# IMPACTS OF CARBON-OPTIMISED LAND USE MANAGEMENT IN SOUTHERN AMAZONIA – MULTI-DISCIPLINARY PERSPECTIVES: AN INTRODUCTION

Gerhard Gerold

With 1 figure and 1 table

In Brazilian Amazonia over 750,000 km² of forest has been cut down from 1970s until 2013 (Nogueira et al. 2015). During this period, Amazonian deforestation rates have always increased until 2003/2004 (INPE 2014; Nepstad et al. 2014), and after a considerable deceleration until 2013 (Boucher et al. 2013), the trend has returned to increase (Schönenberg et al. 2015). The conversion of rainforest and Cerrado into cattle pastures and agricultural land has various impacts on biodiversity, carbon stocks and carbon emissions, which are currently discussed in science, society and politics in the context of climate change (Fearnside 2005; Cox et al. 2000; Malhi et al. 2008). The massive land-use change occurring in the Amazon region attracts world-wide attention, as the Brazilian Amazon is of key importance for the (i) global and regional climate system, (ii) the global and regional water cycle, (iii) the planets genetic resources and (iv) the human cultural heritage. On top of this, the Brazilian Amazon is the world's most prominent biomass carbon (C) pool, with 149 Mg C ha$^{-1}$ being stored above- and below-ground according to Nogueira et al. (2015) and the threat of losing all this carbon to the atmosphere is what explains a large part of the attention being currently paid to the fate of the Amazon rainforest. However, Soares-Filho et al. (2006) predicted another 2.7 million km² of deforestation until 2050 under "business-as-usual"-scenarios and another 0.5 million km² was earlier expected for the Brazilian savannas (Resck et al. 2000), which today presents a highly fragmented Cerrado landscape as a result.

The Brazilian Government and international organizations have developed action programs with high priority on land use change, nature conservation, climate change mitigation and development of sustainable land management practices (e.g. related to the Kyoto-process, Brazilian ABC-program, National Climate Plan of Brazil, Amazon Fund; Fearnside 2005; Nepstad et al. 2014; Soares-Filho 2010; Assuncao et al. 2012; Strassburg et al. 2014). Officially, Brazil aims at reducing deforestation by 80 % for the Amazon by 2020 (Soares-Filho et al. 2010). Since August 2014, deforestation soars again after clear-cutting of mature forest had declined from 19,500 km² a$^{-1}$ to 5,843 km² in 2013 as a result of public policy and frontier governance (PPCDAm: Plan for the Protection and Control of Deforestation in the Amazon; Soy Moratorium; Cattle Moratorium, Arco Verde+, Critical Counties program, Amazon Region Protected Areas Program; Fearnside 2015; Nepstad et al. 2014; Tollefson 2015). Up until today, deforestation concentrated in the "arc of deforestation" along the eastern and southern edges of the Amazon (see Fig. 2 in Barni et al. 2015).

Impact of land-use change (LUC) on various separate ecosystem services (ESS), including C sequestration and climate system stability, has been studied and presented in numerous research articles for the Amazon region. However, a more holistic examination which considers multiple ESSs in the context of local drivers and actors has not yet been sufficiently advanced. In fact, for many ESS touched by LUC in the Amazon region (Fearnside 2005), contrasting – partly contradictory – patterns and processes have been reported (Tab. 1). This underlines the demand for an interdisciplinary, if not transdisciplinary approach to investigate, how the region at the Southern Amazon land-use frontier will develop in future and which consequences will likely arise for the local and global climate, biodiversity and society.

## Study regions

A bilateral Brazilian-German research activity was established along the BR-163 highway from Cuiabá in Mato Grosso to Novo Progresso in Southern Pará, at the southern fringe of the Brazilian rainforest (Fig. 1). Along its course, the highway passes three different agro-scapes, representing a historical land-use gradient. Around Cuiabá, the main

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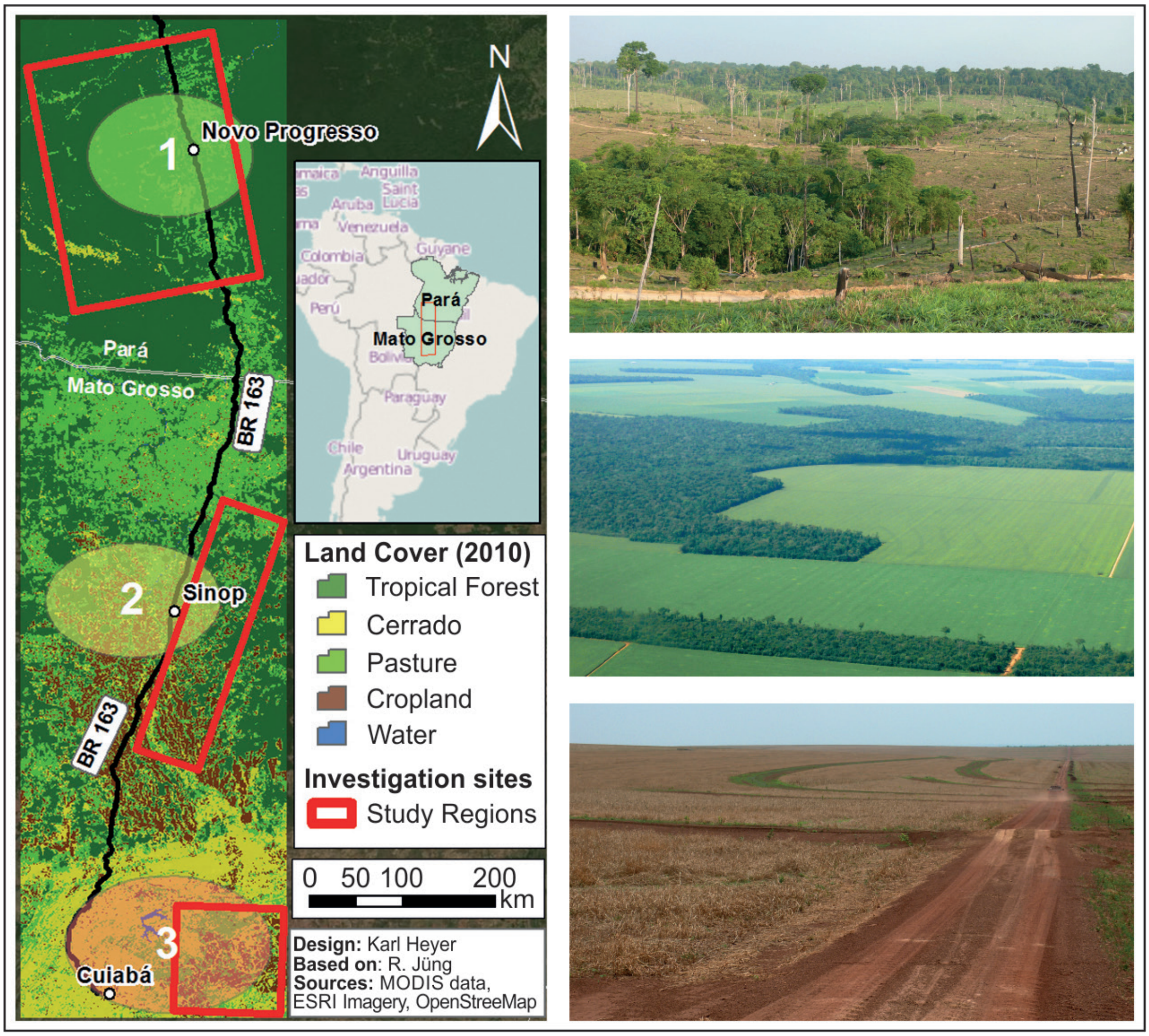


**Fig. 1: Carbiocial research regions with typical views on the agro-landscapes**

agricultural colonization of the southern Amazon started in 1975–1990, and was ever since pushed northwards. It reached the area of Sinop during the 1990ies and recently southern Pará, not more than two decades ago. Central Mato Grosso today is a highly industrialized area, with large-scale soybean, cotton and maize production, while Northern Mato Grosso still exhibits a major fraction of intensive cattle farming on pasture and the pioneers at Southern Pará just recently started cattle farming in its extensive form, which replaces timber logging as another important income source. Crop production is limited to very few examples.

The land-use gradient at the same time accompanies a climatological gradient, from the Cerrado (savannah) biome in the semi-humid tropics at central Mato Grosso to the evergreen rainforest of the humid tropics in Pará (Fig. 1). Along this gradient, mean annual precipitation increases from 1700 mm at Cuiabá, over 1900 mm in northern Mato Grosso, up to 2100 mm in the southern Amazon and seasonality changes from a distinct wet and dry season to an all-year hot and wet tropical pattern (Moreno and Souza Higa 2005).

As representatives of these agro-scapes, three main investigation sites have been selected along the BR-163 (Fig. 1): (1) Novo Progresso (7°02' S; 55°25' W) in southern Pará, representing the highly dynamic agricultural pioneer front with extensive cattle pastures and the first attempts to grow soybeans in the rainforest biome of southern Pará, (2) Sinop (11°51' S; 55°30' W) in northern Mato Grosso as an intermediate stage with industrialized soy, corn, and cattle production; and (3) Campo Verde

**Tab. 1: Contradictory results: ecosystem processes with deforestation (LUC) in the Amazon**

| Ecosystem process | Negative consequence | No change or positive |
|---|---|---|
| Climate Change and rainfall trends | Increasing droughts a. decreasing rainfall (1) | Until 60 % deforestation no rainfall decrease (2); increase of rainfall over large forest patches (3) |
| River discharge a. water stress | Increasing discharge and flood risk (4) | Decreasing discharge with reduced regional P (5) |
| C-stocks and GHG | Large scale forest disturbance with 15-26 Pg C-emissions next 20 years (6) | All protected areas can avoid 5.8-10.8 Pg C-emissions until 2050 (7) |

(1)Malhi et al. 2008, Marengo 2004; (2) Walker et al. 2009; (3) Knox et al. 2011, (4) D´Almeida et al. 2006, Costa et al. 2003; (5) Coe et al. 2009, Lima et al. 2014; (6) Nepstad et al. 2008; (7) Soares-Filho et al. 2010

(15°33 S; 55°10' W) as a typical rural example of the intensively used agricultural area of the Cerrados. At each of these sites, four farms of different size and similar land-use histories were selected. All experimental work has been executed on these farms.

## Inter- and transdiscplinary research in the Southern Amazon region

Two research projects were established to foster Brazilian-German collaboration and Inter- and transdiscplinary research in the Southern Amazon region. In the framework of the German BMBF-FONA program (Federal Ministry for Education and Research – Research for Sustainable Development) the *Carbiocial* consortium (www.carbiocial.de) drives research in the study region since 2011. This consortium investigates C stock changes, greenhouse gas (GHG) emissions, erosion, catchment hydrology, agricultural production, land cover change using experiments, monitoring, remote sensing and dynamic simulation modelling. In Brazil, the counter research project *Carbioma* (hotsites.cnpaf.embrapa.br/carbioma/) focuses more specifically on political programs which were established to mitigate environmental problems which arise from an inappropriate use of land, such as the Agricultura de Baixo Carbono (ABC – Low Carbon Agriculture) - and the National Appropriate Mitigation Actions (NAMAS) and channels research carried out at the different experimental field stations of the Empresa Brasileira de Pesquisa Agropecuária (Embrapa).

The main objective of both project consortia is to investigate viable carbon-optimized land management strategies for this hotspot of global change research. Together with its Brazilian partners, collaborators and local stakeholders, *Carbiocial* concentrates on retrieving parameters for simulation models which are used to test and improve carbon-optimized land use management strategies.

The multidisciplinary project consortia were built around four thematic priorities: 1) closing knowledge and data gaps related to LUC impact on water supply and purification, greenhouse gas reduction, soil C stocks and erosion; 2) management strategy testing using experimental farming; 3) scenario building and simulation of future land-use change using dynamic models; 4) Socio-economic assessments and consequences (www.carbiocial.de). Both projects follow an inter- and transdisciplinary research strategy, which concept is described by Schönenberg et al. (2017, this issue).

Policies of environmental command-and-control, environmental regulation (CAR) and land tenure regularization (Terra Legal) were discussed in relation to the efficiency of recent environmental governance strategies and its potential for alternative land use pathways on local scale (Schaldach et al. 2017, this issue). Together with biographic research and institutional research (e.g. actor constellation) along the BR 163, qualitative data was gathered which was used for scenario development, along with regional and local expert knowledge for the Southern Amazon region (Schönenberg et al. 2015). These narratives were later translated into quantitative information to be used for LUC and impact modelling (Schaldach et al. 2017, this issue). LUC simulations were carried out using LandSHIFT (Schaldach et al. 2011) on data obtained from the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), IBGE statistics and agricultural yield predictions obtained from the MONICA agro-ecosystem model (Nendel et al. 2011). From farm-level insights and from further extrapolation of the current yield trends towards a certain levelling in the near future as observed today in highly industrialized counties the LandSHIFT simulations were driven along the future LUC scenarios (Schaldach et al. 2017, this issue) and produced a land-use distribution which was subsequently used for further impact analysis, such as simulations or calculations for soil organic C (SOC) stock change (Strey et al. 2017, this issue), GHG emissions (Schaldach et al. 2017, this issue), erosion, and catchment hydrology (Lamparter et al. 2016; Meister et al. 2017, this issue).

For the first time a combination of future yields (MONICA) based on climate change simulation results, qualitative socio-political data ("Storylines") and global economic development scenarios were combined to simulate land use change (LUC) by LandSHIFT until 2030 for Southern Amazonia. Based on this, impact of these four LUC-scenarios on greenhouse gas emissions, soil carbon stocks and water supply were pointed out. Some results with the importance of deep soil carbon storage in the rainforest and GHG-fluxes in relation to land use types are presented in this issue (Strey et al. 2017; Meurer et al. 2017).

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**Author**

Prof. Dr. Gerhard Gerold
Georg-August-University of Göttingen
Institute of Geography
Dept. of Landscape Ecology
Goldschmidtstr. 5
D-37077 Göttingen
Germany
ggerold@gwdg.de