Biogeochemical Causes and Consequences of Land Use Change

Christoph Müller[1,2], Alberte Bondeau[2], Hermann Lotze-Campen[2], Dieter Gerten[2], Wolfgang Lucht[2], Pascalle Smith[3], Sönke Zaehle[2]

1 Max Planck Institute for Meteorology, IMPRS, Hamburg, Germany
2 Potsdam Institute for Climate Impact Research, Potsdam, Germany
3 Laboratoire des Sciences du Climat et de l'Environnement, Gif-sur-Yvette, France

e-mail: cmueller@pik-potsdam.de
tel.: +49-331/288-2685

Global Biogeochemistry and Land Use Change

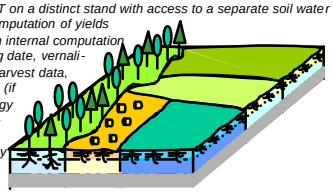
Global biogeochemical cycles and especially the carbon cycle are in the focus of the global change discussion. The interaction of land use and land use change with these cycles has attracted only little attention so far. Land use is driven as well as impacted by biogeochemical cycles.

With the Lund-Potsdam-Jena Dynamic Global Vegetation Model (LPJ-DGVM) that we extended by Crop Functional Types we are capable to quantify the effects of global land use change on the carbon and water budgets.

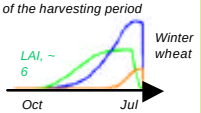
Coupled simulation of carbon and water fluxes via photosynthesis in the LPJ-DGVM

The implementation of 13 Crop Functional Types (CFT) also allows us to assess the impact of changed carbon and water fluxes on agricultural land use suitability. Based on this land use suitability, land use pattern can be derived and potential impacts on the biogeochemical cycles can be assessed consistently.

Adaptation of LPJ to simulate the carbon and water fluxes for crops: each CFT on a distinct stand with access to a separate soil water pool, computation of yields based on internal computation of sowing date, vernalization, harvest data, irrigation (if technology is available), possibility of multi-cropping.



Daily coupled growth and development simulation: Phenology, LAI change, carbon allocation to leaves, roots, storage organs, ... Estimation of the harvesting period

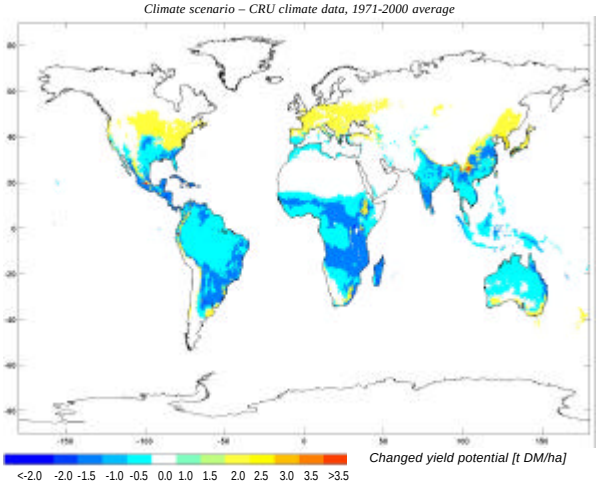


Total biomass, ~ 20 tDM/ha
Grain harvested, ~ 6 tDM/ha

Biogeochemical Causes of Land Use Change

Climate, water availability, soil fertility and agricultural management affect crop yields. The effects of climate, availability of additional irrigation water and agricultural management (via Management Factors) are considered in the LPJ crop simulations.

Changed yield potential of tropical cereals (Millet)
Climate scenario – CRU climate data, 1971-2000 average



Changed yield potential [t DM/ha]

Changes in yield potential, here exemplary for Tropical Cereals (Millet) due to an assumed general climate change of 2°C temperature rise and 10% decline of precipitation. Changes affect length of the growing period (f(T) and f(P)), the fulfillment of heat and water requirements, sowing and harvesting dates and vernalization. The effects of irrigation can be simulated as well, representing different management practices and changed water availability for the plants.

Changed yield patterns influence the profitability of agricultural production types and thus result in changed agricultural land use patterns.

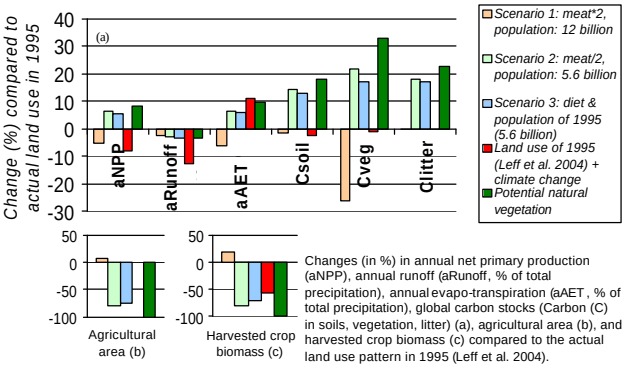
Biogeochemical Consequences of Land Use Change

The effects of land use and land use change on carbon and water pools and fluxes can be simulated with LPJ. Consistency in simulating biogoechemical effects of land use change can be ensured if land use patterns are based on LPJ-simulated yields.

To assess the impact of land use change on global biogeochemical cycles, different land use patterns have been simulated in LPJ. The simulated land use patterns are based on the assumption of a perfect global market (no barriers, no transportation cost, i.e. only the most productive areas are used) and management factors of the year 1995. The land use patterns are based on varying demand (demography, average diet) and agricultural suitability (LPJ simulations). Here, we present results of changes in demography, diet and climate.

Assumptions:
Population: 5.6 vs. 12 billion
Diet: diet of 1995 vs. doubled meat consumption vs. bisected meat consumption
Climate: +2°C, -10% precipitation

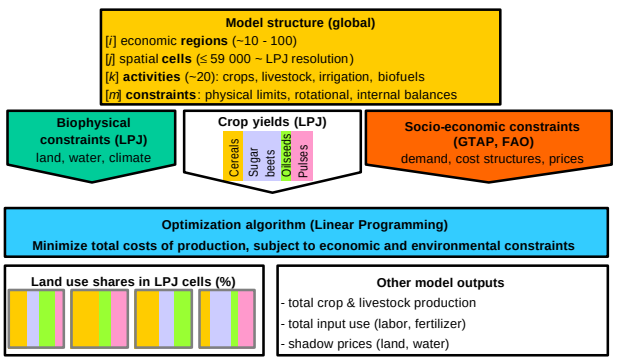
The effects of land use change, driven by demography and lifestyle changes (dietary habits) are comparable to the direct effects of a changed climate (not including additional demand for agricultural area due to reduced productivity).



Changes (in %) in annual net primary production (aNPP), annual runoff (aRunoff, % of total precipitation), annual evapo-transpiration (aAET, % of total precipitation), global carbon stocks (Carbon (C) in soils, vegetation, litter) (a), agricultural area (b), and harvested crop biomass (c) compared to the actual land use pattern in 1995 (Leff et al. 2004).

Simulating Land Use Patterns

Changing yield potentials is an important factor in determining possible future land use pattern. A land use management model that is coupled directly to LPJ is currently under development. A first version of the model is capable of simulating global land use pattern, based on regional demand structures, regional production and input costs, local yield potentials and additional management constraints (e.g. crop rotation).



Model structure of the land use management model MAgPIE. The model minimizes total costs of production, subject to socio-economic and environmental constraints. Outputs of the model are a spatially explicit land use pattern the economic balance (input, output) and shadow prices of the constraints.

IMPRS
International Max Planck Research School on Earth System Modeling
Max Planck Institute for Meteorology, Hamburg, Germany

PIK
Potsdam Institute for Climate Impact Research
BIOS-X: Scenarios of expanded human use of the biosphere