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Land Use and Food Security in 2050: a Narrow Road

Agrimonde-Terra

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1. The 'Land Use and Food Security' System

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Introduction

The central concept of a 'system' embodies "a set of elements connected together which form a whole, thus showing properties which are properties of the whole, rather than properties of its component parts" (Checkland, 1981). Foresight processes borrow heavily from systems analysis (de Jouvenel, 2004; Loveridge, 2009; FTP, 2014). Also, in many countries of the world, systems analysis is seen as a major driver of innovation and sustainability improvement in agriculture. The complexity of questions facing agriculture has led to a wide adoption of the systems approach in this sector, and the expressions farming systems, cropping systems, food systems, agricultural systems etc. are very commonly used. The systems approach makes it possible to overcome disciplinary specialization, simple relations between inputs and outputs, linear schemes and interactions between spatial scales.

CIRAD and INRA opted for a systems approach for the Agrimonde-Terra foresight process on land use and food security in 2050 because it makes it possible to focus on interactions between causes of changes and emerging properties. All the factors that could have an influence on land use and food security were identified and studied, the most important ones were selected and their interrelations were analyzed; then the system was described. Drivers and actors of change were taken into account. The linkages between land use and food security go through the political context, diets, value chains, climate change, consumers' revenues etc. and their interactions. In the 'land use and food security' system, Agrimonde-Terra considers that land-use changes: (i) result from complex and dynamic interactions between direct and external drivers; (ii) may be characterized using five complementary and interlinked dimensions; and (iii) have an impact on the four dimensions of food and nutrition security defined by FAO (CFS, 2009) at different scales ranging from the household to global level. This means that there is a web of processes, actors and interactions involved in land use and leading (or not) to food and nutrition security at global, national or household levels, *i.e.* the Sustainable Development Goal (SDG) No. 2 'Zero hunger'. However, because of the multi-factorial approach, land use will also affect at least another seven SDGs, *i.e.* 'No poverty' (goal 1), 'Good health and

wellbeing' (goal 3), 'Clean water and sanitation' (goal 6), 'Affordable and clean energy' (goal 7), 'Responsible consumption and production' (goal 12), 'Climate action' (goal 13) and 'Life on land' (goal 15). The 'Partnerships for the goals' (goal 17) will be very important and will help in reaching all goals if there is a common and shared vision on the future of land use and food security.

In this chapter, we describe the processes of the 'land use and food security' system, its main actors and its spatial dimensions.

The processes of the 'land use and food security' system

THE FIRST STEP OF THE FORESIGHT APPROACH ADOPTED BY AGRIMONDE-TERRA consisted in defining the system it was going to work on as well as its sub-systems. This was done through literature reviews and four workshops, which involved about 80 researchers (Chapter 2).

Land use and food security

The expression 'land use system' was introduced by FAO in the 1970s (Bouma, 1997) because many countries had developed their own systems of land evaluation which made the exchange of information difficult, and created a need for standardization. It was defined as "a specified land utilization type practiced on a given land unit, and associated with inputs, outputs and possibly land improvements" (FAO, 1976). From there on it was used, although there were further discussions about its definition and no new formal agreement. It was recognized that land use systems should be defined differently at different scales (Bouma, 1997) and that different spatial scales interacted (Verburg *et al*., 2002), often leading to unexpected outcomes with profound implications for sustainability (Liu *et al*., 2013).

The basic concepts underlying the terms 'food security' were articulated in the early 1940s during World War II when more than 40 governments met "to consider the goal of freedom from want in relation to food and agriculture. They concluded that 'freedom from want' meant a secure, adequate and suitable supply of food for every man, woman and child, where 'secure' referred to the accessibility of the food, 'adequate' referred to the quantitative sufficiency of the food supply and 'suitable' referred to the nutrient content of the food supply" (CFS, 2012). The definition of 'food security' at the World Food Summit in 1974 also focused on availability. It was in the 1980s that the 'access' dimension was added to the food security definition. A definition of food security was proposed in 1996 and modified in 2001: "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. The four pillars of food security are availability, access, utilization and stability. The nutritional dimension is integral to the concept of food security and to the work of CFS" (CFS, 2009). Work on indicators

aiming to capture various aspects of food and nutrition insecurity is on-going at FAO and in research projects.

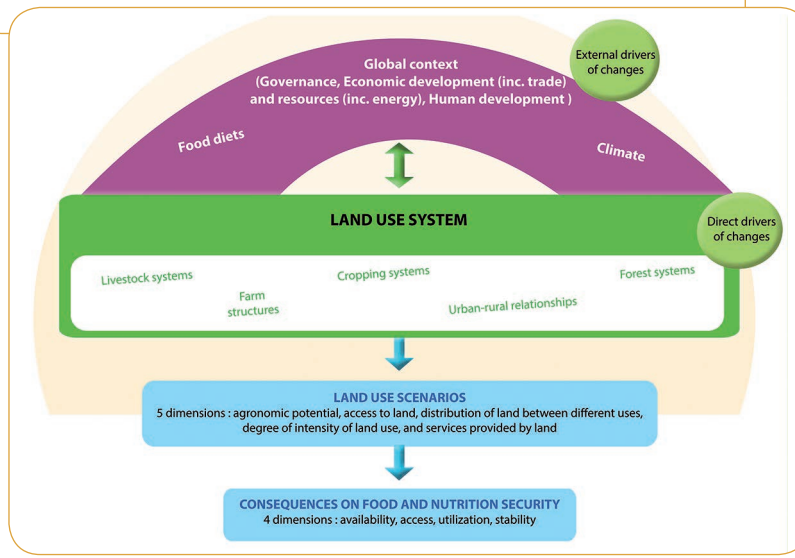
Land-use changes result from interactions between direct and external drivers

Drivers of land-use changes have been identified through the analysis of local situations or sectors (de Koning *et al*., 1999; Geist and Lambin, 2002; Lambin *et al*., 2003; Ostwald *et al*., 2009; Garrett *et al*., 2013; Matthiesa and Karimov, 2014; Nesheim et al., 2014) as well as in conceptual work (Stomph *et al*., 1994; Lambin *et al*., 2001; Lambin and Geist, 2006; Hersperger *et al*., 2010; Meyfroidt *et al*., 2013). They are usually classified as direct (or proximate causes) and underlying (or indirect causes) (Lambin *et al*., 2003).

Indirect (or underlying) causes of land-use changes "are fundamental forces that underpin the more proximate causes of land-cover change. They operate more diffusely (*i.e*., from a distance), often by altering one or more proximate causes" (Lambin *et al*., 2003). Authors identify and classify these drivers in different ways according to the geographical space that is observed and their approach. Geist and Lambin (2002) and Lambin *et al*. (2003) identify demography, economic factors, technologies, policy and institutions, and cultural factors. Observing land-use changes in a Chinese region, Ostwald *et al*. (2009) identify economic, policy, climate and political factors as underlying driving forces of land-use change. In the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) report, van Vuuren *et al*. (2009) identify demography, economics and international trade, socio-political factors, science and technology, education, culture and ethics, and changes in biophysical environment as indirect drivers of agricultural change. Hersperger *et al*. (2010) "have identified five groups of driving forces: political, economic, cultural, technological, and natural driving forces. Population (or demography) usually falls into the category of cultural driving forces but sometimes forms an additional group". Meyfroidt *et al*. (2013) underline that "Land use changes are strongly influenced by globalized flows of commodities, information, capital and people, and are increasingly driven by factors in distant markets, often associated with the growing urban consumer class in emerging markets. Local to national-scale interventions to promote sustainable land use may have unintended effects abroad owing to a displacement of land use across countries." Matthiesa and Karimov (2014) point out the role of financial drivers. Neishem *et al*. (2014) also point out economic growth, technological development, population growth and climate change.

The Agrimonde-Terra team chose to classify the drivers of the 'land use and food security' system as direct and indirect, but adopted a definition for each category which differs from the one found in above mentioned literature. In Agrimonde-Terra, direct drivers are the ones which affect directly land use and then food security, while indirect drivers (called 'external' drivers) affect both and simultaneously land use and food security.

Figure 1.1. The Agrimonde-Terra 'land use and food security' system.



The Agrimonde-Terra team designed a 'land use and food security' system (Figure 1.1) composed of three external drivers and five direct drivers which interact. The foresight approach establishes the causal relationships that exist between all the factors of change. The mix of driving forces of land-use change varies in time and space. In order to have a clearer understanding of the links between natural and human processes that affect land use, and consequently food security, Agrimonde-Terra has decided to focus on one direction: the consequences of the interactions of drivers of land use on food security.

Agriculture and forestry activities (cropping systems, livestock systems and forestry systems), farm structures and urban-rural relationships have a direct impact on land use. External drivers include climate change, food diets and the global context, *i.e.* political context and governance, economic context (including trade, resources and research and innovation) and human development. Each direct and external driver has been studied in detail with the objective of identifying both past and emerging trends as well as potential disruptions, and building alternative hypotheses for the future up to 2050. Table 1.1 reports the list of drivers and their own causes of change. Forest systems had been identified as direct drivers of change but have not been considered in detail during the Agrimonde-Terra foresight process due to lack of resources. Although no hypotheses about the evolution of forest systems in 2050 have been built, the impacts of climate change on the forestry sector and forest area have been taken into account and the competition for land between arable and permanent crops, pasture and forest uses is an outcome of the quantitative simulations.

Table 1.1. External and direct drivers of the Agrimonde-Terra 'land use and food security' system.

Driver	Definition of the driver
Global context	Political context (*i.e.*, the broad conditions that form the context for collective action, alliances, rivalry for power and interdependences between political actors, agreements and policies at international, regional and national scales), the economic context (*i.e.*, the organization of the economy and of trade, the energy mix, economic growth and its distribution between countries and groups of individuals, and research and innovation), and social context (*i.e.*, demography, culture, education, health, employment and migrations) at national, regional and global scales.
Climate	Changes in temperature and precipitation and variations in the frequency, intensity and spatial and time amplitude of climate events. Climate influences agricultural biochemical cycles, and impacts agricultural system performance. It challenges the adaptive capacities of societies.
Food diets	Total energy content and pattern of diets, food supply chain organization, government food policies. Food diets influence health outcomes relating to over- and under-nutrition and nutritional deficiencies.
Urban-rural relationships	Interactions between urban processes and rural dynamics.
Farm structures	Basic unit of agricultural production.
Cropping systems	Result of the implementation on a given surface of the technical, human and financial means available to the farmer to achieve an objective. Cropping systems describe the succession of crops over time and the cropping techniques applied to each crop at the scale of the cultivated plot. The combination of cropping systems at the farm level largely determines the production level, farmers' income and agriculture's environmental impact.
Livestock systems	Result of the implementation in a given location of the technical, human and financial means available to the farmer to achieve an objective regarding livestock farming. Livestock systems describe how animals are fed, the efficiency of feed rations, herd mobility and crop-livestock synergies. The combination of livestock systems at the farm level largely determines the production level, farmers' income and agriculture's environmental impact.

Land-use changes can be characterized by five dimensions

The next step was to identify dimensions of land use in order to provide a thorough characterization of land-use changes. Five complementary, interlinked and dynamic dimensions of land-use change were identified:

– **The land's agronomic potential**. This dimension relies on soil quality and climate. It is important for determining the suitability of land for agriculture and for different crops.

In the case of agricultural use, the land's agronomic potential is generally measured in terms of crop yield potentials under different technical management systems. Agrimonde-Terra uses the GAEZ classification and data on land suitability to identify this dimension of land-use change. [1] The metrics are areas of land suitable for agriculture. The agronomic potential of land varies over time. Firstly, it is linked to land use and changes in land use. For instance, converting an agricultural area into an urbanized area sharply reduces its agronomic potential, regardless of soil quality and climate. Secondly, the land's agronomic potential can evolve even when the activity on the land remains the same. This may occur as a result of climate change, farmers' decisions and technical progress, as well as the policies that affect all three drivers.

– **The distribution of land between different uses**. The evolution in arable and permanent crop areas, permanent pasture areas, forest areas and some other areas (including sparsely vegetated and barren land, for instance) is the result of farmers', herders' and foresters' decisions and interactions, provided land has agronomic potential and there is access to land. Therefore, how land is allocated to different uses depends on all the factors that influence landowners' and users' decisions, including demography and the economic environment. The distribution of land between different uses provides information on the geographic location of activities within regions (for example, areas used predominantly for cereals or pasture, forest areas, urbanized areas etc.) and worldwide. Key factors of change include diets, demography, climate, but international trade and its main drivers, *e.g.* tariff/non-tariff barriers, transport costs etc. are also important. Agrimonde-Terra uses the FAO classification and data on land use (FAOStat) to characterize this dimension of land use.[2]

– **Access to land** and the decision-making powers that determine land use. This depends on land tenure systems and land policy, which are affected by several factors, including the geopolitical situation, the degree of competition for land, farmers' incomes and access to credit etc. Although the national legal framework is a core driver for access to land, in many countries local governance is even more important. It influences how the law is applied and how competing interests linked to land are managed. Land rights do not always have a legal framework. However, 'informal' rights can be secured when institutions recognize that land rights stem from social consensus and when national authorities acknowledge the legitimacy of local arrangements. Agrimonde-Terra provides only a qualitative analysis of access to land.

– **The degree of intensity of land use**. This concerns farming practices, which depend on available techniques and farmers' decisions. Therefore, all factors and policies that

1. In the Global Agro-Ecological Zones (GAEZ) approach, land is classified according to its quality or suitability for agricultural production. There are eight classes ranging from 'very suitable' to 'not suitable'. For more details, http://www.fao.org/nr/gaez/fr/. GAEZ data are used to estimate the maximum cultivable area in each region considered in GlobAgri-AgT (Chapter 3 and Chapter 14).

2. For more details on classification and available data, http://faostat3.fao.org/. FAOStat data are also used for the retrospective analysis of land use provided in Chapter 5.

modify available techniques (*e.g.,* technical progress) and farmers' decisions (farmers' knowledge and level of training, farmers' organization, input and output prices, agricultural support policies etc.) affect the intensity of land use. Agrimonde-Terra uses two main indicators to measure the degree of intensity of land use: observed yields and the ratio of area harvested over area cultivated (Chapter 3).[3] They are interlinked and calculated using FAOStat data.

– **The services provided by the land**. In the case of agricultural land, these depend on land use and farming practices. Therefore, all drivers that influence the allocation of land between different uses and the intensity of land use affect the services provided by the land. Such services include: provision of services, such as food and water quality; regulatory services, such as flood and disease control; cultural services, such as spiritual and recreational; supporting services, such as nutrient cycling that maintains the conditions for life on Earth; other services such as employment. In Agrimonde-Terra, there is a qualitative analysis of the services provided by the land.

Land-use changes have an impact on the four dimensions of food security

The various drivers interact to result in changes in land use, which in turn, impacts food and nutrition security. GlobAgri-AgT, a biomass balance model (Chapter 3), has been used to simulate the impacts of the scenarios on world and regional land use, agricultural production and agricultural trade in 2050. Thus, the information on the four dimensions of food and nutrition security provided in the narratives of the Agrimonde-Terra scenarios is supported, at least partially, by quantitative results (Chapter 14). These quantitative results provide information on the availability dimension of food and nutrition security. As far as the access dimension of food security is concerned, quantitative results do not give direct information. However some quantitative results may provide indirect indication. Indeed, quantitative results show how competition for land could evolve and to what extent trade and the dependence of certain regions on world markets (either as importers or exporters) could change. These quantitative results thus give some indication on potential impacts of the various scenarios in terms of food access, notably output prices changes, in relation to competition for land, and import and export dependence of regions. Overall, one must acknowledge that Agrimonde-Terra has not been able to say much about the impacts of scenarios on the utilization and stability dimension of food security.

3. Both indicators are used for the retrospective analysis of land use (Chapter 5) as well as for the quantification of the hypotheses of change of cropping systems, which are involved in the various Agrimonde-Terra land-use scenarios.

The temporal and spatial dynamics in the 'land use and food security' system

Land use can be examined from different geographical scales, *e.g.* the plot of land, the farm, the territory, the sub-region and the national or global levels. At each scale, the changes that are captured are not the same; the links of causalities between drivers and the influence of actors may also change. The same holds true for food security, which can be examined from the individual or household perspective through to a sub-region, a country or global scale.

Interactions between geographical scales are important (Lambin and Meyfroidt, 2011; Lerin and Louafi, 2012), and decisions on land use should not take into account only the local context (Liu *et al.*, 2013). Displacement of production, expansion or reduction of land use will have major impacts on food security.

Land-use changes can be observed during short periods (a few years), a decade or several decades, and the observation can be done at different geographical scales. The temporal and geographical scales of observation influence the types of changes observed. At the scale of a plot or a territory, land-use changes can be observed rapidly. At larger scales, longer periods of time are necessary to observe changes.

The actors in the 'land use and food security' system

A wide variety of actors are active in the 'land use and food security' system. Their roles, networks and alliances vary over time, as well as the business models, value chain organizations and other institutional arrangements they establish. They are active at different geographical scales, some actors being very local whereas others are present from the local to the global scales. The main actors in the 'land use and food security' system are:

– Farmers, herders, foresters, hunters etc. who use land at a local scale through their cropping, livestock and forestry systems, and their farm structures and their collaborative organizations, *e.g.* farmers' organizations.

– Citizens who live in urban and rural areas and their associations, and are consumers of products. They can buy agricultural products from local or non-local sources.

– Governments, through their different ministries, administrations (agriculture, environment, trade, education, health etc.) and policymakers who set up and implement policies, market rules including norms and facilitate the resolution of conflicts. In some countries, aid agencies provide financial, logistical and material support, including food aid.

– Local, territorial, and national public and private institutions for land and water planning, city planning, sanitation services, infrastructure and roads, conservation areas, environmental protection etc. as well as institutions which provide information and inputs

to farmers, herders, foresters and citizens, or co-construct organizations, knowledge and technologies with them. These are, for example, extension agents, health services for crops and animals, trainers, financial institutions, research and development institutions, and health institutions.
– Financial institutions, local, national or international, which invest in land, agriculture, agribusinesses or provide credits or subsidies.
– International institutions, such as the United Nations institutions, which provide advice, aid, rules for exchanges etc. as well as international conventions.
– Regional political and economic institutions.
– Enterprises, small, large or multinational, who are buyers, traders, processors, transformers and sellers of agricultural products and of inputs for production; logging and mining firms. They can form lobbies.
– Non-governmental organizations (NGOs) active in land and environmental issues including protection of indigenous populations.
– Media.

Conclusion

The Agrimonde-Terra 'land use and food security' system emphasizes interlinkages and interactions between the external and direct drivers of change and their consequences on food security. It demonstrates that achieving food security is dependent not only on increasing production, improving quality and ensuring access and utilization to all, but that external drivers of change such as the political, economic and human context at global, regional, national and territorial levels, food diets and climate change play an extremely important role. It explains why it is so difficult to reach food security. Like the Sustainable Development Goals, it forms an 'indivisible whole' which leads to the necessity of creating connections between policies and actors, and avoiding operating in silos.