Article title	Can our global food system meet food demand within planetary boundaries?
Keywords	Food system, Planetary boundary layer, Sustainability, Phosphorus
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Abstract	Global food demand is expected to increase, affecting required land, nitrogen (N) and phosphorus (P) inputs along with unintended emissions of greenhouse gasses (GHG) and losses of N and P. To quantify these input requirements and associated emissions/losses as a function of food demand, we built a comprehensive model of the food system and investigated the effects of multiple interventions in the food system on multiple environmental goals. Model outcomes are compared to planetary boundaries for land system change, climate change and the global N and P cycles to identify interventions that direct us towards a safe operating space for humanity. Results show a transgression of most boundaries already for 2010 and a drastic deterioration in the reference scenario for 2050 in which no improvements relative to 2010 were implemented. We defined the following improvements for 2050: reduction of waste, less consumption of animal products, higher feed conversion efficiency, higher crop and grassland yields, reduction of N and P losses from agricultural land and reduction of ammonia (NH3) volatilization. The effects of these measures were quantified individually and in combination. Significant trade-offs and synergies in our results underline the importance of a comprehensive analysis with respect to the entire food system, including multiple measures and environmental goals. The combination of all measures was able to partly prevent transgression of the boundaries for: agricultural area requirement, GHG emission and P flow into the ocean. However, global mineral N and P fertilizer inputs and total N loss to air and water still exceeded their boundaries in our study. The planetary boundary concept is discussed in relation to the selected variables and boundary values, including the additional necessity of eliminating the dependency of our food production on finite P reserves. We argue that total N loss is a better indicator of the environmental impacts of the global N cycle than fertilizer N input. Most measures studied in this paper are also on the agenda of the United Nations for Sustainable Development, which gives added support to their implementation.
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