



## Agrimonde-Terra, a foresight exercise on land use and food security in 2050: scenario-building method and conceptual framework

AGRIMONDE-TERRA

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### *Agrimonde-Terra is a foresight exercise on land use and food security*

*Cirad and Inra are building regionalized global land-use scenarios using the best qualitative and quantitative evidence, with the support of a Scenario Advisory Committee. The aim of the land-use scenarios is to explore the possible land-use changes between now and 2050 and their impact on nutrition and food security in the context of climate change. The conceptual framework, the scenarios and the quantitative platform (GlobAgri and its application GlogAgri-AgT) provide tools for discussion, 'food for thought' as it were, for stakeholders involved in land-use and food security on a global, regional or national scale.*

### *Why a foresight project on land use and food security in 2050?*

The Agrimonde-Terra foresight project is pursuing the work of Agrimonde<sup>1</sup>, which explored pathways to feed 9 billion people in a sustainable way in 2050. It also highlighted the complex array of interactions between food (in)security, land and its uses, and the environmental impact of human activities.

In a context of climate change, given the planet's finite resources and the growing competition between different land uses (food-feed-energy, forests, residential, industrial, transport, recreational, biodiversity, carbon sequestration, etc.), the issue of future land use has to be addressed. What impact will population growth, urbanization and life-style changes, climate change and energy demands have on land use in 2050? How can we ensure that land use will provide nutritional and food security for all in 2050? How should land, water and biodiversity be used to meet the many demands of the planet's inhabitants in 2050? How can we ensure that land use will provide sustainable incomes for farmers and affordable prices for consumers? Which public policies should be implemented at different scales and in the different sectors? Here are some of the questions and uncertainties that the Agrimonde-Terra foresight exercise seeks to explore.

The aim of the Agrimonde-Terra foresight exercise is to prepare rigorous and coherent land-use scenarios that will:

- contribute to international debates on land use and food security and help international, regional and national decision makers in their discussions on public policies relating to land use and/or food security issues;
- help develop a shared understanding of the links between the natural and human processes that affect land uses and food security;
- help identify relevant future questions for research.

### *A collective method to build scenarios*

Agrimonde-Terra adopted the following working principles:

- To provide a forum for discussion between researchers working on land-use and food security issues. Agrimonde-Terra has drawn on the knowledge and experience gained by researchers from Cirad, Inra and their partners.
- To develop a systemic and interdisciplinary approach and combine qualitative and quantitative analyses.
- To build scenarios in a rigorous and transparent way so that they also constitute "learning machines"<sup>2</sup>, i.e. tools to raise awareness and encourage debate.

The different groups involved in the Agrimonde-Terra foresight project are:

- The project team: Marie de Lattre-Gasquet (Cirad, coordinator), Chantal Le Mouël (Inra, coordinator), Olivier Mora (Inra, organizer)

<sup>1</sup> Paillard S., Treyer S. and Dorin B. (coord.) (2011). *Agrimonde. Scenarios and Challenges for Feeding the World in 2050*. Paris: Quae.

<sup>2</sup> Berkhout F., Hertin J. and Jordan A. (2002). *Socio-economic futures in climate change impact assessment: using scenarios as "learning machines"*. *Global Environmental Change* 12: 83-95.



for scenario building), Catherine Donnars (Inra), Patrice Dumas (Cirad) and Olivier Rechauchère (Inra), in collaboration with Marco Barzman (Inra), Thierry Brunelle (Cirad), Agneta Forslund (Inra), Elodie Marajo-Petitzon (Inra), Stéphane Manceron (Inra), Pauline Marty (Inra) and Clémence Moreau (Cirad).

- The steering committee: Pierre Fabre (Cirad), Hervé Guyomard (Inra), Etienne Hainzelin (Cirad) and Bertrand Schmitt (Inra).
- The Scenario Advisory Committee, which is made up of international experts selected on an *intuitu personae* basis: Agnes Andersson Djurfeldt (Lund University, Sweden), Leïth Ben Becher (Synagri, Tunisia), Mohamed Elloumi (InraT, Tunisia), Adama Faye (IPAR, Senegal), Richard Guissou (Ministry of Agriculture and Food Security, Burkina Faso), Holger Kray (World Bank, USA), John Lewis (Terra Global Capital, USA), Patrick Meyfroidt (Louvain University, Belgium), Marc Mueller (FAO, Italy), Siwa Msanguu (IFPRI, USA), Antonio Onorati (International Planning Committee on Food Sovereignty, Italy), Stéphane Parmentier (Oxfam, Belgium), Alain Retière (Cap 2100, France), Roberta Sonino (Cardiff University, UK), Sébastien Treyer (IDDRI, France), Dominique van der Mensbrugghe (AgMIP, Purdue University, USA), Joost Vervoort (CCAFS and Oxford University, UK), Hisham Zehni (IFAD, Italy).

- The 80 international experts and the scientific coordinators for the thematic workshops: (i) Francis Aubert (AgroSup, Dijon) and Frédéric Lançon (Cirad) for the workshop on “Urban-rural relationships”; (ii) Jacques Marzin (Cirad) and Laurent Piet (Inra) for the workshop on “Structures of production”; (iii) David Makowski (Inra), Florent Maraoux and Eric Malézieux (Cirad) for the “Cropping systems” workshop; (iv) Philippe Lecomte and Alexandre Ickowitz (Cirad) and Philippe Lescoat (AgroParisTech) for the “Livestock systems” workshop.

## A four-step method for building scenarios

The project team builds scenarios in close collaboration with the Scenario Advisory Committee. The Agrimonde-

Terra’s method for scenario building involves four steps. In the first step, the Agrimonde-Terra’s “land use and food security” system is defined. The main direct and indirect causes of changes in land-use are identified and described. The dimensions used to characterize land-use change are specified. In the second step, alternative micro-scenarios show how the direct and indirect causes of changes in land-use evolve between now and 2050. In the third step, the micro-scenarios are combined in a morphological table to develop contrasting land-use scenarios, called “generic scenarios”, which are described using narratives. The “generic scenarios” are then regionalized, i.e. adapted to each region. This process leads to the building of regionalized global land-use scenarios, which are described using narratives and quantitative illustrations provided by the GlobAgri platform customized for Agrimonde-Terra (GlobAgri-AgT presented p. 4). The fourth step involves a qualitative and quantitative impact analysis of the regionalized global land-use scenarios in relation to food security at different scales.

### Step one: Analytical breakdown of the land-use and food security system

In the “land-use and food security” system (Figure 1), Agrimonde-Terra considers that land-use changes: (i) may be characterized using five complementary and interlinked dimensions; (ii) result from complex interactions

between direct and indirect causes; (iii) have an impact on food security at different scales ranging from household to global.

### Direct and indirect causes of land-use change

Agrimonde-Terra has identified five direct and three indirect causes of land-use change. Agriculture and forestry activities (cropping systems, livestock systems, forestry systems), structures of production and urban-rural relationships have a direct impact on land use. Indirect causes can also have a crucial impact. They include climate change, diets and the global context, i.e. political governance, economic development (including trade), resources (including energy) and human development. The foresight approach is systemic because it establishes the causal relationships that exist between all the factors of change.

### Five dimensions to characterize land-use change

Agrimonde-Terra has identified five complementary, interlinked and dynamic dimensions of land use in order to provide a thorough characterization of land-use changes:

- **The land’s agronomic potential.** This factor depends 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 potential

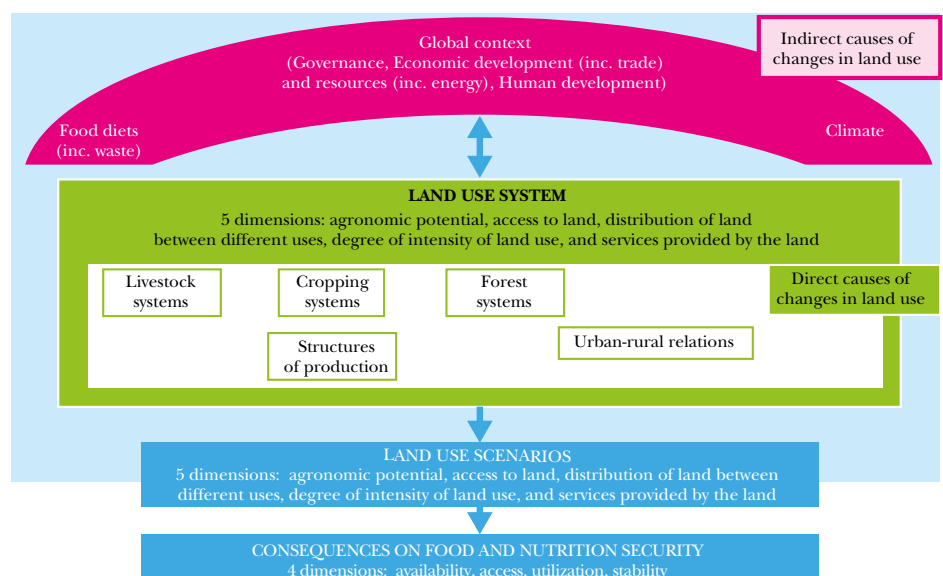


Figure 1. Agrimonde-Terra’s “land-use and food security” system



crop yields under different technical management systems. Agrimonde-Terra uses the GAEZ classification and data on land suitability to identify this dimension of land-use change<sup>3</sup>. 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 land use 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.

- **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 a qualitative analysis of access to land.

- **The distribution of land between different uses.** It is the result of the landowners'/users' decisions and interactions, provided land's agronomic potential and access to land. Therefore, how land is allocated to different uses depends on all the factors that influence landowners'/users' decisions, including demography and the economic environment. The distribution of land for 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 include international trade and its main drivers, e.g. tariff/non-tariff barriers, transport costs, etc.). Agrimonde-Terra uses the FAO classification and data on land use, FAOStat<sup>4</sup>, to characterize this dimension of land-use change.

- **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 modify available techniques (e.g. technical progress) and farmers' decisions (farmers' level of training and knowledge, input and output prices, agricultural support policies, etc.) affect the intensity of land use. When considering the fourth dimension of land-use change, Agrimonde-Terra uses two main indicators to measure the degree of intensity of land use<sup>5</sup>. They are interlinked and calculated using FAOStat data: observed yields and the ratio of area harvested over area cultivated.

- **The services provided by the land.** These depend on land use and farming practices in the case of agricultural land. Therefore, all drivers that influence the allocation of land for different uses and the intensity of land use affect the services provided by the land. Such services include: provisioning services, such as food and water quality; regulatory services, such as flood and disease control; cultural services, such as spiritual, recreational, and employment; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth. These services can provide a source of income. In Agrimonde-Terra, there is a qualitative analysis of the services provided by the land<sup>6</sup>.

## Step two: Building micro-scenarios for direct and indirect causes of change in land use

Direct and indirect causes of changes in land use and the food security system were studied in detail to identify past and emerging trends and potential disruptions. Micro-scenarios of change were built for each direct and indirect cause. For four of the direct causes, micro-scenarios were built during thematic workshops with international experts (see previous section). For all the indirect causes, micro-scenarios were built on the basis of a literature review. The Scenario Advisory Committee reviewed all of the micro-scenarios.

## Step three: Building land-use scenarios

Contrasting land-use scenarios were built in a coherent way by combining micro-scenarios for each direct and indirect cause. The scenario-building work starts with a representation of the current situation and an analysis of the long-term dynamics. Some events create pathways of change. The final picture presents the situation in 2050 and is the result of the paths of change mentioned above. The representation of the current or initial situation, as well as the final picture of land-use scenarios in 2050 are described according to the five complementary and interlinked dimensions of land-use change used by Agrimonde-Terra.

Land-use scenarios were built in close collaboration with the Scenario Advisory Committee. They are called «generic scenarios» because they do not apply to a specific region. Instead, they identify the sources and pathways of change and the interactions between the direct and indirect causes (of change). These «generic scenarios» are described through narratives.

The generic land-use scenarios were then regionalized to provide regionalized global land-use scenarios. This process involves adapting each generic scenario to the different regions in the world<sup>7</sup>. It requires a retrospective analysis of the evolution of land use and of each direct and indirect cause of change in each region. It highlights the main past and current trends, emerging trends, uncertainties and potential

<sup>3</sup> In the Global Agro-Ecological Zones (GAEZ) approach, land is classified according to its quality or suitability for agricultural production. There are seven classes ranging from «very suitable» to «not suitable». For more details, see <<http://www.fao.org/nr/gaez/fr/>>. GAEZ data are used in the retrospective analysis of land use. They are also used for quantifying the maximum cultivable area in each region when simulating the land-use scenarios with GlobAgri-AgT.

<sup>4</sup> For more details on classification and available data, see <http://faostat3.fao.org/>. FAOStat data are used for the retrospective analysis of land use. For the quantitative simulations of land-use scenarios with GlobAgri-AgT, the distribution of agricultural land between crops, forage and grass is endogenous and results from scenario simulations with the biomass balance model (see the output section below).

<sup>5</sup> Both indicators are used for the retrospective analysis of land use. They are also used to quantify the hypotheses of the evolution of cropping systems in each region when simulating the land-use scenarios with GlobAgri-AgT.

<sup>6</sup> The quantitative simulations of land-use scenarios conducted using GlobAgri-AgT will make it possible to assess the changes in quantities of available food and GHG emissions induced by each scenario.

<sup>7</sup> The zoning used by Agrimonde-Terra is the same zoning used by Agrimonde and by the Millennium Ecosystem Assessment (MEA) which groups together countries (or divides up the world) into six regions: Sub-Saharan Africa, Middle-East-North Africa, Latin America, Asia, Former Soviet Union, and OECD 1990.



disruptions in each region. Regionalized global scenarios are described through narratives and the GlobAgri-AgT provides quantitative illustrations (see section on outputs). The quantitative aspect of the work is also used to appraise the regional adaptations of the generic scenarios when building the regionalized global scenarios.

### Step four: the impact of each land-use scenario on food security

When examining the impact of each scenario on the four dimensions of nutrition and food security, i.e. physical availability, economic and physical access, utilization and stability over time, Agrimonde-Terra takes into account the scale of analysis and governance (for land use and food security). The governance of land-use issues tends to be local or national, although the international scale can be important. The governance of food security is both national and international.

GlobAgri-AgT is used to conduct a quantitative analysis of the impact of each scenario on food security for two dimensions (availability and utilization) on a global and regional level. A qualitative analysis is conducted on the impact of each scenario in terms of the dimensions of access and stability.

## Three outputs

### Generic scenarios and regionalized global scenarios

Agrimonde-Terra has prepared five generic scenarios and their patterns have been applied to all regions. These are the regionalized global scenarios. For each region of the world, past tendencies in the land use system have been identified. For each scenario, an analysis of on-going trends as well as challenges for the future have been undertaken. The GlobAgri-AgT platform provides an illustration of what could be the quantitative impact of each scenario on the distribution of land between different uses and on food availability in 2050, at global level as well as in each region.

### A tool for dialogue between stakeholders involved in land use and food security at a national level

Stakeholders from public and private institutions involved in land-use and food security issues rarely have the opportunity to work together. The Agrimonde-Terra method and outputs constitute a tool for dialogue that can help stakeholders, both at national and regional level. Adapting the micro-scenarios to the national situation in order to build land-use scenarios for the country and examine their impact on food security provides a unique opportunity for debate.

## The GlobAgri Platform and its application GlobAgri-AgT

GlobAgri is a quantitative platform allowing for generating consistent databases and biomass balance models from FAOStat data as well as data shared by colleagues from different institutions<sup>8</sup>. The databases generated are balanced and account for the links between products. Biomass balance models provide a balance equation between resources (domestic production plus imports minus exports) and utilization (food, feed other) for each region and each agri-food product. The system of balance equations can simulate land-use change and GHG emissions induced by changes in the uses of agri-food products, provided hypotheses on the evolution of a set of variables (such as plant and animal yields, maximum land area available for agriculture, maximum cultivable area, terms of international trade, etc.). The GlobAgri platform has been used to generate a database and a biomass balance model which are specifically customized for Agrimonde-Terra (specific product and country aggregation, specific rules of coproduct handling, specific rules of model closure). The resulting tool is named GlobAgri-AgT. GlobAgri-AgT considers 32 aggregates of agri-food products (25 plants and 7 animal aggregates) and covers 14 broad regions.

## Agrimonde-Terra publications (as of 30th December 2015)

Manceron S., Ben-Ari T. and Dumas P. (2013). Feeding proteins to livestock: Global land use and food vs. feed competition. *OCL* 21(4). DOI: 10.1051/ocl/2014020.

*In Demeter Cahier No. 15 Agriculture et Foncier* (2014) (<http://www.clubdemeter.com/cahier.php>)

- Lançon F., Mora O. and Aubert F. L'extension urbaine à travers le monde : enjeux pour les villes et les campagnes.
- Guyomard H. and Schmitt B. Les terres agricoles, un enjeu pour la sécurité alimentaire de la planète à l'acuité variable selon les régions du monde.
- De Lattre-Gasquet M., Donnars C., Marzin J. and Piet L. Quel(s) avenir(s) pour les structures agricoles ?

De Lattre-Gasquet M., Brunelle T. and Dumas P. (2015). Agrimonde-Terra: Global and regionalized land-use scenarios taking into account climate change. Poster presented at the conference CFCC15 – Our common future under climate change, Paris, July 7-10.

Le Mouël C., Marajo-Petitson E., Dumas P., Manceron S., Levert F., Schmitt B. and Guyomard H. (2015). How to feed the world: is

reducing meat consumption part of the solution? Paper presented at ICOMST 2015 - 61st International Congress of Meat Science and Technology, Clermont-Ferrand, August 23-28.

Mora O., Lançon F. and Aubert F. (2015). Urban-rural linkages and their future: impacts on agriculture, diets and food security. Paper presented at the AGURB2015 – International conference on reconnecting agriculture and food chains to societal needs, Rome, September 14-17.

Brunelle T. (2015). Vers une prospective des impacts du changement climatique sur la sécurité alimentaire : les enseignements du 5ème rapport du GIEC. *Revue AE&S* vol.5, n°1, 3.

Equipe Agrimonde-Terra (2015). Tendances lourdes. Interactions croissantes dans les usages des terres. *Futuribles Rapport Vigie* 2015.

Moreau C., de Lattre-Gasquet M., Elloumi M., Ben Becher L., Cangiano C. 2015. *The future faces of land use and food security in Tunisia in 2050*. Paper presented at the International Conference on World Food Policy: The Future Faces of Food and Farming, Regional Challenges, Bangkok, December 17-18.

<sup>8</sup> These institutions are the Center for Sustainability and the Global Environment (SAGE), the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the International Institute for Applied Systems Analysis (IIASA), the Institute of Soil Science of the Chinese Academy of Sciences, the Joint Research Center (JRC), Princeton University, the World Fish Institute, the World Resources Institute (WRI), and the Woodrow Wilson School of Public and International Affairs.

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