ARTICLE IN PRESS

Global Food Security xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Global Food Security

journal homepage: www.elsevier.com/locate/gfs

# Trade-offs between environment and livelihoods: Bridging the global land use and food security discussions

Patrick Meyfroidt

*F.R.S. - FNRS, 1000 Brussels, Belgium & Université catholique de Louvain, Earth and Life Institute, Georges Lemaître Centre for Earth and Climate Research (TECLIM), 1348 Louvain-La-Neuve, Belgium*

ABSTRACT

This paper connects the discussion on the trade-offs between agricultural production and environmental concerns, including the asserted need for global land use expansion, and the issues of rural livelihoods and food security. Several widespread narratives are challenged. The key insights are: 1/ There is a severe research gap about how concrete interventions can reduce the need for agricultural expansion through changing consumption. 2/ Increasing global food production can hardly be achieved without environmental trade-offs. 3/ The food security/environment trade-offs can be mitigated by recognizing that some supply chains benefit little to food security, while entailing high environmental impacts such as deforestation. 4/ Through prices, global food production is linked to food security of the - mainly urban - low income, net food buyers. 5/ Developing commercial farming, including medium-scale farms providing high labor productivity employment, can contribute to food security through rural wages. 6/ Developing such value chains based on commodities with high income- and price-elasticity of demand requires interventions to avoid deforestation through a rebound-effect.

## 1. Introduction

Land use, in particular agriculture, is fundamental in ensuring food security. But land is also a nexus for crucial environmental challenges such as land degradation, biodiversity loss, climate change, and provision of multiple ecosystem services. Land use expansion into natural ecosystems, such as through deforestation, plays a critical aspect in these impacts. Identifying solutions to achieve sustainable land uses requires to understand the complex trade-offs and synergies associated with different trajectories of land systems change.

The paper revisits two contrasting rationales. The first argues that the global environmental and food security challenges are directly linked together through the volume of global production, hence assuming that food production for urban middle-class demand is directly substitutable with food security for the undernourished. The second rationale argues that there are little trade-offs between environmental conservation and food security, as the global food supply is already adequate and environmental degradation such as through deforestation for agricultural expansion essentially serves the demands of a wealthy middle-class. This paper argues that although there are elements of truth in each of these rationales, they also insufficiently reflect the complexity of the interactions between environmental conservation, global food production and food security.

The paper reconnects two related but too often disconnected lines of inquiry: On the one hand, the discussion on land use change, addressing the issues of trade-offs between agricultural production and environmental concerns and of the asserted need for global land use expansion over the coming decades; and on the other hand, the issues of rural livelihoods and food security as explored mainly from the local perspective, in particular from agricultural economics. Reaching across these fields is necessary to begin to untangle the complex interactions between environmental conservation, global food production and food security, although this paper is only one step in this necessary dialogue.

The paper is organized by following a series of questions. First, do we need to increase global agricultural (or food) production at the 2050 horizon? I will start with the mainstream projections of global food demand, and then distill the key outputs from the works exploring the option space for managing this demand. Second, based on this global demand, is there a need for agricultural expansion, and are there ways to achieve such expansion with low social and environmental costs? Third, what are the links between these debates about global food production and the issue of food security in rural and urban areas of the developing world? Fourth, how is it possible to channel agriculture for income and food security while managing the trade-offs and synergies with environmental issues related to land use change and agricultural expansion?

## 2. Prospects for global food demand and option space

The debate on the need to increase global food production over the coming decades is often obscured because of unsourced numbers and the lack of disclosure of underlying assumptions. Highly cited sources

http://dx.doi.org/10.1016/j.gfs.2017.08.001
Received 7 February 2017; Received in revised form 31 July 2017; Accepted 4 August 2017
2211-9124/ 

assert a need for a 100–110% increase in global crop demand from 2005 to 2050, based on extrapolations of the relations between per capita demand for crops and per capita real income since 1960 (Tilman et al., 2011). Others argue forcibly that the world already produces enough food to feed 9–10 billion people, the population expected by 2050 (Holt-Giménez et al., 2012). These conflicting statements deserve further scrutiny. I will focus here only on calories, as one issue with solid data, although the other dimensions of nutrition security are increasingly highlighted.

Over 2013–2015, based on the Food and Agriculture Organization (FAO) data, the global average food consumption was 2891 kcal per capita per day (kcal $cap^{-1}$ $d^{-1}$) (FAO, 2016). The global Average Dietary Energy Requirement (ADER), which is a measure of the calories needed based on the demographic structure (gender, age) and level of physical activity of the World's population, was 2353 kcal $cap^{-1}$ $d^{-1}$ (FAO, 2016). Currently, we thus indeed produce enough food for the global needs. The 2050 prospects are different. For 9.7 billion people as forecasted in 2050 (United Nations, 2015), the 2015 agricultural production would translate into an average food consumption of 2153 kcal $cap^{-1}$ $d^{-1}$, clearly below the 2015 ADER. In addition, the global ADER is expected to increase slightly due to a decreased proportion of children in the global population. FAO projections based on demographic (based on a previous projection of global population of 9.15 billion people in 2050), income and supply-side trends forecasted not a doubling, but a +43% increase in calories production, corresponding to a +50% of cereals production and a +60% of overall crop production, and a consumption of 3070 kcal $cap^{-1}$ $d^{-1}$ (Alexandratos and Bruinsma, 2012). This FAO projected increase considered that 400 million people would still be suffering from an insufficient calories intake. The main drivers of increasing food demand are population and income growth. Accordingly, food consumption is not expected to increase significantly in high income economies. Much of the growth is expected to occur from developing and emerging economies, with a relatively stronger role of population growth in Sub-Saharan Africa and Latin America, and of income growth in Asia (Hertel and Baldos, 2015). Overall, the emerging urban middle-class in developing economies will drive the major share of food demand increases.

The disagreement between opposite visions on the need for increasing food production relies essentially on assumptions about possible changes in consumption regimes. Beyond incomes, changes in consumers tastes and regional diets composition can strongly influence future food demand (Le Mouël et al., 2016). One major trend observed e.g. in Asia is the Westernization of diets, with reduced per capita consumption of rice, and increased consumption per capita of wheat and wheat based products; high protein and energy dense food; temperate zone products and convenience food and beverages (Pingali, 2007). Whether there are ways to reduce the overall demand for food by modifying diets or other aspects of food management is thus a central question. Many works have explored this option space, often with a focus on animal products consumption, and even more specifically ruminant meat (Kastner et al., 2012, Bajželj et al., 2014, Hedenus et al., 2014). Animal feed production uses about 560 Mha, or about 40% of the global arable land, including 220 Mha for cereal grains, 66 Mha for cereal and legume silage and fodder beets, 131 Mha for oil seed cakes, and 126 Mha for crop residues (Mottet et al., 2017). Cassidy et al. (2013) estimated that 36% of the calories produced for the main 41 crops were used for animal feed, of which 89% were consumed in the production process, leaving only 4% of crop-produced calories available to humans as animal products. Another 9% of crop-produced calories were used for industrial uses and biofuels. Shifting all these crop calories to direct human food consumption would allow a +70% increase in calories availability. Combining different diets scenarios with varying richness in calories, in overall animal products and in the share of ruminant versus monogastric sources in the latter, Erb et al. (2016) estimated that the total biomass harvest necessary in 2050 could range from 6.7 to 19.9 gigatons of dry matter per year (Gt dm $y^{-1}$), thus covering a range from 1 to 3. Expressed in these units, the total biomass harvest amounted to 10.2 Gt dm $y^{-1}$ in 2000 and the FAO projection for 2050 amounts to around 13 Gt dm $y^{-1}$. The most extreme scenarios, with a global vegan diet or a vegetarian diet relying on monogastric species for animal products (eggs) would require a global biomass harvest of 6.7–12.4 Gt dm $y^{-1}$, depending on yields and land use change assumptions. Yet, although substituting animal products consumption appears more efficient in terms of calories, more nuanced analyses emphasized the importance of meat in global protein supply, showing that on average 1.3 kg of protein from human edible feed was required per kg of meat protein produced, although with large diversity ranging from 0.1 to 0.5 kg edible protein/kg meat protein produced in extensive grazing and backyard monogastric production systems to 4.1–5.2 in industrial systems (Mottet et al., 2017). Optimizing meat production systems first requires to better identify the ways to minimize competition with direct human consumption of plants. Other transformative scenarios are the replacement of meat products by insects, cultured meat or imitation meat, which could potentially reduce agricultural land demand by up to 38% based on current consumption levels of 2011, assuming a 50% replacement of meat products by these substitutes (Alexander et al., 2017).

Yet, we are still severely lacking of knowledge on how to actually change diets, and especially what are the realistic prospects for reducing meat consumption. A handful of studies have used demand elasticities to price changes to explore the effects of a carbon tax on meat or animal products consumption, with unclear results. A tax of 60 EUR/ton of $CO_2$ equivalent ($tCO_2eq$) in the European Union could reduce overall meat consumption by 1% (a decrease in ruminant meat consumption by 15% being compensated by a 1% and 7% increase in that of pork and poultry, respectively), and land use demand for pasture by around 12 Mha and for cropland by around 4 Mha (Wirsenius et al., 2011). Another study estimated that a tax of 80 $/$tCO_2eq$ in developed economies would reduce meat consumption by only 5% (Revell, 2015). In a study for Denmark covering all food products, the most efficient scenario estimated a reduction in calories consumption of 1.2–6.1% for a cost of around 20–230 EUR/$tCO_2eq$ (Edjabou and Smed, 2013). Overall, a review of studies exploring the potential for taxes and subsidies to influence diets for health purposes suggested that the effects were generally modest (Clark et al., 2014; Garnett et al., 2015), but it is unclear how these results translate into calories or meat consumption. Further, these taxes are often considered as regressive – i.e., having a stronger impact on low-income groups than on high-income groups. Health and nutrition studies show that food-related behaviors are also influenced by factors other than prices, such as habits, or taste, trustworthiness and convenience of different foods (Garnett et al., 2015). Beyond regulations directly aimed at incentivizing choices, many other policy levers have been proposed to influence consumption choices, ranging from changing the broader context of food systems through regulatory governance and supporting collaboration and shared agreements, to information, education, and promotion through community initiatives, labelling and other means (Garnett et al., 2015). But even less data is available on the potential effectiveness of these tools than for taxes. In addition, studies point to complex effects, with some measures aimed at reducing the intake of some kinds of food resulting in substitution effects increasing the intake of other food, with patterns difficult to predict (Garnett et al., 2015). Prospects for spontaneous changes in diets related to cultural shifts towards postmaterialist values with increasing living standards are unconvincing either: An inflection point in meat consumption has been identified for annual incomes around 36,000 USD (Cole and McCoskey, 2013) or ranging between 35,000 and 53,000 USD per capita (Vranken et al., 2014), against a global GDP $cap^{-1}$ ranging around 10,000 USD in 2015, expressed in constant 2010 USD. Waste reduction is also frequently mentioned as representing a large potential, but virtually no study quantified the concrete waste reduction that could be achieved by applying a determined policy measure (though see zu Ermgassen et al., 2016).