Agricultural nitrogen pollution: the human food-print

Benjamin Bodirsky

Abstract

The provision of sufficient food for a growing world population is one of the most basic needs of humanity. The agricultural sector, which has the function to provide this food, is at the same time the main interface between anthropogenic and natural systems. The continuous expansion and intensification of agriculture has driven the nitrogen cycle, a central Earth-system process, out of the state it was residing in during the geological Holocene epoch. This disturbance leads to a number of undesirable feedbacks on human society, lowering the benefits of a multitude of ecosystem services and harming human health.

The overarching topic of this dissertation is how future food demand changes the global nitrogen cycle and nitrogen pollution. The research questions are: (1) What are plausible scenarios for global food demand in the 21st century? (2) What is the current state of the agricultural nitrogen cycle? (3) How will the nitrogen cycle evolve into the future? (4) Which additional pressure on the nitrogen cycle might evolve from the production of bioenergy? (5) How would the adoption of nitrogen mitigation action in food demand and in agricultural production change the nitrogen cycle and nitrogen pollution?

To answer these questions, this dissertation develops a new, simple and transparent method to create long-term scenarios of global food demand. These scenarios are subsequently used by the Model of Agricultural Production and its Impact on the Environment (MAgPIE). The model is a hybrid between a socio-economic and a biophysical land-use model that can be used to derive scenarios of the future development of the agricultural sector. The existing model was extended by a nitrogen mass-balance module, simulating the major nitrogen flows on cropland soils, in livestock production, in food processing and in household consumption. Finally, this extended model is used to create long-term scenarios of the agricultural nitrogen cycle and nitrogen related pollution, and to analyze the effect of nitrogen mitigation measures.

Reference scenarios without mitigation action indicate that until 2050, growing demand for food will expand most nitrogen flows in the agricultural sector, with global nitrogen pollution rising to unprecedented levels. An extension of bioenergy production would add additional pressure on the nitrogen cycle. Diverging from business-as-usual projections, this study shows that reduced food waste and livestock consumption, in combination with strong efficiency improvements in agricultural production, could reduce nitrogen pollution below current levels. However, even under such ambitious mitigation actions, the global nitrogen cycle will not return to pre-disturbance Holocene conditions and the remaining nitrogen pollution will continue to be detrimental to human welfare.