Greenhouse Gases Emissions Estimates from a Projected Hydroelectrical Dam in Mexico

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Abstract
We describe a study to estimate the potential GHG emissions from a projected 765 MW hydroelectric dam in the southern part of Mexico, near the port of Acapulco. We describe the methods used to estimate the biomass to be flooded, the procedures to measure and estimate current fluxes of GHG from soils. This will enable to build a base line of emissions without the dam to extract the net emissions from the dam. Surrogate measurements of GHG emissions from an eight years old similar dam will be used to test emission models applied to the project.

Introduction

Recent research indicates that hydroelectric dams may be significant sources of greenhouse gases (GHG). Hydropower is generally considered “clean” in comparison with fossil fuel combustion which since well ago is acknowledged an important source of GHG (IRN 2002). However, dams are know to produce large environmental and social problems, particularly the larger ones (Rashad and Ismail 2000). Dams may emit considerable amounts of GHG as CO_2 and CH4 (Rashad and Ismail 2000; Fearnside 2002) Other studies indicate that N_2O and CF_4 should have to be considered (Gagnon and Van-de-Vate 1997). All source activities, since construction through all the life cycle of the dam, need to be considered to estimate the GHG emissions from hydroelectric dams

The Mexican state owned electricity generator and provider Federal Electricity Commission (CFE for its acronym in Spanish Language) is planning to build an hydro electrical dam over the Papagayo River not far from Acapluco, a world wide known port and resort. To get approval for the project from the environmental authority, the Mexican environmental legislation requires that a manifesto of environmental impact (MEI) be submitted. Although not required by law in that rules (SEMARNAT 2002a), CFE decided to include an estimation of emissions of GHG from the project. This estimate should comply, to the largest extent as possible with the same rules for the MEI as any other pollutant or environmental impact.

Therefore, following MEI requirements, emissions need to be estimated for all activities related to: The building of the dam, including terrain preparation, making of roads, resettlement of affected population etc. Activities related to the operation of the dam for power generation, these include emissions from the reservoir surface, use of turbines and drains. Emissions form the abandonment of the dam. Finally, a base line needs to be estimated for emissions form the area to be flooded in the scenario of no dam built. This will enable to estimate the net emissions from the project. Another requirement from MEI rules is the need to propose mitigation alternatives.

Emissions from land clearing and energy use during the construction stage can be estimated by conventional procedures (EPA 1993). Estimating emissions from anoxic degradation of flooded biomass depends on accurate estimation of biomass in the area to be flooded and use of a model for biomass degradation. Another source to be considered is the amount of sediments to be retained by the dam. These sediments may have a varying content of nitrogen and organic carbon content. Factors affecting emissions are temperature, latitude, altitude, depth of the reservoir, the surface/volume ratio (WDC 2000).

In this context, there is not enough information in Mexico about the C reservoirs by type of ecosystem and land use. Neither about net fluxes of CO_2, and even less about CH_4 and N_2O relate to the dynamic of land us change at regional level. Current studies have focused in quantifying the Carbon storage and the land use change dynamic without considering other GHG gases.

To approach the problem an assortment of sampling and analysis techniques are used to estimate the aerial biomass (Ordoñez 2000), including foliar(Chen et al. 1991; Frazer et al. 2001) and litter biomass. Underground biomass was estimated by expansion factors from literature. Enclosure methods are used to sample fluxes from soils (Ambus et al. 1993) and water surfaces. Other methods are used to sample dissolved gases in the water column, gas bubbles in the water column and in sediments(Adams et al. 2001; Huttunen et al. 2001) in another hydroelectric dam eight years old very similar in design and ecosystem to the one being proposed. This data will provide a small database that will serve to choose and test models and to improve the design of further studies. In this paper, we show our experimental design and some preliminary results.

Method

The site to be flooded lies between 405,000 and 465,000 East and 1,845,000 and 1,907,000 North in UTM Coordinates of zone 14 of Clarke's1866 spheroid and DATUM NAD27. The area of the water surface at its highest level will be 13,850 ha

Land use and vegetation cover was first obtained form the National Forestry Inventory of year 2000 (SEMARNAT 2002b) The original LANDSAT TM bands used to estimate the inventory were obtained and reprocessed to obtain the land use and vegetation cover improved with some field observations. Analysis of the resulting map and a field visit yielded 28 sampling sites. However, large of hydroelectric dams are not free of controversy and consensus of farmers and peasants to be affected is hard to obtain. For this reason, the sampling team had access to only nine of those sites. Nevertheless, from the similarities between the sampled sites we concluded that those were representative enough for the whole area. Two sampling campaigns were carried out, one in the dry season and the other in the rainy season.

In each site, three sampling plots were drawn (Figure XX) to estimate the aerial plant biomass by conventional allometric procedures. The sampling sites size and shape were modified to account for slope (Ordoñez 2000). This will enable a one to one comparison with satellite images. In each site, three static sampling chambers were distributed to take two gas replicate samples for N_2O and (CH_4 + CO_2). Six samples were taken from each chamber at several minutes of interval. For each one, 20 ml gas samples were transferred with a gas tight syringe to a 20 ml vial, filled up with N_2 in the laboratory and evacuated with the same syringe in the field. One sample was used to analyze N_2O by GC/ECD the other to analyze CH_4 and CO_2 by GC/FID with catalytic reduction of CO_2 to CH_4 after separation in a Poropack packed column. Then the two vials were exchanged to do a replicate analysis of the other gas. Once the sampling concluded the biomass litter lying within the chamber wall was collected. Foliar biomass was estimated by non-destructive methods. Upward looking hemispherical photos were taken at the center of each biomass sampling plot and analyzed with the software WINPHOTO (Frazer et al. 2001) to obtain the three leaf biomass for the plot. Underground biomass was estimated using expansion factors from the literature.

Preliminary sampling to test the procedures was carried in the hydroelectric dam Aguamilpa, in the state of Nayarit about 500 km north of La Parota, with somewhat similar ecosystem and the same design and about the same capacity. The same enclosure chambers were used with the help of floating platforms. Sampling and analysis were done in similar way as above for fluxes from soils. Samples of water at different deeps were taken using Van Door bottles. Water was transferred to sealed vials and gases were analyzed by GC as before using dead-volume procedures. Gas bubbles were collected following (ref) and samples of gases in sediments down to 20 m were taken following Huttunen *et al* (2001) Gases were transferred to sealed vials as before and analysis of gases was also done following the above GC procedures.

Results and discussion

The land use/cover after re-processing the LANDSAT TM image using our field data to apply supervised classification is given in Table 1.

Table 1. Land use/cover class surface in the study area.

Land use / cover class	**Surface (ha)**
Temporal agriculture with annual crops	3,407.81
Temporal agriculture with permanent and semi permanent crops	274.24
Urban land	12.43

Crop pasture	70.00
Induce pasture	73.89
Savannah	316.54
Tropical deciduous and sub deciduous	1,791.29
Tropical deciduous with secondary vegetation, shrubs and grass	8,953.40
Tropical medium, deciduous and sub deciduous	5.16
Tropical medium, deciduous and sub deciduous with secondary vegetation, shrubs and grass	21.10
Total surface in ha	14,925.86

The total biomass stock by land use/cover is given in Table 2. The carbon stock stock in the area to be flooded is 98 851.43 Mg C. Most of the area is tropical deciduous and sub deciduous with secondary vegetation and rain-fed crop land (one crop per year). Most of it is low yield very stepped land. Most of tropical deciduous area is abandoned farming land that will be recycled into farming or grazing.

Table 2. Preliminary estimation of carbon stock in aerial biomass by land cover / use class in the study area (at La Parota).

Land use / cover class	Sup. in ha	MgC/ha	Mg C
Temporal agriculture with annual crops	3,407.81	5.6	19,083.72
Temporal agriculture with permanent and semi permanent crops	274.24	11.1	3,033.83
Urban land	12.43	n.d.	n.d.
Crop pasture	70.00	6.9	483.56
Induce pasture	73.89	4.5	333.60
Savannah	316.54	9.0	2,858.33
Tropical deciduous and sub deciduous	1,791.29	10.7	19,128.32
Tropical deciduous with secondary vegetation, shrubs and grass	8,953.40	6.0	53,497.13
Tropical medium, deciduous and sub deciduous	5.16	21.3	109.83
Tropical medium, deciduous and sub deciduous with secondary vegetation, shrubs and grass	21.10	15.3	323.04
Total	**14,925.86**		**98,851.34**

The annually averaged fluxes of CO_2, N_2O and CH_4 from soils are given in Table 3. This is a coarse and first approach to estimate the fluxes. To sustain extended field measurement programs is increasingly expensive. In this case, the point data (in time) may be used to check model outputs that may produce realistic profile of emissions along a year. The base line for emissions may be built with these data and a study of land use dynamics for the area, currently under way by another team.

Table 4 shows very preliminary and qualitative results of fluxes from the eight years old dam Aguamilpa. Here we observe very different values depending on the sampling site. Some qualitative comments need to be done. The first sampling in May 2003 at the end of the five/six months dry season, not reported here, was done to test the sampling devices and procedures. Fast accumulation of bubbles was observed in all sites. In addition, considerable amount of gases was released from the sediments. One month later when we returned with improved sampling devices almost no bubbles were trapped, even after long sampling periods. A much lesser amount of gas was released from the sediments than before. This sampling was carried out just at the beginning of the raining season, after the first big tropical storm reaching the region. This behavior is indicative of strong seasonality beyond those environmental parameters as temperature. We may assume that the large amount of water reaching the reservoir at lower temperatures than that at its surface may have induced convective motions leading to fast release of dissolved gases in the water column(Huttunen et al. 2001). This will be tested in the future planned sampling.

Conclusions

An integrated approach to obtaining the zero time for making the base line of GHG emissions from a proposed hydroelectric dam is being carried out. Field data are available to try models of land use dynamics and GHG emissions from soils. Some data area available to start considering emissions from the water body of the future dam.

Table 3. Annually averaged fluxes by area of land cover class and annual fluxes from those areas

Land use / cover class	Annually averaged flux (g N_2O/ha año)	Annually averaged flux (g $CO_{2/ha\ año}$)	Annually averaged flux (g $CH_{4/ha\ año}$)	Surface (ha)	Annual emissions (g N_2O/ año)	Annual emissions (g $CO_{2/\ año}$)	Annual emissions (g $CH_{4/\ año}$)
Temporal agriculture with annual crops	2.49	5.19	0.20	3407.81	8.48E+03	1.77E+04	6.66E+02
Temporal agriculture with permanent and semi permanent crops	42.82	5489.33	9.41	274.24	1.17E+04	1.51E+06	2.58E+03
Urban land	n.d.	n.d.	n.d.	12.43	n.d.	n.d.	n.d.
Crop pasture	216.61	5193.23	1.24	70.00	1.52E+04	3.64E+05	8.66E+01
Induce pasture	118.44	3325.49	-21.75	73.89	8.75E+03	2.46E+05	-1.61E+03
Savannah	-196.11	20135.15	-1.95	316.54	-6.21E+04	6.37E+06	-6.17E+02
Tropical deciduous and sub deciduous	4.71	21.30	0.22	1791.29	8.45E+03	3.81E+04	3.92E+02
Tropical deciduous with secondary vegetation, shrubs and grass	8.56	8.61	0.12	8953.40	7.67E+04	7.71E+04	1.09E+03
Tropical medium, deciduous and sub deciduous	n.d.	n.d.	n.d.	5.16	n.d.	n.d.	n.d.
Tropical medium, deciduous and sub deciduous with secondary vegetation, shrubs and grass	n.d.	n.d.	n.d.	21.1	n.d.	n.d.	n.d.
Total (g/año)					6.72E+04	8.62E+06	2.59E+03
Total in CO_2 equivalent					2.08E+07	8.62E+06	5.43E+04

Table 4 Emissions from the surface at different sites in the Hydroelectric dam Aguamilpa in Mexico (μg $m^{-2}h^{-1}$).

		CO_2	CH_4	N_2O
Site 1	Near the wall	-455.00	-2.60	417.00
Site 2	Side, deforested hills in the shore, somewhat fast currents felt in the boat, less flooded vegetation underwater.	202.00	20.00	-72.70
Site 3	Quiet side, less deforested shore, less strong currents felt in the boat, possible flooded vegetation underwater.	417.00	66.60	88.10

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