Impact of land use and land-use change on CO_2 emissions in Mexico

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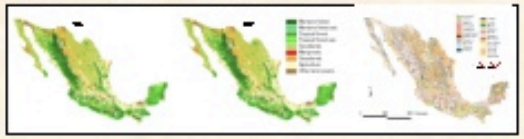
Introduction

Since 1990, Mexico has released two national inventories of GHG emissions. According to these estimates, land use emissions are the country's second most important source of CO_2 emissions. The present is part of Mexico's more recent effort to improve GHG inventory for the Land Use, Land-Use Change and Forest (LULUCF) sector. In this paper, we summarize results of CO_2 emissions estimation, as indicated by the revised IPCC guidelines (2004). Our results include spatial analysis of land-use dynamics, national stock inventory and uncertainty analysis of the most important sources of information (i.e. land use maps, national stock inventory estimates).

Available data

- Land use/Land cover: digital land use maps (1:250,000-INEGI 2001, 2002)

Vegetation classes were distinguished according to differences in biomass densities and primary productivity. Some classes were combined due to similar biomass densities and uncertainty. The 27 soil types were reclassified into 5 groups, according to IPCC guidelines.



- Ecoregions of Mexico (Arriaga): digital map; precipitation: maps (1961-1990); Forest inventory: (1994) digital; soil inventory: digital database

Mexico's first (1994) forest inventory plots (5,673+ ha) were available. These plots were classified according to precipitation classes (INEGI) and ecoregions. Mexico's first (1994) soil sampling sites were available (SEMARNAT-CP-INEGI) and were classified according to the available soil and vegetation maps.

Uncertainty analysis

One important aspect of the project was to calculate the uncertainties related to all estimations and to identify the major sources of these uncertainties. We calculated combined uncertainty of each parameter and summed the overall uncertainty according to the default methods (IPCC 2004, Good Practice Guidance for Land Use, Land-Use Change and Forestry).

$$U_{total} = \frac{\sqrt{(U_1 \cdot X_1)^2 + (U_2 \cdot X_2)^2 + \ldots + (U_n \cdot X_n)^2}}{X_1 + X_2 + \ldots + X_n}$$

Where:
U_{total} = Percentage uncertainty in the sum of the quantities,
U_i = Percentage uncertainty associated with the quantity X_i,
X_i = Quantity of the calculation by source i.

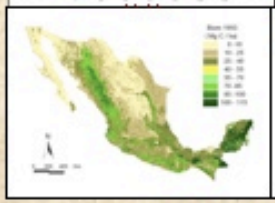
Land Use/Land Cover Change

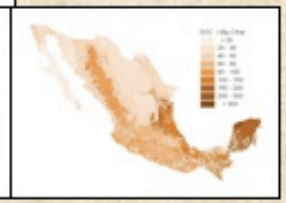
We harmonized 1991 and 2002 Land Use/Land Cover (LULC) maps to assess land cover changes. The LULC change matrix (table 1) was the basis to calculate emissions when there was a shift from a low-carbon to a high-carbon land use, to estimate carbon sequestration when there was no change in land use, and to calculate carbon flows from soils.

Km²	Montane Forests	Sub Montane Forests	Lowland Forests	Sub Lowland Forests	Scrublands	Grass & Agriculture	Other land covers	Total 2002
Montane Forests	14,190	1,264			5	189	1	15,649
Sub Montane Forests	471	6,561			5	512	1	7,550
Lowland Forests			15,591	1,307	255	1,147	19	18,319
Sub Lowland Forests			2,243	6,879	37	1,332	22	10,513
Scrublands	3	19	390	30	11,889	979	34	13,343
Grass & Agriculture	314	382	633	462	210	83,479	224	85,704
Other land covers	1	1	9	12	24	326	7,486	7,859
Total 1991	15,000	8,227	19,264	11,223	12,540	87,875	7,787	161,916

Biomass and soil carbon densities

From the old forest inventory, we calculated mean and stock biomass densities for each land cover type and were from differences between ecoregions. In the stage 1 we assumed the biomass densities in the same land cover class are accepted as no change between 1991 and 2002, other than the changes calculated in managed forest and soil carbon. Carbon flows from managed forest, soil carbon densities were calculated from available soil types, applying the IPCC soil groups, aggregated for each land cover. We assume biomass and soil density maps for 1991 and 2002 for illustrative purposes only. To calculate emissions, we applied the IPCC guidelines.





Carbon absorption from abandoned lands

We used published data of average volume increments of different managed forest types to estimate C absorption on abandoned lands. About 30% of total abandoned land was located in scrublands, grasslands and cultivated fields, however 70% of the total C absorbed comes from abandoned forest lands.

- Mean annual volume increments (average based forests)

Forest type		Mg ha⁻¹ y⁻¹
Montane	Coniferous	1.3
	Broadleaf	1.3
	Conif-Broadleaf	1.1
Tropical	Deciduous	1
	Relatively moist	2

- Carbon uptake (Mg biomass ha⁻¹ year⁻¹) from abandoned forest lands, $\Delta C_{B,P,T}$

Carbon emissions from harvested roundwood consumption

We assigned biomass and carbon densities to each land cover to calculate carbon flows from Land-Cover change. We used the-highest averaged biomass densities of the healthy land use classes to estimate biomass density after forest conversion.

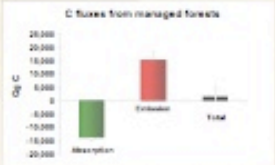
Carbon fluxes from soils

We calculated total C stocks in each soil inventory plot and assigned average values of C densities to each soil type and land cover/use general. Higher C densities were found in soils of volcanic origin and soils associated with mangroves and namely under vegetation types. Net C emissions from soil reached 6,270 Gg C, with an estimated uncertainty value of 83%.

Carbon fluxes from managed forests

We used published data of forest with sustainable management plans to estimate C flows from managed forest lands. The annual production of timber was of managed forests averaged 1.5 Mt m³ over the last two decades, about 10% from natural mixture forests. Fuelwood extraction was estimated at 17.5 Mt m³ of biomass, but at this stage $\Delta C_{B,P,T}$ extraction is assumed to be sustainable, this is all extracted was replaced by regrowth.

Total net estimated net C emission/sequestration when shifting from managed forest was 1,295 Gg C, with an uncertainty of 29%, mainly due to the use of default biomass expansion factors, average biomass increments, and to the uncertainty related to unsustainable harvesting.

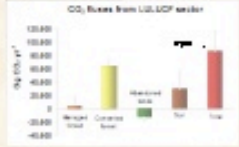


Conclusions

From 1991 to 2002, annual emissions estimated from the LULUCF sector in Mexico reached 85,175 Gg of CO_2 and 1,470 Gg of non-CO_2 gases (127 Gg CH_4, 1,113 Gg of CO, 1 Gg N_2O and 233 Gg NO_x). These emissions reduced from the balance every emissions from managed forest lands (-9,210 Gg CO_2). Emissions from biomass combustion contributed most to land converted (29,198 Gg CO_2), absorption from abandoned forest lands (10,981 Gg CO_2), and emissions from harvested wood products contributed (16,778 Gg CO_2).

The overall uncertainty was very high, annual emissions using the policy value between 50,000 and 90,175 Gg CO_2 per year. This is the first time the GHG emissions due to land-use change are presented with national estimates and maps, which indicate levels of uncertainty in all major sub sectors.

A proposal is being prepared by 16 researchers of 10 research institutions to set up a national monitoring system of carbon cycling in terrestrial ecosystems, including continuous monitoring of land use and land-use change, and of natural emission fluxes and the measurement in-situ, to reduce the uncertainty and to evaluate Mexico mitigation actions.



Acknowledgements

We thank INEGI, CONAFOR, SEMARNAT, CONABIO, and INE for providing national maps and local inventory data. We also thank CONACYT, SEMARNAT and PNUD for their financial support.