Land and water for agriculture
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future prospects and trade-offs

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Summary

Land and water are among the most vital resources for human wellbeing and terrestrial life in general. Therefore, sustainable management strategies for land and water need to be developed in order to sustain a growing world population and important natural ecosystems. Agricultural activity for food, material, and energy production constitutes the most profound anthropogenic influence on global land and water resources. Thus, agricultural land and water-use is a key determinant of the sustainability of resource management strategies.
The main research objective of this thesis is to explore, how agriculture might affect global land and water resources in the future. In individual studies, projections of agricultural land and water-use are developed, considering important drivers such as population growth, economic development, bioenergy demand, terrestrial climate change mitigation strategies, and sustainable water-use strategies. In a synthesis, the results of the individual studies are combined in order to answer the following research questions: (1) How do different agricultural strategies compare in terms of environmental implications for land and water resources and required transformation of the system? (2) How large is the operating space for land and water management strategies in agriculture?
Methodologically, this thesis relies on the Model of Agricultural Production and its Impacts on the Environment (MAgPIE). MAgPIE can be used to derive scenarios of future agricultural activity by considering socioeconomic drivers and biophysical constraints in a cost optimization framework. For this thesis, the model was extended by a detailed water sector that features an improved representation of water availability, irrigation infrastructure, non-agricultural water demand, and environmental water requirements.
Results indicate that protecting freshwater ecosystems from degradation due to agricultural activity can be achieved without fundamental trade-offs in terms of cropland expansion into terrestrial ecosystems. Terrestrial climate change mitigation strategies will likely require a fundamental transformation of the agricultural system. Environmental consequences differ between mitigation strategies. While afforestation and strategies to avoid land-use change emissions can help to protect or even create important terrestrial ecosystems, large-scale bioenergy production can put a severe threat to terrestrial and freshwater ecosystems. Pronounced trade-offs between land and water for bioenergy production suggest that it is crucial to consider both, land and water-use, when aiming at sustainable bioenergy production.
Based on the here presented results, there is hope that the operating space for agriculture is large enough to support a variety of management strategies. On the one hand, resource constraints still leave ample space for increasing land and water inputs for agriculture. On the other hand, the system seems flexible enough to allow for increasing food production with a reduced environmental footprint in terms of land and water appropriation.