# HOW RESILIENT MAY THE AMAZON RAIN FOREST CARBON BALANCE BE TO CLIMATE CHANGE?

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## ABSTRACT
The Amazon region represents a large stock of biomass as well as a potentially important sink for additional atmospheric $CO_2$. Climate change, land-use changes and their interaction present a risk to this role in the global carbon cycle. Both positive and negative feedbacks exist in the system that can lead to resilience but also to accelerated break-down of the carbon stocks and sinks. A set of linked projects will investigate elements of these processes in the coming years.

## INTRODUCTION
The Amazon region stocks vast amounts of biomass that could be potentially emitted to the atmosphere as $CO_2$ in short time as a result of climate-induced or anthropogenic disturbance [*Cox et al.*, 2000]. In recent years, several lines of research indicate that the region's ecosystems are not, as has often been assumed previously, always in a state of carbon equilibrium, but instead that the rainforests are extremely dynamic and are likely to, on the whole, be taking up (between 0.5 and 2 Mg $ha^{-1}$) carbon from the atmosphere [*Araujo et al.*, 2002]. This sink is variable, is higher in the western than in the eastern Amazon, depends on disturbance history [*Saleska et al.*, 2003] and is likely to vary with rainfall. Not enough information is available yet about the sink capacity of degraded forest, pasture and savanna, but the carbon balance of the region is likely to be closely linked to the fate of the rain forests. To estimate the carbon balance of the region under various scenarios of change (here: hypothetic pathways of climate and development), it should be a priority to explore both the sink capacity of these ecosystems and the dynamics of the interacting climate and land-use changes under such scenarios. Here we report on work under the Large-scale Biosphere-Atmosphere experiment in Amazonia (LBA) over the past years as well as planned in the near future, assisted by Brazilian government, the EU and a Netherlands-funded program (WOTRO).

## LOCAL ECOSYSTEMS
Prolonged reductions in rainfall will decrease productivity of the rain forests, and enhance losses through fire and respiration [*Saleska et al.*, 2003; *Nepstad et al.*, 2004] In large parts of the central Amazon, however, the landscape is undulating, with wet, frequently inundated valleys. With moderately extended drought, these valleys might become less waterlogged and the productivity of their generally less well-developed forests might increase. On the other hand, these valleys have poor soils with thick organic layers, which might degrade if drained, leading to nutrient loss and development of suppressed-growth 'Campina' vegetation. This implies a typical non-linear ecosystem response, with some resilience under moderate disturbance but high vulnerability if disturbance increases. Through a set of small-scale, artificial drainage experiments in a central Amazon valley bottom, combined with investigating natural sensitivity of productivity to dry periods, we will begin to understand and model this resilience-vulnerability balance.

## REGIONAL CLIMATE
The effects of local-scale heterogeneity in hydrology, evaporation and ecology on regional climate is being investigated through a coupled hydrology-meteorology model and field studies [*Quartas et al*, in prep]. A paired catchment study in Central Amazonia is well underway, stressing the importance of scale [*Tomasella et*

*al*, in press]. Deforestation will lead to reductions in rainfall, but moderate reductions may lead to increased mesoscale circulation and convergence enhancing rainfall [*Avissar et al.*, 2002], but at larger scales the patterns of deforestation may affect the extent to which moisture is transported and recirculated from the Atlantic into the western and southern parts of the region. These interactions induce a degree of resilience of the region's carbon balance to the disturbances by climate and deforestation, and this resilience will be assessed using coupled models, in relation to hypothetical land-use scenarios.

## DYNAMICS AND FEEDBACKS IN LAND-USE CHANGE

The patterns of deforestation, affecting climate and hydrology, result from socio-economical processes and political choices as well as from geographical and physical suitability of land. Many studies exist of the extent, patterns and dynamics of deforestation with some emphasis on the consequences of road building (www.obt.inpe.br/prodes/; *Camara et al.*, [2005]). Enhancement of deforestation as a result of roads would likely affect the regional circulation of moisture, hence affect climate. But at smaller scales, changes in climate and soils, as described above, may feed back on the suitability of land for exploitation and on human vulnerability, potentially feeding back on and creating resilience against further disturbance of the rain forests. To include elements of such feedback processes in models of land-use change drivers [*Verburg et al.*, 2002] is the third element of the linked research program.

## CONCLUSIONS

The strength or sign of the carbon sink of the Amazon has not been established conclusively as yet, but is likely to be important and prone to disturbance. A new research program is in its early days, but plans are to link research results on local, regional and socio-economical resilience into a set of 'narrative' models enabling at least a qualitative assessment of the joint effects of climate and people on the Amazon and its carbon sink in the next 10-50 years.

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