Geophysical Research Abstracts
Vol. 15, EGU2013-5756, 2013
EGU General Assembly 2013

A theoretical framework to distinguish direct and indirect anthropogenic perturbations of the terrestrial carbon cycle; and its implications in the definition of "emissions from land-use change"

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We present a theoretical analysis of the net land-to-atmosphere CO_2 flux, so as to discuss possible definitions of "emissions from land-use change" at global scale.
Our work is based on the fact that the terrestrial carbon cycle is affected by two anthropogenic perturbations. The first is the perturbation of the global Carbon-Climate-Nitrogen (CCN) system as observed with elevated CO_2, climate change and increased nitrogen deposition; it impacts the intensive parameters of the terrestrial biosphere. The second is the Land-Use and Land-Use Change (LUC) perturbation induced by human activities; impacting the extensive parameters of the biosphere. Previous global carbon budgets tried to separate these two perturbations by defining two CO_2 fluxes: the emissions from land-use change (LUC perturbation) and the land sink (CCN perturbation).
Here, through successive mathematical demonstrations, we isolate four (not two) generic components of the net land-to-atmosphere CO_2 flux. The two first components are the fluxes that would be observed if only one perturbation occurred. The two other components are due to the coupling of the CCN and LUC perturbations, highlighting the non-linear behavior of the terrestrial carbon cycle. Thanks to this, we introduce three possible definitions of "emissions from land-use change", that are indeed used in the scientific literature (often without clear distinctions), and we draw conclusions as for their absolute and relative behaviors.
Finally, we illustrate our theoretical results thanks to two models: a simple carbon-climate model using a bookkeeping module to estimate emissions from land-use change (named OSCAR), and the spatialized land-surface model ORCHIDEE. Our preliminary results show that comparing results from studies that do not use the same definition can lead to a bias of up to 20% between estimates of "emissions from land-use change". This makes our study of major interest to reconcile modeling and observation of "emissions from land-use change", and ultimately to distinguish direct and indirect effects of anthropogenic activities.