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Mapping drivers of climate change: Carbon budget index for Mauritius

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ABSTRACT

Climate change has been a burning issue since quite a long time and its effects can be perceived around the world. Carbon dioxide (CO_2) is the main driver of climate change among other greenhouse gases (GHGs). Despite increasing emissions, CO_2 is fortunately also absorbed or sequestered by plants and other biotic media which form the carbon sinks. These sinks have been diminishing, for instance due to deforestation. Therefore no effort should be spared to assess CO_2 emissions and sequestrations. In this paper, we down-scaled the conventional Inter-Governmental Panel on Climate Change (IPCC) methods, to calculate CO_2 emissions and removals, and we developed a carbon budget index as a case study for Mauritius. Emissions and sequestrations for different land categories (ecosystems) have been assessed for each district. The index revealed important carbon sinks and emission sources from the mappings. Index values for districts ranged from −1.988 metric tonnes (−1998 kg) of CO_2 per km^2 to over 288 metric tonnes (288,000 kg) of CO_2 km^{-2}. Negative values indicated areas that were net carbon sinks where more carbon was sequestered than emitted. The index can be used to measure national or regional achievements in meeting set targets to reduce emissions. In the context of the Millennium Developments Goals (MDGs), we found that some areas were above the target of 1.4 tonnes per capita for reducing CO_2 emissions.

1. Introduction

The drivers of climate change have been widely acclaimed to be the emissions of greenhouse gases (GHGs), of which carbon dioxide (CO_2) is of main concern. International agreements such as the Kyoto Protocol are trying to limit the emission of GHGs through the imposition of emission controls. In this regards, modern technologies, such as carbon capture and storage (CCS) are also useful (Fiigueroa et al., 2008). Since more CO_2 is being released into the atmosphere, through anthropogenic activities, than are being 'fixed' through photosynthesis by plants and uptakes by the ocean, the carbon cycle is being severely disrupted (IPCC, 2003a). Natural processes regulate the carbon cycle. The carbon budget, with its emissions and removals of CO_2, is closely linked to this carbon cycle. To understand how the changing global environment may alter the carbon cycle, it is necessary to further analyze the fluxes and examine the physicochemical and biological processes that determine them (IPCC, 2003a). In this paper, we down-scaled the conventional IPCC methods (IPCC, 1997, 2000, 2003b, 2006), to calculate CO_2 emissions and removals, and developed a carbon budget index (CBI) as a case study for Mauritius, more specifically for the Land Use, Land Use Change and Forestry (LULUCF) or for the Agriculture, Forestry and Other Land Uses (AFOLU) sectors, which are important ecosystems.

Carbon budgets point to sustainable development strategies to be adopted, by revealing the direct environmental impact of carbon emissions. They provide information about the flow of carbon in both the global scales as well as the local or national scales. Understanding the budget allows us to take necessary actions to mitigate climate change and global warming. Appropriate policy actions can be taken if an index is developed showing the net emissions per unit of land area.

Our calculations are based on the definition given by Gilbert and Reece (Gilbert and Reece, 2006) as "a carbon budget is a set amount of carbon that can be emitted in a given amount of time, either by the whole economy, or a pre-selected sub-population or set of activities and includes fluxes". Fluxes can be said to be the emissions and removals per unit of land surface. According to Canadella et al. (2007), to quantify the changes in the carbon cycle, one can update and analyze datasets on CO_2 emissions from fossil fuel combustion and cement production, as well as CO_2 emissions from land use change, among others. The relative efficiency of the land and ocean sinks can be measured by the annual airborne fraction (AF) which is the ratio of the atmospheric CO_2 increase in a given year

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to that year's total emissions (Canadella et al., 2007). The AF and its components, the sink fraction (SF), are:

$$AF = \frac{(dC_a/dt)}{(F_{Foss} + F_{LUC})}$$

$$SF = 1 - AF = \frac{F_{Sinks}}{(F_{Foss} + F_{LUC})}$$

where dC_a/dt is the growth rate of the atmospheric CO_2 store (C_a, Pg C year^{-1})[1], F_{Foss} and F_{LUC} are the CO_2 emission fluxes from fossil fuels and land use change, respectively; and F_{Sinks} is the total surface-atmosphere CO_2 sink flux to land and ocean carbon stores.

Based on a modified form of the above carbon emissions and removals functions, we formulated our study for Mauritius, taking the emissions net of carbon uptakes to build up the carbon budget index which necessitated several steps involving calculations of emissions and uptakes at various spatial levels. Ocean sink was omitted due to lack of data. Since our focus was to find the carbon balance[2], we focused on CO_2 only and excluded methane (CH_4) and nitrous oxide (N_2O), the other main GHGs, which are normally not accounted as sequestration.

As a starting point, we calculated the CO_2 emissions. We next applied Geographical Information Systems (GIS) techniques to estimate the CO_2 uptake by the different land use patterns. The IPCC guidelines are commonly used in GHG calculations and they describe processes of the GHG and other gases formation, for instance from fossil fuel combustion activities and land use change patterns. Fuel combustion activities normally account for most of the emissions, and in the case of Mauritius (SM, 2011), fossil fuels are the main accountable anthropogenic emission source of CO_2 since its release from biomass combustions, such as from bagasse, are considered as a carbon neutral process.

1.1. Objectives

The main objective of our study was to downscale the carbon budget, by calculating the emissions net of removals, from the national to the local or regional levels. Additionally, we aimed to develop a method for an index that can be applied to look at emission targets. This paper therefore presents the carbon budgets in terms of the emissions and removals of CO_2 for Mauritius, calculated from years 2002 and 2007 data obtained from the national data collection exercises, namely the Census of Economic Activities (CEA) and the Household Budget Survey (HBS) conducted by Statistics Mauritius (SM). We thus showed how these types of surveys, normally carried out in many countries, can be also very useful for environmental assessments, in addition to their main economic and social objectives. Since anthropogenic processes are accepted as driving climate change and global warming, we consider carbon emissions from these processes. We calculated the emissions of CO_2 by using data on fossil fuel combustions in industries as well as those from households. We targeted the spatial locations from where the emissions are released for calculating the carbon budget index and carrying out the mapping.

2. Study area, materials and methods

According to Yuen and Kong (2009), GHG emissions can be quantified by either directly measuring them or by estimating them. The World Resources Institute (WRI and WBCSD, 2011) identifies four main quantification methods—the emission factor-based method, the mass balance method, the Predictive Emissions Monitoring System (PEMS) and the Continuing Emissions Monitoring System (CEMS). Due to the ease of availability of data and other advantages (quality control, costs), the emission factor based approach is by far the most widely used quantification method for local GHG inventories. The accuracy of the emission factor based quantification depends on the accuracy of the emission factor value itself and on the accuracy of the activity data. Since the most accurate data are often also those that are most difficult to obtain, compilation of a GHG inventory face therefore a trade-off between the accuracy of the quantification and its feasibility (Yuen and Kong, 2009).

2.1. Study area: Mainland Mauritius

Mauritius is a Small Island Developing State (SIDS) located on the sub-tropical belt of the Indian Ocean in the eastern side of Madagascar at 20° 10′S and 57° 30′E. The mainland area is 1875 km^2 while the Exclusive Economic Zone (EEZ) extends nearly 2 million km^2 (MPF, 2012). The population is about 1.2 million and its economy has progressed from an annual gross domestic product (GDP) per capita of US $3656 in 1999 to US$ 8755 (+139%) in 2011 (World Bank, 2013).

Mauritius has a tropical climate where usually in winter (May to October) the temperatures vary between 20 °C and 26 °C and in summer (November to April), between 26 °C and 32 °C. Annual mean rainfall varies from 1600 mm to 4000 mm.

The relief of the island, of volcanic origin, has an upland central plateau with low lying areas at near sea level. Land use in Mauritius is dominated by sugar cane plantations which occupies around 55% of the total area and 98% of the cultivated land. Forests cover roughly 27%, scrubs and sparse vegetations 11%, built up areas 6% and others including water bodies, 1%. According to estimates, forests and some other lands in Mauritius were a net sink of CO_2 from living biomass during the period 2000–2006 with an annual average of about 293 Giga grammes (Gg)[3] (SM, 2011; MMS, 2010).

Most of the pristine forests are located in the southwestern parts of the island where the Black River Gorges National Park is located and therefore contains most of the carbon sinks. Mountain regions and coastal areas also have much vegetation. The carbon absorptions are, however, not restricted to the forests as there are numerous green belts along road sides and trees within settlements. These are, in fact, important sinks which are not extensively accounted for and we intend to carry a separate study to evaluate these sinks in the future. The maps in Fig. 1 show the nine districts for which the carbon budget index was developed, together with an indication of the land use classes representing extents of carbon sinks.

The study area essentially consists of the different land use patterns and the administrative regions known as Municipal/Village Council Areas (MVCAs) within districts. The proportions of each main land classes give an indication of emission sources as well as where CO_2 are sequestered. The MVCAs, totaling 144, are presented in Table 1 together with their corresponding districts.

2.2. The general calculation concept

The calculations of the carbon budget involved several steps as shown in Fig. 2. We first calculated the emissions and then the carbon uptakes by vegetations. Our study covered the vegetations and soil from forests, agricultural fields and settlements. We obtained the carbon budget by subtracting the uptakes from the emissions. Our spatial consideration resulted in maps of carbon budgets.

[1] Pg: petagramme; 1 Pg = 10^{15} g = 10^{12} kg.

[2] Emissions minus sequestrations here is not a complete carbon balance, for instance carbon in traded goods or carbon transfers from one pool to the other are excluded due lack of data.

[3] 1 Gg = 1000 metric tonnes or 1000,000 kg.