Biogeosciences Discuss., 7, C2297–C2302, 2010
www.biogeosciences-discuss.net/7/C2297/2010/

Biogeosciences Discussions

Interactive comment on "Contributions of secondary forest and nitrogen dynamics to terrestrial carbon uptake" *by* X. Yang et al.

X. Yang et al.

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Received and published: 12 August 2010

Note: For clarity purpose, we have listed the reviewer's comments in bold, and our response in the normal font.

One critical weak point is that the discussions on precision or uncertainty of simulated results are poor. The authors used their simulated results for conclusions without any examinations their uncertainties. Considering of the applications of the simulations using this model for the actual scenario making or countermeasure planning, the reliability of simulated results is critically important. I understand that the authors were not directly aiming to show the utility value on these practical applications, but the careful examination on calculation uncertainty is obviously needed also for the research level.

We concur with the reviewer's comments. Similar comment has also been made by the Reviewer 1. In response to both reviewers' comments, the discussion on the sources of uncertainties in various input variables and model results will be added (see below the text) in the concluding section of the revised.

Our results presented here are subject to uncertainties related to uncertainty in the data used, incomplete representation and/or simplifying assumptions of processes in the model. First, we believe there is a large uncertainty in the land use change data used in this study. Since global spatial historical land use change data is not available directly, land use change data used in this study was reconstructed based on earlier land use history reconstruction for agricultural land (Ramankutty and Foley, 1999; Klein Gokdewijk, 2001), and wood harvest in spatial detail based on several assumptions (Hurtt et al., 2006). In our previous study (Jain and Yang, 2005) we estimated the uncertainties in the land use emissions and net land-atmosphere CO2 fluxes using two different land cover data sets for croplands (Ramankutty and Foley, 1999; Houghton and Hackler, 2001), each was combined with one single set of pastureland data (Klein Goldewijk, 2001). We concluded that differences between the two sets of land use fluxes are primarily due to the differences in the rates of changes in land area amount for croplands and argued that further investigation in data for croplands with ground and satellite-based measurements is needed. The introduction of wood harvest (Hurtt et al., 2006) in this study might have further amplified the uncertainty range associated with land use change data. In the case of secondary forests, this study assumes that secondary forests are naturally developed through reforestation and forest regrowth on abandoned land. However, in some parts of the world, for example in Japan and South East Asia, secondary forests are not naturally developed, but are planted (Kenji, 2000; Merker et al., 2004). So, this study may be underestimating the secondary forest area.

Another potential area of uncertainty is that the representation of certain processes, such as fire suppression and woody encroachment, which are suggested to contribute greatly to regional carbon sink (Pacala et al., 2002), are not included in this study, *because the effects of these processes have not been well defined yet due to lack of comprehensive data (Denman et al., 2007). Moreover, shifting cultivation activity is not included in this study because neither the area in shifting cultivation nor the carbon dynamics related to this process is well understood. This could lead to the underestimation of both the land use emissions and secondary carbon sink. Lastly, we assume that plants only take up mineral nitrogen in soils. We are not considering the pathway for nitrogen uptake through the stomata of leaves, which has been suggested as an important pathway for forest to assimilate deposited nitrogen (Jenkinson 1999; Sievering 1999; Sievering et al., 2000). This may cause the underestimation of carbon sink due to secondary forest, especially in regions where nitrogen deposition level is high.*

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All other reference cited here are given in the references section of the original manuscript.

There is another factor potentially generate the heterogeneity in the N cycling effect in the tropical regions. Except the tropical rain forests closely distributed near equator, there are various types of seasonal variations of precipitation in tropical and subtropical regions. Conventions of two independent seasonalities; N dynamics seasonality (mineralization, nitrification, and denitrification rates) and hydrological seasonality regulating dissolved nitrogen leaching, controls pool size and its seasonal variations of available N in soils. Influences of monsoon climatic system generate significant seasonal variations of precipitation in the East Asia, Northern Australia, Eastern Africa and Southeast American US. These regional discussions can be possible using their simulated results. In general, terrestrial N dynamics is strongly controlled and regulated by various regional conditions, such as regional climatic system, distribution of emissions and vegetation conditions. Therefore, the discussion on heterogeneity of terrestrial N dynamics naturally requires regional focus and information. If the authors could address this issue, the discussions and conclusions on the effect of the N dynamics on carbon uptake can be more robust.

We agree with the reviewer's comments that the effect of N dynamics on the terrestrial C uptake is both temporally and spatially variable as are the influences of changing N-availability. However, we have addressed this issue in detail in our recently published paper:

Jain, A. K., X. Yang, H. Kheshgi, A.D. McGuire, W.P. Post, Kicklighter, 2009: Nitrogen Attenuation of Terrestrial Carbon Cycle Response to Global Environmental Factors, Global Biogeochemical Cycles, 23, GB4028, doi:10.1029/2009GB003519.

Jain et al. (2009) paper not only discusses the influence the N dynamics on net carbon uptake on a global scale, but also evaluates how the spatial variation in nitrogen availability influences terrestrial carbon sinks and sources in response to changes in global environmental factors including atmospheric CO2 concentration, nitrogen inputs, temperature, precipitation and land use. As suggested by the reviewer, we will add a brief discuss on the effect of N dynamics on carbon uptake in the revised manuscript. Following is the suggested text:

In our previous study [Jain et al., 2009], the terrestrial carbon and nitrogen cycle components of the Integrated Science Assessment Model (ISAM) are used to evaluate how variation in nitrogen availability influences terrestrial carbon sinks and sources in response to changes over the 20th Century in global environmental factors including atmospheric CO2 concentration, nitrogen inputs, temperature, precipitation and land use. While Jain et al. (2009) did not consider the LUC changes for wood harvest, and pasturelands; our model results demonstrate that the impact of N limitation on terrestrial net C flux during the 1990s is spatially heterogeneous across the globe. In general, the inclusion of N dynamics significantly reduces the CO2 fertilization response relative to the case where N is sufficiently available for plants to grow, in particular in moist temperate regions where N is a primary limiting nutrient. While high latitude boreal forests and tundra regions are also limited in N availability, the response of these regions to N limitation is less pronounced than the temperate evergreen deciduous and evergreen forest regions because ecosystem productivity in high latitudes is limited by shorter growing seasons and relatively less N is required for plant growth. While tropical regions are highly productive, our previous study [Jain et al., 2009] results indicate that N does not limit productivity in tropical forests.

Moreover, this paper focuses on the role of secondary forests and their impacts on the carbon uptake on a spatial scale, while considering the effect of N dynamics on carbon uptake. As pointed out in our paper, in general, we are seeing less C uptake associated with secondary forests when N dynamics are considered (Figure 6b) as compared to the case when N dynamics are not considered (Figure 6a). However, secondary forests in two regions, India and Southern Europe, are sequestering more C when N dynamics

are considered. This, to a large extent, has to do with the specific climate condition and land use history in these regions. We have now given further explanation for the mechanisms responsible for this response. Following is the suggested revised text with additional points 2-5, which explains the regionally specific mechanisms:

However, southern Europe and Indian secondary forests are sequestering more C when N dynamics are considered. Possible reasons are: 1) when natural vegetation was cleared for cropland, pastureland, or wood harvest, both above- and below-ground litter increases because of the unburned slash and the buried roots. The increased litter associated with LUC would lead to more litter decomposition and N mineralization, therefore increasing N availability in soils; 2) ash additions resulted from burned slash immediately increases inorganic N supply; 3) the warm and moist climate in India leads to the rapid decomposition of soil organic matter, which releases mineral N due to nitrogen mineralization. These released mineral N is taken by the plants for the regrowth of secondary forests, thus enhancing secondary forest carbon sink; 4) the temperature and precipitation conditions in India region favors biological nitrogen fixation, which provides substantial amount of nitrogen for India secondary forests and enhance their productivity; 5) nitrogen deposition effect in southern Europe is enhancing the productivity of secondary forests in this region.

Interactive comment on Biogeosciences Discuss., 7, 2739, 2010.