Earth Syst. Dynam. Discuss., 4, C431–C442, 2013
www.earth-syst-dynam-discuss.net/4/C431/2013/

Earth System Dynamics
Discussions
Open Access

ESDD
4, C431–C442, 2013

Interactive Comment

Interactive comment on "Terminology as a key uncertainty in net land use flux estimates" *by* J. Pongratz et al.

T. Gasser (Referee)

gasser@centre-cired.fr

Received and published: 23 September 2013

This paper by Pongratz et al. presents a symbolic framework describing the net land-to-atmosphere CO_2 flux, that is then used to review the various definitions of "emissions from land use and land-cover change" that can be found in the literature.

Although we did write a paper about this issue several months ago (Gasser and Ciais, 2013; GC13 hereafter), some of our conclusions being similar to the ones of Pongratz et al., this new paper has the real added-value of making a full review of the literature, which we did not. Besides, the framework they developed, using only symbols, may be a good pedagogical alternative to our more mathematical framework.

Thus I believe this article is of good interest for the community. However, I have several

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

concerns related to the framework itself, and some suggestions and/or corrections that I would like to see be answered before publication.

1 Introduction

I think it is important to recall the reader that there is an arbitrary, human-made, decision behind the notion of "emissions from land use and land-cover change". Surely for political reasons (negotiations), we have been willing to isolate direct and indirect effects of human activities over the terrestrial ecosystems. However, since Earth is not a simple – linear – system, the sum of two causes (direct + indirect) leads to more than two effects, which in turn leads to all the issues raised in this paper.

p.680 l.16–18 It is actually possible to build book-keeping models that respond to transient changes in e.g. CO_2. Though the paper fully describing our model (OSCAR v2) is not yet published, the appendix A of GC13 also provides the equations necessary to do so. Note that the original version of our model (Gitz and Ciais, 2003) was also a book-keeping model accounting for environmental changes.

p.681 l.3–8 The net land use flux is not always defined with respect to a reference state. See the definition S of this very paper, or my comment on definition B. Here, I would introduce a specific notation for $\Phi_{\mathtt{noLULCC}}$ to highlight that there is no land use ; e.g. Φ^*, that I will use hereafter, since I think the "*" already used for simulation at the equilibrium is useless. Hence, the net land use flux becomes : $F = \Phi - \Phi^*$ for definitions using a reference state.

p.681 l.11–14 Do we really, in GC13, "consider only a subset of relevant flux components"? All the definitions given by Pongratz et al. can easily be expressed with our framework. But I acknowlegde that not all were discussed, since we thought that some definitions were clearly wrong definitions! See key issue number 1).

ESDD

4, C431–C442, 2013

Interactive Comment

2 Materials and methods

I am concerned that this whole section could be hard to understand. Despite being well organized, as it progressively introduces the notations, I think some rewriting, with the aim of simplifying the section, could improve the paper.

Now, about the framework :

2.1 The three fluxes I, L and E

Since the authors acknowledge that the distinction between I and L "is not relevant for [this] study", a point on which I agree, why keep on writing the two fluxes in all subsequent equations? In the following, I will use only L.

2.2 The LULCC perturbation only

Hence, the preindustrial case is: $F = L_U + E_U = L_U$

2.3 The environmental perturbation only

I think the changes in environmental conditions should **not** be presented as being either LULCC or fossil. Although this paper focuses on the CO_2 flux related to land use, the environmental perturbation is not only CO_2-driven! Actually, the complementary perturbation to LULCC is non-LULCC, and it includes everything else, from aerosols emitted by fossil fuel burning to nitrogen compounds emitted because of fertilizers. Hence, I strongly suggest the use of three environmental conditions : "U" (for preindustrial), "L" (for land use-related) and "X" (for anything else). When both land use and others are present, I use the "LX" notation. (Plus, I'd rather use upper case subscripts

ESDD

4, C431–C442, 2013

for environmental conditions).

It should be noted that almost all the papers cited consider that X is only fossil fuel. But it is not a reason to restrict the framework, especially as it could mislead the reader.

Plus, I don't find equation 4 very relevant for the paper, as it is not used at all after that point.

2.4 Effect of E over L

The term "managed" might be misleading: abandoned (hence, not managed) lands are included here. The "managed" land are what we called, in GC13, "disturbed" lands ; the "natural" are our "undisturbed" lands.

With my notations, the equation becomes: $L = L_U + \tilde{\delta}_Z L$; with Z being LX, L, X or U; and $\tilde{\delta}$ being an operator that describes the perturbation.

p.686 l.7 δI and δL are consequences of δE prior **and posterior** to the LULCC event (e.g. changes in temperatures will affect the rate of soil carbon density stabilization).

2.5 Effect of L over E

With my notations : $LASC = \tilde{\delta}_Z E_m - \tilde{\delta}_Z E_p = \tilde{\delta}_Z [E_m - E_p]$.

2.6 Non-linearity

This section is a bit unclear. And it reveals a shortcoming of the framework : the authors acknowledge that the $\delta_X E_n$ flux is also a (second order) function of the LULCC perturbation! This raises the question of the consistency of the notation, and hence of the framework.

ESDD
4, C431–C442, 2013

Despite being more complicated, I suggest that the details of the non-linearity issue should be exposed, and dealt with thanks to a relevant notation. My proposal uses the operator notation that encompasses different definition of the δ-fluxes, depending on the environmental conditions :

$$\begin{aligned}\tilde{\delta}_L &= \delta_L \\ \tilde{\delta}_X &= \delta_X \\ \tilde{\delta}_{LX} &= \delta_L + \delta_X + \delta^2_{LX}\end{aligned}$$

The δ^2_{LX} is the (second order) non-linearity. With this detailled notation, the δ_X does not depend on the LULCC perturbation, in any case.

I want to highlight that these so-called "second order" components are not necessary negligible. A quick simulation with OSCAR v2.1 brings that the excess atmospheric CO_2 estimated in 2008 when only fossil fuel burning occurs is $\Delta_F[CO_2] =$ 62 ppm; when only LULCC activities occur is $\Delta_L[CO_2] =$ 32 ppm; and when both occur is $\Delta_{LF}[CO_2] =$ 104 ppm. Hence, a non-linearity for the atmospheric CO_2 of about 10% that will then propagate in the biospheric carbon cycle through e.g. NPP.

2.7 Direct and indirect fluxes

I don't find this section relevant, the main reason being that the distinction made by the authors between the direct and indirect fluxes is arbitrary and doesn't help the reader understand the framework or the physics behind. For instance, why should the author's $\delta_{\gamma=f}L$ be accounted for as direct, and $\delta_{\lambda=lf}L$ as indirect? Why should the extra-emissions induced by fossil fuels be more direct than the ones induced by fossil fuels and land use? I believe there are enough arbitrary definitions in the land use-related issues to avoid adding one. Once again : this section isn't helpful to understand either the framework or the results of section 3. Furthermore, removing that section also avoid the use of λ and γ.

Generally speaking, I do not recommend the use of the "direct" or "indirect" adjectives when naming things specifically (like fluxes or effects), as many authors before did use them with different meanings. Sometimes "direct" refers to the instantaneous flux (as it is still visible in Table 2, where one can see the authors of this article initially named the I-flux "D"), others to the land use feedback, or to the full effect of environmental conditions change on LULCC emissions, etc.

3 Results

p.692 l.13 E1 and E2 descriptions are inverted.

In this section, I will express the net land use fluxes obtained with the modified framework, commenting when necessary.

Definition E1:

$$\begin{aligned} F(E1) &= \Phi_{mn,L} - \underbrace{\Phi^*_{pn,U}}_{=0} \\ &= L_U + \delta_L L + \delta_L E_{mn} \end{aligned} \quad (1)$$

Definition E2:

$$\begin{aligned} F(E2) &= \Phi_{mn,LX} - \Phi^*_{pn,X} \\ &= L_U + \tilde{\delta}_{LX} L + \tilde{\delta}_{LX} E_{mn} - \delta_X E_{pn} \\ &= L_U + [\delta_L + \delta_X + \delta^2_{LX}]L + [\delta_L + \delta^2_{LX}]E_{mn} + \delta_X[E_m - E_p] \end{aligned} \quad (2)$$

Here, the detailed notation becomes interesting! One can see were the non-linear term is accounted for.

ESDD

4, C431–C442, 2013

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Definition S:

$$F(S) = \Phi_{mn,LX} \qquad (3)$$
$$= L_U + \tilde{\delta}_{LX} L + \tilde{\delta}_{LX} E_{mn}$$
$$= L_U + [\delta_L + \delta_X + \delta_{LX}^2] L + [\delta_L + \delta_X + \delta_{LX}^2] E_{mn}$$

Definition D1:

$$F(D1) = \Phi_{mn,U} - \underbrace{\Phi^*_{pn,U}}_{=0} \qquad (4)$$
$$= L_U$$

Definition D2:

$$F(D2) = \Phi_{mn,L} - \Phi^*_{pn,L} \qquad (5)$$
$$= L_U + \delta_L L + \delta_L [E_m - E_p]$$

Definition D3:

$$F(D3) = \Phi_{mn,LX} - \Phi^*_{pn,LX} \qquad (6)$$
$$= L_U + \tilde{\delta}_{LX} L + \tilde{\delta}_{LX} [E_m - E_p]$$

Definition D4:

$$F(D4) = \Phi_{mn,LX\_\mathrm{CO2}} - \Phi^*_{pn,LX\_\mathrm{CO2}} \qquad (7)$$
$$= L_U + \tilde{\delta}_{LX\_\mathrm{CO2}} L + \tilde{\delta}_{LX\_\mathrm{CO2}} [E_m - E_p]$$

Actually, the framework should be extended for this particular case D4. Introducing the notation $\tilde{\delta}_{Z_1,Z_2}$, where Z_1 is the specific environmental condition “atmospheric CO2”

ESDD

4, C431–C442, 2013

Interactive Comment

and Z_2 represents all the other environmental conditions (climate, etc.). However, doing so implies to go further with the infinitesimal notation, since we have (by definition) :

$$\begin{aligned} \tilde{\delta}_{LX,LX} &= \delta_{L,L} + \delta_{X,X} \\ &+ \delta^2_{L,X} + \delta^2_{X,L} \\ &+ \delta^3_{LX,X} + \delta^3_{LX,L} + \delta^3_{X,LX} + \delta^3_{L,LX} \\ &+ \delta^4_{LX,LX} \end{aligned} \tag{8}$$

For consistency, we can link the elements of $\tilde{\delta}_{Z_1,Z_2}$ to the ones of $\tilde{\delta}_Z$:

$$\begin{aligned} \delta_L &= \delta_{L,L} \\ \delta_X &= \delta_{X,X} \\ \delta^2_{LX} &= \delta^2_{L,X} + \delta^2_{X,L} + \delta^3_{LX,X} + \delta^3_{LX,L} + \delta^3_{X,LX} + \delta^3_{L,LX} + \delta^4_{LX,LX} \end{aligned} \tag{9}$$

And finally, the correct expression of $F(D4)$ shoud be :

$$\begin{aligned} F(D4) &= \Phi_{mn,LX,LX} - \Phi^*_{pn,LX,X} \\ &= L_U + \tilde{\delta}_{LX,LX} L + \tilde{\delta}_{LX,LX} E_{mn} - \tilde{\delta}_{LX,X} E_{pn} \\ &= L_U + \tilde{\delta}_{LX,LX} L + [\tilde{\delta}_{LX,LX} - \tilde{\delta}_{LX,X}] E_{mn} + \tilde{\delta}_{LX,X} [E_m - E_p] \end{aligned} \tag{10}$$

I won't expand that equation : it is clear that the notations are becoming too heavy. So staying at the level of my equation 7 (same as the authors' equation 14d) may be the best compromise. I just wanted to insist on the question of non-linearity, and by the way show that the experiment by Brovkin et al. calculates a pretty far-fetched land use flux...

Definition D5:

$$\begin{aligned} F(D5) &= \Phi_{mn,LX(t=today)} - \Phi^*_{pn,LX(t=today)} \\ &= L_U + \tilde{\delta}_{LX(t=today)} L + \underbrace{\tilde{\delta}_{LX(t=today)} E_{mn}}_{=0} - \underbrace{\tilde{\delta}_{LX(t=today)} E_{pn}}_{=0} \end{aligned} \tag{11}$$

ESDD
4, C431–C442, 2013

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Here, it is sufficient to explain that, because t is set for environmental conditions (it is not a transient simulation), all E-fluxes are equal to zero. Hence, no need to introduce the notation for the equilibrium of the pools.

Definition B:

$$\begin{aligned} F(B) &= \Phi_{m,LX(t=ref)} \\ &= L_U + \tilde{\delta}_{LX(t=ref)} L \end{aligned} \tag{12}$$

The previous remark still stands for the book-keeping definition. Note that there is no reference simulation, and we only consider "managed" lands since natural lands are not represented in a book-keeping model.

And finally, there is a second book-keeping definition of LULCC emissions in the literature. We proposed it in GC13 (and use it in our model), in the case of a book-keeping model coupled with changing environmental conditions. We call it "book-keeping definition" in GC13, as definition B is the particular case of it when the LX conditions are not transient. It is based on making the difference, for managed lands, between the calculated flux and the one that would occur if the managed ecosystem's carbon pools and fluxes were not disturbed by LULCC. It gives :

$$\begin{aligned} F(B2) &= \Phi_{m,LX} - \Phi^*_{m,LX} \\ &= L_U + \tilde{\delta}_{LX} L + \tilde{\delta}_{LX} E_m - \tilde{\delta}_{LX} E_m \\ &= L_U + \tilde{\delta}_{LX} L \end{aligned} \tag{13}$$

To be exhaustive, we could add the definition used in OSCAR v1, where the F-flux was supposed to be the net flux occuring over managed lands that had been disturbed up to e.g. 60 years before the year of estimation. That reference age of separation being dependent on the type of land (forest, corps, etc.) :

$$\begin{aligned} F(B3) &= \Phi_{m(t<ref),LX} \\ &= L_{U(t<ref)} + \tilde{\delta}_{LX} L_{(t<ref)} + \tilde{\delta}_{LX} E_{m(t<ref)} \end{aligned} \tag{14}$$

ESDD
4, C431–C442, 2013

But maybe this definition should be ignored, as I know no currently used model using it. And it wouldn't really help the reader to add a new definition with new notations related to the "ref" year.

4 Discussion

4.1 Land use feedback

I strongly believe including the so-called "land use feedback" in LULCC emissions without the non-LULCC feedback is unwise. First, because I don't think the environmental conditions related only to LULCC (i.e. δ_L) were calculated correctly in any of the cited studies. Second, because nobody would do that if the feedback flux wasn't CO_2 (e.g. CH_4 release from permafrost thawing induced by LULCC emissions) or the driver wasn't LULCC (e.g.CO_2 natural fluxes induced by warming induced by fossil fuel burning are not included in "emissions from fossil fuel burning"). Third, because I think it is a confusion between trying to quantify the **effects of LULCC** within the Earth system and just choosing an arbitrary definition for the **emissions from LULCC** (see my first remark in this review).

Anyway, the technical difficulty related to non-linearity has to be mentioned in this section. None of the given definitions completely isolate that " land use feedback", especially because the non-linear term δ_{LX}^2 always remains somewhere in the expression. Besides, since this term is due to LULCC **and** non-LULCC, there is no way to decide whether it should be included into LULCC emissions or not.

ESDD
4, C431–C442, 2013

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

4.2 LASC

We give estimates of the LASC in GC13: about 0.5 GtC/yr in 2005 and up to 5 GtC/yr in 2100 under the RCP8.5 if no more LULCC activities occur after 2005.

4.3 Legacy

—

4.4 Observable?

I think definition S is comparable to what is observable, given one knows the exact proportion of wood-products.

Maybe it should be reminded that (again) LULCC emissions are an arbitrary partitioning of the net land-to-atmosphere flux. Hence, one cannot expect them to be easily comparable to the observations, which raises all the issues about validation presented in this section.

4.5 Indirect effects

That L_U should be included in the LULCC flux is almost an agreement, isn't it? Only Lawrence et al. did not include all sub-components of L_U, but it is a very uncommon choice.

Note also that, even if it is not the role of scientists to choose what is the "best" definition, there can be very clear – scientific –arguments in favor or against certain definitions. In GC13, we tend to prefer the "book-keeping" definition since, with this definition, emissions from LULCC tend to zero if the LULCC pertubation is stopped, which is not

ESDD

4, C431–C442, 2013

the case for all definitions! Wanting that no LULCC activities implies no emissions is not a too ethical choice, I believe (much more a logical choice).

p.704 l.15 “separate” is misspelled.

ESDD

4, C431–C442, 2013