INTERNATIONAL CONFERENCE
Agrimonde-Terra
Land use and global food security in 2050
A FORESIGHT EXERCISE

Friday June 24, 2016
Paris, Espace Grenelle - SNHF
(Société Nationale d’Horticulture Française)
1. Objectives and method

2. Determinants of land use and food security

3. The five Agrimonde-Terra scenarios and their assumptions

4. Consequences of the five scenarios on land use and food security
1. Objectives and method

Marie de Lattre-Gasquet
Cirad
On-going challenges: 795 million undernourished and 1.9 billion overweight adults. Nutritional deficiencies

Growing competition on land:
• Population growth, especially in SSA
• Economic growth: diets have changed in China and South East Asia, and could change in other regions
• Growing energy needs
• Loss of forests and biodiversity

Future challenges:
• Climate change: uncertain effects on production
• Diverse access to factors of production by farming structures

\[\rightarrow\text{Environmental challenges and their human roots concern and affect us all}\]
Objectives of Agrimonde-Terra

To facilitate informed decision-making and multi-stakeholder approach about the possible futures of land use and food security by providing:

- Drivers of land use and food security systems (global and regional) and alternative hypotheses about future changes
- 5 scenarios of land use and food security (narratives and quantitative analysis)
- A quantitative platform, GlobAgri, for generating consistent databases and biomass balance models → GlobAgri-AgT
A four-step participative process

<table>
<thead>
<tr>
<th>Steps</th>
<th>Done in collaboration with</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Analytical breakdown of the land use and food security system</td>
<td>Scientific coordinators and 80 international experts for 4 workshops</td>
</tr>
<tr>
<td>3. Building land-use scenarios</td>
<td></td>
</tr>
<tr>
<td>4. Examining the impact of each land use scenario on food security</td>
<td></td>
</tr>
</tbody>
</table>
Agrimonde-Terra organization

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(iii) “Cropping systems”: D. Makowski (Inra), E. Malézieux & F. Maraux (Cirad)
(iv) “Livestock systems” A. Ickowitz & P. Lecomte (Cirad) & P. Lescoat (APT)

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2. Determinants of land use and food security

Marie de Lattre-Gasquet
Cirad
The land use and food security system and the five dimensions of land use

- Global context (Governance, Economic development (inc. trade) and resources (inc. energy), Human development)
- Climate
- External drivers of changes
- Food diets

LAND USE SYSTEM
- Livestock systems
- Farm structures
- Cropping systems
- Urban-rural relationships
- Forest systems

LAND USE SCENARIOS
5 dimensions: agronomic potential, access to land, distribution of land between different uses, degree of intensity of land use, and services provided by land

CONSEQUENCES ON FOOD AND NUTRITION SECURITY
4 dimensions: availability, access, utilization, stability
### Global context 2050

<table>
<thead>
<tr>
<th>Sustainable and cooperative world</th>
<th>Regionalization and energy transition</th>
<th>Economic and political fragmentation</th>
<th>Conventional development led by market forces</th>
<th>Non-State actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>States cooperate with businesses, CSO, international institutions</td>
<td>States join in large regional blocs</td>
<td>Crises amplifying each other</td>
<td>MNCs, investments funds and international organizations</td>
<td>Networks of NGOs, associations, MNCs, foundations, academic institutions.</td>
</tr>
<tr>
<td>GDP per cap: 20 000$ Trade liberalization</td>
<td>GDP per cap: 20 000$ Regional trade</td>
<td>GDP per cap: 18 000$ Limited trade</td>
<td>GDP per cap: 24 000$ Low trade barriers</td>
<td>No trade barriers. Globalization</td>
</tr>
<tr>
<td>Commitment to climate change mitigation and regulation of nutritional quality of foods</td>
<td>Commitment to food sovereignty and subsidiarity High level of biomass energy</td>
<td>Informal economy</td>
<td>Low cost of fossil fuel. Science will overcome limits of natural resources</td>
<td>Commitment to climate change stabilization, fight against poverty</td>
</tr>
</tbody>
</table>

Demographic hypothesis: 9.7 billion persons in 2050
### Climate 2050

<table>
<thead>
<tr>
<th>Stabilisation of global warming</th>
<th>Moderate warming</th>
<th>Runaway climate change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global temperature below +1°C to 2050</td>
<td>Global temperature reach +1°C in 2050</td>
<td>Global temperature: +2°C in 2050</td>
</tr>
<tr>
<td>Limited changes in precipitation &lt;=+0.05 mm/day in 2100</td>
<td>Changes in precipitation +0.08 mm/day in 2100</td>
<td>Changes in precipitation +0.15 mm/day in 2100</td>
</tr>
<tr>
<td>No change in world cultivable land area</td>
<td>Moderate increase in world cultivable area, increase in Northern latitude and decrease in the tropics</td>
<td>Increase in world cultivable area, increase in Northern latitude, but decrease in the tropics</td>
</tr>
<tr>
<td>No impact on crop yields</td>
<td>Moderate negative impact on crop yields (in average)</td>
<td>In average negative impact on crop yields</td>
</tr>
<tr>
<td>102 EJ biomass</td>
<td>150 EJ biomass</td>
<td>60 EJ biomass</td>
</tr>
</tbody>
</table>
Quantitative hypotheses: Average world in 2010 and in 2050 following the various food diets Pathways; but regional differences
<table>
<thead>
<tr>
<th>Large metropolitan regions</th>
<th>Multi-local and multi-active households in a rural-urban archipelago</th>
<th>Rural areas integrated within urban networks through value chains</th>
<th>Urban fragmentation and counter-urbanization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massive rural migration in large metropolitan centers. Consumerism, standardization of lifestyles</td>
<td>Temporary migrations to cities. Multi-activity in rural households</td>
<td>Medium-size cities. Rural development based on agri-food activities</td>
<td>Redeployment of population growth to medium-size and small cities. Increase in rural population and agricultural workers</td>
</tr>
</tbody>
</table>
Farm structures 2050

Hit and run strategy for agro-investment

Resilient farms embedded in urban processes

Independent farms but commercial dependency

Farms producing goods and services to community

Agricultural cooperatives emphasizing quality

Marginalized farms for livelihood survival
### Cropping systems

<table>
<thead>
<tr>
<th>Conventional intensification</th>
<th>Sustainable intensification</th>
<th>Agro-ecology</th>
<th>Collapse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yields increase via simplification, specialization industrial inputs</td>
<td>Input substitution or maximisation of inputs efficiency</td>
<td>Redesign cropping systems: crops diversification, agroforestry, biological control...</td>
<td>Impasses due to cropping systems weaknesses: climatic, biotechnical, socio-economic</td>
</tr>
<tr>
<td>No attention to environmental impact. End of pipe approach</td>
<td>Intensification with reduction of environmental impact</td>
<td>Autonomy and economic and ecosystemic resilience</td>
<td></td>
</tr>
</tbody>
</table>

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Dancette© Cirad Torquebiau© Cirad
Cropping systems 2050

Per-hectare yield of wheat in 2010 and in 2050 under the different cropping systems pathways, various regions
Cropping systems 2050

Per-hectare yield of other cereals in 2010 and in 2050 under the different cropping systems pathways, various regions
# Livestock systems

<table>
<thead>
<tr>
<th>Conventional intensive livestock with local resources</th>
<th>Agro-ecological livestock on land in synergy with agriculture or urbanization</th>
<th>Livestock on marginal land</th>
<th>Backyard livestock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional availability of forage, concentrates and by-products. Scarce land → competition with crops</td>
<td>Global availability of forage, concentrates and by-products, as well as genetics, medication, etc.</td>
<td>Autonomy in feed and inputs. Local land used for feed and pastures. Hardy animals</td>
<td>Raising ruminants on extensive or pastoral systems. Use of land with medium to low agronomic potential. Synergy between production and environment. Low dependency on inputs, feed. Essential for household’s food security.</td>
</tr>
</tbody>
</table>

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No specific hypotheses prepared but mitigation hypotheses (driver: climate change) may impact the forest sector and area.

As far as the area is concerned, deforestation-afforestation is calculated ex-post as an outcome of the model. It is also checked ex-post that deforestation-afforestation is coherent with mitigation hypotheses.
The five Agrimonde-Terra scenarios and their assumptions

Olivier Mora
Inra
### Drivers and alternative hypotheses used in the scenarios

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Alternative assumptions for 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global Context</strong></td>
<td></td>
</tr>
<tr>
<td>Sustainable and cooperative world</td>
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</tr>
<tr>
<td>Stabilization of global warming</td>
<td>Moderate warming</td>
</tr>
<tr>
<td>Transition to diets based on ultra-processed products</td>
<td>Transition to diets based on animal products</td>
</tr>
<tr>
<td><strong>Climate Change</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Food Diets</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Urban – Rural Relationships</strong></td>
<td>Large metropolitan region</td>
</tr>
<tr>
<td>Marginalized farms for a livelihood survival</td>
<td>Hit-and-run strategy for agro-investment</td>
</tr>
<tr>
<td>Backyard livestock</td>
<td>Conventional intensive livestock with local resources</td>
</tr>
<tr>
<td>Collapsing cropping systems</td>
<td>Conventional intensification</td>
</tr>
</tbody>
</table>
Five scenarios of land use and food security in 2050

With the Scenario Advisory Committee, we developed alternative futures by combining all the drivers of the system.

Three scenarios based on current trends:
• Land use driven by metropolization
• Land use for regional food system
• Land use for multi-active and mobile households

Two scenarios based on potential breaks:
• Land use for food quality and healthy nutrition
• Land as commons for rural communities in a fragmented word
Land Use Driven by Metropolization

- megacities, international trade, spatial and economic inequalities, high levels of migration from rural areas
- globalized food value chains and urbanization drive diet transition toward ultra-processed and animal products
- conventional development and strong climate change
- conventional intensification of livestock and crop systems linked to global value chains; maize, wheat, soyabean, rice
- spatial segregation: areas without connexion with international markets, rural areas with poor small farmers
- price volatility - food crises for vuln. pop.
- High levels of diet-related non-communicable diseases and obesity
Land Use for Regional Food Systems

- supranational regional blocs
- medium-size cities connecting rural and large urban areas
- food sovereignty and subsidiarity
- reconnection agri-food industry with regional production, positive knock-on effect for agriculture and for rural dev.

- Distinct dominant productions by region: tuber and root crops // coarse grains // pulses // fruits and vegetables
- agricultural cooperatives and contract agreements with agrofood industries
- animal feed sourced from region,
- crops varieties suited to regional climatic situations
Land Use for Multi-Active and Mobile Households

- **highly globalized** and hybrid world
- **ad hoc networks** supersed sovereign governments, public debates
- **rural-urban mobility**
- supply chain **disintermediation**, 
- **concerned groups** engaged with farming, nutrition and health, climate change, biodiversity, water quality and local identity

- households both in rural and urban areas, in farm and **non-farm activities**
- **numeric platforms drive organizational and technical innovations** in food value chains
- **diverse farm structures**, from small farms with family labor to highly-capitalized farms
- multi-activity systems ensure food security for households by **diversifying income** and access to foodstuffs
Land Use for Food Quality and Healthy Nutrition

- **Global cooperation** to stabilize climate change
- **Policy** measures to shift consumption patterns towards **healthier diets**
- **Diets lower** in animal products (in developed countries), fats, ultra-processed foods, sugars and sweeteners, and **higher** in fresh produce, coarse grains and pulses
- **Rural-urban integration**
- **Diverse**, high-quality agricultural products
- **Rediversification** of crops, and crop systems / agroecology
- Livestock **associated** with crops
- Agricultural coops and farms embedded in rural-urban relationships
- **Reduced** food losses and **waste**
- **Limiting** agricultural GHG, increasing **carbon storage** in soil
Land as Commons for Rural Communities in a Fragmented World

- **crises**: financial, energy, geopolitical and ecological; fragmentation
- **slow down in urban concentration**: increase of medium-size and small towns, and of rural population in some regions.

// organization in communities, to develop agro-ecological farms:
- sustainable production of foodstuffs, energy and environmental services;
- **agroecology based** on biological self-regulation and community...

// subsistence farming elsewhere:
- declining farm sizes and conventional intensification ... **overexploitation or over-intensification**

- fragility of technical systems and the lack of a resource management strategy...

Food insecurity
## Five scenarios of land use and food security in 2050

<table>
<thead>
<tr>
<th>Land Use Driven by Metropolization</th>
<th>Land Use for Regional Food Systems</th>
<th>Land Uses for Multi-active and Mobile Households</th>
<th>Land Use for Food Quality and Healthy Nutrition</th>
<th>Land as Commons for Rural Communities in a Fragmented World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metropolization</td>
<td>Regionalization</td>
<td>Households</td>
<td>Healthy</td>
<td>Communities</td>
</tr>
<tr>
<td>Global markets, megacities and spatial divide with rural areas, global food value chains, ultra-processed and animal-based foods. external feed-livestock, conventional intens., Small farmers marginalized diet-related diseases</td>
<td>Supranational regional blocs, medium-size cities linked with rural areas, regional food systems and diets, food sovereignty and subsidiarity. re-location of livestock and crop systems, association of prod. and cons.</td>
<td>Globalization based on non-State actor and networks, value chain disintermediation, rural-urban mobility. Agricultural households: multi-activity, multi-local, non-farm activities, Diverse farm structures</td>
<td>Global cooperation, climate change stabilization, international policies on health and nutrition, food diversification crop system diversification, agroecology, crop–livestock integration, soil carbon storage</td>
<td>Global fragmentation Crises: governance, economic, energy and ecology. local communities, commons, agro-ecology. collapse of cropping systems, subsistence farming. food insecurity</td>
</tr>
</tbody>
</table>
### Impacts of the scenarios on land use (1)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>«Variants» (assumptions used)</th>
<th>Running name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metropolization</td>
<td>With ultra-processed products: Transition to diets based on ultra-processed products</td>
<td>Metropolization_Ultrap</td>
</tr>
<tr>
<td></td>
<td>With animal products: Transition to diets based on animal products</td>
<td>Metropolization_Animp</td>
</tr>
<tr>
<td>Regionalization</td>
<td>With agricultural technology A: Sustainable intensification for cropping systems + Conventional intensification with local resources for livestock systems</td>
<td>Regionalization_A</td>
</tr>
<tr>
<td></td>
<td>With agricultural technology B: Agroecology for cropping systems + Agroecological livestock</td>
<td>Regionalization_B</td>
</tr>
<tr>
<td>Healthy</td>
<td>With agricultural technology C: Sustainable intensification for cropping systems + Agroecological livestock</td>
<td>Healthy_C</td>
</tr>
<tr>
<td></td>
<td>With agricultural technology D: Agroecology for cropping systems + Agroecological livestock</td>
<td>Healthy_D</td>
</tr>
<tr>
<td>Communities</td>
<td>With agroecology: Agroecology for cropping systems + Agroecological livestock</td>
<td>Communities_AE</td>
</tr>
<tr>
<td></td>
<td>With collapse: Collapse of crop production + Backyard livestock</td>
<td>Communities_Collapse</td>
</tr>
</tbody>
</table>
### Impacts of the scenarios on land use at the world level (2)

<table>
<thead>
<tr>
<th>Land use changes in Mha</th>
<th>Total agricultural land area</th>
<th>Arable and permanent crops (cropland) area</th>
<th>Permanent meadows and pastures (pastureland) area</th>
<th>Forest land area</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Metropolization&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Metropolization_Ultrap</td>
<td>-54 (-1%)</td>
<td>+243 (+16%)</td>
<td>-297 (-9%)</td>
<td>+11 (+0.3%)</td>
</tr>
<tr>
<td></td>
<td>+1318 (+27%)</td>
<td>+620 (+40%)</td>
<td>+698 (+21%)</td>
<td>-1297 (-32%)</td>
</tr>
<tr>
<td>- Metropolization_Animp</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regionalization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Regionalization_A</td>
<td>+249 (+5%)</td>
<td>+70 (+4.5%)</td>
<td>+179 (+5.5%)</td>
<td>-352 (-9%)</td>
</tr>
<tr>
<td></td>
<td>+691 (+14%)</td>
<td>+174 (+11%)</td>
<td>+517 (+15.5%)</td>
<td>-733 (-19%)</td>
</tr>
<tr>
<td>- Regionalization_B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Healthy_C</td>
<td>+29 (+0.6)</td>
<td>-56 (-4%)</td>
<td>+85 (+2.5%)</td>
<td>-62 (-1.5%)</td>
</tr>
<tr>
<td></td>
<td>+269 (+5.5%)</td>
<td>+50 (+3%)</td>
<td>+219 (+6.5%)</td>
<td>-279 (-7%)</td>
</tr>
<tr>
<td>- Healthy_D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Communities_AE</td>
<td>+142 (+3%)</td>
<td>+277 (+18%)</td>
<td>-135 (-4%)</td>
<td>-154 (-4%)</td>
</tr>
<tr>
<td></td>
<td>+2013 (+41%)</td>
<td>+555 (+36%)</td>
<td>+1458 (+43.5%)</td>
<td>-1863 (-46%)</td>
</tr>
</tbody>
</table>
First elements of comparaison of the five scenarios

• A diversity of pathways for land use and food security in 2050

• Strong uncertainties regarding:
  – impact of climate change and global socio-economic context,
  – extent and nature of diet transition,
  – rural transformation and urbanisation,
  – livestock and cropping systems changes

• Two scenarios with extreme consequences on both land use and food security: metropolization (globalization) and communities (fragmentation)

• And three possible pathways to reduce impacts on land use and to improve food security: healthy, regionalization, households

• But with limits and with diverse impacts on regions...
Consequences of the five scenarios on land use and food security

Chantal Le Mouël
Inra
Some key elements for a good understanding of the land-use change simulation results

- The daily calories availability per capita increases in all scenarios in India and ECS Africa.
- The animal products content of the food diet increases in all scenarios in India, ECS Africa and West Africa.
- ECS Africa and West Africa are the both regions in the world where the population is expecting to increase the most up to 2050.
Some key elements for a good understanding of the land-use change simulation results

- Initially, agricultural production in West Africa and ECS Africa is very land demanding:
  - low per-hectare yields of crops
  - high feed-to-output ratios of livestock
Per-hectare yields for some cereals in 2010
Feed-to-output ratios for the various production systems in the dairy sector in 2010
Some key elements for a good understanding of the land-use change simulation results

- The GlobAgri-AgT model is a biomass balance model and involves rigidities:

  - through our hypotheses, we set:
    - food needs in each region
    - production performances per ha in each region
    - share of each region’s food needs covered by imports
  - and the model calculates:
    - cropland and pastureland area required

  no price signals indicating over- or under- supply, which would change decisions of agents and flows of trade
GlobAgri-AgT

- One resources-utilization balance equation per product per region (links between products)
- Imports as a fixed share of domestic total uses
- Exports as a fixed share of the world market
- one trade balance equation per product
- one constraint per region:
  - cropland ≤ max cultivable land area (GAEZ 1-4)
  - binding constraint: export coeff reduced; import coeff increased
- Pastureland adjusts freely
- Deforestation is calculated ex-post
Ensuring world food availability in 2050 will involve expanding world agricultural land ...
... especially pastureland ...
... to the detriment of forests
Ensuring world food availability in 2050 without further deforestation will crucially depend on agricultural technologies and their future changes.

- The land area required to cover the world food needs in 2050 differs widely according to scenarios but also according to technology variants within scenarios:
  - world agriculture less land demanding with technology variants A (Regionalization) and C (Healthy)
  - result from our hypotheses on changes in:
    - crop yields under « Sustainable intensification » and « Agroecology » for cropping systems
    - feed-to-output ratios in livestock sectors under « Conventional intensive livestock » and « Agroecological livestock »
Ensuring world food availability in 2050 without further deforestation will crucially depend on agricultural technologies and there future changes

- The land area required to cover the world food needs in 2050 will depend closely from:

  - the future change of cropping systems in regions with increasing population and nearly reaching their max cultivable land, such as India

  - the future change of livestock systems in regions where they are currently very land demanding and with highly increasing population such as West Africa and ECS Africa
Increasing food and nutritional diversity while limiting agricultural land expansion will require greater diversification in cropping and livestock systems

• Two scenarios involve increased food and nutritional diversity in 2050: Healthy and Regionalization
  - Healthy is less land demanding at the world level
  - increased food and nutritional diversity needs appropriate diversification of cropping and livestock systems (composition of rations)
  - implies huge changes of production systems in some regions such as Brazil/Argentina
Whatever the scenario, trade will play a key role for ensuring world food availability in 2050

Net import dependence: (imports-exports)/total uses (kcal)
Two scenarios are clearly not able to ensure world food security in 2050

• Metropolization:
  - overweight, obesity and diet-related diseases
  - degradation of resources and sensitive to climate change
  - increased instability on world agricultural markets
  - increased spatial and economic inequalities

• Communities:
  - serious tensions on land and degradation of resources
  - rebuilding local food systems based on agroecological cropping and livestock systems could be an option but ...
  - -10% decrease in daily calories availability per capita
  - food access difficulties in urban areas
Other scenarios are likely able to ensure world food security in 2050, but under conditions

- Healthy:
  - healthier diets, contributes most to reducing overnutrition and related diseases, but also undernutrition
  - limited agricultural land area expansion at world level
  - protection/restoration of natural resources
  - but potential tensions between food security and CC mitigation objectives

- Regionalization:
  - contributes to reducing overnutrition and related diseases
  - development of agri-food industries in small and medium-sized cities, contributes positively to rural development, rural employment, rural incomes
  - but significant land expansion
  - clearly unsustainable for some regions
Conclusion

• Strong, consistent and coordinated policies needed to impulse the change towards healthier diets while limiting agricultural land expansion:
  - Food and health policies
  - climate and energy policies; environmental policies
  - agricultural policies; rural and urban policies
  - trade policies

• Ensuring access to land for all types of farm structures is essential

• The change in rural-urban relationships is a key driver
Conclusion

• Further research is needed:

  - Assessment of relative economic, nutritional, environmental and social performances of cropping and livestock systems

  - livestock and pasture

  - Hypotheses for the future of Future of food wastes &losses

  - Assessment of the impacts of the scenarios in terms of GHG emissions
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