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Future Food Demand Drivers and Pathways Towards Sustainability
Background Note

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[1] The views expressed in this paper do not necessarily reflect those of the United Nations Secretariat. The paper is reproduced as submitted by the authors without formal editing.

1. Introduction

With a global population expected to increase by 8.5 billion by 2030 and reach 9.7 billion inhabitants by 2050 (United Nations, 2019), legitimate concerns arise about the capability of our planet to sustain basic human needs in the future. Seventeen Sustainable Development Goals (SDGs) were defined in 2015 by the United Nations to push transformation on a sustainable development path, but the current situation of countries against key targets and indicators show the extent of the challenge to be met (Schmidt-Traub and others, 2017). In particular, in the case of food and nutrition, more than 820 million are still undernourished (FAO, 2018) and the agricultural sector is under multiple pressure of i) increased production demand for food but also other material needs related to economic growth, ii) increasing effect of environmental degradations—climate change impacts, water scarcity, land desertification, soil degradation—and iii) an increased demand for additional land services, in particular, return of land to nature for biodiversity and carbon sequestration, notwithstanding prescriptions of long-term climate stabilization scenarios relying on large scale deployment of energy plantations (IPCC, 2019).

For these reasons, understanding better the link between food demand, food security and environmental impacts is critical not only for the success of SDG2 (“End hunger, achieve food security and improved nutrition and promote sustainable agriculture”), but also of many others related to the environment (SDG6 on water, SDG7 on energy, including from biogenic sources, SDG12 on sustainable consumption, SDG14 and 15 on life in water and on land, SDG 13 on climate stabilization) and to human development (SDG1 on poverty, SDG8 on economic welfare and employment). Therefore, the question of food demand and sustainability hides a much broader set of challenges that this short note can only briefly touch upon. the focus here will be only on a subset of elements, with an emphasis on the drivers of the impacts of food demand and food security on the environment, and the expected effect of the key transformations required to alleviate these impacts.

2. Drivers of future food demand

A Malthusian reading of the challenge of feeding the world usually designates population growth as the primary driver of pressure on the natural systems (Malthus, 1798). With 2 billion additional persons expected on the planet in the next 30 years, this concern is legitimate. However, population growth is only one of a larger set of drivers shaping the demand for agricultural products (Kearney, 2010). Among other crucial parameters is also economic growth, as increased income allows population to spend more on food (Valin and others, 2014). This translates into higher consumption of calorie per capita, consumption of higher standard products, based on more resource intensive production processes (e.g., animal products), and potentially increased wasting habits as the economic value of food becomes marginal in the total consumer revenue. Adverse environmental impacts of this increased consumption can however be compensated by production-side benefits of economic growth, in particular, more efficient production through access to improved technologies, which illustrates the ambivalent role of economic development on environmental resources (Alston and others, 2010).

Beyond the question of food caloric consumption level, economic and human development also leads to change in the nutritional composition of the diet (Gouel and Guimbard, 2018). With nutritional transition, the share in diets of luxury food products such as animal products rich in proteins (meat, dairy, fish) and higher consumption of sugar and fat (notably vegetable oils) strongly changes the nature of the pressure on the natural ecosystems (Kastner and others, 2012). For instance, it is estimated that livestock is responsible for 30 per cent of the terrestrial land area for grazing and, one third of cropland use for feeding and 11-15 per cent of total anthropogenic greenhouse gas (GHG) emissions depending on the accounting approach (Herrero and others, 2016).

Many other drivers are shaping the growth of food demand, some of them sometimes overlooked. Urbanization and changes in lifestyle associated with socioeconomic transitions can play an important role in some regions. Population moving to cities usually occupy less energy intensive work occupations compared to those working in rural areas (Satterthwaite and others, 2010). And physical activity level (PLA) is a primary driver of the calorie intake requirement (WHO, 1985). Economic development and globalization also affect the food distribution chains and the retailing structure, which strongly shape the food products proposed to consumers, their production modalities and finally their impacts (Kearney and others, 2010). Marketing strategies of firm can influence the food preferences of consumers and play an important role. However, beside this influence, other individual factors can determine changes in personal preferences, based on religious beliefs, cultural or moral values and be influenced by some general trends (e.g., secularization of society, emergence of environmental concerns). From that extent, the role played by education can be significant and the change in social norms in some regions of the world shape significantly future patterns (e.g., in India, Pingali and others, 2006).

Food demand is also strongly affected by population ageing in some regions of the world. Different ages correspond to different dietary requirements and dietary preferences. According to USDA (2015), an individual older than 60 years old consume about 20 per cent less food than a young adult. Children under 10 years of age also have much lower caloric intake requirements. Therefore, the change in the population age structure can strongly influence the evolution of the overall food demand. In the case of India, the International Institute for Applied Systems Analysis (IIASA) estimates show for instance, that taking into account population ageing shifts decreases the burden of future population increase by 2050 from +40 per cent increase to +33 per cent increase (KC and others, 2017).

Last, beside the aggregate level of economic wealth, the structure of economic inequalities and food distribution also play a role (Cirera and Masset, 2010). Food security is dependent on food availability but even more on food access, which is closely linked to poverty. Therefore, inclusive economic growth is crucial, whether it is supported by revenue increase for the poorest or by other accommodating social policies ensuring better access to food. Our recent research at IIASA shows that under a scenario where the poorest are targeted for food access, the needs to produce more calories would be decrease by 85 per cent compared to a scenario where more food availability would be privileged without any change in the food distribution structure (Hasegawa and others, 2019).

3. Consistent modelling of socioeconomic pathways

Research at IIASA on future food demand and the environmental trade-offs has naturally structured around the work of the integrated assessment modeling community, already supporting research on climate change impact and mitigation for the Intergovernmental Panel for Climate Change (IPCC). Integrated assessment models (IAMs) provide a consistent dynamic representation of the food and agricultural system at the mid- or end-century horizon, in combination with socioeconomic drivers and other environmental variables related to land, water and climate (Popp and others, 2017).

Drivers of global changes have been organized into shared socioeconomic pathways (SSPs) that constitute the primary matrix. The five SSPs used by the IAM community have been structured around a large set of socioeconomic elements, many of those affecting food demand and environmental impacts (O’Neil and others, 2016). It is interesting to note that some elements, such as population and economic growth, have been quantified by IAMs teams and taken as shared assumptions (Riahi and others, 2016; Dellink and others, 2017). However, not all the socioeconomic elements have been consistently used or aligned across models. In the case of population, the Population Program at IIASA has produced a consistent set of population projection by country, sex, age and education level (Lutz and others, 2014).

However, this information has usually only been used under an aggregated form, without, for instance, looking at the implication of ageing. Some other SSP elements have been quantified unevenly across teams (diet changes) or not systematically applied to food demand (urbanization). Last, some SSP elements have only been qualitatively defined (e.g., income inequality) and not always transposed in modeling.

4. Land use modelling of SSPs

Projection of land use change and environmental impacts for a different future depend on a scenario of food demand, but also on the agricultural and environmental policy development that determines how much a given level of production will generate land footprint and associated environmental impacts. IAMs have produced various sets of projections in the past, associated to different SSPs. In the case of IIASA research, projections are based on the land use model GLOBIOM (Havlik and others, 2011; Schneider and others, 2011). This model represents global agricultural and forestry markets across the world, with a gridded representation of land use (2 x 2 degrees resolution), and a precise account of GHG emissions and other environmental accounts such as water, nutrient balances and biodiversity. When looking at SSP projections, the GLOBIOM model predicts for the unsustainable scenario (SSP3, "Regional Rivalry") a cropland projection increase of 255 Mha between 2010 and 2050, whereas for the most sustainable one (SSP1 "Sustainability") predicts a 144 Mha. Pasture land would increase by 61 Mha under SSP3 but decrease by -24 Mha under SSP1 (Riahi and others, 2017).

The projections above however mix contributions from both drivers on the consumption side and production side. Recent research has shown how diversely the different socioeconomic drivers within SSPs contribute to land use change, comparing the results of a large set of IAMs, including GLOBIOM (Stehfest and others, 2019). On the demand side were analyzed the contribution of population growth, economic growth and diet preferences. On the production side, the key drivers analyzed were crop productivity, trade policies and land use protection. The analysis showed that although, in addition to population growth, economic growth was usually found having a consistent effect across modelling frameworks. However, assumptions on the extent of diet change would vary strongly across modelling frameworks, but for some models would overweight the role of population growth.

One important point of remark is that, despite its name, the most sustainability-oriented scenario from the SSPs—SSP1—does not necessarily achieve all the key sustainability targets. In particular, without additional climate mitigation policies, SSP1 does not lead to climate stabilization well below 2 degrees as required by the Paris Agreement (Gidden and others, 2019). Similarly, the extent of land cover change in SSP1 does not allow large biodiversity restoration. For these reasons, deeper transformations are required to deliver on all the SDGs dimensions and to reach the required sustainability targets at the mid-century horizon.

5. Deep transformations for sustainability targets

Stronger societal choices and ambitious policies will be needed to meet the challenges posed by the growing demand for natural resources extraction in the face of climate mitigation and biodiversity preservation needs. Most of the levers to be activated will likely not suffice individually and will therefore need to be used in combination (Foley and others, 2011; Springmann and others, 2018). These are in particular:

- More sustainable and healthy diets. By reducing the consumption of most resource intensive products, in particular meat (and dairy) consumption, but also commodities the most subject to unsustainable expansion in tropical forest areas (palm oil, soybean, etc.), very large area of land could be returned to nature (Stehfest and others, 2009; Springmann and others, 2016). Indeed, grassland area represents 3.5 Gha according to FAOSTAT, more than twice the area of cropland. Furthermore, a large part of cropland (30 per cent) is today used for animal feed. Healthier diets would also lead to reduction of overconsumption and obesity and decrease the average caloric intake per capita.

- Less losses and waste along the food chain. Large fractions of food are today lost (Guvstavsson and others, 2011) on the production side (crop failures, post-harvest losses), in the supply chain, or on the consumption side (waste in retail sector and at household level). Although the exact extent of losses and waste are still unprecise, there is a wide agreement that reduction of food lost through these would trigger large benefits to the sustainability of the food demand (Alexander and others, 2017).
- Increased yield productivity. Average global yield has more than doubled since the 1960s, which has mitigated potentially devastating impacts associated with the increased demand of food otherwise. For instance, according to Burnet and others (2010), yield increase has saved 590 $GtCO_2$ of emissions from land use change between 1961 and 2005. These benefits have outweighed by a large extent the extra fertilizer emission required by the intensification of agricultural practices.
- Massive land restoration programmes. Biodiversity will only be restored if large areas of land are returned to nature (Newbolt and others, 2015). This implies active protection of biodiverse areas and restoration of forests in the many areas degraded for agriculture or other anthropogenic needs (Leclere and others, 2018). In particular, afforestation will be key to both regenerate biodiversity in some regions and at the same time sequester large quantities of carbon for climate change mitigation (Lewis and others, 2019).
- Climate smart production practices. Current agricultural production practices are in many regions too GHG emission intensive and also lack of resilience for future climate change impacts and accompanying extreme events. Climate smart agriculture would. in particular, involve adapting crops to the local changing environment, decrease inefficiencies in input use (fertilizers, water), using add-on technologies to limit GHG emissions, adopt soil conservation practices to sequester soil organic carbon (FAO, 2010; Wollenberg and others, 2011). Some of these policies could, in particular, be triggered through targeted carbon tax, although most likely farm contracts and offset programmes would be more widely adopted in the case of most sensitive products for rural livelihoods and food security.
- More inclusive growth. Reducing inequalities and putting in place social programmes targeted at reducing food insecurity would allow the poorest to fulfill their food needs without any significant need in food availability increase. Regions with high poverty rate and institution failures are also those where environmental degradations are the most significant (Duraiappah, 1998).

The list above is not exhaustive. Among other possible leverages, some are however more disputed. That is the case for instance, of the deployment of bioenergy at large scale (with carbon capture and sequestration), to achieve climate stabilisation at the level of ambition in the Paris Agreement (Anderson and Peters, 2016). Similarly, the wider adoption of “future food” products at lower environmental footprint could deliver high potential benefits, but economic feasibility or social acceptance are still to be demonstrated (Parodi and others, 2018).

6. Modelling deep transformation impacts on the land system and SDGs

Most recent IAM research has attempted to move away from the SSP x RCP (Representative Concentration Pathways) scenario matrix to broaden the scope of analysis of sustainability pathways and encompass a broader set of SDGs. This was undertaken by investigating for instance the various trade-offs among SDG variables of the land use system (Obersteiner and others, 2016) or how some key environmental variables could transgress some planetary boundaries (Springmann and others, 2018). Combining the transformations above has demonstrated a large capacity to put the food and land use systems on a sustainable pathway (Deppermann and others, 2019). However, transposing this global transformation vision into more local agendas and national policies remains an important challenge. International cooperation has an important role to play to forge solutions, as illustrated by the Paris Agreement in the case of climate change, by the Aichi targets for biodiversity protection in the context of the Convention on Biological Diversity, or by the Bonn Challenge in the case of land restoration. Scientific collaborations are also key to translate global targets into locally workable solution, as illustrated by transnational integrated assessment exercises, such as initiated by the Food, Agriculture, Biodiversity, Land Use and Energy (FABLE) Consortium of the United Nations Sustainable Development Solutions Network and IIASA (Schmidt-Traub and others, 2019).

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