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The future of food supply in a constraining environment

Modelling the impact of trade, intensification, and cropland expansion on agricultural and environmental systems

Abstract

Agriculture plays a key role in the 21st century, due to its importance regarding major challenges, like food security, poverty reduction, climate change mitigation, ecosystem service provision, water conservation, and bioenergy supply. One of the most prevailing questions in this context is how to provide enough food for a growing population under increasing environmental and climatic constraints. The demand for agricultural goods will rise in the coming decades, foremost due to population growth, higher incomes, increasing consumption of animal products and additional demand for bioenergy. At the same time, the potential for increasing agricultural production is highly uncertain.

In this thesis, I will examine the most important processes behind higher food production, like intensification, cropland expansion, and international trade, and its interaction with the environment. The processes are implemented in the global economic land use model MAgPIE ("Model of Agricultural Production and its Impact on the Environment"), which simulates spatially-explicit land use and land use change. Moreover, it examines procedures related to agricultural production, trade, production costs, greenhouse gas emissions, and water scarcity. Agricultural intensification is represented by endogenous technological change based on a measure of agricultural land use intensity and by improvements in irrigation agriculture. Both processes improve yields under additional costs and lead to lower pressure to expand cropland. The decision to expand cropland is based on the quality of converted land and the relative costs for expansion. Finally, international trade involves the potential to allocate the production more efficient and to save resources.

Results of the thesis reveal the importance of the interplay between intensification and cropland expansion. Countries in Africa, the Middle East and South and East Asia require high investments in technological change to cope with future demand. If forest area is protected against cropland expansion, investments in Pacific Asia, Latin America and especially Sub-Sahara Africa have to be further increased. Trade liberalisation lowers required yield improvements but leads to additional deforestation, especially in Latin America due to comparative advantages in agriculture. In terms of water scarcity, an opening of trade has foremost positive implications since water-scarce regions can save water through imports. This does not hold for Australia, Japan, and Central Asia, which additionally strain their water resources due to higher exports. Appropriate policies on international level can diminish the impact on environment and climate. The inclusion of avoided deforestation into a global emission trading scheme would be able to prevent deforestation. Similarly, policies

reducing the consumption of animal products in developed countries would lower the pressure on water resources in water-scarce regions.

Four general conclusions are drawn from this thesis. First, future rates of technological change play a decisive role for meeting required demands and protect the environment. As a result, more domestic and international financial resources have to be allocated to the agricultural sector, foremost in Sub-Saharan Africa and South Asia. Second, increased trade liberalisation leads to higher economic benefits but partly at the expense of the climate and local environment, if no joint international regulations are put in place. Third, the interaction between local water scarcity and international demand needs higher political attention. Fourth, uncertainty in land use modelling is considerable and has to be addressed by science in terms of methodological advancements and novel communication approaches.