International Max Planck Research School on Earth System Modelling

Modeling the Interplay between Land Use, Bioenergy Production and Climate Change

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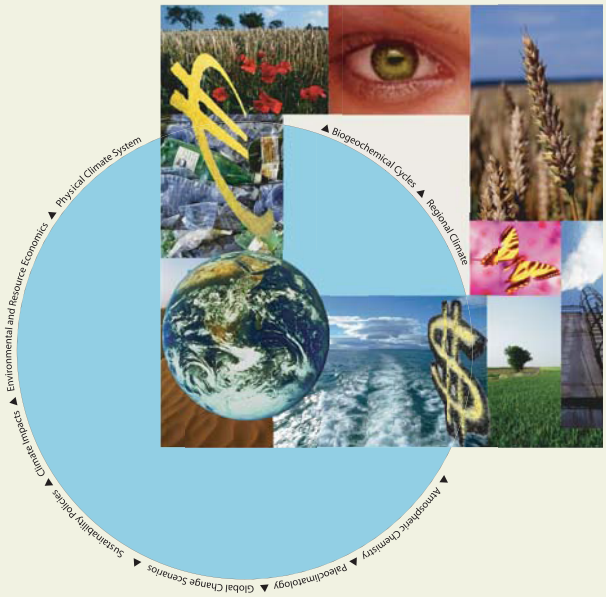

Summary

Land use has become a force of global importance, considering that 34% of the Earth's ice-free surface was covered by croplands or pastures in 2000. The expected increase in global human population together with eminent climate change and associated search for energy sources other than fossil fuels can, through land-use and land-cover changes (LUCC), increase the pressure on nature's resources, further degrade ecosystem services, and disrupt other planetary systems of key importance to humanity. This thesis presents four modeling studies on the interplay between LUCC, increased production of biofuels and climate change in four selected world regions.

In the first study case two new crop types (sugarcane and jatropha) are parameterized in the LPJ for managed Lands dynamic global vegetation model for calculation of their potential productivity. Country-wide spatial variation in the yields of sugarcane and jatropha incurs into substantially different land requirements to meet the biofuel production targets for 2015 in Brazil and India, depending on the location of plantations. Particularly the average land requirements for jatropha in India are considerably higher than previously estimated. These findings indicate that crop zoning is important to avoid excessive LUCC.

In the second study case the LandSHIFT model of land-use and land-cover changes is combined with life cycle assessments to investigate the occurrence and extent of biofuel-driven indirect land-use changes (ILUC) in Brazil by 2020. The results show that Brazilian biofuels can indeed cause considerable ILUC, especially by pushing the rangeland frontier into the Amazonian forests. The carbon debt caused by such ILUC would result in no carbon savings (from using plant-based ethanol and biodiesel instead of fossil fuels) before 44 years for sugarcane ethanol and 246 years for soybean biodiesel. The intensification of livestock grazing could avoid such ILUC. We argue that such an intensification of livestock should be supported by the Brazilian biofuel sector, based on the sector's own interest in minimizing carbon emissions.

In the third study there is the development of a new method for crop allocation in LandSHIFT, as influenced by the occurrence and capacity of specific infrastructure units. The method is exemplarily applied in a first assessment of the potential availability of land for biogas production in Germany. The results indicate that Germany has enough land to fulfill virtually all (90 to 98%) its current biogas plant capacity with only cultivated feedstocks. Biogas plants located in South and Southwestern (North and Northeastern) Germany might face more (less) difficulties to fulfill their capacities with cultivated feedstocks, considering that feedstock transport distance to plants is a crucial issue for biogas production.

In the fourth study an adapted version of LandSHIFT is used to assess the impacts of contrasting scenarios of climate change and conservation targets on land use in the Brazilian Amazon. Model results show that severe climate change in some regions by 2050 can shift the deforestation frontier to areas that would experience low levels of human intervention under mild climate change (such as the western Amazon forests or parts of the Cerrado savannas). Halting deforestation of the Amazon and of the Brazilian Cerrado would require either a reduction in the production of meat or an intensification of livestock grazing in the region. Such findings point out the need for an integrated/multicisciplinary plan for adaptation to climate change in the Amazon.

The overall conclusions of this thesis are that (*i*) biofuels must be analyzed and planned carefully in order to effectively reduce carbon emissions; (*ii*) climate change can have considerable impacts on the location and extent of LUCC; and (*iii*) intensification of grazing livestock represents a promising venue for minimizing the impacts of future land-use and land-cover changes in Brazil.