

The Role of Climate and Land Use Change on the Riverine Carbon Fluxes in Amazonia

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Summary

Amazonia is one of the Earth's hotspots for biodiversity and carbon storage, covers about six million square kilometres. Besides its importance as diversity reservoir, also its climate regulation function has long been known. However, the Amazon basin was identified as one of the potential tipping elements in the climate system. The combined effects of climate and land use change have the potential to shift the Amazon forest into another state, in which the forest partly collapses and is replaced by other vegetation types such as savannah.

Annual flooding acts as an integrating agent between land and river, is one of these areas. Here large amounts of terrestrial fixed carbon are exported to the river, converted within it and finally exported to the atmosphere and the ocean. About 20% of the global freshwater input to oceans is discharged by the Amazon river, and with this about 10% of the organic carbon transported by rivers to the oceans.

In this PhD thesis, the effects of climate and land use change on the riverine carbon budget of the Amazon basin have been investigated. This study aimed to analyse climate change induced changes in inundation patterns and climate and land use change induced changes in riverine carbon fluxes and the overall carbon budget of Amazonia.

The direct effects of precipitation change on inundation patterns, have been investigated by applying 24 climate scenarios, each under the SRES A1B emission scenario. The inundation will be up to three months longer in the western basin and up to one month shorter in the eastern basin. This will lead to changes in terrigenous carbon exported, as well as species composition in the floodplain forests.

To assess changes in the export of carbon and the further processing of it, the model RivCM has been developed during the course of this thesis. In tight coupling with the dynamic global vegetation and hydrology model framework LPJmL, it simulates import of terrigenous organic carbon to the river, its conversion within and the export of organic and inorganic carbon from the river. RivCM reproduces observed amounts of carbon in the water, namely particulate and dissolved organic carbon and inorganic carbon (POC, DOC, and IC, respectively) within the range of observations. The total organic carbon exported to the ocean is about 30% above observed values, and the export to the atmosphere is about 60% below the range of observations. This divergence might be reduced by implementing omitted aspects, like floodplain lakes or aquatic macrophytes. However, for the purpose to assess effects of climate and land use change on the carbon budget, relative changes are calculated, which show the effect although the absolute values might differ from observations. Therefore, this model is applicable to assess consequences of climate and land use change.

Applying RivCM the effects of climate and land use change have been assessed by simulated combinations of five climate scenarios, three emission scenarios, and three land use scenarios. These scenarios represent a wide range of potential developments for climate and deforestation to indicate the uncertainties related to future climate and land use change on riverine carbon pools.

The results show that climate change alone leads to a mean increase of 10-20% in POC and DOC towards the end of the current century, but the high uncertainty of about $\pm 40\%$ indicating no clear signal for increase or decrease. The changes are heterogeneously distributed within the basin, with increasing amounts concentrated in the Western basin and decreasing amounts in the North-Eastern basin. The projected increase for IC is about 60-150%, and for outgassed carbon is about 30-50%, with uncertainties of about $\pm 40-80\%$ and $\pm 20-40\%$, respectively. Also in the inorganic carbon pools the changes are heterogeneously distributed within the basin, but in contrast to the organic carbon pools, it increases basin wide, with higher increase in the Western and lower increase in the Eastern basin. The export of organic carbon to the Atlantic Ocean also changes with $\pm 10\%$ due to climate change, but the positive or negative trend in change depends on the emission scenario.

Additionally to the estimation of climate change impacts, the impacts of land use change could be elaborated from the further simulations. Forcing RivCM with a combination of climate and land use change scenarios shows that land use change alone leads to a 15-25% decrease in POC and DOC amounts towards 2099, especially in regions with high deforestation (e.g. in the South-East) with an uncertainty of $\pm 5\%$. The outgassed carbon decreases likewise (-10% to -30%). Changes in riverine inorganic carbon of about $\pm 2\%$ show that this pool is only marginally affected by land use change. The export of organic carbon to the ocean is reduced by about 40% due to deforestation. The combined analysis of climate and land use change impacts reveals that generally POC, DOC, and outgassed carbon are mainly affected by land use change, whereas IC is mainly affected by climate change.

Decreasing riverine particulate and dissolved organic carbon might affect the floodplain forests, since the organic carbon can act as nutrient input, whereas increasing POC and DOC will have consequences for the riverine oxygen status, the oxygen is consumed for the respiration of the enhanced carbon amounts. Therefore, both changes can affect the floodplain as well as the river and the inhabiting species. The overall increase in riverine inorganic carbon will lower the pH of the river water and therewith affect for instance bacteria and fungi, since a low pH fosters fungi which happens at the cost of bacteria. Also animals with calcium carbonate shells, like snails are affected by the lower pH. Increasing outgassed carbon will enhance the additional flux of CO_2 to the atmosphere, already caused by deforestation. Both effects will lower the CO_2 sink of the Amazon basin. Finally the discharge of riverine material to the ocean is reduced. This will lead to changes in the heterotrophic respiration and productivity off the mouth of the Amazon.

In most parts of the Amazon basin the effect of land use change exceeds the effect of climate change on the carbon pools. This is in particular of importance since deforestation might be more directly mitigated through policy change and market intervention.