

## **Food Demand and Supply under Global Change**

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Anthropogenic activities have transformed the Earth's environment, not only on local level, but on the planetary-scale causing global change. Besides industrialization, agriculture is a major driver of global change. This in turn impairs the agriculture sector, reducing crop yields namely due to soil degradation, water scarcity, and climate change. However, this is a complex issue than it seems in the surface. Crop yields can be increased by use of agrochemicals and fertilizers which are mainly produced by fossil energy. This is important to meet the increasing food demand driven by global demographic change, which is further accelerated by changes in regional lifestyles. In this dissertation, we attempt to address this complex problem exploring agricultural potential globally but on a local scale. For this, we considered influence of lifestyle changes (dietary patterns) as well as technological progress and their effects on climate change, mainly greenhouse gas (GHG) emissions. Furthermore, we examined options for optimizing crop yields in the current cultivated land with the current cropping patterns by closing yield gaps. Using this, we investigated in a five-minute resolution the extent food demand can be met locally, and/or by regional and/or global trade. Globally, food consumption habits are shifting towards calorie rich diets. Due to dietary shifts combined with population growth, the global food demand is expected to increase by 60–110% between 2005 and 2050. Hence, one of the challenges to global sustainability is to meet the growing food demand, while at the same time, reducing agricultural inputs and environmental consequences. In order to address above described complex problem, we used several freely available datasets and applied multiple interconnected analytical approaches that include artificial neural network, scenario analysis, data aggregation and harmonization, downscaling algorithm, and cross-scale analysis.

Globally, we identified sixteen dietary patterns between 1961 and 2007 with food intakes ranging from 1,870 to 3,400 kcal/cap/day. These dietary patterns also reflected changing dietary habits towards more meat rich diets worldwide. Due to the large share of animal products, very high calorie diets that are common in the developed world, exhibit high total per capita emissions of 3.7–6.1 kg CO<sub>2eq.</sub>/day. This is higher than total per capita emissions of 1.4–4.5 kg CO<sub>2eq.</sub>/day associated with low and moderate calorie diets that are common in developing countries. Currently, 40% of the global crop calories are fed to livestock and the feed calorie use is four times the produced animal calories. However, these values vary from less than 1 kcal to greater 10 kcal around the world. On the local and national scale, we found that the local and national food production could meet demand of 1.9 and 4.4 billion people in 2000, respectively. However, 1 billion people from Asia and Africa require intercontinental agricultural trade to meet their food demand. Nevertheless, these regions can become food self-sufficient by closing yield gaps that require location specific inputs and agricultural management strategies. Such strategies include: fertilizers, pesticides, soil and land improvement, management targeted on mitigating climate induced yield variability, and improving market accessibility. However, closing yield gaps in particular requires global N-fertilizer application to increase by 45–73%, P<sub>2</sub>O<sub>5</sub> by 22–46%, and K<sub>2</sub>O by 2–3 times compare to 2010. Considering population growth, we found that the global agricultural GHG emissions will approach 7 Gt CO<sub>2eq.</sub>/yr by 2050, while the global livestock feed demand will remain similar to 2000. This changes tremendously when diet shifts are also taken into account, resulting in GHG emissions of 20 Gt CO<sub>2eq.</sub>/yr and an increase of 1.3 times in the crop-based feed demand between 2000 and 2050. However, when population growth, diet shifts, and technological progress by 2050 were considered, GHG emissions can be reduced to 14 Gt CO<sub>2eq.</sub>/yr and the feed demand to nearly 1.8 times compare to that in 2000. Additionally, our findings shows that based on the progress made in closing yield gaps, the number of people depending on international trade can vary between 1.5 and 6 billion by 2050. In

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medium term, this requires additional fossil energy. Furthermore, climate change, affecting crop yields, will increase the need for international agricultural trade by 4% to 16%.

In summary, three general conclusions are drawn from this dissertation. First, changing dietary patterns will significantly increase crop demand, agricultural GHG emissions, and international food trade in the future when compared to population growth only. Second, such increments can be reduced by technology transfer and technological progress that will enhance crop yields, decrease agricultural emission intensities, and increase livestock feed conversion efficiencies. Moreover, international trade dependency can be lowered by consuming local and regional food products, by producing diverse types of food, and by closing yield gaps. Third, location specific inputs and management options are required to close yield gaps. Sustainability of such inputs and management largely depends on which options are chosen and how they are implemented. However, while every cultivated land may not need to attain its potential yields to enable food security, closing yield gaps only may not be enough to achieve food self-sufficiency in some regions. Hence, a combination of sustainable implementations of agricultural intensification, expansion, and trade as well as shifting dietary habits towards a lower share of animal products is required to feed the growing population.