-Dairy	0-1 years old	5.388.243	2.537	0.471
	1-2 years old	4.189.959	2.922	0.697
	2-3 years old	3.513.076	3.082	0.877
	+3 years old	1.421.357	1.406	0.989
	Cows	10.875.963	9.465	0.870

* = Emission factors obtained by use of equation 4.1 y 4.2 were used for each one of the age categories given in table 4.1 and 4.2

Standard Data Table 4
Agriculture: 4 B Manure management
Cool/arid regions

Source and sink categories		Activity data	Emission estimates	Aggregate emission factor
		A Number of Animals (1000)	B Animal manure ($GgCH_4$)	C Animal manure (KG CH_4 per animal) C=(B/A) x 1000
1 Cattle		11.941.133	5.449	*
	a Dairy	2.558.140	1.129	*
	b Non-Dairy	9.382.993	4.320	*
a Dairy	0-1 years old	578.031	0.165	0.285
	1-2 years old	268.401	0.122	0.454
	2-4 years old	278.682	0.156	0.560
	+3 years old	103.754	0.081	0.781
	Cows	1.311.273	0.605	0.461
Non-Dairy	0-1 years old	2.118.283	0.607	0.287
	1-2 years old	1.403.851	0.581	0.414
	2-3 years old	1.038.413	0.535	1.025
	+3 years old	521.903	0.324	0.621
	Cows	4.300.542	2.273	0.529

* = Emission factors obtained by use of equation 4.1 y 4.2 were used for each one of the age categories given in table 4.1 and 4.2

Standard Data Table 4
Agriculture: 4 B Manure management
Temperate regions

Source and sink categories		Activity data	Emission estimates	Aggregate emission factor
		A Number of Animals (1000)	B Animal manure ($GgCH_4$)	C Animal manure (KG CH_4 per animal) C=(B/A) x 1000
1 Cattle		9.620.515	7.849	*
	a Dairy	3.046.514	2.797	*
	b Non-Dairy	6.574.001	5.052	*
a Dairy	0-1 years old	673.177	0.404	0.600
	1-2 years old	351.047	0.296	0.843
	2-4 years old	379.074	0.375	0.989
	+3 years old	140.881	0.183	1.299
	Cows	1.502.335	1.539	1.024
Non-Dairy	0-1 years old	1.364.481	0.654	0.479
	1-2 years old	1.091.471	0.747	0.684
	2-3 years old	931.619	0.775	0.832
	+3 years old	383.772	0.384	1.001
	Cows	2.802.658	2.492	0.889

* = Emission factors obtained by use of equation 4.1 y 4.2 were used for each one of the age categories given in table 4.1 and 4.2

Standard Data Table 4
Agriculture: 4 B Manure management
Warm regions

Source and sink categories		Activity data	Emission estimates	Aggregate emission factor
		A Number of Animals (1000)	B Animal manure ($GgCH_4$)	C Animal manure (KG CH_4 per animal) C=(B/A) x 1000
1 Cattle		10.494.768	11.499	*
	a Dairy	1.061.047	1.460	*
	b Non-Dairy	9.432.721	10.039	*
a Dairy	0-1 years old	248.515	0.225	0.905
	1-2 years old	104.304	0.127	1.218
	2-4 years old	126.386	0.180	1.424
	+3 years old	62.753	0.114	1.817
	Cows	519.089	0.814	1.568
Non-Dairy	0-1 years old	1.905.707	1.276	0.670
	1-2 years old	1.694.820	1.593	0.940
	2-3 years old	1.543.205	1.772	1.148
	+3 years old	515.757	0.698	1.353
	Cows	3.773.232	4.700	1.246

* = Emission factors obtained by use of equation 4.1 y 4.2 were used for each one of the age categories given in table 4.1 and 4.2

Standard data table 4
Agriculture: 4C Rice Cultivation
Flooded Rice Fields

Source and sink Categories	Activity data		Emission Estimates	Aggregate Emission Factor
	A Area Cultivated in megahectares (Mha)	B Megahectare days of cultivation (Mha-days)*	C Methane (Gg CH_2	D CH_4 Average Emission Factor D=C/B
1 Flooded regime	54.500	130	35.0	0.269
2 Intermitent regime	ND	ND	NC	NC
3 Dry regime	65.108	135	0.0	0.000
Total	119.61	- - -	35.0	- - -

* = Source: Anuario Estadístico de los Estados Unidos Mexicanos. INEGI, 1991
NC = Non Calculated
ND = Non Data

Standard data table 4
Agriculture: 4D Agricultural soils

Source and Sink Categories		Activity data	Emissions	Aggregate Estimates **	Emission factor(s)
Corp type*	A Amount of nitrogen applied in fertilizer and manure (t N)	B Area cultivated (ha)	C Amount of biological fixation of nitrogen (t N)	D Emissions of N_2 (Gg)	E ($t\ N_2O/t\ N$) 1000D/A
All crops	2.409.730	24.710 X 10^3 [a]	617.750[b]	5.51	0.00271

* = This values are to all crops of the country and it corrspond to median emission coefficient.

** = The emission estimates and emission factor are only for N_2O.

[a] = Source: Anuario Estadístico de los Estados Unidos Mexicanos. Instituto Nacional de Estadística, Geografía e Informática, 1991.

[b] = With a nitrogen input from atmospheric deposition of 25 kg N ha^{-1} yr^{-1}.

5. LAND USE CHANGE & FORESTRY

O. Masera, T. Hernández, A. Ordoñez, A. Guzmán

The present study aims at presenting improved estimates of greenhouse gas emissions from land use changes in Mexico in the year 1990.

It is part of an effort to produce a national greenhouse gas emission inventory. Incorporating emissions from land use changes to the national inventory is important because earlier studies have estimated that deforestation might constitute the second largest source of greenhouse gas emissions in Mexico, after the combustion of fossil fuels (Masera et al. 1992).

It needs to be pointed out that the categories in which this section has been divided do not correspond exactly with those on the IPCC common reporting frame.

5.A. METHODS

In this study we estimated carbon emissions from deforestation through an in-depth review of the existing information on forest cover, forest deforestation rates, areas afforested or currently regrowing as well as on forests' carbon-related biological characteristics. To estimate carbon emissions we followed the procedure proposed by IPCC (1994).

We relied on local information –both from official sources and from case-studies– as extensively as possible, using the IPCC default values only when local data were not available. The study covers all closed forest types in the country, that is: tropical evergreen, tropical deciduous, temperate coniferous, and temperate broadleaf, as well as open forests.

A spreadsheet that mimics the IPCC's proposed accounting procedure–i.e., the MINERGG model- was created. This allowed keeping our results consistent with the methodology proposed by IPCC at the same time providing far more flexibility in changing parameters, using multiple estimates and conducting sensibility analyses.

Below we explain the main assumptions and methods used for estimating the most relevant parameters needed for the analysis.

5.A.1. Classification of Forests

The proposed IPCC classification of forests is inadequate to Mexico. Also the proposed forest sub-categories such as "productive", "unproductive", and "logged" are not reported in the Mexican official statistics. To cope with these problems we used an alternative classification, separating temperate forests in broadleaf and coniferous, tropical forests in evergreen and deciduous, and including open forests. Annex 5.1 and 5.2 present the description of each forest category. In the absence of information about forest sub-types such as "undisturbed" and "logged", we assumed that "undisturbed" forests are those belonging to natural protected areas (NPA). "Logged" forests are simply the difference between the total forest area and the NPA.

5.A.2. Area by Forest Type

Accurate information about existing forest areas by forest type exists only for NPA (Annex 5.3). For the remaining forests, while the information has improved since the undertaking of forest remote sensing inventories, there are still large discrepancies in the precise areas. Part of these discrepancies have to do with the continuous changes in the meaning of each forest category (for example, the two most recent forest inventories, "Inventario Forestal de Gran Visión" and "Inventario Forestal Periódico 1992-1994" include major changes in the proposed forest categories, making comparisons very difficult).

For the present study we relied on the forest areas presented in the "Inventario Forestal Nacional de Gran Visión" (SARH, 1992), which is the only inventory that estimates forest areas for the year 1990. Annex 5.4 presents the information as available from the forest inventory. Annex 5.5 and 5.6 show the forest areas that result by applying the proposed classification of forest types to the data in the forest inventory.

5.A.3. Deforestation Rates

Estimates about deforestation rates in Mexico in the 1980's range from 329,000 ha to 1,500,000 million ha (Annex 5.7). Official sources (SARH, 1991 and 1992) report deforestation rates of 370,000 ha, including open and closed forests. The most detailed analysis of deforestation rates currently available in the country (Masera et al. 1992) suggests that 804,000 ha/yr are deforested annually and affected by forest fires in closed forests alone. This last figure is more consistent with the deforestation rates found in case studies located in the different forest ecosystems.

Given the large differences between official and non-official estimates of deforestation rates, we decided to use a "high" and a "low" estimate for the present study. The "high" estimate uses the figures derived by Masera et. al (1992) for closed forests, and incorporates SARH (1991) estimates about deforestation rates in open forests. The "low" estimates uses the SARH (1991) estimates for open and closed forests (Annex 5.8 presents the estimates by state and main forest type).

Using the suggested procedure we obtain deforestation rates close to 1% for temperate forests and around 2% for tropical forests in the "high" estimate; while the same figures are 0.5% and approximately 0.8% for temperate and tropical forests, respectively, in the "low" estimate. For open forests we use a deforestation rate of 0.08% (Annex 5.9).

It should be noted that the deforestation rates used in the "high" estimate include all the area affected by forest fires, while the "low" estimate incorporates only the area affected by forest fires that is assumed to do not regenerate. This discrepancy makes necessary handling differently the assumed biomass "after" deforestation in the two cases (see below).

5.A.4. Aboveground biomass before forest clearing

Inventories based on destructive sampling are currently available only for tropical deciduous forests in Mexico. For the remaining forests, expansion factors need to be used to convert commercial volume to total biomass.

Annex 5.10 present existing estimates of total aboveground biomass for the different forest types considered in this study. For temperate forests, we decided to use data from the latest forest inventory, expanding from commercial to total biomass using the IPCC suggested expansion factors. We also assume that the most dense forests (both broadleaf and conifer) are concentrated in NPA, while logged forests represent the area-weighed average biomass for dense and non-dense forests.

For tropical evergreen forests we used the estimate derived by Masera et al. (1992) which estimates total aboveground biomass from data about basal areas. The estimates for tropical deciduous forests come from detailed destructive sampling inventories conducted in a research station from the National University of Mexico.

There is no local information about aboveground biomass for open forests. In this case we relied on estimates from other studies.

5.A.5. Aboveground biomass after forest clearing

The amount of biomass remaining after deforestation heavily depends upon the land conversion activity that replaces the original forest cover. Thus, an estimate of the share of different forest conversion activities by forest type is needed. Knowing the share of the different forest conversion activities a weighed average of the aboveground biomass "after" forest clearing could be calculated.

In the present study we first estimated the shares of the main forest conversion activities by forest type for both the "high" and "low" deforestation rates. In the "low" estimate, forest conversion activities correspond largely to agriculture and pasture (Annex 5.11 and 5.12), thus we used the default values suggested by IPCC (10 ton/ha for temperate and tropical forests and 5 ton/ha for open forests). However, in the "high" estimate, forest fires play a large role, particularly in temperate forests, where they reach 49% of the area perturbed annually (Annex 5.13). Thus, in this case, we estimated a weighed average, considering the IPCC default values for the area converted to agriculture and pasture, and the values estimated by Masera et al. (1992) for the area affected by forest fires. The resulting estimates are, 25 ton/ha for temperate conifer forests; 19 ton/ha for temperate broadleaf; 42 ton/ha for tropical evergreen, and 13 ton/ha for tropical deciduous forests.

5.A.6. Decay of aboveground biomass and changes in soil carbon content

We used the "high" and "low" estimate of forest clearing to estimate the average area cleared in the last 10 and 25 years (Annex 5.14 and 5.15). Different estimates of soil carbon content of Mexican forests have been used in previous studies (Annex 5.16). However, none of these studies use estimates derived from measurements in Mexico. Therefore, we decided to use the IPCC default values. We assume that no change in the carbon content of soils happens when tropical forests are cleared. Thus, soil carbon releases are assumed to come entirely from temperate and open forests.

5.A.7. Conversion of grasslands to agriculture

Areas with natural grasslands are concentrated in Northern Central Mexico. In these regions part of these grasslands have been converted to agriculture in the past decades (currently the process is not thought to be very important). However, we were not able to collect reliable information on the rate of conversion of grasslands to agriculture and decided to leave the whole section blank.

5.A.8. Biomass uptake from abandoned lands

There is little information about abandoned lands in the country. Relatively accurate information is available only for degraded forest lands. We re-classified these lands in three types, according to the original forest cover: "tropical", "temperate" and "open forests". We then substracted the amount of lands severely degraded to each category and made the assumption that the remaining degraded forest lands have been created at the same rate as forests have been cleared. We thus obtained a "high" and "low" estimate of degraded and re-growing forest lands created in the last 100 years by main forest type (Annex 17).

The net biomass uptake in these forest lands was obtained using the IPCC suggested procedure (i.e. assuming that forests regrow only to 80% of the original forest biomass; and that they reach 50% and 70% of total assumed biomass in temperate and tropical forests, respectively, in the first 20 years) (Annex 18).

5.A.9. Carbon Uptake and Emissions from Managed Forests

a. Reforested/Afforested lands: Total annual biomass uptake was estimated using the total land afforested by state in the last 20 years, corrected by the tree's average survival ratio (34The uptake per hectare was estimated using conservative biomass growth rates, as afforestation programs are conducted in Mexico mostly for restoration of severely degraded lands. It was not possible to estimate the amount of urban and village trees.

b. Managed Forests: Annex 20 shows the forest area and estimated annual increment by the different categories of commercially managed forests existing in Mexico: native temperate forests (both under improved and traditional harvesting systems), native tropical forests and forest plantations, and forests managed for fuelwood. This last area and uptake was assumed to be equivalent to the area and uptake needed to cope with the amount of fuelwood sustainably harvested in the country.

The total biomass consumption of forest products was obtained from data about wood harvested by main tree species, expanding to total biomass using an average factor between IPCC's and Cannell's (1992) (Annex 21). The consumption of fuelwood that does not come from deforestation was added to the previous figures.

Balancing the consumption of forest products with the biomass production is difficult because there are no reliable statistics about subsistence uses of forest products. For these reasons, we had to leave the column of "other wood uses" blank, even if it is known that villagers use non-negligible amounts of wood for housing, fencing and other domestic uses.

As a reference to the analysis conducted following the IPCC methodology, Annex 22 shows the estimated biomass uptake in the forest areas of Mexico, using the data provided by the 1990 forest inventory.

5.B. CARBON DIOXIDE EMISSIONS

Tables 5.1 to 5.6 show the carbon emissions for each of the main emission categories stated in the IPCC methodology. Emissions from burning aboveground biomass on and off site due to forest clearing reach from 13.8 to 33.4 MtonC/yr, depending on the estimate about deforestation rates. Additional 9.7 to 18 MtonC/yr are estimated to be emitted by changes in the carbon content of soils from temperate forests. Thus total emissions from land clearing reach from 23.5 to 51.4 MtonC/yr (Table 5.6)

The total estimated carbon uptake ranges from 14.2 to 20.9 MtonC/yr, out of which 7.2 MtonC/yr come from managed forests (Table 5.6). The fact that managed forests are currently net carbon sinks is explained because actual timber harvesting is less than the volume authorized by the Government on the basis of forest growth rates, as the forest industry is currently undergoing a deep economic crisis. There is also a significant uptake coming from abandoned lands.

Subtracting uptake from emissions, we get net carbon emissions reaching from 9.3 to 30.5 MtonC/yr depending on the assumed deforestation rates (Table 5.6). This result confirms that forests are the second largest source of greenhouse gas emissions in Mexico, only after the combustion of fossil fuels. The figures obtained for emissions from forest clearing (high estimate) are within the range of previous studies on the topic, i.e., Masera et al. (1992) and WRI (1993). However, net emissions (again for the high estimate) are considerably lower than the figures reported in these and other studies (Cairns et al. 1995). This discrepancy might be partly explained by the inclusion of a more detailed analysis of carbon sinks from managed forests and abandoned lands in the present study.

5.C. EMISSIONS OF OTHER GREENHOUSE GASES

Emissions of trace greenhouse gases reach from 58 to 195 kt for methane, 504 to 1,704 kt for carbon monoxide, about 1 kt for nitrous oxide, and 9 to 32 kt for nitrogen oxides (NOx), depending on the assumed deforestation rate.

5.D. Conclusions: Research Priorities for Further Work

The present work has attempted to improve existing estimates of greenhouse gas emissions from forestry and land use changes in Mexico. To that end a thorough review of available information and primary data has been conducted.

However, large uncertainties remain about the precise amount of carbon emissions from land use changes. This is because there are important gaps of information regarding most of the critical parameters that affect carbon emissions and uptake in Mexican forests. To reduce these information gaps future work should be devoted to:

a) Improve the estimates about deforestation rates by forest type. These estimates should be derived from high resolution remote sensing techniques, with field validation.

c) Better ascertain the dynamics of land use change by forest type. Usually forests are not directly converted to agriculture or pasture, but are subject to different perturbations; also some of the forests originally converted to agriculture are abandoned. Thus, an estimate of the "average" composition of different forest conversion activities through time is needed.

b) Obtain more precise estimates of aboveground biomass densities for the main forest ecosystems. Here a combination of destructive sampling with a detailed processing of existing forest inventories might be appropriate. Remote sensing techniques could also be applied to show the spatial variability of forest aboveground biomass. In any case, it is important that information from the existing permanent forest sites (which includes not only total volume, but also the distribution of trees by age or diameter class) is made available.

c) Ascertain to what extent clearing of tropical forests actually leads to changes in soil carbon content or not. In these regards, more research is also needed to obtain local estimates of the "average" carbon content of different forest ecosystems. Currently these estimated had to be drawn from the international literature.

d) Better analyze the annual carbon uptake from abandoned lands and from managed forests. In the case of abandoned, or perturbed forest lands, more information is needed on productivities by main forest type, the share of perturbed lands that ultimately completely degrade, etc. For managed forests, more information is needed particularly for subsistence uses (fuelwood, fencing, housing, etc.). The actual vs reported extent of harvesting, together with improved estimates of the area of forests affected by these activities is needed in order to better estimate the balance of emission/uptake in these forests.

5. E. UNCERTAINTY

The present study constitues an improvement over previous estimates of carbon emissions from land use change in Mexico. However, because of information gaps and lack of reliable primary data large uncertainties still remain in the resulting estimates.

The main uncertainties regarding carbon emissions, include discrepancies or lack of information about land cover, deforestation rates, and carbon densities (soil plus vegetation) before and after land clearing by forest type. There are also uncertainties regarding the carbon sequestration in abandoned lands, secondary forests, and managed forests.

We have tried to partly cope with these uncertainties deriving a low and high estimate for carbon emissions. We feel that the "high" estimate better represents the more likely amount of emissions coming from land use changes in Mexico. However, only more through detailed research on the lines suggested in the previous section, these uncertainties might be reduced.

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Table 5.1
Summary of net carbon and trace gas emissions
from the forest sector of Mexico

	Emissions from forest clearing			Total Emissions	Uptake Aban-donded lands	Uptake/ Emissions managed forest	Total Uptake	Total Net Emissions	Total Net Emissions	Other trace green-house gases	Trace gas Emissions for burn-ing of cleared forest
	Burning Above-ground	Decay Above-ground	Soils								
	(Kt C)	(Kt C)	(Kt C)	(Kt C)	(Kt C)	(Kt C)	(Kt C)	(Kt C)	(Kt CO2)		(Kt)
High estimate										High estimate	
Temperate	1,769	2,053	16.397	20,219	-3,644					CH4	195
Tropical	13,045	16,087	0	29,133	-9,732					CO	1,704
Open Forests	214	238	1,600	2,052	-350					N2O	1
Total	15,029	18,378	17,996	51,403	-13,725	-7,192	-20,917	30,487	111,784	NOx	32
Low estimate										Low estimate	
Temperate	1,263	1,435	8,133	10,831	-2,738					CH4	58
Tropical	4,951	5,697	0	10,648	-3,919					CO	504
Open Forests	214	238	1,600	2,052	-350					N2O	0
Total	6,427	7,370	9,732	23,530	-7,007	-7,192	-14,199	9,331	34,215	NOx	9

Module:Land use change and forestry
Submodule: forest clearing - CO_2 release from burning above ground biomass on and off site
Worksheet 5-1
Sheet A-B

Forest types (High estimate)				A Area Cleared Annually (Kha)	B Biomass before clearing (t dm/ ha)	C Biomass after clearing (t dm/ ha)	D Net change in biomass (t dm/ ha) D=(B-C)	E Annual loss of biomass (kt dm) ha) E=(AxD)	F Fraction of biomass burned on site	G Quality of biomass burned on site (kt dm) G=(ExF)	H Fraction of biomass oxidized on site (contribution efficiency)	I Quality of biomass oxidized on site (kt dm) I=(GxH)	J Carbon fraction of aboveground biomass (burned) on site	K Quality of carbon released (kt C) K=(ixJ)
		Broad-leaf	Undisturbed	0	64	n.a	64	0	0.4	0	0.90	0	0.45	0
	Closed		Logged	79	46	19	27	2 105	0.4	852	0.90	767	0.45	345
	Forests	Conifer	Undisturbed	0	90	n.a	90	0	0.4	0	0.90	0	0.45	0
Temperate			Logged	164	65	25	40	6 633	0.4	2 686	0.90	2 418	0.45	1 088
		Unproductive		n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
	Open forests		Productive	0	37	n.a	37	0	0.4	0	0.90	0	0.45	0
			Unproduct	53	25	5	20	1 056	0.4	428	0.90	385	0.45	173
	Evergreen	undisturbed		0	240	n.a	240	0	0.4	0	0.90	0	0.45	0
Tropical		Logged		212	240	42	198	41 960	0.4	16 994	0.90	15 294	0.45	6 883
	Deciduous	Undisturbed		0	85	n.a	85	0	0.4	0	0.90	0	0.45	0
		Logged		312	85	13	72	22 462	0.4	9 079	0.90	8 187	0.45	3 684
Other														
				820	113		91	74 216		30 057		27 052	Sub-total	12 173
						3			2		1		1	

otes:
) IPCC default values
) Assumption. Total fuelwood used in Mexico 37 million m'*0.6 density *0.3 coming from deforestationm * 7 million ton dm fw (Masera, 1993)
) See text for explanation about the assumption used

Module:Land use change and forestry
Submodule: forest clearing - CO_2 release from burning above ground biomass on and off site
Worksheet 5-1
Sheet A-B

Forest types (Low estimate)				A Area Cleared Annually (Kha)	B Biomass before clearing (t dm/ha)	C Biomass after clearing (t dm/ha)	D Net change in biomass (t dm/ha) D=(B-C)	E Annual loss of biomass (kt dm) ha) E=(AxD)	F Fraction of biomass burned on site	G Quality of biomass burned on site (kt dm) G=(ExF)	H Fraction of biomass oxidized on site (contribution efficiency)	I Quality of biomass oxidized on site (kt dm) I=(GxH)	J Carbon fraction of aboveground biomass (burned) on site	K Quality of carbon released (kt C) K=(ixJ)
		Broad-leaf	Undis-turbed	0	64	10	54	0	0.3	0	0.9	0	0.45	0
	Closed		Logged	42	46	10	36	1 489	0.3	419	0.9	377	0.45	170
	Forests	Conifer	Undis-turbed	0	90	10	80	0	0.3	0	0.9	0	0.45	0
Temper-ate			Logged	86	65	10	55	4 738	0.3	1 327	0.9	1 194	0.45	573
		unpro-ductive		n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
	Open forests		Product-ive	0	37	0	37	0	0.3	0	0.9	0	0.45	0
			Unpro-duct	53	25	5	20	1 056	0.3	296	0.9	266	0.45	120
	Ever-green	undis-turbed		0	240	0	240	0	0.3	0	0.9	0	0.45	0
Tropical		Logged		66	240	10	230	15 182	0.3	4 251	0.9	3 826	0.45	1 722
	Decid-uous	Undis-turbed		0	85	0	85	0	0.3	0	0.9	0	0.45	0
		Logged		124	85	10	75	9 266	0.3	2 595	0.9	2 335	0.45	1 051
Other														
				370	95		86	31 740		8 887		7 999	Sub-total	3 599
						1			2		1		1	

Notes:
1) IPCC default values
2) Assumption: Some as for high estimate, adjusted to 0.8 to account for 7 million ton tw coming from deforestation.

Module: Land use change and forestry
Submodule: Forest clearing - CO_2 release from burning above ground biomass on and off site
Worksheet 5-1
Sheet C

Forest Types (High estimate)				L Fraction of biomass burned off site	M Quality of biomass burned off site (kt dm) M= (ExL)	N Fraction of biomass oxidized off site (combustion efficency)	O Quality of biomass oxidized off site kt(dm) 0= (MxN)	P Carbon fraction of aboveground biomass (burned off site)	Q Quality of carbon released as CO2 (from biomass off site) Q= (QxP)	R Total carbon released as CO2 (From on &off site burning) R= (K+Q)	S Total of released CO2 re- (kt CO2) S=Rx (44/12)
		Broad leaf	Undis-turbed	0.10	0	0.9	0	0.45	0	0	0
	Closed		Logged	0.10	200	0.9	180	0.45	81	426	1 563
	forests	Conifer	Undis-turbed	0.10	0	0.9	0	0.45	0	0	0
Temperate			Logged	0.10	630	0.9	567	0.45	255	1 343	4 925
		Unpro-ductive		n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
	Open		product-ive	0.10	0	0.9	0	0.45	0	0	0
	forest		Unpro-duct	0.10	100	0.9	90	0.45	41	214	784
	Ever-green	Unids-turbed		0.10	0	0.9	0	0.45	0	0	0
Tropical		Logged		0.10	3 986	0.9	3 588	0.45	1 614	8 497	31 155
	Decid-uous	Undis-turbed		0.10	0	0.9	0	0.45	0	0	0
Other		Logged		0.10	2 134	0.9	1 920	0.45	864	4 549	16 678
				Sub-total	7 051		6 345	Sub-total	2 855	15 029	66 106
						1		1			

Note: 1) IPCC default values

Module: Land use change and forestry
Submodule: Forest clearing - CO_2 release from burning above ground biomass on and off site
Worksheet 5-1
Sheet C

Forest Types (Low estimate)				L Fraction of biomass burned off site	M Quality of biomass burned off site (kt dm) M= (ExL)	N Fraction of biomass oxidized off site (combustion efficency)	O Quality of biomass oxidized off site kt(dm) 0= (MxN)	P Carbon fraction of aboveground biomass (burned off site)	Q Quality of carbon released as CO2 (from biomass off site) Q= (QxP)	R Total carbon released as CO2 (From on &off site burning) R= (K+Q)	S Total of released CO2 re- (kt CO2) S=Rx (44/12)
		Broad leaf	Undisturbed	0.22	0	0.9	0	0.45	0	0	0
	Closed		Logged	0.22	330	0.9	297	0.45	133	303	1 112
	forests	Conifer	Undisturbed	0.22	0	0.9	0	0.45	0	0	0
Temperate			Logged	0.	1 042	0.9	938	0.45	422	959	3 518
		Unproductive		n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
	Open		productive	0.22	0	0.9	0	0.45	0	0	0
	forest		Unproduct	0.22	232	0.9	209	0.45	92	214	784
	Evergreen	Unidsturbed		0.22	0	0.9	0	0.45	0	0	0
Tropical		Logged		0.22	3 340	0.9	3 006	0.45	1 353	3 074	11 273
	Deciduous	Undisturbed		0.22	0	0.9	0	0.45	0	0	0
		Logged		0.22	2 039	0.9	1 835	0.45	826	1 876	6 880
Other				Sub-total	6 983		6 286	Sub-total	2 828	6 427	23 667
						1		1			

Note: 1) IPCC default values

Module: Land use change and forestry
Submodule: Forest clearing - CO_2 release from decay of above ground biomass
Worksheet 5-1
Sheet D

Forest types (High estimate)				A Annual Area cleared (10 year average) (Kha)	B Biomass Before clearing (t dm/ha)	C Biomass After clearing (t dm/ha)	D Net change in biomass (kt dm) D=(B-C)	E Average annual loss of biomass (kt dm) E=(AxD)	F Fraction left to decay	G Quantity of biomass to decay (kt dm) G=(ExF)	H Carbon fraction in above-ground biomass	I Portion C Released as CO_2 (kt C) I=(GxH)
Temperate	Closed forests	Broad leaf	Undisturbed	0	64	n.a	64	0	0.5	0	0.45	0
			Logged	82	46	19	27	2 196	0.5	1 098	0.45	494
		Conifer	Undisturbed	0	90	n.a	90	0	0.5	0	0.45	0
			Logged	172	65	25	40	6 927	0.5	3 463	0.45	1 559
		Unproductive		n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
	Open forests		Productive	0	37	n.a	37	0	0.5	0	0.45	0
			Unproductive	53	25	5	20	1 060	0.5	530	0.45	238
Tropical	Evergreen	Undisturbed		0	240	n.a	240	0	0.5	0	0.45	0
		Logged		237	240	42	198	46 880	0.5	23 440	0.45	10 548
	Deciduous	Undisturbed		0	85	n.a	85	0	0.5	0	0.45	0
		Logged		342	85	13	72	24 618	0.5	12 309	0.45	5 539
Other				886	116		92	81 681		40 840		18 378
						2			1		1	

Notes:

1) IPCC default values

2) See text for explanation about the assumption used.

Module: Land use change and forestry
Submodule: Forest clearing - CO_2 release from decay of above ground biomass
Worksheet 5-1
Sheet D

Forest types (Low estimate)				A Annual Area cleared (10 year average) (Kha)	B Biomass Before clearing (t dm/ha)	C Biomass After clearing (t dm/ha)	D Net change in biomass (kt dm) D=(B-C)	E Average annual loss of biomass (kt dm) E=(AxD)	F Fraction left to decay	G Quantity of bio-mass to decay (kt dm) G=(ExF)	H Carbon fraction in above-ground biomass	I Portion C Released as CO_2 (kt C) I=(GxH)
Temperate	Closed forests	Broad leaf	Undisturbed	0	64	10	54	0	0.5	0	0.45	0
			Logged	43	46	10	36	1 532	0.5	766	0.45	345
		Conifer	Undisturbed	0	90	10	80	0	0.5	0	0.45	0
			Logged	87	65	10	55	4 846	0.5	2 423	0.45	1 090
		Unproductive		n.a	n.a	n.a	n.a	n.a	n.a	n.a	b.a	n.a
	Open forests		Productive	0	37	0	37	0	0.5	0	0.45	0
			Unproductive	53	25	5	20	1 060	0.5	530	0.45	238
Tropical	Evergreen	Undisturbed		0	240	0	240	0	0.5	0	0.45	0
		Logged		68	240	10	230	15 712	0.5	7 856	0.45	3 535
	Deciduous	Undisturbed		0	85	0	85	0	0.5	0	0.45	0
		Logged		128	85	10	75	9 607	0.5	4 804	0.45	2 162
Other				380	96		86	32 767		16 378		7 370
						1			1		1	

Note:

1) IPCC default values

Module: Land use change and forestry
Submodule: Forest clearing - Soil carbon release
Worksheet 5-1
Sheet E

Forest types (High estimate)				A Average annual forest cleared (25 year average) (kha)	B Soil carbon content of forest soil (t/ha)	C Total annual potential soil carbon loss (kt C) C=(AxB)	D Fraction of carbon released	E Carbon released from soil carbon (kt C) E=(CxD)
		Broad leaf	Undisturbed	0		0	0.5	0
	Closed forests		Logged	89	120	10 637	0.5	5 319
		Conifer	Unidsturbed	0		0	0.5	0
Temperate			Logged	185	120	22 156	0.5	11 078
		Unproductive		n.a	n.a	n.a	n.a	n.a
	Open forests		Productive	0		0	0.5	0
			Unproductive	53	60	3 199	0.5	1 600
	Ever-Green	Undisturbed		0		0	0.0	0
Tropical		Logged		287	115	33 041	0.0	0
	Deciduous	Undisturbed		0		0	0.0	0
		Logged		401	100	40 072	0.0	0
Other								
				1 015	108	109 106		17 996
					1		2	

lotes:

) IPCC default values probably overestimate the soil carbon content of broadleaf forests

) IPCC default values

Module: Land use change and forestry
Submodule: Forest clearing - Soil carbon release
Worksheet 5-1
Sheet E

Forest types (Low estimate)				A Average Annual forest cleared (25 year average) (kha)	B Soil Carbon content of forest soil (t/ha)	C Total Annual potential soil carbon loss (kt C) C=(AxB)	D Fraction of carbon released	E Carbon released from soil carbon (kt C) E=(CxD)
		Broad leaf	Undis-turbed	0		0	0.5	0
	Closed forests		Logged	45	120	5 360	0.5	2 680
		Conifer	Unids-turbed	0		0	0.5	0
Temperate			Logged	91	120	10 906	0.5	5 453
		Unproduc-tive		n.a	n.a	n.a	n.a	n.a
	Open forests		Productive	0		0	0.5	0
			Unproduc-tive	53	60	3 199	0.5	1 600
	Ever-green	Unids-turbed		0		0	0.0	0
Tropical		Logged		72	115	8 325	0.0	0
	Deciduous	Unids-turbed		0		0	0.0	0
		Logged		136	100	13 617	0.0	0
Other								
				397	104	41 408		9 732
					1		2	

Notes:

1) IPCC default values probably overestimate the soil carbon content of broadleaf forests.

2) IPCC default values

Module: Land use change and forestry
Submodule: Forest clearing - Total CO_2 emissions
Worksheet 5-1
Sheet F

Forest Types (High estimate)				A Inmediate released from burning (kt C)	B Delayed emissions from decay (kt C)	C Long term emissions from soil (kt C)	D Total annual carbon release from forest clearing (kt C) D=(A+B+C)	E Total annual CO_2 release from forest clearing (kt CO_2) E=(DX[44/12])
Temperate	Closed forests	Broad leaf	Undis-turbed	0	0	0	0	0
			Logged	426	494	5 319	6 239	22 876
		Conifer	Undis-tubed	0	0	0	0	0
			Logged	1 343	1 559	11 078	13 980	51 260
		Unpro-ductive		n.a	n.a	n.a	n.a	n.a
	Open forests		Productive	0	0	0	0	0
			Unpro-ductive	214	238	1 600	2 052	7 524
Tropical	Ever-green	Undis-turbed		0	0	0	0	0
		Logged		8 497	10 548	0	19 045	69 832
	Deciduous	Undis-turbed		0	0	0	0	0
		Logged		4 549	5 539	0	10 088	36 988
Other				0	0	0		
				15 029	18 378	17 996	51 403	188 478

Module: Land use change and forestry
Submodule: Forest clearing - Total CO_2 emissions
Worksheet 5-1
Sheet F

Forest Types (Low estimate)				A Inmediate released from burning (kt C)	B Delayed emissions from decay (kt C)	C Long term emissions from soil (kt C)	D Total annual carbon release from forest clearing (kt C) D=(A+B+C)	E Total annual CO_2 release from forest clearing (kt CO_2) E=(DX[44/12])
Temperate	Closed forests	Broad leaf	Undis-turbed	0	0	0	0	0
			Logged	303	345	2 680	3 328	12 203
		Conifer	Undis-tubed	0	0	0	0	0
			Logged	959	1 090	5 453	7 503	27 509
		Unpro-ductive		n.a	n.a	n.a	n.a	n.a
	Open forests		Productive	0	0	0	0	0
			Unpro-doctive	214	238	1 600	2 052	7 524
Tropical	Ever-green	Undis-turbed		0	0	0	0	0
		Logged		3 074	3 535	0	6 609	24 235
	Deciduous	Undis-turbed		0	0	0	0	0
		Logged		1 876	2 162	0	4038	14 806
Other				0	0	0		
				6 427	7 370	9 732	23 530	86 277

Module: Land use change and forestry
Submodule: On - site burning of cleared forests
Worksheet 5-2
Sheet A

A Carbon Released (High estimate) (kt C) Wsh 5.1 Sh B Col K	B Nitrogen Carbon Ratio	C Total Nitrogen Released (kt N)		D Trace Gas Emissions Ratios	E Trace gas Emissions (kt C) E=(AxD)	F Conversion Factor	G Trace gas Emissions from Burning of Cleared Forests (kt CH4,CO) G=(ExF)
12 173			CH4	0.012	146.08	1.33	195
12 173			CO	0.060	730.40	2.33	1 704
		C=(AxB)			(kt N) E=(CxD)		(kt N2O, NOx) G=(ExF)
12 173	0.01	121.73	N_2O	0.007	0.85	1.57	1
12 173	0.01	121.73	NOx	0.121	14.73	2.14	32
				1		1	

Note:

1) IPCC default values

Module: Land use change and forestry
Submodule: On - site burning of cleared forests
Worksheet 5-2
Sheet A

A Carbon Released (Low estimate) (kt C) Wsh 5.1 Sh B Col K	B Nitrogen Carbon Ratio	C Total Nitrogen Released (kt N)		D Trace Gas Emissions Ratios	E Trace gas Emissions (kt C) E=(AxD)	F Conversion Factors	G Trace gas Emissions from Burning of Cleared Forests (kt CH4,CO) G=(ExF)
3 599			CH4	0.012	43.19	1.33	58
3 599			CO	0.060	215.96	2.33	504
		C=(AxB)			(kt N) E=(CxD)		(kt N2O, NOx) G=(ExF)
3 599	0.01	35.99	N_2O	0.007	0.25	1.57	0
3 599	0.01	35.99	NOx	0.121	4.36	2.14	9
	1			1			

1) IPCC default values

Moldule: Land use change and forestry
Submodule: Abandonment of managed lands
Worksheet 5-4
Sheet A

Growth land Type (High estimate)	A 20 year total area abandoned (kha)	B Annual rate of aboveground biomass uptake (t dm/ha)	C Annual aboveground biomass uptake (kt dm) C=(AxB)	D Carbon content of aboveground biomass	E Annual carbon uptake in aboveground biomass (kt C) E=(CxD)	F Annual rate of uptake of carbon in soils (tc/ha)	G Total annual carbon uptake in soils (kt C) G=(AxF)
Temperate	1 054	1.2	1 244	0.45	560	1.2	1 265
Tropical	4 444	4.2	18 538	0.45	8 342	0	0
Open forest	81	0.7	60	0.45	27	1.2	97
	5 578		19 842	Sub-total	8 929		1 362
		2		1		1	

Notes:

1) IPCC default values.

2) These growth rates are obtained by assuming that forests regrow to 80% of the original biomass (i.e. the biomass corresponding to logged tropical and temparate forests). It is also assumed that tropical forest regrow to 70% of the assumed total biomass in the first 20 years and temperate forest regrowth to 50% of the forest biomass in the first 20 years.

Moldule: Land use change and forestry
Submodule: Abandonment of managed lands
Worksheet 5-4
Sheet A

Growth land Type (Low estimate)	A 20 year total area abandoned (kha)	B Annual rate of aboveground biomass uptake (t dm/ha)	C Annual aboveground biomass uptake (kt dm) C=(AxB)	D Carbon content of aboveground biomass	E Annual carbon uptake in aboveground biomass (kt C) E=(CxD)	F Annual rate of uptake of carbon in soils (tc/ha)	G Total annual carbon uptake in soils (kt C) G=(AxF)
Temperate	531	1.2	627	0.45	282	1.2	637
Tropical	1 347	4.2	5 622	0.45	2 530	0	0
Open forest	81	0.7	60	0.45	27	1.2	97
	1 959		6 308	Sub-total	2 839		734
		2		1		1	

Notes:

1) IPCC default values.

2) These growth rates are obtained by assuming that forests regrow to 80% of the original biomass (i.e. the biomass corresponding to logged tropical and temparate forests). It is also assumed that tropical forest regrow to 70% of the assumed total biomass in the first 20 years and temperate forest regrowth to 50% of the forest biomass in the first 20 years.

Module: Land use change and forestry
Submodule: Abandonment of managed lands
Worksheet 5-4
Sheet B-C

Regrowth land type (Low estimate)	H Total area abandoned more than 20 years (kha)	I Annual rate of aboveground biomass uptake (t dm/ha)	J Annual aboveground biomass uptake (kt dm) J=(HxI)	K Carbon content of aboveground biomass	L Annual carbon uptake in aboveground biomass (kt C) L=(JxK)	M Annual rate of uptake of carbon in soils t C/ha)	N Total annual carbon uptake in soils (kt C) N=(HxM)	O Total carbon uptake from abandoned lands (kt C) O=(E+G+L+N)	P Total carbon dioxide uptake (kt CO_2) P=(Ox[44/12])
Temperate	2 483	0.32	730	0.45	330	0.60	1 490	3 644	13 360
Tropical	6 908	0.45	3 088	0.45	1 389	0.00	0	9 732	35 683
Open forests	331	0.19	61	0.45	28	0.60	198	350	1 282
	9 721		3 881	Sub-total	1 747	Totals	1 688	-13 725	-50 325
	3	2		1		1		4	4

Notes: 1) IPCC default values

2) These growth rates are obtained by assuming that forests regrow to 80% of the original biomass (i.e. the biomass corresponding to logged tropical and temperate forests). It is also assumed that tropical forest regrow to 70% of the assumed total biomass in the first 20 years and temperate forest regrowth to 50% of forest biomass inthe first 20 years.

3) Only the low estimate was used because the high estimate of the deforestation rates is not applicable more than 20 years into the past.

4) Assumption: Emissions are positive and Uptake is negative

Module: Land use change and forestry
Submodule: Abandonment of managed lands
Worksheet 5-4
Sheet B-C

Regrowth land type (Low estimate)	H Total area abandoned more than 20 years (kha)	I Annual rate of aboveground biomass uptake (t dm/ha)	J Annual aboveground biomass uptake (kt dm) J=(HxI)	K Carbon content of aboveground biomass	L Annual carbon uptake in aboveground biomass (kt C) L=(JxK)	M Annual rate of unptake of carbon in soils t C/ha)	N Total annual carbon uptake in soils (kt C) N=(HxM)	O Total carbon uptake from abandoned lands (kt C) O=(E+G+L+N)	P Total carbon dioxide uptake (kt CO_2) P=(Ox[44/12])
Temperate	2 483	0.30	732	0.45	330	0.60	1 490	2 738	10 041
Tropical	6 908	0.45	3 088	0.45	1 389	0.00	0	3 919	14 370
Open forests	331	0.19	61	0.45	28	0.60	198	350	1 282
	9 721		3 881	Sub-total	1 747	Totals	1 688	-7 007	-25 693
	3	2		1		1		4	4

Notes:

1) IPCC default values

2) These growth rates are obtained by assuming that forests regrow to 80% of the original biomass (i.e. the biomass corresponding to logged tropical and temperate forests). It is also assumed that tropical forest regrow to 70% of the assumed total biomass in the first 20 years and temperate forest regrowth to 50% of forest biomass inthe first 20 years.

3) Only the low estimate was used because the high estimate of the deforestation rates is not applicable more than 20 years into the past.

4) Assumption: Emissions are positive and Uptake is negative

Module: Land use change and forestry
Submodule: Managed forests
Worksheet 5-5
Sheet A

Harvest categories (specify)	A Area of managed forest (kha)	B Annual growth rate (t dm/ha)	C Annual biomass increment (kt dm) C=(AxB)	D Carbon content of dry matter	E Total carbon increment (kt C) E=(CxD)
Temparate conifer forest (Traditional management)	3 500.00	1.28	4 463	0.45	2 008
Temperate conifer forest (Improved management)	2 600.00	5.95	15 470	0.45	6 962
Plantations	2.80	6.04	17	0.45	8
Tropical evergreen forest	900.00	2.94	2 644	0.45	1 190
Traditional management (fuelwood)*	17 411.76	1.28	22 200	0.45	9 990
Sub-total	24 414.56	1.83	44 793		20 157
	Number of trees (1000s of trees)	Annual growth (t dm/1000 trees)			
Afforestation programs	170 234	3.46	588 866	0.45	265
Village and farm trees	0	0	0	0	0
Sub-total					20 422
				1	

Notes:

1) IPCC default values

* Traditional management (fuelwood): Approximate area harvested considering the amount of fuelwood that is consumed on a sustainable basis. It assumed that increst growth rates are the same as those corresponding to the traditional management of conifer forests.

Module: Land use change and forestry
Submodule: Managed forests
Worksheet 5-5
Sheet B-C

Harvest categories (specify)	F Commer-cial harvest (km^2 round wood)	G Biomass expansion factor ($t\ dm/m^2$)	H Total biomass removed in commer-cial harvest (kt dm) H=(FxG)	I Total traditional fuelwood consumed (kt dm)	J Other wood use (kt dm)	K Total biomass consump-tion (kt dm) K=(H+I+J)	L Wood removed from forest clearing (kt dm)	M Total biomass consump-tion from managed forest (kt dm) M=(K-L)	N Carbon fraction	O Annal carbon release (kt C) O=(MxN)	P Annual carbon uptake or release (kt C) P=(E-O)	Q Convert to CO2 annu[al] emissions [or] removal ($Gg\ CO_2$) Q=(Px [44/12])
Pine tree	6 817	1.76	12 016	0		12 016	12 016	0.45	5 407			
Sacred fir	226	1.76	399	0		399		399	0.45	179		
Other conifer	77	1.76	135	0		135		135	0.45	61		
Oak tree	383	1.76	675	8 880		9 555		9 555	0.45	4 300		
Other broadleaves	190	1.76	334	2 220		2 554		2 554	0.45	1 150		
Subtotal	7 693		13 559	11 100		24 659		24 659		11 097		
Precious woods	40	1.69	67	0		67		67	0.45	30		
Common tropical woods	369	1.69	625	11 100		11 725		11 725	0.45	5 276		
Other tropical woods	0	1.69	0	0		0		0	0.45	0		
Subtotal	409		692	11 100		11 796		11 792		5 306		
Totals	8 102		14 251	22 200		36 451	7 051	29 401	13 230	-7 192	-26 369	
		2		3	4			5	1		6	6

Notes:

1) IPCC default values

2) Average of Cannell, 1982 and IPCC, 1994 expansion factors.

3) From Masera (1993). Total fuelwood consumed at 37 million m' or 22 200 kt dm, assuming an average wood density of 0.6.

4) Wood is used for subsistence uses such as housing, fencing, etc., however there are not statistics regarding the consumption for the state uses.

5) Wood removed from forest clearing substracted from the total

6) Assumption: Emissions are positive and uptake is negative.

Annex 5.1. Comparison of the vegetation types considered in the inventory

Classification used for IPCC			Corresponding Mexico's classification		
Temperate forests	Broadleaf	Undisturbed	Temperate Forests	Broadleaf (Oaks)	Natural protected areas
		Logged			Remaining broadleaf*
	Conifer	Undisturbed		Conifer, conifer-broadleaf and cloud forests (mostly pine and pine-oak trees)	Natural protected areas
		Logged			Remaining conifer*
Tropical forests	Evergreen	Undistrurbed	Tropical Forests	Tropical evergreen and semievergreen	Natural protected areas
		Logged			Remaining evergreen and semievergreen*
	Deciduous	Undistrubed		Tropical deciduous	Natural protected areas
		Logged			Remaining deciduous*
Open forests		Productive (Undisturbed)	Open forests		Natural protected areas
		Unproductive			Remaining areas*
Unproductive forests			Unproductive forests		

* Managed and unmanaged.

ANNEX 5.2

BIOLOGICAL CHARACTERISTICS OF EACH TYPE OF VEGETATION CONSIDERED IN THE INVENTORY

Broadleaf forests. Forests with different species of broadleaf trees and less than 20% of conifer trees. Broadleaf and conifer forests constitute the main forest cover in the areas with semi-humid temperate and cold climates. Broadleaf forests are located from the sea level to 3,100 m, however most of these forests are between the 800 and 1,200 m.

Conifer forests. Forests with a mix of conifer tree species and less than 20% of broadleaf trees. Most the conifer species are from the genus Pinus. These forests are distributed mainly in the mountain regions of Mexico, in climates where the annual temperature is between 6 and 28°C, and elevations between 1,500 and 3,000 m. However, Pinus caribaea grows at sea level and Pinus hartwegii grows in elevations higher than 3,000 m. Some other genus found in less proportion are: Abies, Juniperus, Pseudotsuga, Picea, and Cupressus.

Conifer-broadleaf forests. Forests with mixtures of the genus Pinus and Quercus. They are distributed in mountain regions of the country, at elevations ranging from the sea level to 3,100 m, with an average annual temperate between 10 and 26°C, and with an average annual precipitation between 600 and 1,200 mm.

Cloud forests. Forests located in the slopes of the mountains where fogs are present almost all the year round and in places protected from the wind and from the sunstroke. This type of forest grows at elevations between 400 and 1,000 m. They are distributed on the Sierra Madre Oriental in a thin and long non-continuous strip, from the southwest of Tamaulipas up to the north of Oaxaca; in Chiapas this forest is located in the center and both slopes of the Sierra Madre. Near the Pacific ocean its distribution is more spread, being found in the Sierra Madre Occidental from the north of Sinaloa up to Michoacan; also it is found in small areas in the Cuenca del Balsas, Valle de Mexico and the exterior slopes of the Sierra Madre del Sur in Guerrero and Oaxaca.

Tropical evergreen and semi-evergreen forests. These types of forests include the tropical evergreen forests which are represented by community with a high density of trees and with a complex composition, considered as the type of vegetation more exuberant in the tropical climates. Their superior stratum is about 30 m high, frequently there are trees higher than 45 m. The other two or three wooded stratums cover the remaining space from 5 to 20 m. Generally not all the components are evergreen, because some of them loose their leaves during a short period of time in the dry season. The tropical semi-evergreen forests are communities with trees measuring from 20 to 30 m high; they are located in hot-humid climates and are very similar to the tropical evergreen forest in components and ecological conditions.

Tropical deciduous forests. Forests with trees from 4 to 15 m high, more frequently between 8 to 12 m. Almost all of the species loose their leaves during several months. This type of forest includes patches of tropical evergreen, semi-evergreen, deciduous and sub-deciduous, and thorny forests. Tropical deciduous forests are found in regions with average annual temperatures higher than 200C and annual precipitation of 1,200 mm maximum, generally of 800 mm, with a dry season as long as 8 months. They are distributed in elevations ranging from sea level to 1,700 m. This type of vegetation is widely distributed in small and big spots; the more important areas with this type of forests are located in Sonora and Sinaloa; some other States with this kind of vegetation include: Campeche, Guerrero, Jalisco, Quintana Roo and Tamaulipas.

Mezquital and huizachal. Forests with small thorny trees from 4 to 15 m high, including the genus Prosopis and Acacia. They grow in dryer climates than the tropical deciduous forest but more humid than the "matorral xerofilo". The mezquital (Prosopis spp.) constitutes the characteristic vegetation of lands with deeper soils and they can be found in elevations ranging from 1,000 to 2,000 m. At the present time most of their distribution area is occupied by irrigation agriculture, as in the Bajio area and large tracts of Sonora, Sinaloa, Tamaulipas and San Luis Potosi. Prosopis is frequently found mixed with Acacia spp., Pithecellobium spp., and Cercidium spp., in the southeast of San Luis Potosi, mountains of Tamaulipas, south of Sonora, central part of Durango and Coahuila.

Chaparral. Forests with fire resistant shrubs of 1-2 m high; they grow mainly in the slopes of the mountains, further uphill than the matorral of arid and semiarid lands, of natural grasslands. Sometimes it is mixed with pine and oak forests. Its distribution is in the north of Mexico, with climates between those of arid lands and semi-humid lands in Coahuila, Chihuahua, Durango, Nuevo Leon, San Luis Potosi, Sonora, and Zacatecas; in the center of the country they are located in Guanajuato, Hidalgo, Oaxaca, Tlaxcala, and in the region of Tehuacan, Puebla; and also they can be found in the region of Comitan, Chiapas.

Matorral xeroflo. Forests of the arid lands with matorral of the types crassicaule, microphyllus, and rosetophyllus. The crassicaule matorral is the type of vegetation with plants of succulent stems and many cactuses. The microphyllus matorral is the type of vegetation with arid species of small leaves. The rosetophyllus matorral is the type of arid vegetation with species of long and narrow leaves and aspect of rosette at the end of the stem.

Open forest. Forests constituted by the following vegetal communities: mezquital-huizachal, chaparral, and xerophyllus matorral. According with FAO the open forest is an area characterized by the combination of forests and grasslands with trees that cover a surface higher or equal to 10continuous cover of grass through the forest soil.

Unproductive forest. Undisturbed forests frequently submitted to land use changes, like as agriculture, livestock, infrastructure and population centers, that show rests of temperate or tropical forest distributed on irregular form. In this type of forest there are also crops or grasses in combination with natural regeneration areas of vegetation.

Source: SARH, 1991 and SARH, 1994.

ANNEX 5.3. Natural Protected Areas of Mexico by type of vegetation

Type of vegetation	Area (ha)
Reserves	**5 421 293**
Tropical forests	**1 872 939**
Evergreen	1 765 963
Deciduous	106 976
Wetlands	**302 706**
Temperate forests	**357 989**
Conifer	357 989
Broadleaf	0
"Matorrales" (Thorny forest, "Chaparral")	**2 887 659**
National Parks	**688 953**
Tropical forests	93 743
Evergreen	89 851
Deciduous	3 892
Temperate forests	314 075
Conifer	314 075
Broadleaf	0
"Matorrales" (Thorny forest, "Chaparral")	282 135
Reefs	51 238
Total	**6 110 246**

Modified from Masera, et al., (1992) cited by Ordóñez and Villela (1995). (In press)

Quadri de la Torre (1994).

ANNEX 5.4. FOREST AREA OF MEXICO BY FOREST TYPE AND STATE (ha)

State	Conifer	Cloud forest	Subtotal Conifer and Cloud Forest	Broadleaf	Total TEMPERATE FORESTS	Tropical Evergreen	Evergreen and Semi-evergreen	Deciduous	Subtotal Tropical Deciduous	Total TROPICAL FORESTS	"Mezquital-Huizachal"	"Chaparral"	"Matorral xerofilo"	Forest areas Perturbed	Forest areas Very Perturbed	Total OPEN FORESTS	Total PERTURBED FORESTS	GRAND TOTAL
Aguascalientes	8 213	0	8 213	56 087	64 300	0	0	0	0	0	811	23 287	131 260	3 279	3 792	166 368	7 071	222 937
Baja California	158 008	0	158 008	4 374	162 382	0	0	215 312	215 312	216 312	305 267	1 216 320	3 517 287	272 107	556 885	6 038 874	828 992	6 888 676
Baja California S.	38 605	0	38 605	136 200	174 806	0	0	1 512 316	1 512 316	1 612 316	0	15 420	4 296 833	452 182	343 481	4 312 263	796 663	6 461 666
Campeche	0	0	0	0	0	2 460 318	264 180	743 216	1 007 396	3 467 714	0	0	0	298 139	214 575	0	512 714	3 766 853
Coahuila	127 911	0	127 911	54 420	182 331	0	0	0	0	0	84 201	345 905	11 765 212	465 629	280 165	12 196 318	746 794	12 843 278
Colima	1 621	6 870	8 491	32 430	40 921	57 700	0	163 342	163 342	221 042	0	0	4 864	45 621	0	4 864	46 621	312 448
Chiapas	869 326	27 526	896 852	277 693	1 174 646	1 636 612	7 343	273 117	280 460	1 917 072	0	0	0	1 243 934	462 709	0	1 706 643	4 336 661
Chihuahua	4 027 516	0	4 027 516	921 458	4 948 974	0	0	97 852	97 852	97 852	0	1 182 921	8 347 222	431 110	84 017	9 630 143	616 127	16 008 079
Distrito Federal	37 088	0	37 088	1 011	38 099	0	0	0	0	0	0	0	0	671	1 556	0	2 227	38 770
Durango	3 527 312	0	3 527 312	325 425	3 862 737	0	11 527	353 921	365 448	366 448	36 624	1 451 408	3 184 620	321 617	148 265	4 672 662	469 882	9 212 464
Guanajuato	123 104	0	123 104	205 417	328 521	0	0	0	0	0	425 616	72 425	217 108	316 205	84 523	716 149	400 728	1 369 876
Guerrero	1 142 722	14 156	1 156 878	611 059	1 767 937	217 321	0	1 147 596	1 147 596	1 364 917	0	258 615	125 314	1 045 917	122 624	383 929	1 168 641	4 662 700
Hidalgo	198 467	21 641	220 108	210 273	430 381	9 806	0	54 693	54 693	64 499	13 219	12 508	427 344	590 482	27 611	463 071	618 093	1 638 433
Jalisco	987 234	0	987 234	1 425 756	2 412 990	136 514	0	526 635	526 635	663 149	45 962	392 856	1 169 026	498 113	35 143	1 607 844	633 266	5 182 096
México	396 654	0	396 654	75 571	472 226	0	1 868	8 857	10 725	10 726	14 220	2 500	9 398	257 434	63 619	26 118	321 063	766 602
Michoacán	1 124 916	0	1 124 916	421 341	1 646 267	289 427	0	571 932	571 932	861 369	87 851	141 683	274 101	1 325 604	23 732	603 636	1 349 336	4 238 866
Morelos	31 285	0	31 285	712	31 997	0	0	34 544	34 544	34 644	0	0	0	116 014	0	0	116 014	182 666
Nayarit	477 542	0	477 542	210 421	687 963	311 621	0	247 602	247 602	669 223	0	486 304	62 976	119 213	10 484	649 280	129 697	1 916 679
Nuevo León	319 615	0	319 615	187 473	507 088	0	0	0	0	0	264 322	492 785	3 714 969	126 346	12 813	4 472 076	139 169	5 106 510
Oaxaca	972 418	35 217	1 007 635	860 098	1 867 733	427 519	12 818	798 886	811 704	1 239 223	742	121 301	556 641	2 448 917	239 392	678 684	2 688 309	6 234 667
Puebla	268 416	7 452	275 868	25 168	301 036	118 464	0	462 020	462 020	680 484	218 114	0	139 035	884 436	112 285	367 149	996 721	2 123 106
Querétaro	93 622	0	93 622	99 642	193 264	0	0	6 720	6 720	6 720	0	0	409 309	220 305	14 730	409 309	236 035	829 698
Quintana Roo	0	0	0	0	0	1 570 620	499 080	1 104 896	1 603 976	3 174 696	0	0	0	1 216 338	35 534	0	1 251 872	4 390 934
San Luis Potosi	75 854	17 184	93 038	301 299	394 337	4 207	0	311 918	311 918	316 125	98 472	179 643	2 800 112	917 525	219 314	3 078 227	1 136 839	4 706 214
Sinaloa	417 251	0	417 251	608 324	1 026 676	725 615	205 519	1 294 445	1 499 964	2 226 679	0	213 915	141 126	305 423	32 094	366 041	337 617	3 911 618
Sonora	846 437	0	846 437	560 200	1 406 637	0	0	1 420 575	1 420 575	1 420 676	765 427	505 216	8 291 612	611 213	243 573	9 662 266	864 786	13 000 680
Tabasco	0	0	0	0	0	106 415	3 920	12 623	16 543	122 968	0	0	0	420 086	27 042	0	447 128	643 044
Tamaulipas	85 354	0	85 354	375 297	460 661	5 326	707 211	651 673	1 358 884	1 364 210	425 963	52 100	2 054 722	226 995	42 209	2 632 786	269 204	4 684 641
Tlaxcala	48 532	0	48 532	4 151	52 683	0	0	0	0	0	0	2 843	6 730	62 138	51 443	9 673	113 581	124 394
Veracruz	215 678	12 325	228 003	42 916	270 919	537 215	28 132	725 817	753 949	1 291 164	0	24 141	6 213	1 327 911	22 444	30 364	1 350 356	2 920 348
Yucatán	0	0	0	0	0	70 555	32 404	871 697	904 101	974 656	0	0	0	1 416 093	3 079	0	1 419 172	2 390 749
Zacatecas	345 927	0	345 927	375 201	721 128	0	0	57 901	57 901	67 901	7 624	513 727	3 854 812	96 104	28 917	4 376 983	126 021	6 261 096
Total	16 966 628	142 371	17 108 999	8 409 417	25 518 416	6 686 266	1 774 002	13 670 106	15 444 108	24 129 363	2 794 436	7 707 823	66 607 646	18 083 101	3 648 060	66 009 904	21 631 161	133 740 784

Source: SARH-Inventario Nacional Forestal de Gran Visión (1992).

ANNEX 5.5. Forest area of Mexico by forest type and state (ha)

State	Temperate Conifer	Temperate Broadleaf	Tropical Evergreen	Tropical Deciduous	TOTAL CLOSED FORESTS	TOTAL OPEN FORESTS	TOTAL FORESTS	UNPRODUCTIVE FORESTS	GRAND TOTAL
Aguascalientes	8 213	56 087	0	0	64 300	155 358	219 668	3 279	222 937
Baja California	158 008	4 374	0	215 312	377 694	5 038 874	5 416 568	272 107	5 688 675
Baja California S.	38 605	136 200	0	1 512 316	1 687 121	4 312 253	5 999 374	452 182	6 451 556
Campeche	0	0	2 460 318	1 007 396	3 467 714	0	3 467 714	298 139	3 765 853
Coahuila	127 911	54 420	0	0	182 331	12 195 318	12 377 649	465 629	12 843 278
Colima	8 491	32 430	57 700	163 342	261 963	4 864	266 827	45 621	312 448
Chiapas	896 852	277 693	1 636 612	280 460	3 091 617	0	3 091 617	1 243 934	4 335 551
Chihuahua	4 027 516	921 458	0	97 852	5 046 826	9 530 143	14 576 969	431 110	15 008 079
Distrito Federal	37 088	1 011	0	0	38 099	0	38 099	671	38 770
Durango	3 527 312	325 425	0	365 448	4 218 186	4 672 652	8 890 837	321 617	9 212 454
Guanajuato	123 104	205 417	0	0	328 521	715 149	1 043 670	316 205	1 359 876
Guerrero	1 156 878	611 059	217 321	1 147 596	3 132 854	383 929	3 516 783	1 045 917	4 562 700
Hidalgo	220 108	210 273	9 806	54 693	494 880	453 071	947 951	590 482	1 538 433
Jalisco	987 234	1 425 756	136 514	526 635	3 076 139	1 607 844	4 683 983	498 113	5 182 096
México	396 654	75 571	0	10 725	482 950	26 118	509 068	257 434	766 502
Michoacán	1 124 916	421 341	289 427	571 932	2 407 616	503 635	2 911 251	1 325 604	4 236 866
Morelos	31 285	712	0	34 544	66 541	0	66 541	116 014	182 556
Nayarit	477 542	210 421	311 621	247 602	1 247 186	549 280	1 796 466	119 213	1 915 679
Nuevo León	319 615	187 473	0	0	507 088	4 472 076	4 979 164	126 346	5 105 510
Oaxaca	1 007 635	860 098	427 519	811 704	3 106 956	678 684	3 785 640	2 448 917	6 234 557
Puebla	275 863	25 168	118 464	462 020	881 520	357 149	1 238 669	884 436	2 123 106
Querétaro	93 622	99 642	0	6 720	199 984	409 309	609 293	220 305	829 598
Quintana Roo	0	0	1 570 620	1 603 976	3 174 596	0	3 174 596	1 216 338	4 390 934
San Luis Potosí	93 038	301 299	4 207	311 918	710 462	3 078 227	3 788 689	917 525	4 706 214
Sinaloa	417 251	608 324	725 615	1 499 964	3 251 154	355 041	3 606 195	305 423	3 911 618
Sonora	846 437	560 200	0	1 420 575	2 827 212	9 562 255	12 389 467	611 213	13 000 680
Tabasco	0	0	106 415	16 543	122 958	0	122 958	420 086	543 044
Tamaulipas	85 354	375 297	5 326	1 358 884	1 824 861	2 532 785	4 357 646	226 995	4 584 641
Tlaxcala	48 532	4 151	0	0	52 683	9 573	62 256	62 138	124 394
Veracruz	228 003	42 916	537 215	753 949	1 562 083	30 354	1 592 437	1 327 911	2 920 348
Yucatán	0	0	70 555	904 101	974 656	0	974 656	1 416 093	2 390 749
Zacatecas	345 927	375 201	0	57 901	779 029	4 375 963	5 154 992	96 104	5 251 096
Total	17 108 999	8 409 417	8 686 255	15 444 108	49 647 779	66 009 904	115 657 683	18 083 101	133 740 784

Source: SARH-Inventario Nacional Forestal de Gran Visión (1992).

AREA BY FOREST TYPE (Kha)

	Temperate Conifer	Temperate Broadleaf	Tropical Evergreen	Tropical Deciduous	Total Closed Forests	Total Open Forests	Total Forests	Unproductive Forests	GRAND TOTAL
Total	17 109	8 409	8 686	15 444	49 648	66 010	115 658	18 083	133 741
Undisturbed	672	0	1 855	111	2 638	3 170	5 808		5 808
Logged	16 437	8 409	6 830	15 333	47 010	62 840	109 850		127 933

ANNEX 5.6. AREA BY FOREST TYPE IN MEXICO

			Kha	Kha
Temperate forests				
	Broadleaf		8 409	
		Undisturbed		0
		Logged		8 409
	Conifer		17 109	
		Undisturbed - 1		672
		Logged		16 437
Tropical forests				
	Evergreen		8 685	
		Undisturbed - 2		1 855
		Logged		6 830
	Deciduous		15 444	
		Undisturbed - 3		111
		Logged		15 333
Open Forests			66 010	
		Undisturbed		3 170
		Unproductive		62 840
Unproductive Forests			21 631	
		Degraded		18 083
		Severely degraded		3 548
TOTAL			**137 288**	**137 288**

Sources: SARH-Inventario Nacional Forestal de Gran Visión (1992)

Modified from Masera, et al., (1992) cited by Ordóñez and Villela (1995). (In press)

NOTES:

1) Natural Protected Areas (Reserves and National Parks). We assume that temperate forests include pine, pine-oak and cloud forests (358 Kha + 314 Kha = 672 Kha).
2) Reserves (1 765 Kha) and National Parks (90 Kha).
3) Reserves (107 Kha) and National Parks (4 Kha).

ANNEX 5.7. RANGE OF ESTIMATES FOR DEFORESTATION RATES IN MEXICO

('000 ha/yr)

SOURCE	TEMPERATE FOREST	TROPICAL FOREST	OPEN FOREST	TOTAL
PND, 1983.	n.a.	n.a.	n.a.	**400**
Toledo, 1989	n.a.	n.a.	n.a.	**1 500**
Repetto, 1988.	n.a.	460	n.a.	**460**
Myers, 1989.	n.a.	700	n.a.	**700**
FAO, 1988; WRI, 1990.	125	470	20	**615**
SARH, 1990.	127	202	n.a.	**329**
Castillo, at al., 1989.	273	473	n.a.	**746**
Masera, et al., 1992	245	559	n.a.	**804**
SARH, 1992.	n.a.	n.a.	n.a.	**365**
SARH, 1991b	127	189	54	**370**

Source: Modified from Masera, et al., 1992; adding SARH, 1991b and SARH, 1992.

ANNEX 5.8. Deforestation by state and forest type (ha)

State	Temperate Forests	Tropical Forests	Open forests	Total
Aguascalientes	1 935	0	1 052	**2 987**
Baja California	58	0	73	**131**
Baja California Sur	0	0	4	**4**
Campeche	0	53 341	0	**53 341**
Coahuila	256	318	3 595	**4 169**
Colima	8	23 989	0	**23 997**
Chiapas	12 907	3 428	0	**16 335**
Chihuahua	1 810	0	2 617	**4 427**
Distrito Federal	217	0	0	**217**
Durango	4 204	0	272	**4 476**
Guanajuato	22	0	952	**974**
Guerrero	1 693	7 459	1 242	**10 394**
Hidalgo	290	769	17	**1 076**
Jalisco	658	0	0	**658**
México	24 960	0	0	**24 960**
Michoacán	50 685	86	0	**50 771**
Morelos	5 286	124	0	**5 410**
Nayarit	1 368	6 461	24	**7 853**
Nuevo León	0	0	8 874	**8 874**
Oaxaca	14 164	11 875	0	**26 039**
Puebla	357	392	279	**1 028**
Querétaro	491	107	82	**680**
Quintana Roo	0	53 814	0	**53 814**
San Luis Potosí	210	1 068	164	**1 442**
Sinaloa	2 881	5 883	119	**8 883**
Sonora	7	0	33 037	**33 044**
Tabasco	0	3 642	0	**3 642**
Tamaulipas	167	7 810	69	**8 046**
Tlaxcala	2 383	0	0	**2 383**
Veracruz	173	5 469	0	**5 642**
Yucatán	0	2 887	0	**2 887**
Zacatecas	61	0	1 355	**1 416**
Total	**127 251**	**188 922**	**53 827**	**370 000**

Source: SARH (1991b).

ANNEX 5.9. Estimated deforestation rates for the Mexican forest areas

HIGH ESTIMATE (Masera et al, 1992)	Conifer	Broadleaf	Evergreen	Deciduous	Open forests	Unprod. forests
Total deforestation	**0.96%**	**0.94%**	**2.44%**	**2.02%**	**0.08%**	**0.00%**
Undisturbed	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Logged	1.00%	0.94%	3.10%	2.03%	0.08%	0.00%
Total deforestation (Kha)	**164**	**79**	**212**	**312**	**53**	**0**
Undisturbed (Kha)	0	0	0	0	0	0
Logged (Kha)	164	79	212	312	53	0

LOW ESTIMATE (SARH, 1991b)	Conifer	Broadleaf	Evergreen	Deciduous	Open forests	Unprod. forests
Total deforestation	**0.50%**	**0.50%**	**0.76%**	**0.80%**	**0.08%**	**0.00%**
Undisturbed	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Logged	0.52%	0.50%	0.97%	0.81%	0.08%	0.00%
Total deforestation (Kha)*	**86**	**42**	**66**	**124**	**53**	**0**
Undisturbed (Kha)	0	0	0	0	0	0
Logged (Kha)	86	42	66	124	53	0

Source: SARH- Programa Nacional de Desmontes (1991b).

* The deforestation rates between conifer and broadleaf, as well as between evergreen and deciduous are distributed proportionally to the area of each type of forest.

ANNEX 5.10. Aboveground biomass estimates by forest type

Before clearing

Forest type	Masera et al., 1992 (t dm / ha)	Olson et al., 1983; 1985 (t dm / ha)	Brown et al., 1985; 1989 (t dm / ha)	IPCC 1994 (t dm / ha)	Inventario Forestal 1992* (t dm / ha)	This study (preliminary) (t dm / ha)
Temperate						
Broadleaf	60	93				
Undisturbed					64	64
Logged					46	46
Conifer	86	111				
Undisturbed			172	150	90	90
Logged			69	60	65	65
Tropical						
Evergreen	240	277				
Undisturbed			170	230	89	240
Logged			140	190		240
Deciduous	85	79				
Undisturbed					23	85
Logged						85
Open Forest		37				
Productive			59	60		37
Unproductive				25		25
Unproductive forests						
Degraded		74				0
Severely degraded						0

Source: Olson et al, 1983 & 1985, reported by Cairns et al., (1994); SARH-Inventario Nacional Forestal (1992).

*Original data was in commercial volume from ha. To convert from commercial to total biomass we used the expansion factors suggested by IPCC (1994).

ANNEX 5.11. Deforestation by forest type and type of causes

Cause	Temperate forest		Tropical forest		Open forest		Total	
	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
Clearing without permission*	84%	106 597	89%	167 425	7%	3 978	**60%**	**278 000**
Authorized land use change*	0%	64	4%	7 772	75%	40 164	**26%**	**48 000**
Illegal clearing, forest fires, forest pest and disease, others	16%	20 590	7%	13 725	18%	9 685	**14%**	**44 000**
Total	100%	127 251	100%	188 922	100%	53 827	100%	370 000

Source: SARH, 1991b.

*Most of this land is converted to agriculture and pasture land

ANNEX 6.12. Deforestation percentages by state, forest type and main causes of deforestation

State	TEMPERATE FORESTS				TROPICAL FORESTS				OPEN FORESTS			
	Clearing without permission	Authorized land use change	Forest fires and others	Total (ha)	Clearing without permission	Authorized land use change	Forest fires and others	Total (ha)	Clearing without permission	Authorized land use change	Forest fires and others	Total (ha)
Aguascalientes	0.00	0.00	100.00	**1 936**	0.00	0.00	0.00	**0**	0.00	1.69	98.31	**1 062**
Baja California	60.34	0.00	0.00	**58**	0.00	0.00	0.00	**0**	10.96	0.00	89.04	**73**
Baja California Sur	0.00	100.00	0.00	**0**	0.00	100.00	0.00	**0**	0.00	100.00	0.00	**4**
Campeche	0.00	0.00	0.00	**0**	94.02	0.37	5.61	**63 341**	0.00	0.00	0.00	**0**
Coahuila	87.50	0.00	12.50	**256**	100.00	0.00	0.00	**318**	59.30	1.15	39.55	**3 596**
Colima	50.00	0.00	50.00	**8**	89.27	9.27	1.47	**23 989**	0.00	100.00	0.00	**0**
Chiapas	82.29	0.00	17.71	**12 907**	0.00	0.00	100.00	**3 428**	0.00	0.00	0.00	**0**
Chihuahua	0.00	0.00	100.00	**1 810**	0.00	0.00	0.00	**0**	0.00	0.00	100.00	**2 617**
Distrito Federal	0.00	0.00	100.00	**217**	0.00	0.00	0.00	**0**	0.00	0.00	0.00	**0**
Durango	0.00	0.00	100.00	**4 204**	0.00	100.00	0.00	**0**	63.24	36.76	0.00	**272**
Guanajuato	100.00	0.00	0.00	**22**	0.00	0.00	0.00	**0**	3.47	0.00	96.53	**962**
Guerrero	68.75	0.00	31.25	**1 693**	99.26	0.00	0.74	**7 459**	0.00	0.00	100.00	**1 242**
Hidalgo	82.07	0.00	17.93	**290**	86.48	0.00	13.52	**769**	0.00	0.00	100.00	**17**
Jalisco	0.00	0.00	100.00	**668**	0.00	0.00	0.00	**0**	0.00	0.00	0.00	**0**
México	92.00	0.00	8.00	**24 960**	0.00	0.00	0.00	**0**	0.00	0.00	0.00	**0**
Michoacán	93.22	0.00	6.78	**50 685**	0.00	0.00	100.00	**86**	0.00	0.00	0.00	**0**
Morelos	97.18	0.00	2.82	**5 286**	0.00	0.00	100.00	**124**	0.00	0.00	0.00	**0**
Nayarit	73.10	3.73	23.17	**1 368**	89.58	0.00	10.42	**6 461**	100.00	0.00	0.00	**24**
Nuevo León	0.00	100.00	0.00	**0**	0.00	0.00	0.00	**0**	0.00	96.56	3.44	**8 874**
Oaxaca	86.32	0.00	13.68	**14 164**	96.25	0.00	3.75	**11 876**	0.00	0.00	0.00	**0**
Puebla	89.32	3.68	7.00	**367**	91.58	0.00	8.42	**392**	39.43	0.00	60.57	**279**
Querétaro	95.11	0.00	4.89	**491**	94.39	0.00	5.61	**107**	63.41	0.00	36.59	**82**
Quintana Roo	0.00	0.00	0.00	**0**	93.60	0.83	5.57	**63 814**	0.00	0.00	0.00	**0**
San Luis Potosí	27.14	0.00	72.86	**210**	33.05	9.83	57.12	**1 068**	7.32	0.00	92.68	**164**
Sinaloa	95.83	0.00	4.17	**2 881**	87.83	0.00	12.17	**5 883**	0.00	0.00	100.00	**118**
Sonora	0.00	0.00	100.00	**7**	0.00	100.00	0.00	**0**	2.83	94.72	2.45	**33 037**
Tabasco	0.00	0.00	0.00	**0**	98.98	0.00	1.02	**3 642**	0.00	0.00	0.00	**0**
Tamaulipas	0.00	0.00	100.00	**167**	35.31	60.42	4.26	**7 810**	0.00	0.00	100.00	**69**
Tlaxcala	82.63	0.00	17.37	**2 383**	0.00	0.00	0.00	**0**	0.00	0.00	0.00	**0**
Veracruz	80.92	0.00	19.08	**173**	88.08	0.00	11.92	**5 469**	0.00	0.00	0.00	**0**
Yucatán	0.00	0.00	0.00	**0**	94.42	2.77	2.81	**2 887**	0.00	0.00	0.00	**0**
Zacatecas	0.00	0.00	100.00	**61**	0.00	100.00	0.00	**0**	36.90	10.18	52.92	**1 356**
TOTAL	**83.77**	**0.06**	**16.18**	127 261	**88.62**	**4.11**	7.26	**188 922**	**7.39**	**74.62**	**17.99**	**63 827**

Source: SARH (1991b).

ANNEX 5.13. Estimates of deforestation and forest fires shares by conversion activity ('000 ha/year)

Activity	Temperate coniferous		Temperate broadleaf		Tropical evergreen		Tropical deciduous		Total	
	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
Deforestation	100%	163	100%	82	100%	237	100%	322	**100%**	**804**
Pasture	28%	45	28%	23	58%	139	57%	187	**49%**	**394**
Agriculture	16%	26	17%	14	10%	24	14%	45	**13%**	**105**
Harvesting	5%	8	5%	4	2%	5	5%	16	**4%**	**32**
Forest fires	49%	79	47%	39	22%	52	7%	23	**24%**	**193**
Other*	3%	5	3%	2	7%	17	16%	52	**10%**	**80**

Source: Modified from Masera,et al., 1992.

* Other land include forest losses through erosion, road building, etc.

ANNEX 5.14. High and low estimates of annual deforestation rates, average of 10 years (1981-1990)

High estimate (Masera et al., 1992)	Temperate Conifer 0.96%	Temperate Broadleaf 0.94%	Tropical Evergreen 2.44%	Tropical Deciduous 2.02%	Total Closed Forests	Open Forests 0.08%	Total Forests	Unproductive Forests 0.00 %	TOTAL
Total (Kha)	172	82	237	342	**833**	53	886	0	**886**
Undisturbed (Kha)	0	0	0	0	**0**	0	0	0	**0**
Logged (Kha)	172	82	237	342	**833**	53	886	0	**886**

Low estimate (SARH, 1991b)	Temperate Conifer 0.50%	Temperate Broadleaf 0.50%	Tropical Evergreen 0.76%	Tropical Deciduous 0.80%	Total Closed Forests	Open Forests 0.08%	Total Forests	Unproductive Forests 0.00 %	TOTAL
Total (Kha)	87	43	68	128	**327**	53	380	0	**380**
Undisturbed (Kha)	0	0	0	0	**0**	0	0	0	**0**
Logged (Kha)	87	43	68	128	**327**	53	380	0	**380**

ANNEX 5.15. High and low estimates of annual deforestation rates, average of 25 years (1966-1990)

High estimate (Masera et al., 1992)	Temperate Conifer 0.96%	Temperate Broadleaf 0.94%	Tropical Evergreen 2.44%	Tropical Deciduous 2.02%	Total Closed Forests	Open Forests 0.08%	Total Forests	Unproductive Forests 0.00 %	TOTAL
Total (Kha)	185	89	287	401	**961**	53	1 015	0	**1 016**
Undisturbed (Kha)	0	0	0	0	**0**	0	0	0	**0**
Logged (Kha)	185	89	287	401	**961**	53	1 015	0	**1 016**

Low estimate (SARH, 1991b)	Temperate Conifer 0.50%	Temperate Broadleaf 0.50%	Tropical Evergreen 0.76%	Tropical Deciduous 0.80%	Total Closed Forests	Open Forests 0.08%	Total Forests	Unproductive Forests 0.00 %	TOTAL
Total (Kha)	91	45	72	136	**344**	53	397	0	**397**
Undisturbed (Kha)	0	0	0	0	**0**	0	0	0	**0**
Logged (Kha)	91	45	72	136	**344**	53	397	0	**397**

ANNEX 5.16. Estimates of soil carbon by forest type

Forest types	Masera et al., 1992 (t C/ha)	Zinke et al., 1984 (t C/ha)	Sombroek et al., 1993* (t C/ha)	IPCC, 1994 (t C/ha)	This study (preliminary) (t C/ha)
Temperate					
Broadleaf	29.5	161	102		
Undisturbed				134	134
Logged				120	120
Conifer	109.1	132	102		
Undisturbed				134	134
Logged				120	120
Tropical					
Evergreen	66.0	104	109	115	115
Undisturbed					
Logged					
Deciduous	29.5	112	105	100	100
Undisturbed					
Logged					
Open Forests		77		60	60
Productive					
Unproductive					

Note: *Cited by Cairns et al., (1995).

ANNEX 5.17. PERTURBED FOREST LANDS

State	Perturbed forest lands (SARH, 1992) (ha)	Estimates of perturbed lands: Temperate (ha)	Tropical (ha)	Open forests (ha)	Percentage of perturbed forest lands: Temperate (%)	Tropical (%)	Open forests (%)
Aguascalientes	3 279	960	0	2 319	29.27	0.00	70.73
Baja California	272 107	8 157	10 816	253 133	3.00	3.98	93.03
Baja California Sur	452 182	13 175	113 986	325 021	2.91	25.21	71.88
Campeche	298 139	0	298 139	0	0.00	100.00	0.00
Coahuila	465 629	6 859	0	458 770	1.47	0.00	98.53
Colima	45 621	6 997	37 793	832	15.34	82.84	1.82
Chiapas	1 243 934	472 587	771 347	0	37.99	62.01	0.00
Chihuahua	431 110	146 365	2 894	281 851	33.95	0.67	65.38
Distrito Federal	671	671	0	0	100.00	0.00	0.00
Durango	321 617	139 369	13 220	169 028	43.33	4.11	52.56
Guanajuato	316 205	99 533	0	216 672	31.48	0.00	68.52
Guerrero	1 045 917	525 797	405 936	114 183	50.27	38.81	10.92
Hidalgo	590 482	268 086	40 177	282 220	45.40	6.80	47.79
Jalisco	498 113	256 607	70 522	170 984	51.52	14.16	34.33
México	257 434	238 803	5 424	13 208	92.76	2.11	5.13
Michoacán	1 325 604	704 070	392 210	229 324	53.11	29.59	17.30
Morelos	116 014	55 787	60 227	0	48.09	51.91	0.00
Nayarit	119 213	45 653	37 110	36 450	38.30	31.13	30.58
Nuevo León	126 346	12 867	0	113 479	10.18	0.00	89.82
Oaxaca	2 448 917	1 208 230	801 649	439 038	49.34	32.73	17.93
Puebla	884 436	214 946	414 478	255 012	24.30	46.86	28.83
Querétaro	220 305	69 879	2 430	147 996	31.72	1.10	67.18
Quintana Roo	1 216 338	0	1 216 338	0	0.00	100.00	0.00
San Luis Potosí	917 525	95 498	76 558	745 469	10.41	8.34	81.25
Sinaloa	305 423	86 860	188 493	30 070	28.44	61.72	9.85
Sonora	611 213	69 394	70 082	471 737	11.35	11.47	77.18
Tabasco	420 086	0	420 086	0	0.00	100.00	0.00
Tamaulipas	226 995	23 996	71 063	131 936	10.57	31.31	58.12
Tlaxcala	62 138	52 583	0	9 555	84.62	0.00	15.38
Veracruz	1 327 911	225 916	1 076 684	25 312	17.01	81.08	1.91
Yucatán	1 416 093	0	1 416 093	0	0.00	100.00	0.00
Zacatecas	96 104	13 444	1 079	81 581	13.99	1.12	84.89
Total	18 083 101	5 063 088	8 014 833	5 005 180	30.32	32.16	37.53

Estimates of perturbed forest lands produced in the period (1971-1990) using high and low deforestation rates

Estimates of perturbed forest lands produced in the period (1891-1970) using high and low deforestation rates

State	1971-1990 Temperate: High estimate 0.95%	Low estimate 0.50%	Tropical: High estimate 2.23%	Low estimate 0.78%	Open forests: High and low est. 0.08%	1891-1970 Temperate: High estimate 0.95%	Low estimate 0.50%	Tropical: High estimate 2.23%	Low estimate 0.78%	Open forests: High and low est. 0.08%
Aguascalientes	200	101	0	0	37	1 085	471	0	0	153
Baja California	1 698	856	5 887	1 818	4 081	9 223	4 000	52 331	9 322	16 723
Baja California Sur	2 743	1 382	63 195	19 163	5 240	14 896	6 460	551 470	98 240	21 473
Campeche	0	0	165 293	50 123	0	0	0	1 442 416	256 956	0
Coahuila	1 428	719	0	0	7 396	7 755	3 363	0	0	30 309
Colima	1 466	734	20 953	6 354	13	7 910	3 431	182 844	32 572	55
Chiapas	98 376	49 572	427 647	129 678	0	534 315	231 727	3 731 829	664 798	0
Chihuahua	30 468	15 353	1 804	487	4 544	165 483	71 768	14 001	2 494	18 621
Distrito Federal	140	70	0	0	0	759	329	0	0	0
Durango	28 012	14 619	7 329	2 222	2 726	157 573	68 338	63 958	11 394	11 167
Guanajuato	20 719	10 441	0	0	3 483	112 534	48 805	0	0	14 314
Guerrero	109 463	55 154	225 068	68 246	1 841	594 477	257 819	1 963 946	349 863	7 544
Hidalgo	56 806	28 121	22 275	8 754	4 550	303 103	131 453	194 377	34 627	18 645
Jalisco	53 417	26 917	39 098	11 856	2 767	290 125	125 824	341 189	60 780	11 298
México	48 710	25 049	3 007	912	213	269 995	117 094	26 240	4 674	873
Michoacán	146 683	73 854	217 447	65 938	3 697	796 035	345 233	1 897 536	338 032	15 150
Morelos	11 613	5 852	33 381	10 125	0	63 073	27 354	291 384	51 908	0
Nayarit	9 503	4 789	20 674	6 239	688	51 616	22 385	179 540	31 984	2 408
Nuevo León	2 679	1 350	0	0	1 830	14 548	6 309	0	0	7 497
Oaxaca	251 512	126 738	444 447	134 772	7 078	1 366 048	592 442	3 878 429	690 914	29 005
Puebla	44 744	22 547	228 793	69 682	4 111	243 022	105 386	2 005 271	357 224	16 847
Querétaro	14 546	7 330	1 347	408	2 388	79 007	34 265	11 755	2 094	9 777
Quintana Roo	0	0	674 367	204 490	0	0	0	5 884 721	1 048 320	0
San Luis Potosí	19 879	10 017	42 445	12 871	12 019	107 972	46 827	370 390	65 982	49 250
Sinaloa	18 081	9 111	104 504	31 689	486	98 206	42 591	911 942	162 456	1 967
Sonora	14 446	7 279	38 864	11 782	7 606	78 458	34 027	339 059	60 401	31 165
Tabasco	0	0	232 902	70 624	0	0	0	2 032 403	362 058	0
Tamaulipas	4 996	2 517	38 399	11 947	2 127	27 130	11 766	343 809	61 247	8 716
Tlaxcala	10 946	5 516	0	0	164	59 452	25 784	0	0	631
Veracruz	47 028	23 698	598 930	181 011	408	255 425	110 775	5 209 065	927 957	1 672
Yucatán	0	0	786 104	238 072	0	0	0	6 851 149	1 220 482	0
Zacatecas	2 789	1 410	598	181	1 316	15 200	6 592	5 222	930	5 390
Total	1 053 961	531 096	4 443 560	1 347 445	80 694	5 724 426	2482 828	38 776 275	6 907 708	330 668

ANNEX 5.18. Calculations of Annual Biomass Uptake in Abandoned Lands

Forest Type	Avg. Biomass Forest Cleared*	% of Original Biomass Reached	Total Biomass Abandoned Lands	% that Regrows in 20 yr	Annual Uptake < 20 yr	Annual Uptake 20 to 100 yr
Temperate	59	80.00%	47.2	50.00%	1.2	0.30
Tropical	149	80.00%	119.2	70.00%	4.2	0.45
Open Forests	37	80.00%	29.6	50.00%	0.7	0.19

*Weighed average taking into account the difference in deforestation rates by forest sub-types.

ANNEX 5.19. Area under restoration plantations from 1960 to 1990

State	Trees ('000)	Reforest. (ha)	Trees ('000)	Reforest. (ha)	Trees ('000)	Reforest. (ha)	Trees ('000)	Reforest. (ha)	Trees ('000)	Reforest. (ha)	Trees ('000)	Reforest. (ha)
	1960-1976		1977-1982		1983-1988		1989		1990		Total	Total
Aguascalientes	716	716	425	425	1 603	1 603	1 042	1 042	1 965	963	5 751	4 749
Baja California	240	240	36	36	872	872	36	36	532	227	1 716	1 411
Baja California Sur	n.a.	n.a.	n.a.	n.a.	1 790	1 790	64	64	279	67	2 133	1 921
Campeche	858	858	348	348	2 628	2 628	183	183	796	351	4 813	4 368
Coahuila	998	998	4 071	4 071	8 845	8 845	57	57	1 949	1 800	15 920	15 771
Colima	420	420	201	201	2 366	2 366	68	68	329	439	3 384	3 494
Chiapas	2 935	2 935	4 455	4 455	11 167	11 167	750	750	19 239	3 104	38 546	22 411
Chihuahua	782	782	256	256	9 743	9 743	526	526	2 593	1 238	13 900	12 545
Distrito Federal	362	362	1 671	1 671	29 017	29 017	4 000	4 000	14 315	2 987	49 365	38 037
Durango	326	326	55	55	6 893	6 893	838	838	1 193	3 001	9 305	11 113
Guanajuato	688	688	309	309	4 539	4 539	424	424	836	792	6 796	6 752
Guerrero	250	250	411	411	4 348	4 348	456	456	2 614	1 101	8 079	6 566
Hidalgo	288	288	974	974	2 330	2 330	452	452	1 271	535	5 315	4 579
Jalisco	1 307	1 307	754	754	13 089	13 089	660	660	2 163	483	17 973	16 293
México	9 185	9 185	965	965	31 992	31 992	802	802	21 351	11 050	64 295	53 994
Michoacán	n.a.	n.a.	13 163	13 163	38 345	38 345	16 000	16 000	23 324	9 800	90 832	77 308
Morelos	624	624	429	429	5 402	5 402	201	201	413	533	7 069	7 189
Nayarit	112	112	2 437	2 437	5 153	5 153	505	505	700	202	8 907	8 409
Nuevo León	n.a.	n.a.	134	134	2 212	2 212	160	160	284	126	2 790	2 632
Oaxaca	48	48	1 449	1 449	8 886	8 886	315	315	101	436	10 799	11 134
Puebla	1 627	1 627	3 574	3 574	7 847	7 847	718	718	1 000	947	14 766	14 713
Querétaro	588	588	1 920	1 920	4 317	4 317	254	254	560	332	7 639	7 411
Quintana Roo	428	428	680	680	3 149	3 149	382	382	1 418	4 791	6 057	9 430
San Luis Potosi	319	319	655	655	3 764	3 764	272	272	2 087	525	7 097	5 535
Sinaloa	n.a.	n.a.	330	330	996	996	95	95	351	384	1 772	1 805
Sonora	638	638	6 050	6 050	1 054	1 054	125	125	450	167	8 317	8 034
Tabasco	5 526	5 526	1 430	1 430	5 371	5 371	540	540	2 286	1 553	15 153	14 420
Tamaulipas	114	114	1 153	1 153	5 712	5 712	245	245	462	4 170	7 686	11 394
Tlaxcala	2 455	2 455	1 998	1 998	5 079	5 079	3 000	3 000	8 400	2 600	20 932	15 132
Veracruz	3 582	3 582	2 635	2 635	13 426	13 426	3 013	3 013	10 551	3 657	33 207	26 313
Yucatán	1 108	1 108	975	975	2 384	2 384	278	278	619	279	5 364	5 024
Zacatecas	305	305	813	813	1 355	1 355	320	320	2 218	310	5 011	3 103
Total	36 829	36 829	54 756	54 756	245 674	245 674	36 781	36 781	126 648	58 950	500 688	432 990

Source: SARH (1990)

Total number of trees (SARH, 1991a) ('000)	Survival (FAO, 1990) (%)	Total number of alive trees ('000)	Density of plantation (trees/ha)	Growth for ha for year (tms)	Growth for 1000 trees for year (tms)
500 688	34.00%	170 234	1 156	4.00	3.46

Note: The estimate growth is 3-5 ton/ha/year. We proposed 4 tons.

ANNEX 5.20. Estimate of mean annual increment in temperate and tropical managed forests

Type of vegetation	Area (Kha)	Production (m^3/ha)	Density (ton/m^3)	Expansion factor (tdm/m^3)	Annual growth (tdm/ha)	Total annual increment (Ktms)
Temperate conifer forest (Traditional management)	3 500.0	1.5	0.5	1.70	1.28	**4 462.50**
Temperate conifer forest (Improved management)	2 600.0	7.0	0.5	1.70	5.95	**15 470.00**
Plantations	2.8	7.1	0.5	1.70	6.04	**16.90**
Tropical evergreen forest	900.0	2.7	0.7	1.56	2.94	**2 643.73**

Notes: The estimated growth is 3-5 ton/ha/year we proposed 4 tons.

In some other plantations there is a production up to 8.0 m^3/ha.

Other estimations of the annual growth (commercial harvest) are:

a) 1.22-1.86 m^3/ha/year (SARH, 1994).

b) 1.0-2.0 m^3/ha/year (Bellón et al., 1994).

ANNEX 5.21. Estimates of total biomass harvested from commercial wood harvested

Species	Production (m^3 roundwood)	Density (ton/m^3)	Expansion factor (Cannell, 1982)	Total wood produced (ktdm)	Expansion factor (IPCC, 1994)	Total wood produced (ktdm)	Average of two expansion factors	Average of total wood produced (IPCC-CANNELL)
Pine tree	6 817 425	0.5	1.7	5 795	1.825	6 221	1.76	**6 008**
Sacred fir	226 215	0.5	1.7	192	1.825	206	1.76	**199**
Other conifers	76 820	0.5	1.7	65	1.825	70	1.76	**68**
Oak tree	382 851	0.6	1.7	391	1.825	419	1.76	**405**
Other broadleaves	189 783	0.6	1.7	194	1.825	208	1.76	**201**
Subtotal	7 693 094			6 636		7 124		**6 880**
Precious wood	39 638	0.7	1.56	43	1.825	51	1.69	**47**
Common tropical woods	369 104	0.7	1.56	403	1.825	472	1.69	**437**
Other tropical woods	150	0.7	1.56	0	1.825	0	1.69	**0**
Subtotal	408 892			447		522		**484**
Total	**8 101 986**			7 083		7 647		**7 365**

Sources: Cannell, 1982; cited by Bellón et al., (1994).

CNIF (1991).

ANNEX 5.22. Estimate of total increment in the forest of Mexico (tdm)

Parameters	Type of vegetation			
	Temperate conifer forest	Temperate broadleaf forest	Tropical evergreen forest	Tropical deciduous forest
Existences (m^3) SARH, 1992	1 417 808 488	355 549 780	725 475 886	301 132 627
Increment in volumen (m^3/ha)	1.48	1.00*	2.70	2.70
Total increment (m^3)	25 225 560	8 409 347	23 450 188	41 699 092
Density (ton/m^3)	0.50	0.60	0.70	0.70
Expansion factor (Cannell, 1982)	1.70	1.70	1.56	1.56
Expansion factor (IPCC, 1994)	1.825	1.825	1.825	1.825
Average expansion factor	1.7625	1.7625	1.6925	1.6925
Total (tdm) (Cannell, 1982)	21 441 726	8 577 534	25 607 605	45 535 408
Total (tdm) (IPCC, 1994)	23 018 324	9 208 235	29 957 615	53 270 590
Total average (tdm)	22 230 025	8 892 884	27 782 610	49 402 999

*Notes: We assumed that the temperate broadleaf forest grows 30% less than temperate conifer forest.

The expansion factor of IPCC, 1994 (1.825) is the average of the undisturbed forests = 1.75 and logged forests = 1.90

6. WASTE

J. L. Arvizu

6.A. LANDFILLS

Methane from landfills contributes a significant portion of annual global methane emissions, although the estimation is subject to a great deal of uncertainty. Estimates of global methane emissions from landfills range from 20 to 70 Tg/year, which means for 6 to 20% of total methane emissions. (IPCC,1992).

Uncertainty related to methane emissions from waste landfilled in Mexico is not different. Therefore, by this study, an Alternative Methodology based on field and laboratory testings was applied in parallel to the IPCC Methodology, to reduce uncertainty.

6.A.1. General Methodology

Two different but of equal order magnitude values for methane emissions from sanitary landfills in Mexico were obtained by using the following two methodologies. The IPCC Methodology is divided into three parts: 1. Quantification of disposed Urban Solid Waste; 2. Annual biogas quantification of emissions from disposed Solid Waste; 3. Determination of Methane Emissions.

Information requested by IPCC methodology was processed using worksheets 6-1 (table 6.1) and supplementary worksheets 6-1 (table 6.2) enclosed.

On the other side, in the Alternative Methodology two parameters were used, namely biodegradability and methane yield, which were determined experimentally in local conditions and with local waste composition (4-8).

These parameters are equivalents to IPCC factors termed DOC (degradable organic carbon) and DOC dissimilated (degradable organic carbon dissimilated) which are general parameters.

6.A.2. Classification of waste

Organic landfill materials such as yard waste, household garbage, food waste, and paper, can descompose and produce methane. Methane production typically begins one or two years after waste in placed in a landfill and may last from 10 to 60 years.

In the study Mexico was divided into five regions, according with waste composition. These regions are presented in tables 6.3 and 6.4, which show the composition of waste materials throughout the country. Each waste composition shows particular values in the biodegradability and methane yield, as well as differnet contents of DOC and DOC Dissimilated.

6.A.3. IPCC Methodology

Results from the application of the first step of the IPCC methodology are presented in supplementary worsheet 6-1 (table 6.1), which shows the disposed urban solid waste.

Column A of the Supplementary Worksheet 6-1 gives the total population per region and was derived from figure published in the 1990 Official Populaion Census. Column B from the same worksheet referes to solid waste production rate, and was derived from information compiled by the former Secretaría de Desarrollo Urbano y Ecología (SEDUE) and by the Departamento del Distrito Federal (DDF). These figures are referred to one million people.

Column C is the product of Column A and B. Information on the fraction of solid waste landfilled (column D) comes from SEDUE and DDF. Two figures can distinguish; 0.65 for

Federal District (Mostly Mexico City) and 0.22 for the rest of the nation. Finally, Column E referred to solid waste landfilled is the product of columns C and D.

Worksheet 6-1 (table 6.2) was derived by applying the next two steps of the IPCC Methodology, that is, the quantification of annual biogas production and net methane emissions from urban solid waste.

Figures in Column A of worksheet 6-1 are the same as figures presented in Column E of supplementary worksheet 6-1, and are called landfilled urban solid waste.

Figures presented in columns B, D, and F of worksheet 6-1 are default figures proposed by IPCC Reference Manual in table 6-1, and the corresponding text of the Methodology.

In Column B figures of 0.19 for Mexico city and of 0.15 for the rest of the country, are due to differences in solid waste characteristic among these regions, and are the same proposed by the IPCC Methodology in table 6-1.

Figures presented in Column H are a constant which is obtained by divided the methane atomic weight by the carbon atomic weight. No figures are presented in Column J, because biogas or Methane from landfills is not recovered in Mexico for any practical purpose. The rest of the columns (C, G, I and K) are the product of the values of solid waste landfilled and default constant figures given in the previous columns. In the last column I, the Net Methane Emissions are presented for the disposed Solid Waste.

It can be seen in the last Column of table 6.2 (the methane emissions by regions of the country), that Mexico City (DF) accounts for 50% of emissions in this concept.

From the available official information (SEDUE), and applying IPCC Methodology it is shown that Urban Solid Waste in Mexico generates 551 Gg of methane, which represents all the methane emitted by waste disposal in 1990.

6.A.4. Alternative Methodology

The same information required by the IPPC Methodology was used to establish waste biodegradability and methane yield. Applying the empiric factors, results in the information presented in table 5. It can be observed that to the Border and DF regions correspond larger figures for biodegradability and methane yield (194.4 and 214.3 kg of waste dry biodegradable waste/ton of waste, and 80.6 and 88.9 m3 CH_4/ton of waste, respectibily). For the remaining three regions practically the same figures were obtained in the two parameters.

In table 6.6 figures are presented for waste generated by year, fraction of waste landfilled and total waste landfilled, for DF region and the rest of the country, taking into account as the main factor the fraction of waste landfilled for this classification. Table 6.7 presents the information on methane yield and annual methane emissions by volume and weight obtained in this case. Annual metane emissions were estimated at 386 Gg of methane by using the Alternative methodology.

6.A.5. Results.

The annual figure for methane emissions obtained by following both methodologies are of the same order of magnitude. The average value of the two figures for Methane Emissions is 468.5 Gg CH_4/year with an uncertainty of about 17%. Taking into account that both methodologies start from the same data base, and that each methodology represents the empirical and theorical points of view respectively, we consider the average value as the Net Methane Emissions from Lanfills in Mexico in 1990.

6.A.6 Uncertainty

Both higher and lower figures obtained with the two methodologies are considered as the, bounds of the uncertainty of the estimate.

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Table 6.1
Sheet 6–1
Wastes: Methane Emissions from Underground Landfills

A Population 10^6	B DSW Production Rate Gg DSW/10 6 cap/year	C USW Generated Gg USW	D Fragment placed on landfill	E USW placed on landfill Gg USW
Fontier 8	235	1,880	0.22	413.60
North 18	255	4,590	0.22	1,009.80
Center 37	225	8,325	0.22	1,831.50
Federal District 12	350	4,200	0.65	2,730.00
South 12	242	2,904	0.22	638.88

Table 6.2
Work Sheet 6–1
Wastes: Methane Emissions From the Underground Landfills

A Annual USW Gg	B Fraction COD	C Annual USW from landfill Gg	D Real degradated fraction	E Biogass Annual liberated Carbon Gg	F Fraction CH4 Gg CH4/ Gg biomass	G CH4–C Gg,C Emissions	H Convertion Factor 16/12	I CH4 Emissions Gg	J CH4 Recovered Gg	K CH4 Net Emissions Gg
413.60	0.15	62.04	0.75	46.53	0.50	23.26	1.333	31.02	0.00	31.02
1,009.8	0.15	151.47	0.75	113.60	0.50	56.79	1.333	75.73	0.00	75.73
1,831.5	0.15	274.73	0.75	206.05	0.50	103.02	1.333	137.37	0.00	137.37
2,730.0	0.19	518.70	0.75	389.03	0.501	194.51	1.333	259.35	0.00	259.35
638.88	0.15	95.83	0.75	71.87	0.50	35.93	1.333	47.91	0.00	47.91
6,623.8 Total	0.17	1,102.7	0.75	827.08	0.50	413.53	1.333	551.38	0.00	551.38

Table 6.3
Population and Urban Solid Waste Production in Mexico 1990

Zone	Number of inhabitants Millions	Production kg/per/day	Dayly production Ton/year Thounsands	Annual Production Ton/year Thousands	%
Border	8.06	0.645	5.2	1,898	8.7
North	17.53	0.698	12.2	4,453	20.6
Center	36.54	0.617	22.5	8,212	37.9
Federal District	11.97	0.960	11.5	4,197	19.5
South	11.99	0.663	7.9	2,883	13.4
Average		0.718			
Totals	86.05		59.3	21,643	100.00

Table 6.4
Percentual Composition of Urban Solid Waste by Country Regions

Component	Border	North	Center	South	Federal District
Food wastes	25.22	37.73	37.46	40.26	44.14
Garden wastes	15.05	7.34	6.92	7.73	3.97
Paper wastes	16.75	14.16	12.71	11.20	17.78
Plastic wastes	10.95	9.37	8.82	10.47	13.01
Textile wastes	2.48	1.91	1.97	1.23	2.37
Wood wastes	—	—	—	—	0.58
Inorganic wastes	30.31	29.47	31.4	29.07	18.15
Totals	100.0	100.0	100.0	100.0	100.0

Table 6.5
Methane yield by region

Region	USW Biodegradables Kg dry/Ton USW	Methane Yiield CH4 m³/Ton USW
Border	194.4	80.6
North	183.4	76.1
Center	173.1	71.8
South	170.0	70.5
D. F.	4.3	88.9

Note. The second column values were obtain from the values on the before tables. The values on the third column were obtain from multiply the second column by 0.415 factor. This number is the methane yield by each biodegradable Kg of urban solid waste (USW).

Table 6.6
Urban Solid Wastes (USW) Placed on Sanitary Landfills

Country zone	Thousands of USW tones produced per year	USW Percentage placed on sanitary Landfills	USW Thousands of Tons Annualy placed on sanitary landfills
Federal District	4.197	65.50	2.749
Rest of the country	17.446	22.25	3.881
Total	21.643	30.63 (average)	6.630

Table 6.7
All Country Preliminar Urban Solid Waste Methane
Estimation (1990)

Country zone	USW Placed in Sanitary landfills (millions Ton/ Year)	USW Methane Yield (m^3N/ Ton USW)	Annual Methane emissions (Millions of m^3/year)	Annual Methane emissions (Thousand of Tons/year)
Federal District	2.75	88.9	244.38	174.5
Rest of the Country	3.88	74.75	296.60	211.4
Total	6.63	- - -	540.98	385.9

6.B. WASTE WATER

Methane emissions from wastewater occurs when this is treated in an anaerobic biological way. Anaerobic treatment remotes from more than one century, but in Mexico its use in wastewater treatment starts in the present decade. Basically, anaerobic term refers to an ambient condiciton without air or oxygen requirements. Actually anaerobic conditions are also reached in some degree in oxidation ponds and municipal drain grids.

In 1990 in Mexico, there were 310 municipal wastewater treatment plants using several aerobic technologies, with a total capacity of 19.3 m^3/second, equivalent to 12% of total wastewater volume generated in those years. One hundred and thirty eight of this plants were oxidation ponds, this technology combines anaerobic and aerobic processes. Methane emissions from these plants were calculated to be of 7.1 Gg CH_4/year.

For 1990 urban population of Mexico was 70%, and municipal drain grid reached 63.6% of households. Taking into account these two factors and default values from IPCC Methodology for 0.04 kg BOD/capita/day, 0.22 kg CH_4/kg BOD, and assuming 50% anaerobic degradation of BOD, gives as a result methane emissions of 58 Gg CH_4/year. The population considered was the total population multiply by fraction of urban population and by municipal drain grid. Equation used for methane emissions estimation is from IPCC Methodology and is given below:

Gg CH_4/yr = (Population)(0.04 kg BOD/capita/day)(365 days/yr)(0.22 kg CH_4/kg BOD)(0.5 Fraction Anaerobically Digested)

From approximations cited previously, the second option is more realistic, and established a 58 Gg CH_4/year as methane emissions from municipal wastewater.

In reference to industrial wastewater, the industries that produce the larger volumes of waste water are: suger cane, chemical, paper, petroleum, beberages, textil, steel electric goods and food industries. They sum 82% of watewater generated in the country. And of these, sugar cane an chemical industries contribute with 60% of the total. In sugar cane industries, traditionaly wastewater is used as a crop irrigation water. In the same way as in municipal sector, anaerobic treatment was not used until 90's decade, therefore it was not possible to estimate emissions from this source.

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Title of Inventory	National Greenhouse Gas Inventory
Contact Name	México Dr. Carlos Gay García
Title	Coordinador de la Unidad de Cooperación y Convenios Internacionales
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Address	Río Elba 20, piso 14 Col. Cuauhtémoc México, D. F., 06500
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E-mail	cgay@servidor.unam.mx
Is uncertainty addressed?	Yes
Related documents filed with IPCC	

Table 7A Summary Report for National Greenhouse Gas Inventories
Summary Report for National Greenhouse Gas Inventories (Sheet 1)
Botton-up methodology
(Gg)

Greenhouse Gas Source and sink categories	CO_2 Emissions	CO_2 Removals	CH4	N2O	NOx	CO	NMVOC	HFCs	PFCs	SF6
Total National Emissions and Removals	398425		5654	9.12	1822.2	14292	1046.5			
1 All Energy (Fuel Combustion + Fugitive)	275020		1286.78	2.61	1790.2	12588	1046.5			
A Fuel Combustion	275020		247.2	2.61	1790.2	12588	1046.5			
1 Energy and Transformation Industries										
2 Industries (ISIC)	1381.40		2.07		1141	187.9	1046.5			
3 Transport	94460		222.8	1.37	573	6910				
4 Small Combustion	42420		22.3	1.24	76.2	5490				
5 Other										
6 Traditional Biomass Burned for Energy										
B Fugitive Emissions from Fuels			1039.58							
1 Solid Fuels			70.27							
2 Oil and Natural Gas			969.31							
2 Industrial Process**	11621									
3 Solvent and Other Product Use										

Table 7A Summary Report for National Greenhouse Gas Inventories
Summary Report for National Greenhouse Gas Inventories (Sheet 2)
(Gg)

Greenhouse Gas Source and sink categories	CO_2 Emissions	CO_2 Removals	CH4	N2O	NOx	CO	NMVOC	HFCs	PFCs	SF6
4 Agriculture			1888.138	5.51						
A Enteric Fermentation			1804.336							
B Manure Management			48.802							
C Rice Cultivation			35							
D Agricultural Soils				5.51						
E Prescribed Burning of Agricultura Residues										
F Other										
5 Land Use Change and Forestry	111784		195	1	32	1704				
A Changes in Forest and other Woody Biomass Stocks	188479									
B Forest and Grassland Conversion										
C Abandonment of Managed Lands		76695								
D Other										
6 Waste			526							
A Solid Waste Disposal on Land			468							
B Waste water Treatment (urban)			58							
C Waste Incineration										
D Other Waste										
7 Other										
International Bunkers										

This sheet is not affected by the differences between button/up or top/down methodologies used to estimate emissions in the energy sector.

Table 7B Short Summary Report for National Greenhouse Gas Inventories
Short Summary Report for National Greenhouse Gas Inventories (Sheet 1)
Bottom-up methodology
(Gg)

Greenhouse Gas Source and sink categories	CO_2 Emissions	CO_2 Removals	CH4	N2O	NOx	CO	NMVOC	HFCs	PFCs	SF6
Total National Emissions and Removals	398425		5654	9.12	1822.2	14291.9	1046.5			
1 All Energy (Fuel Combustion + Fugitive)	275020		1286.78	2.61	1790.2	12587.9	1046.5			
A Fuel Combustion	275020		247.2	2.61	1790.2	12587.9	1046.5			
B Fugitive fuel emission			1039.58							
2 Industrial Processes	11621									
3 Solvent and other product use										
4 Agriculture			1888.138	5.51						
5 Land Use Change and Forestry	111784		195	1	32	1704				
6 Waste			526							
7 Other										
International Bunkers										

Table 7A Summary Report for National Greenhouse Gas Inventories
Summary Report for National Greenhouse Gas Inventories (Sheet 1)
Top-down methodology
(Gg)

Greenhouse Gas Source and sink categories	CO_2 Emissions	CO_2 Removals	CH4	N2O	NOx	CO	NMVOC	HFCs	PFCs	SF6
Total National Emissions and Removals	433721		5654	9.12	[illegible]	14291.9	1046.5			
1 All Energy (Fuel Combustion + Fugitive)*	310316		1286.78	2.61	1790.2	12587.9	1046.5			
A Fuel Combustion	310316		247.2	2.61	1790.2	12587.9	1046.5			
1 Energy and Transformation Industries										
2 Industries (ISIC)			2.07		1141	187.9	1046.5			
3 Transport			222.8	1.37	573	6910				
4 Small Combustion			22.3	1.24	76.2	5490				
5 Other										
6 Traditional Biomass Burned for Energy										
B Fugitive Emissions from Fuels			1039.58							
1 Solid Fuels										
2 Oil and Natural Gas			70.27							
2 Industrial Process**	11621									
3 Solvent and Other Product Use										

Table 7A Summary Report for National Greenhouse Gas Inventories
Summary Report for National Greenhouse Gas Inventories (Sheet 2)
(Gg)

Greenhouse Gas Source and sink categories	CO_2 Emissions	CO_2 Removals	CH4	N2O	NOx	CO	NMVOC	HFCs	PFCs	SF6
4 Agriculture			1888.138	5.51						
A Enteric Fermentation			1804.336							
B Manure Management			48.802							
C Rice Cultivation			35							
D Agricultural Soils				5.51						
E Prescribed Burning of Agricultura Residues										
F Other										
5 Land Use Change and Forestry	111784		195	1	32	1704				
A Changes in Forest and other Woody Biomass Stocks	188479									
B Forest and Grassland Conversion										
C Abandonment of Managed Lands		76695								
D Other										
6 Waste			526							
A Solid Waste Disposal on Land			468							
B Waste water Treatment (urban)			58							
C Waste Incineration										
D Other Waste										
7 Other										
International Bunkers										

This sheet is not affected by the differences between button/up or top/down methodologies used to estimate emissions in the energy sector.

Table 7B Short Summary Report for National Greenhouse Gas Inventories
Short Summary Report for National Greenhouse Gas Inventoires (Sheet 1)
Top-down methodology
(Gg)

Greenhouse Gas Source and sink categories	CO_2 Emissions	CO_2 Removals	CH4	N2O	NOx	CO	NMVOC	HFCs	PFCs	SF6
Total National Emissions and Removals	433721		5654	9.12	1822.2	14291.9	1046.5			
1 All Energy (Fuel Combustion + Fugitive)	310316		1216.48	2.61	1790.2	12587.9	1046.5			
A Fuel Combustion	310316		247.2	2.61	1790.2	12587.9	1046.5			
B Fugitive fuel emission			969.31							
2 Industrial Processes	11621									
3 Solvent and other product use										
4 Agriculture			1888.138	5.51						
5 Land Use Change and Forestry	111784		195	1	32	1704				
6 Waste			526							
7 Other										
International Bunkers										

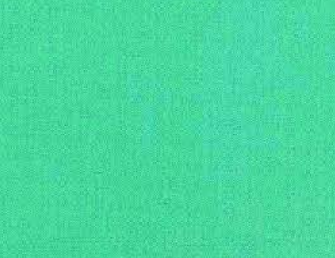
TABLE 8 OVERVIEW TABLE FOR NATIONAL GREENHOUSE GAS INVENTORIES

OVERVIEW TABLE (SHEET 1)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2		CH4		N2O		NOx		CO		NMVOC		HCFs		PFCs		SF6		Documentation	Disaggregation	Foot notes
	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality			
Total National Emissions and removals	PART	M	PART	M	PART	L	PART	L	PART	M	PART	L							M	2	
1 All Energy (Fuel Combustion + Fugitive)																					
A Fuel combustion	ALL	M	ALL	M	PART	L	PART	L	PART	L	PART	L							M	2	
1 Energy and transformation Industries	ALL	M	ALL	M	PART	L	PART	L	PART	L	PART	L							M	2	
2 Industry (ISIC)	ALL	M																	M	2	
3 Transport	ALL	M																	M	2	
4 Small Combustion	PART	M	PART	M	PART	M	PART	M	PART	M									M	2	*
5 Other																					
6 Traditional Biomass Burned for Energy																					
B Fugitive Emissions From Fuels																					
1 Solid Fuels																					
2 Oil and Natural Gas			ALL	L															L	2	
2 Industrial Processes	PART	M																	L	1	**
3 Solvent and Other Product Use																					

*Residential, Public and Comertial

**Only Cement



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