

ALLENVI - Alimentation et changements majeurs

Agrimonde-Terra

Land use and global food security  
in 2050

A FORESIGHT EXERCISE



Tuesday June 28, 2016  
Paris, INRA, 147 rue de l'Université

- 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



# Why Agrimonde-Terra ?

**On-going challenges:** 795 million undernourished and 1.9 billion overweight adults. Nutritional deficiencies

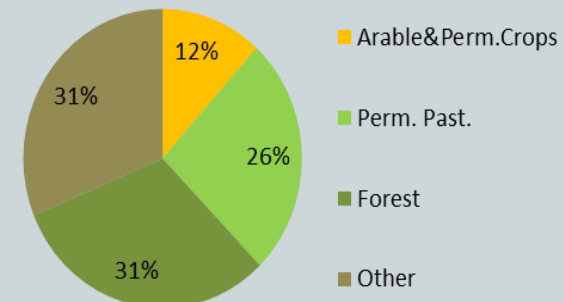
## Growing competition on land:

- 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

→ **Environmental challenges and their human roots concern and affect us all**



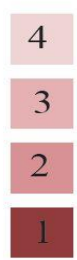
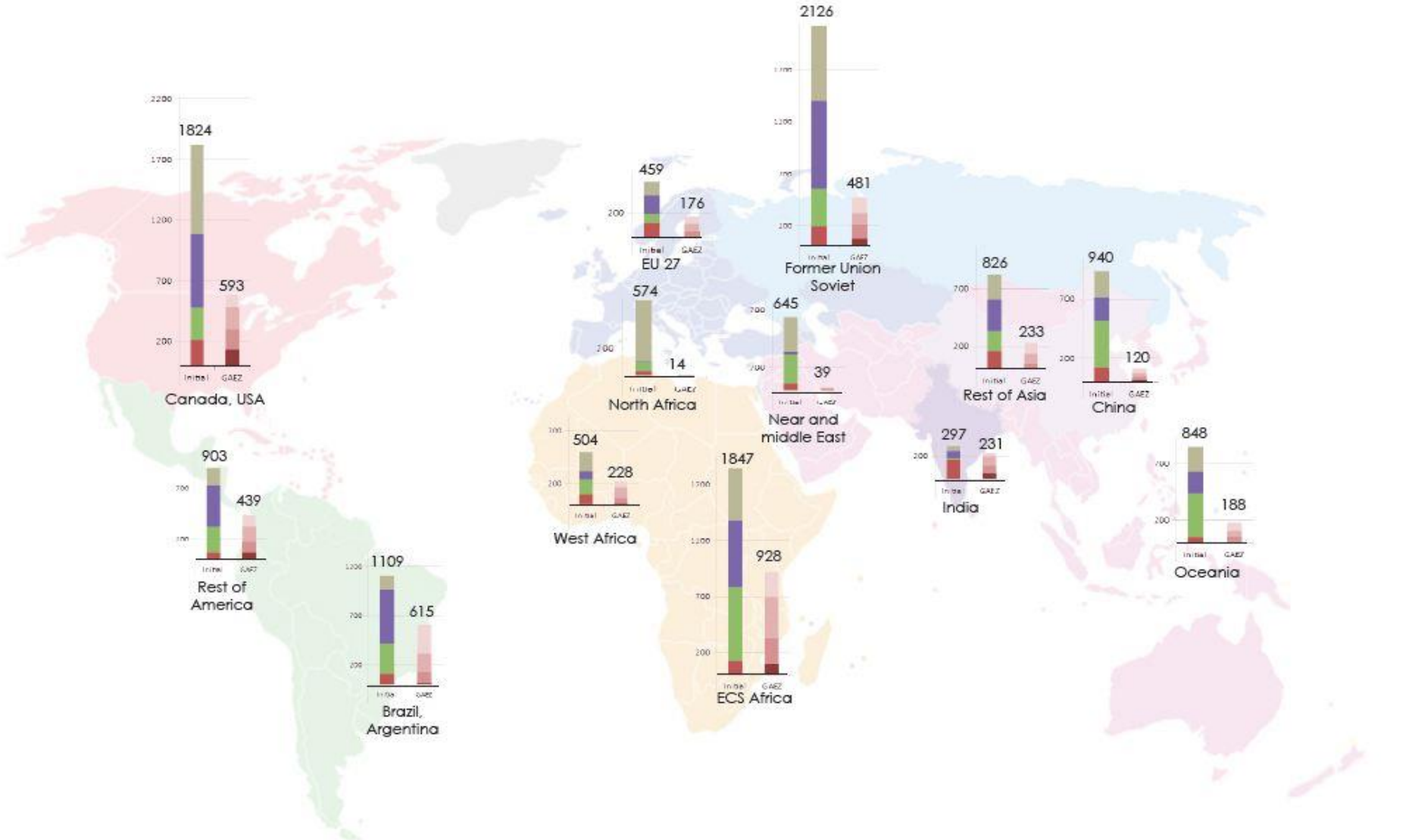
# Objectives of Agrimonde-Terra

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



GAEZ



# A four-step participative process

Steps	Done in collaboration with
1. Analytical breakdown of the land use and food security system	Scientific coordinators and 80 international experts for 4 workshops
2. Building hypotheses for direct and external drivers of change	
3. Building land-use scenarios	Scenario Advisory Committee (4 meetings: Dec. 2014, April 2015, Feb. 2016, April 2016)
4. Examining the impact of each land use scenario on food security	



# Agrimonde-Terra organization

## Project team:

**M. de Lattre-Gasquet** (Cirad, coordinator), **Ch. Le Mouël** (Inra, coordinator), **O. Mora** (Inra, organizer for scenario building), C. Donnars (Inra), P. Dumas (Cirad) & O. Rechauchère (Inra), in collaboration with M. Barzman (Inra), T. Brunelle (Cirad), A. Forslund (Inra), E. Marajo-Petizon (Inra), S. Manceron (Inra), P. Marty (Inra) & C. Moreau (Cirad).

## Thematic workshops and scientific coordinators:

- (i) *“Urban-rural relationships”*: F. Aubert (Agro-Sup, Dijon) & F. Lançon (Cirad)
- (ii) *“Structures of production”*: J. Marzin (Cirad) & L. Piet (Inra)
- (iii) *“Cropping systems”*: D. Makowski (Inra), E. Malézieux & F. Maraux (Cirad)
- (iv) *“Livestock systems”* A. Ickowitz & P. Lecomte (Cirad) & P. Lescoat (APT)

## Scenario Advisory Committee:

A. Andersson Djurfeldt (LundUniversity, Sweden), L. Ben Becher (Synagri, Tunisia), M. Elloumi (Inrat, Tunisia), A. Faye (IPAR, Senegal), R. Guissou / Y. G. Bazie (Ministry of Agriculture and Food Security, Burkina Faso), H. Kray (World Bank, USA), J. Lewis (Terra Global Capital, USA), P. Meyfroidt (Louvain University, Belgium), M. Mueller (FAO, Italy), S. Msangui (IFPRI, USA), A. Onorati (International Planning Committee on Food Sovereignty, Italy), S. Parmentier (Oxfam, Belgium), A. Retière (Cap 2100, France), R. Sonnino (Cardiff University, UK), S. Treyer (IDDRI, France), D. van der Mensbrugge (AgMIP, Purdue University, USA), J. Vervoort (CCAFS and Oxford University, UK), H. Zehni (IFAD, Italy).

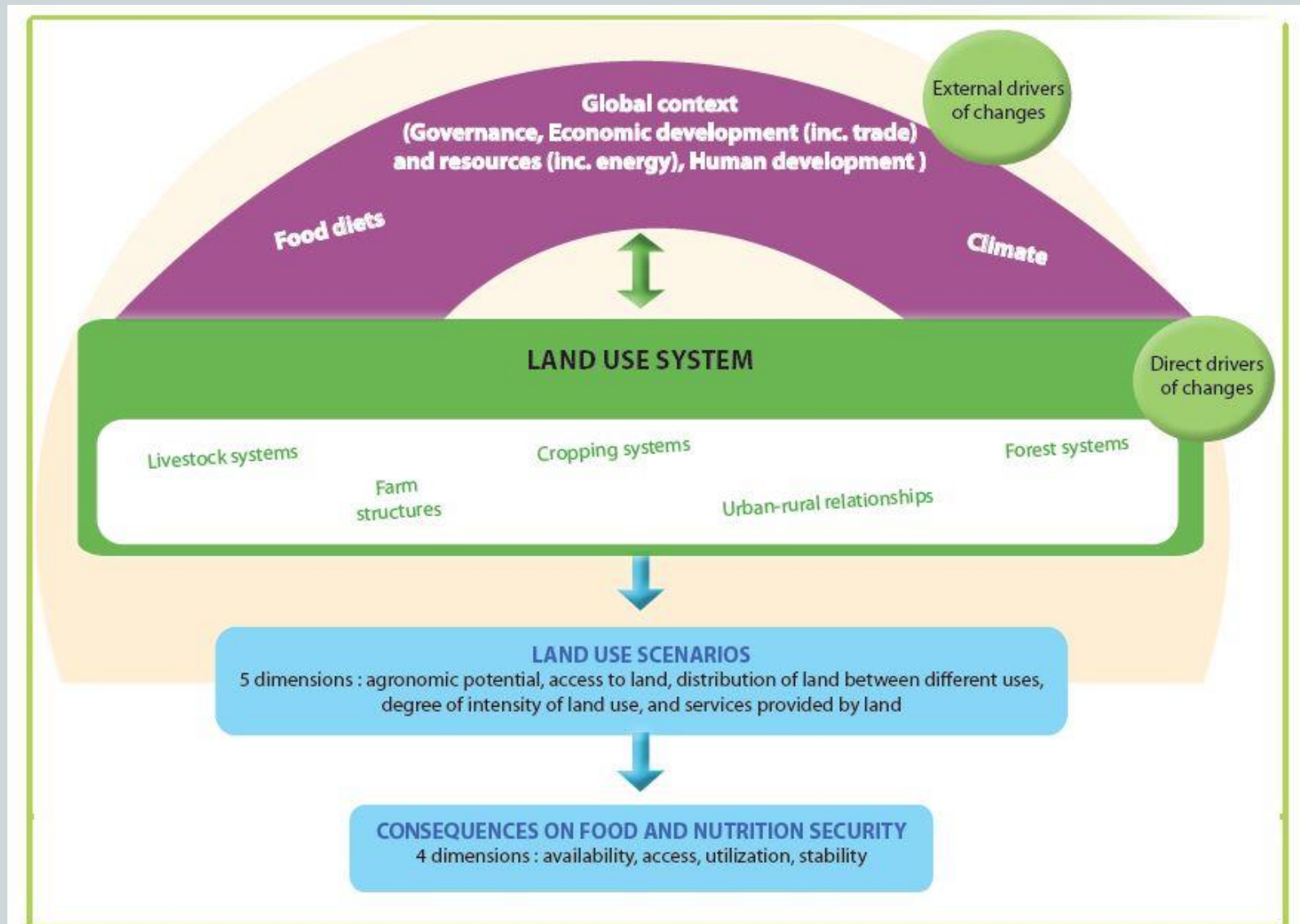
## **2. Determinants of land use and food security**

**Marie de Lattre-Gasquet**

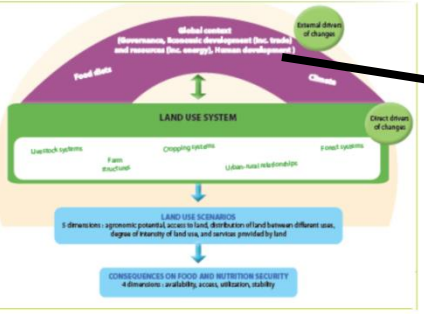
**Cirad**



# The land use and food security system and the five dimensions of land use



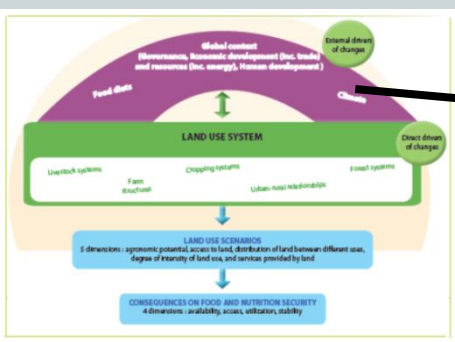
# Global context 2050



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

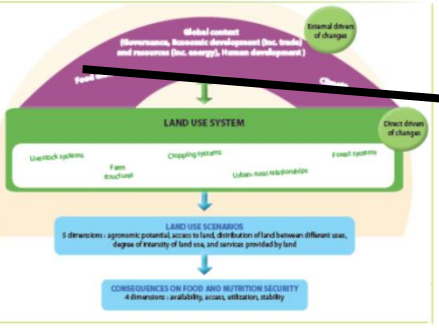
Demographic hypothesis : 9,7 billion persons in 2050

# Climate 2050



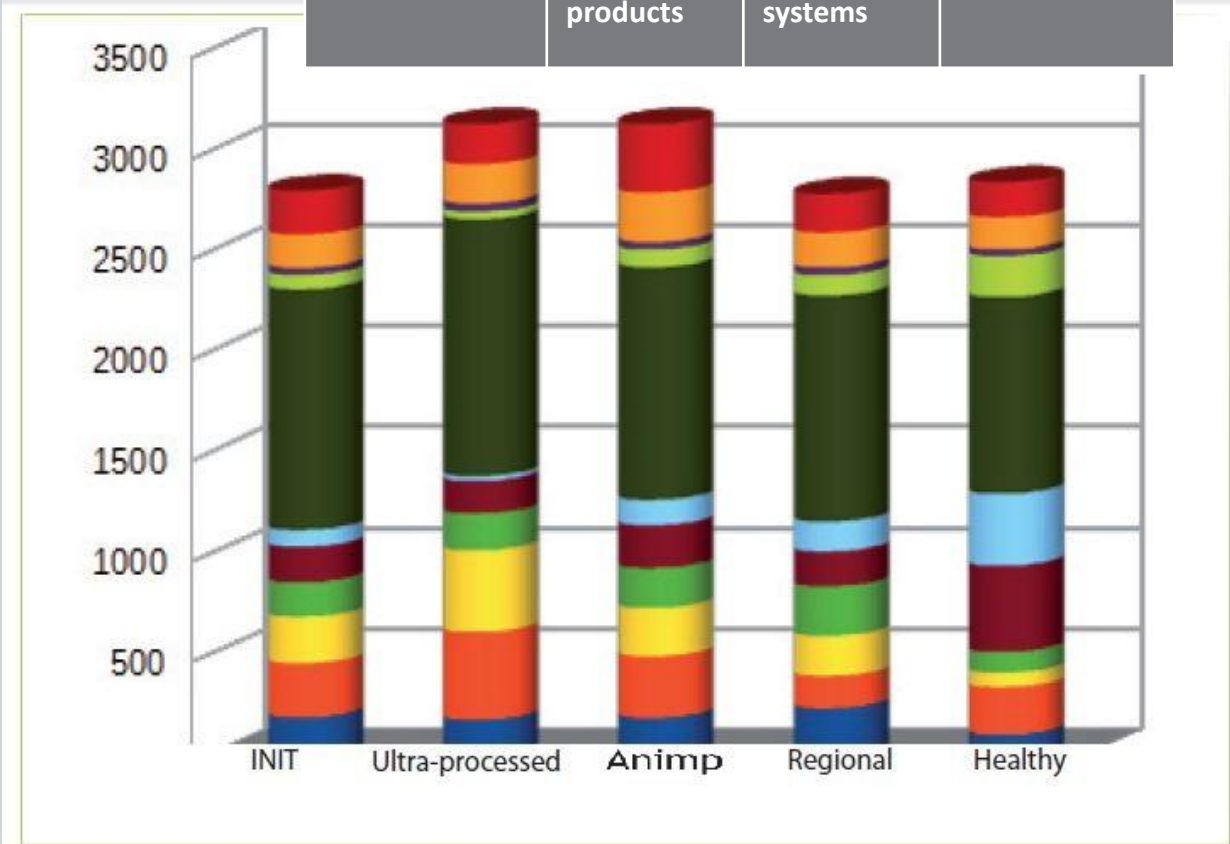
Stabilisation of global warming	Moderate warming	Runaway climate change
Global temperature below +1°C to 2050	Global temperature reach +1°C in 2050	Global temperature: +2°C in 2050
Limited changes in precipitation <+0.05 mm/day in 2100	Changes in precipitation +0.08 mm/day in 2100	Changes in precipitation +0.15 mm/day in 2100
No change in world cultivable land area  No impact on crop yields	Moderate increase in world cultivable area, increase in Northern latitude and decrease in the tropics Moderate negative impact on crop yields (in average)	Increase in world cultivable area, increase in Northern latitude, but decrease in the tropics In average negative impact on crop yields
102 EJ biomass	150 EJ biomass	60 EJ biomass

# Food diets 2050



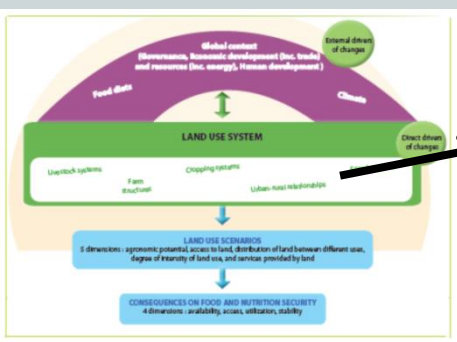
Quantitative hypotheses:  
Average world in 2010 and in 2050 following the various food diets Pathways; but regional differences

- Transition to diets based on ultraprocessed products
- Transition to diets based on animal products
- Regional diversity of diets and food systems
- Healthy diets based on food diversity



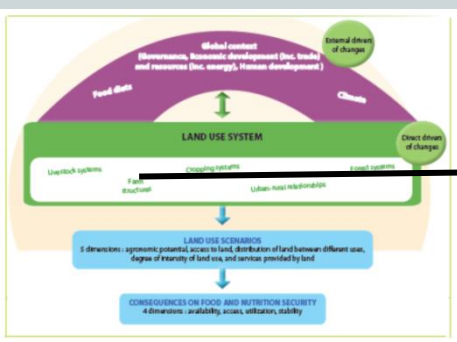
- Meat
- Dairy and Eggs
- Aquatic animal products
- Pulses
- Maize, Rice and Wheat
- Other cereals
- Fruits and vegetables
- Roots and Tuber
- Sugar and sweeteners
- Vegetable Oils
- Other

# Rural–urban relationships 2050



Large metropolitan regions	Multi-local and multi-active households in a rural-urban archipelago	Rural areas integrated within urban networks through value chains	Urban fragmentation and counter-urbanization
<p>Massive rural migration in large metropolitan centers. Consumerism, standardization of lifestyles</p>	<p>Temporary migrations to cities. Multi-activity in rural households</p>	<p>Medium-size cities. Rural development based on agri-food activities</p>	<p>Redeployment of population growth to medium-size and small cities. Increase in rural population and agricultural workers</p>

# Farm structures 2050



Hit and run strategy for agro-investment



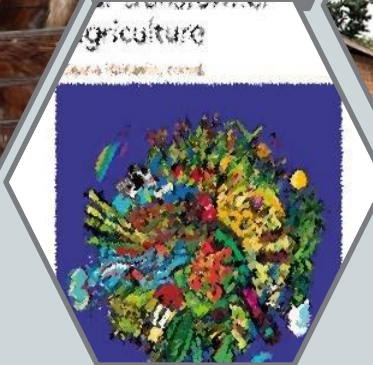
Resilient farms embedded in urban processes



Independent farms but commercial dependency



Farms producing goods and services to community



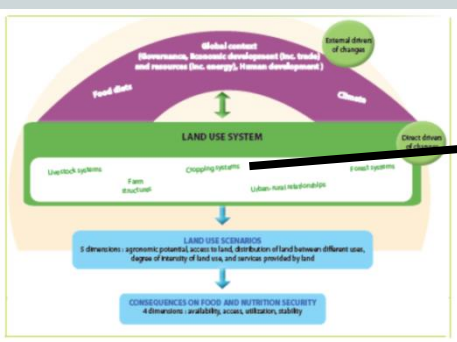
Agricultural cooperatives emphasizing quality



Marginalized farms for livelihood survival



# Cropping systems



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

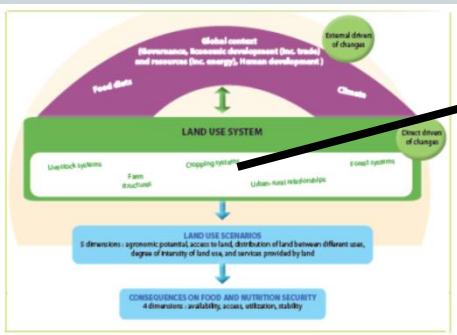


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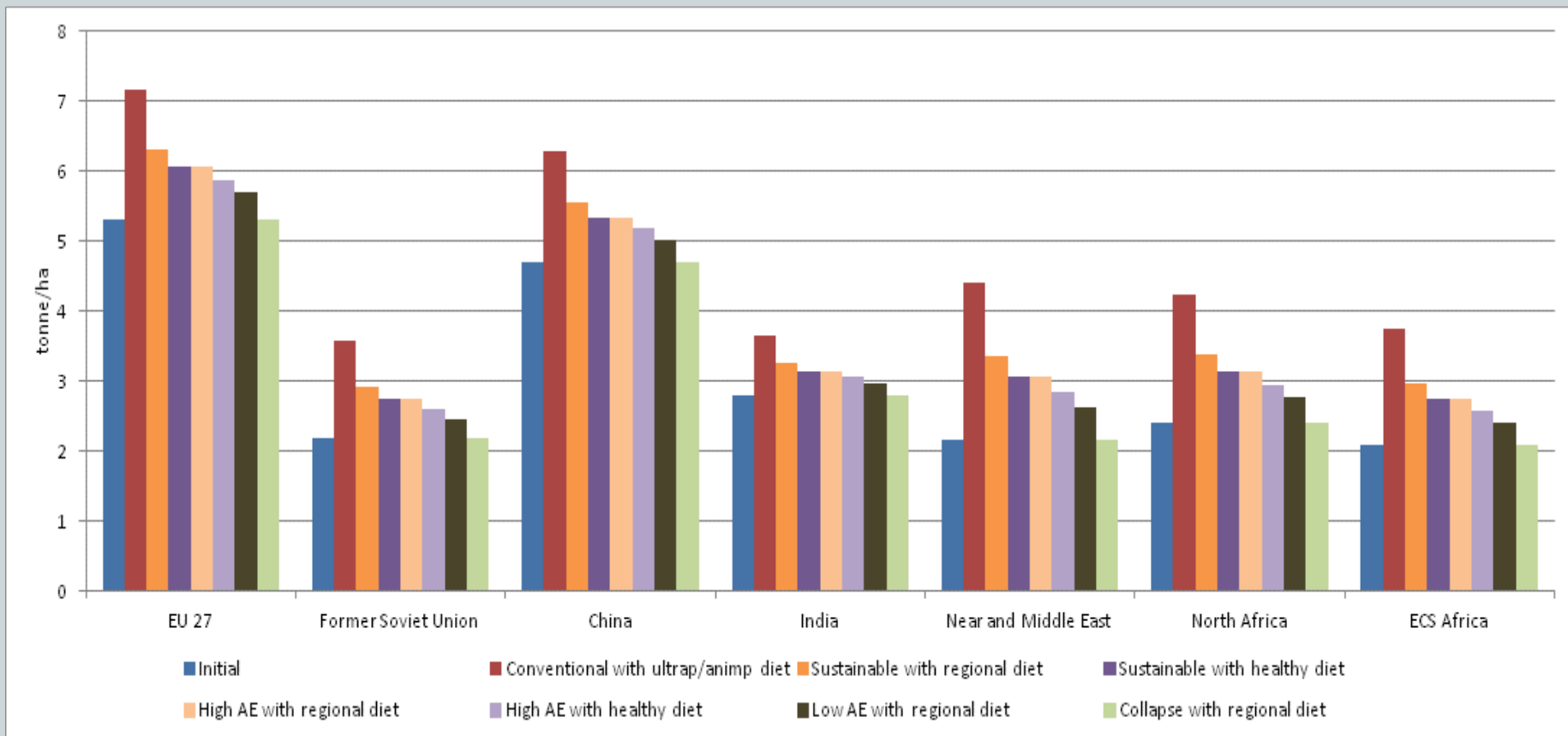
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# Cropping systems 2050

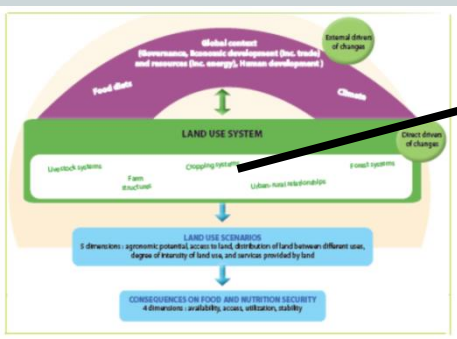


# Cropping systems 2050

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

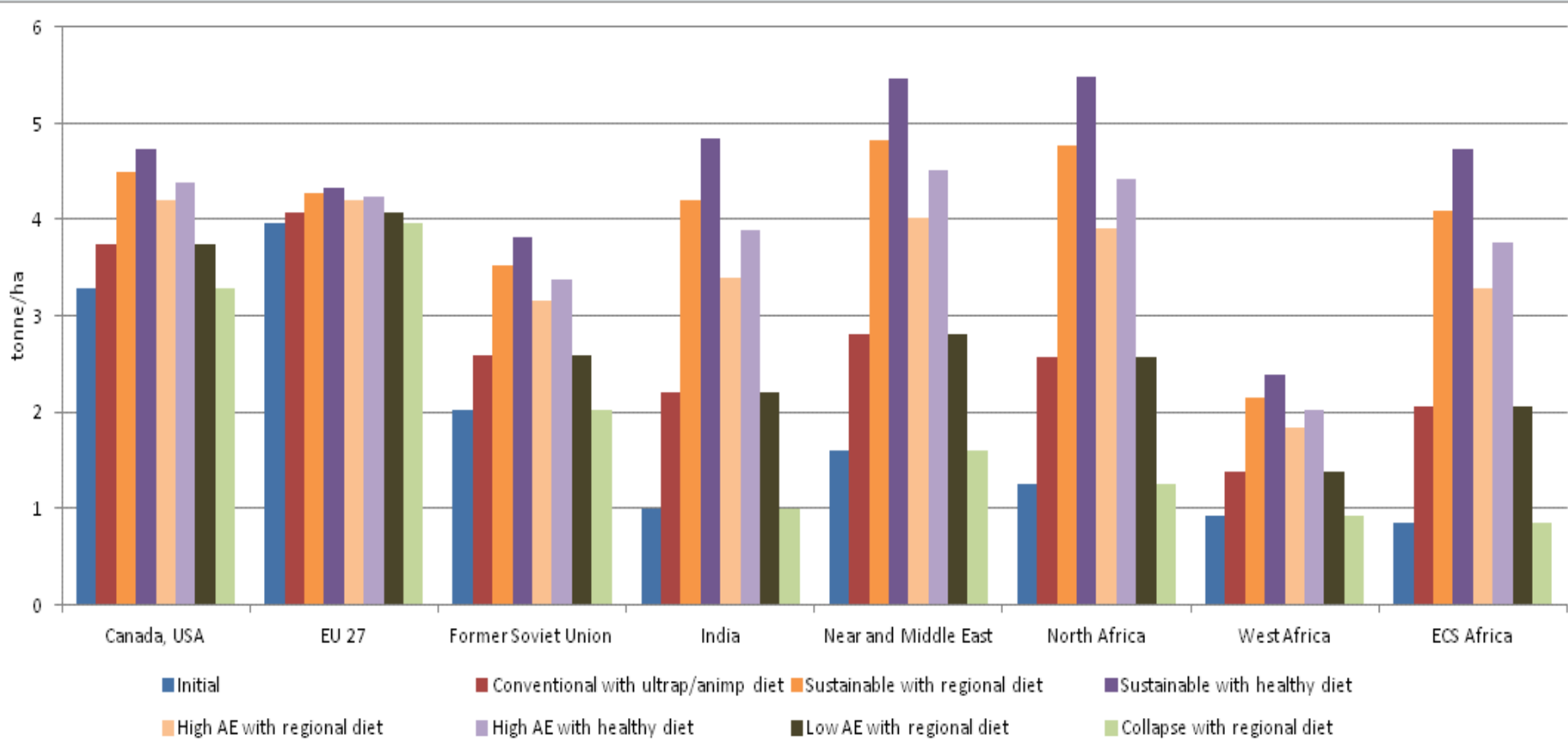


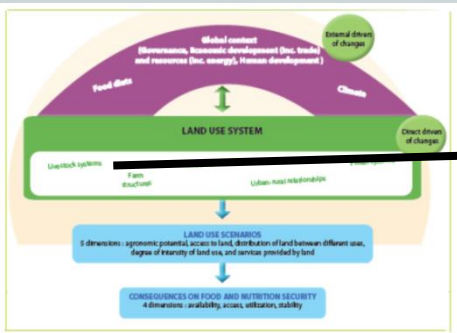
# Cropping systems 2050



# Cropping systems 2050

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





# Livestock systems

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



Dugué© Cirad



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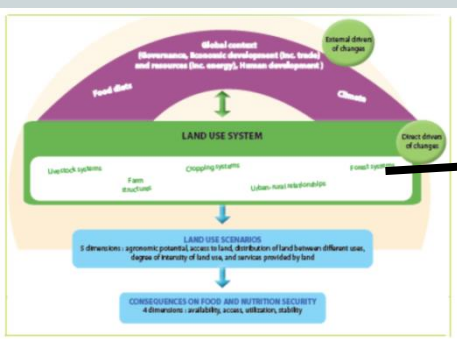
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Penot© Cirad



Janelle© Cirad



# Forestry systems

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

# **3. The five Agrimonde-Terra scenarios and their assumptions**

**Olivier Mora**

**Inra**



# Drivers and alternative hypotheses used in the scenarios

Drivers	Alternative assumptions for 2050					
Global Context	Sustainable and cooperative world	Regionalization and energy transition	Economic and political fragmentation	Conventional development by market forces	Non-State actors	
Climate Change	Stabilization of global warming		Moderate warming	Runaway climate change		
Food Diets	Transition to diets based on ultra-processed products	Transition to diets based on animal products	Healthy diets based on food diversity	Regional diversity of diets and food systems		
Urban – Rural Relationships	Large metropolitan region	Multilocal and multi-active households in rural–urban archipelagos		Rural areas integrated within urban networks through value chains	Urban fragmentation and counter-urbanization	
Farm Structures	Marginalized farms for a livelihood survival	Hit-and-run strategy for agro-investment	Independent farms but commercial dependency	Farms producing goods and services to surrounding community	Agricultural cooperatives emphasizing quality	Resilient farms embedded in urban processes
Livestock Systems	Backyard livestock	Conventional intensive livestock with local resources	Conventional intensive livestock with imported resources	Agro-ecological live-stock on land in synergy with agriculture or urbanization	Livestock on marginal land	
Cropping Systems	Collapse of cropping systems	Conventional intensification	Sustainable intensification	Agro-ecology		

# Five scenarios of land use and food security in 2050

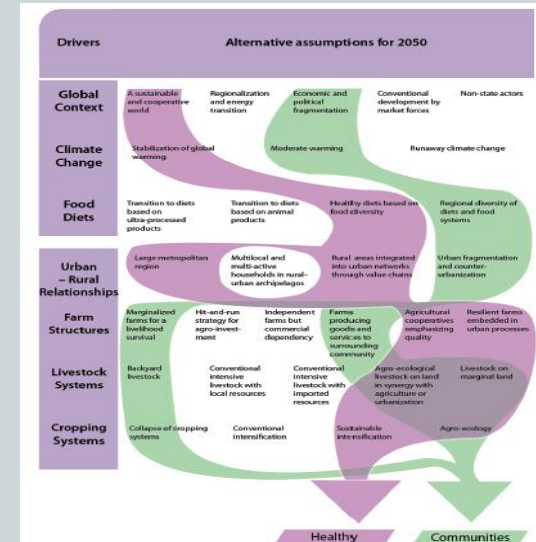
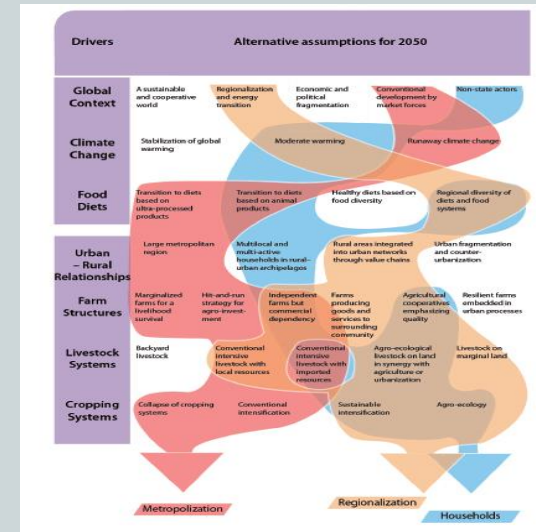
With the Scenario Advisory Committee, we developed alternative futures by combining all the drivers of the system.

Three scenarios based on current trends:

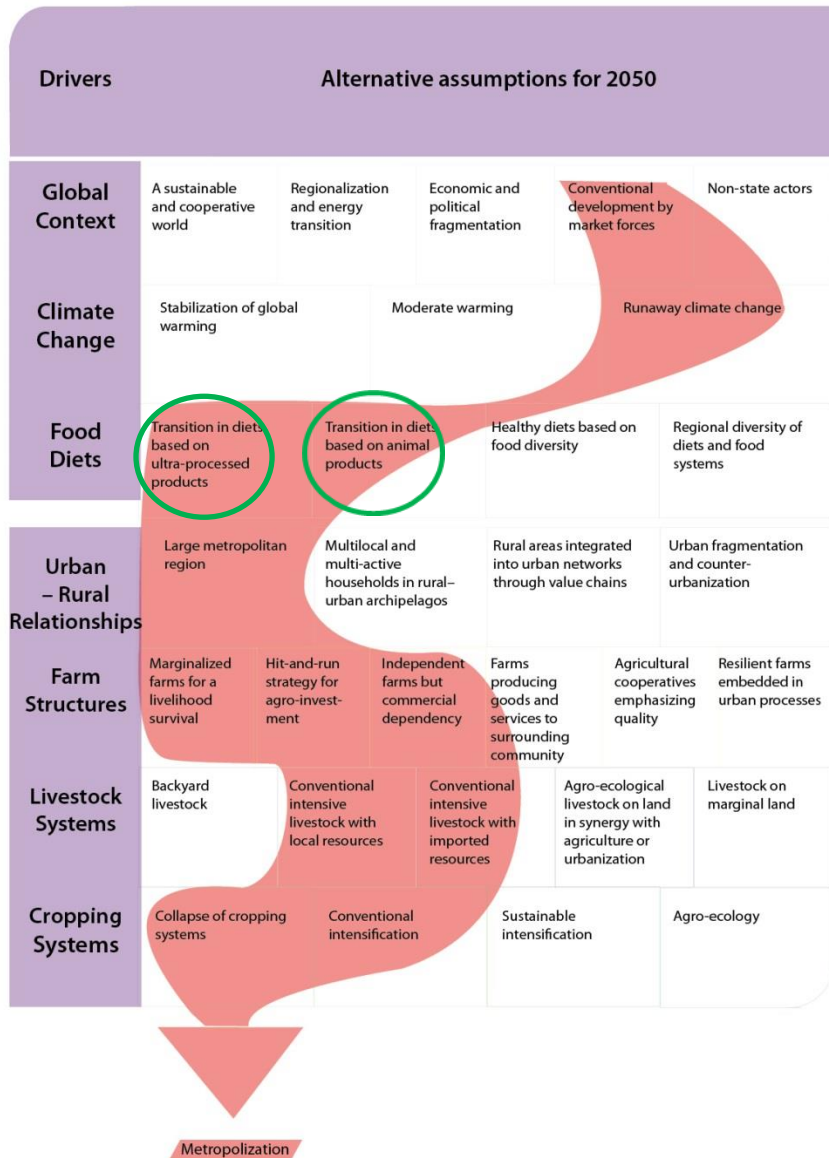
- Land use driven by metropolization
- Land use for regional food system
- Land use for multi-active and mobile households

Two scenarios based on potential breaks:

- Land use for food quality and healthy nutrition
- Land as commons for rural communities in a fragmented world



# Land Use Driven by Metropolization



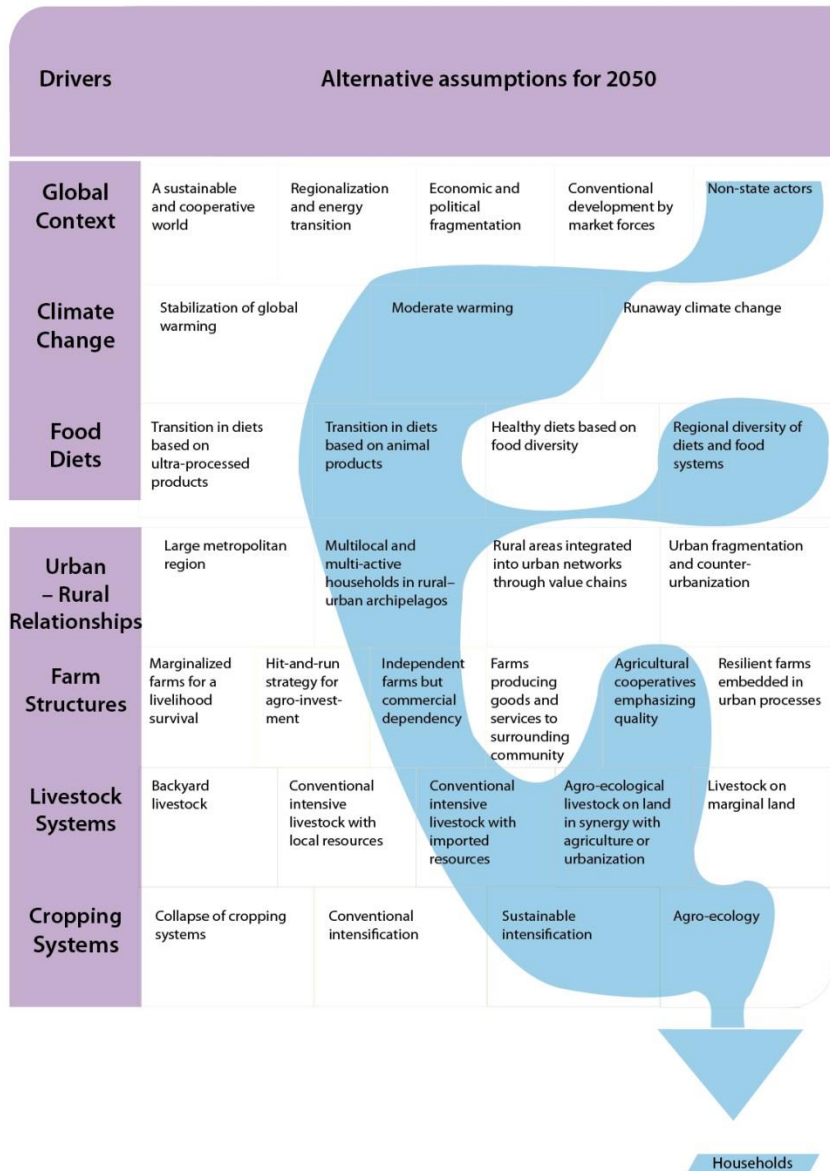
- **megacities, international trade, spatial and economic inequalities, high levels of migration from rural areas**
- **globalized food value chains and urbanization drive diet transition toward ultra-processed and animal products**
- **conventional development and strong climate change**
- **conventional 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



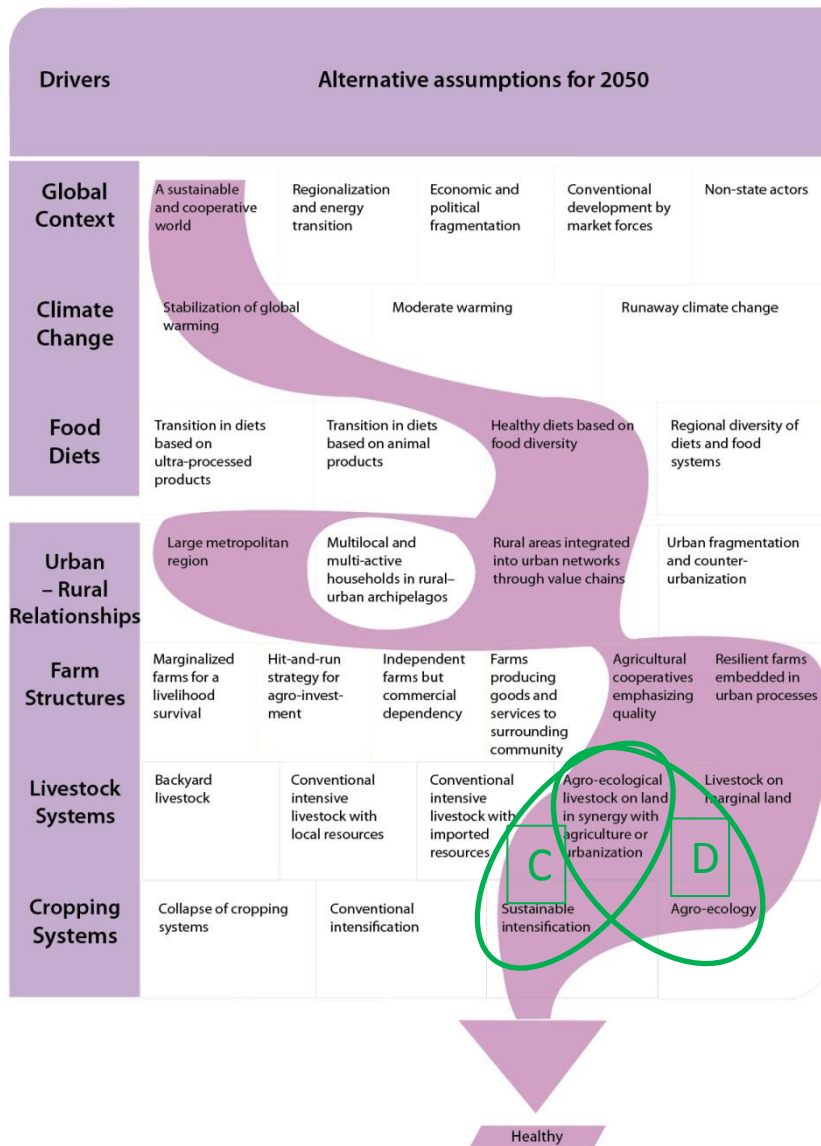
- **supranational regional blocs**
- medium-size cities connecting rural and large urban areas
- **food sovereignty and subsidiarity**
- **reconnection agri-food industry with regional production**, positive knock-on effect for agriculture and for **rural dev.**
- Distinct dominant productions by region: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



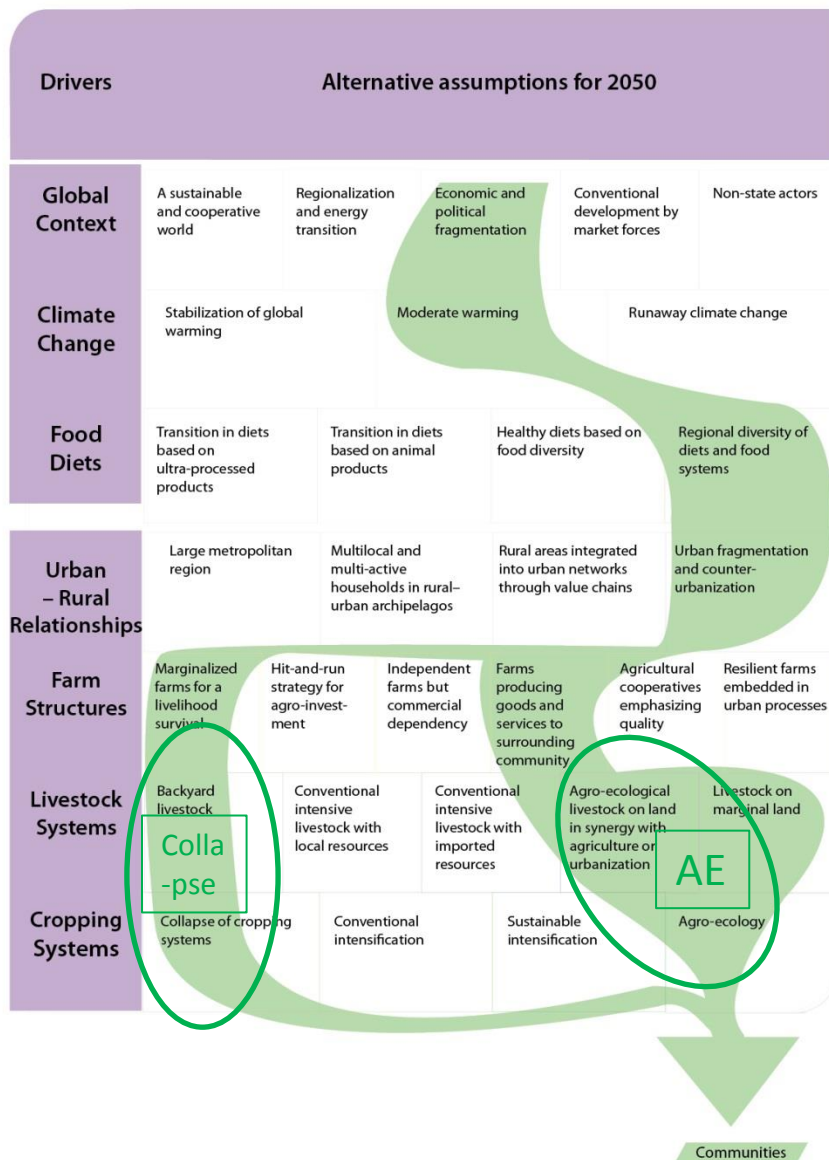
- **highly globalized** and hybrid world
- **ad hoc networks** superseded sovereign governments, public debates
- **rural-urban mobility**
- supply chain **disintermediation**,
- **concerned groups** engaged with farming, nutrition and health, climate change, biodiversity, water quality and local identity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

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

# Impacts of the scenarios on land use (1)

Scenario	«Variants» (assumptions used)	Running name
<b>Metropolization</b>	<b>With ultra-processed products:</b> Transition to diets based on ultra-processed products	Metropolization_Ultrap
	<b>With animal products:</b> Transition to diets based on animal products	Metropolization_Animp
<b>Regionalization</b>	<b>With agricultural technology A:</b> Sustainable intensification for cropping systems + Conventional intensification with local resources for livestock systems	Regionalization_A
	<b>With agricultural technology B:</b> Agroecology for cropping systems + Agroecological livestock	Regionalization_B
<b>Healthy</b>	<b>With agricultural technology C:</b> Sustainable intensification for cropping systems + Agroecological livestock	Healthy_C
	<b>With agricultural technology D:</b> Agroecology for cropping systems + Agroecological livestock	Healthy_D
<b>Communities</b>	<b>With agroecology:</b> Agroecology for cropping systems + Agroecological livestock	Communities_AE
	<b>With collapse:</b> Collapse of crop production + Backyard livestock	Communities_Collapse

# The GlobAgri-AgT model

The GlobAgri-AgT model is a biomass balance model :

- 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

One constraint per region:

- cropland  $\leq$  max cultivable land area (GAEZ 1-4)
- binding constraint: export coeff reduced; import coeff increased

Pastureland adjusts freely

Deforestation is calculated ex-post

# Impacts of the scenarios on land use at the world level (2)

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

# First elements of comparaision of the five scenarios

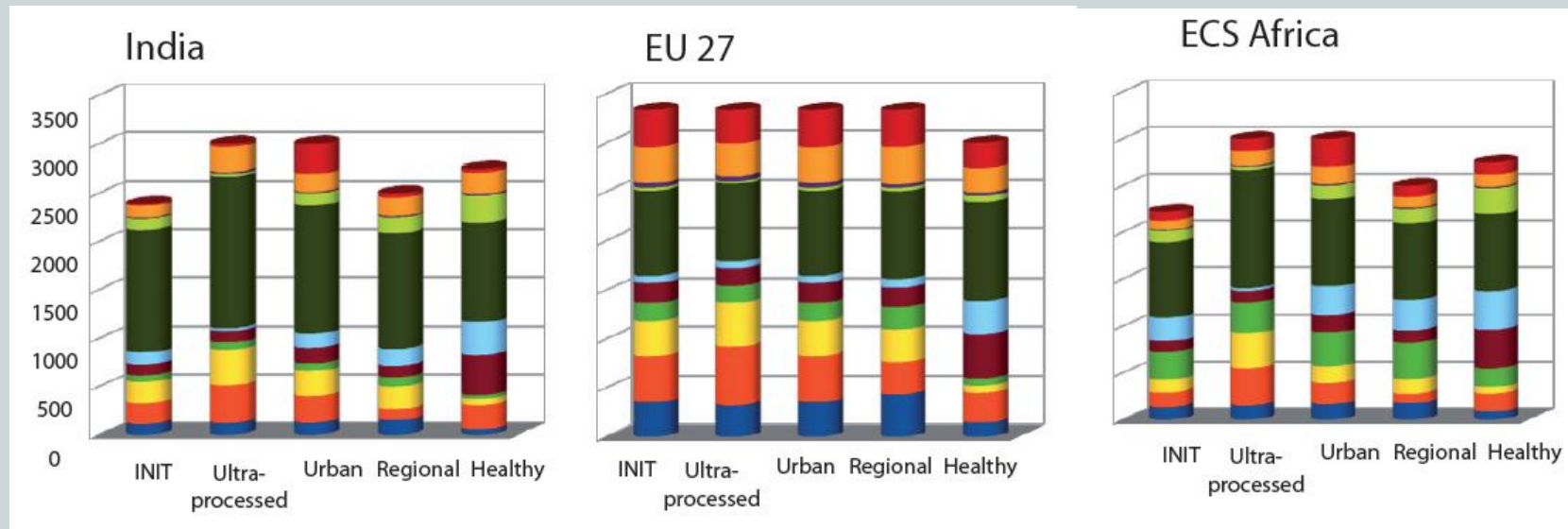
- A diversity of pathways for land use and food security in 2050
- Strong uncertainties regarding:
  - impact of climate change and global socio-economic context,
  - extent and nature of diet transition,
  - rural transformation and urbanisation,
  - livestock and cropping systems changes
- Two scenarios 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...

## **4. Consequences of the five scenarios on land use and food security**

**Olivier Mora (Inra) and  
Marie de Lattre-Gasquet (Cirad)**



# Some key elements for a good understanding of the land-use change simulation results: alternative diets in the scenarios

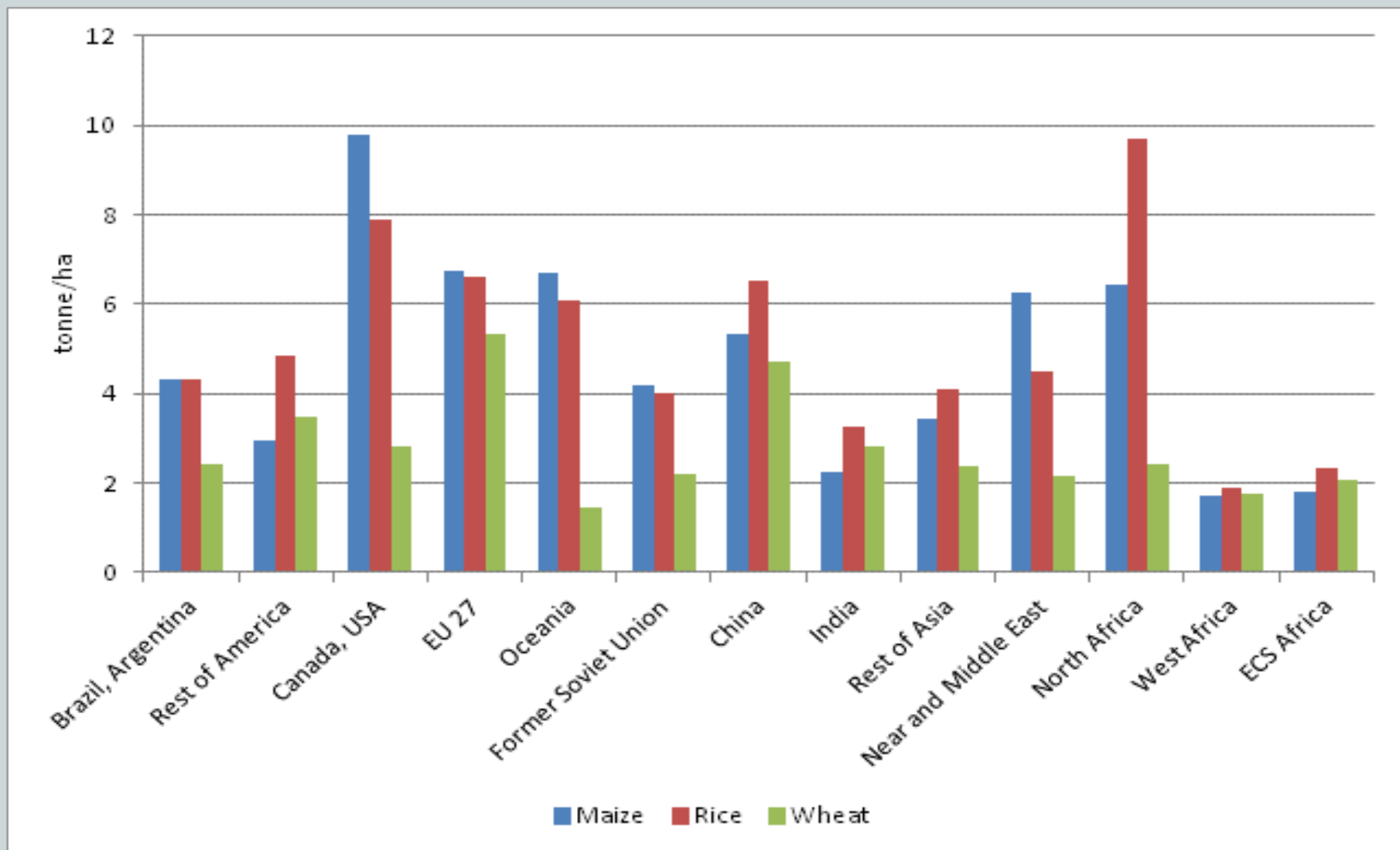


In the scenario « Communities »: - 10% kcal/cap/day relative to 2010 except in India and ECS Africa

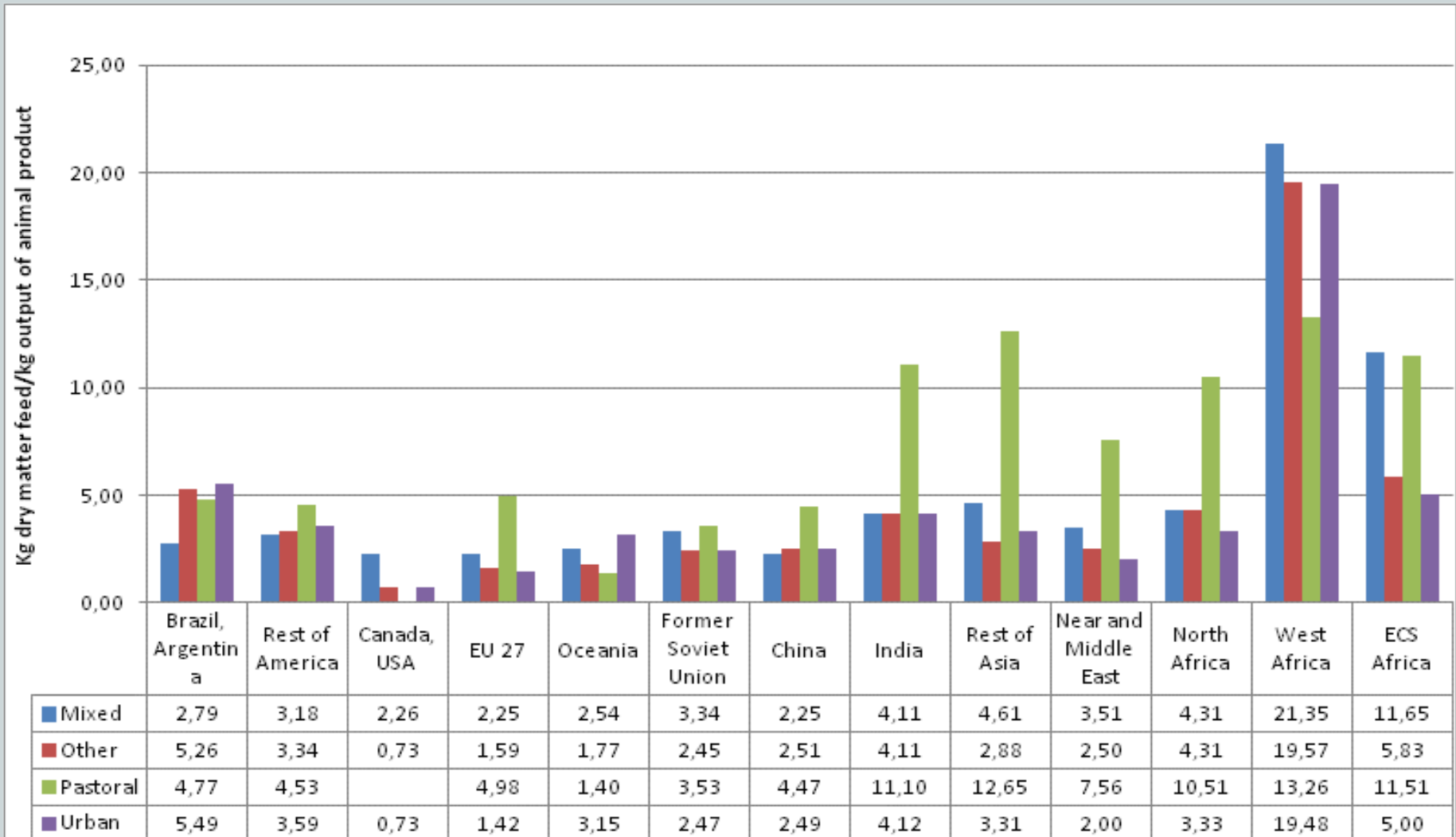
## Some key elements for a good understanding of the land-use change simulation results

- 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
- 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

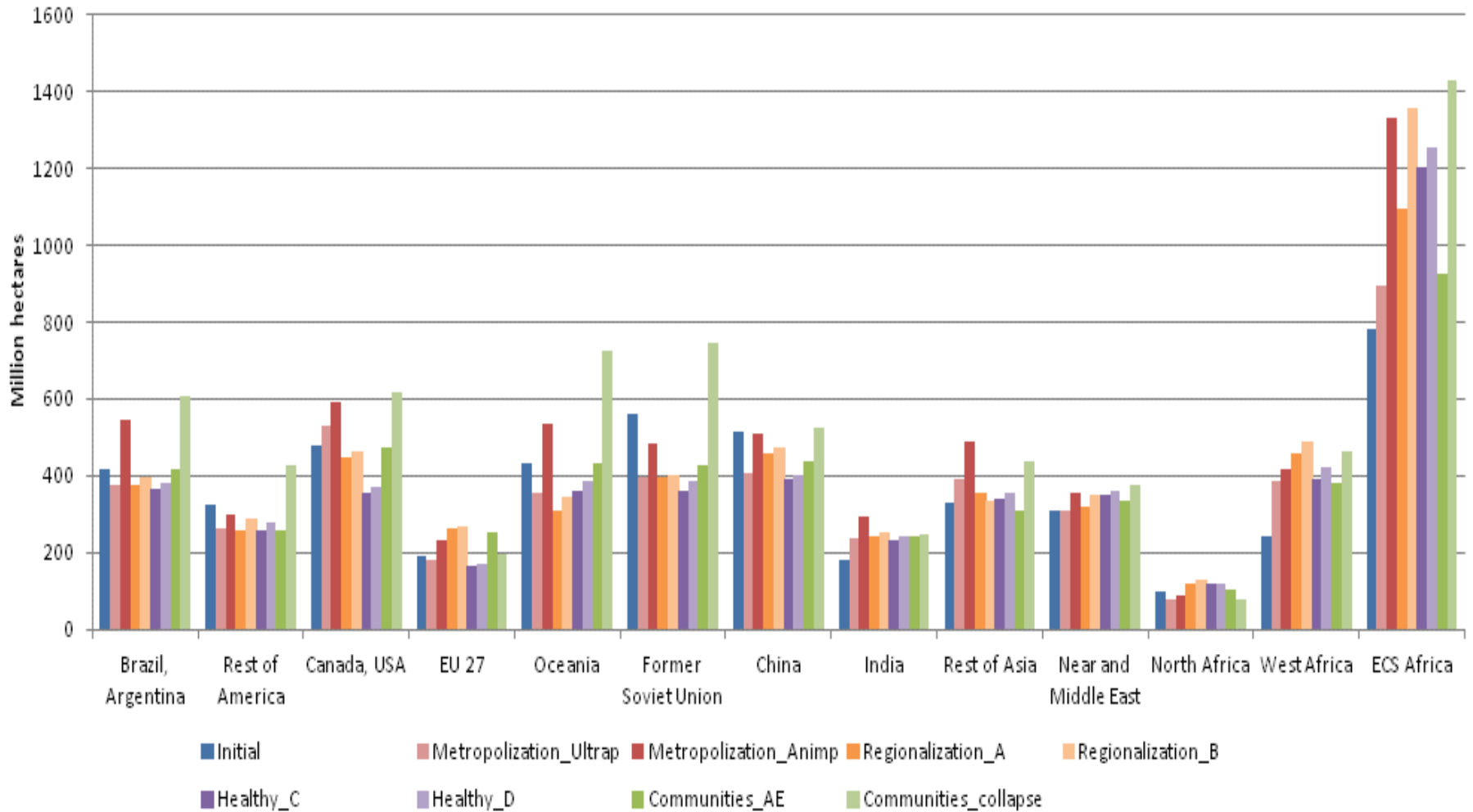
# Per-hectare yields for some cereals in 2010



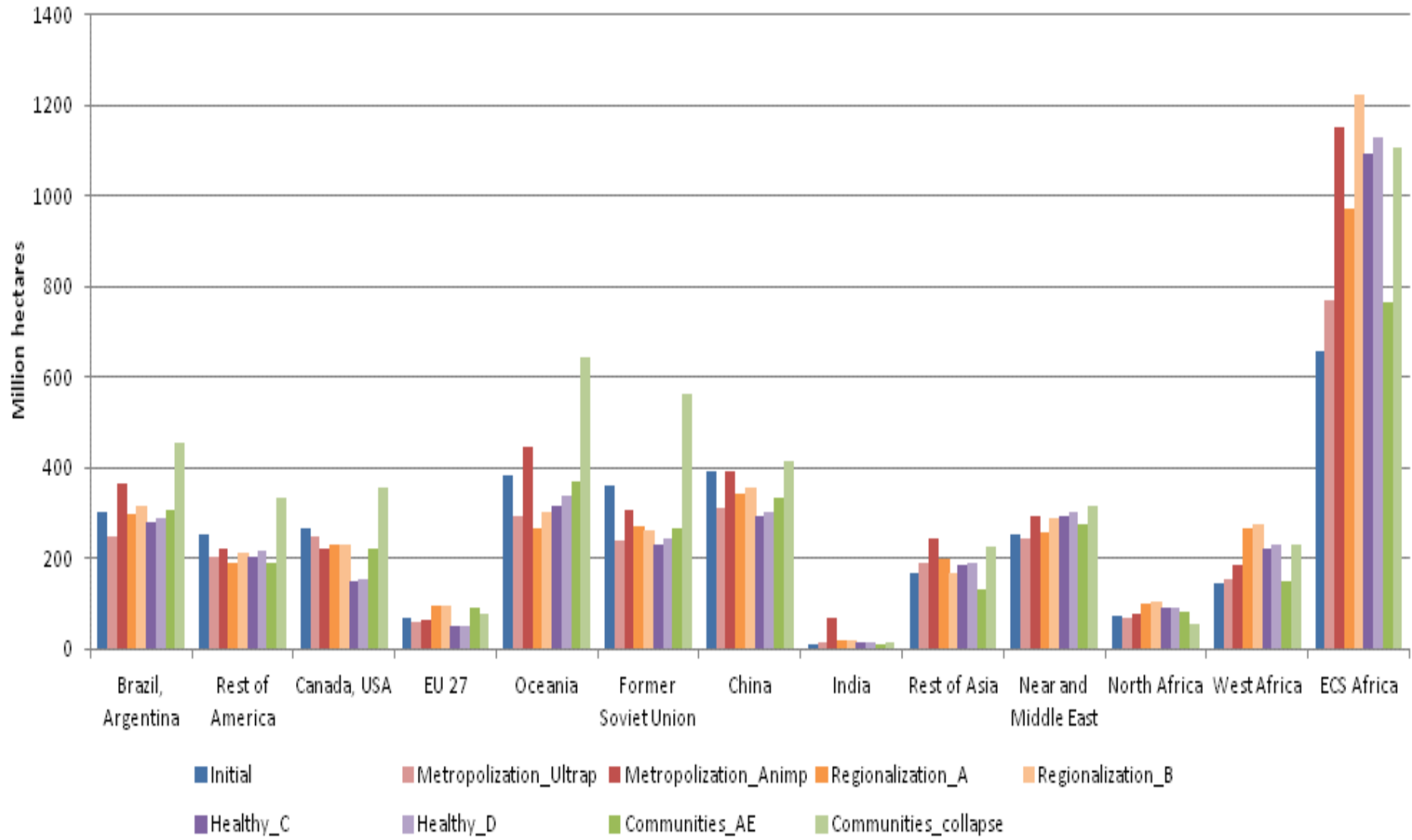
# Feed-to-output ratios for the various production systems in the dairy sector in 2010



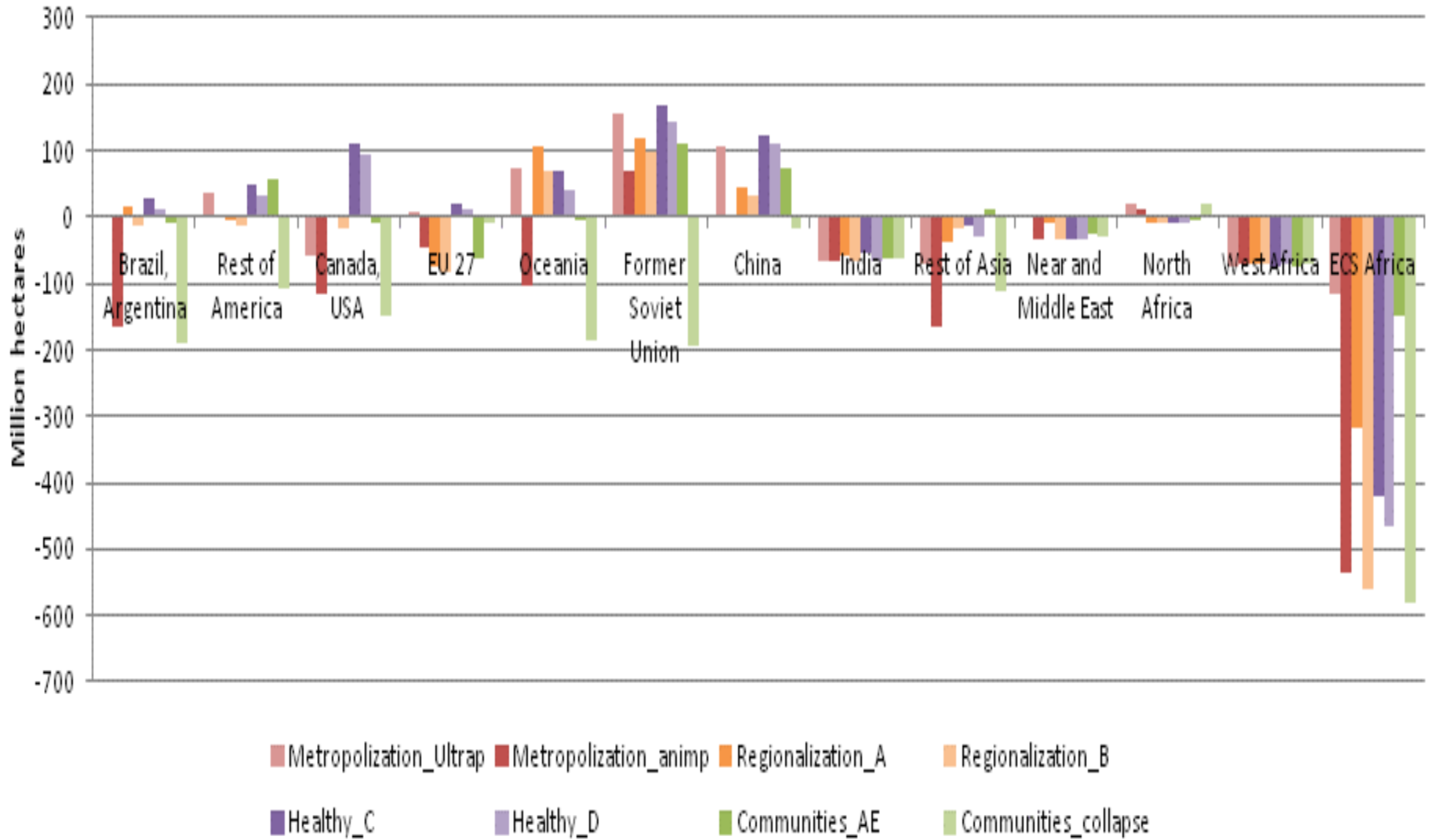
# Ensuring world food availability in 2050 will involve expanding world agricultural land ...



# ... 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 their future changes

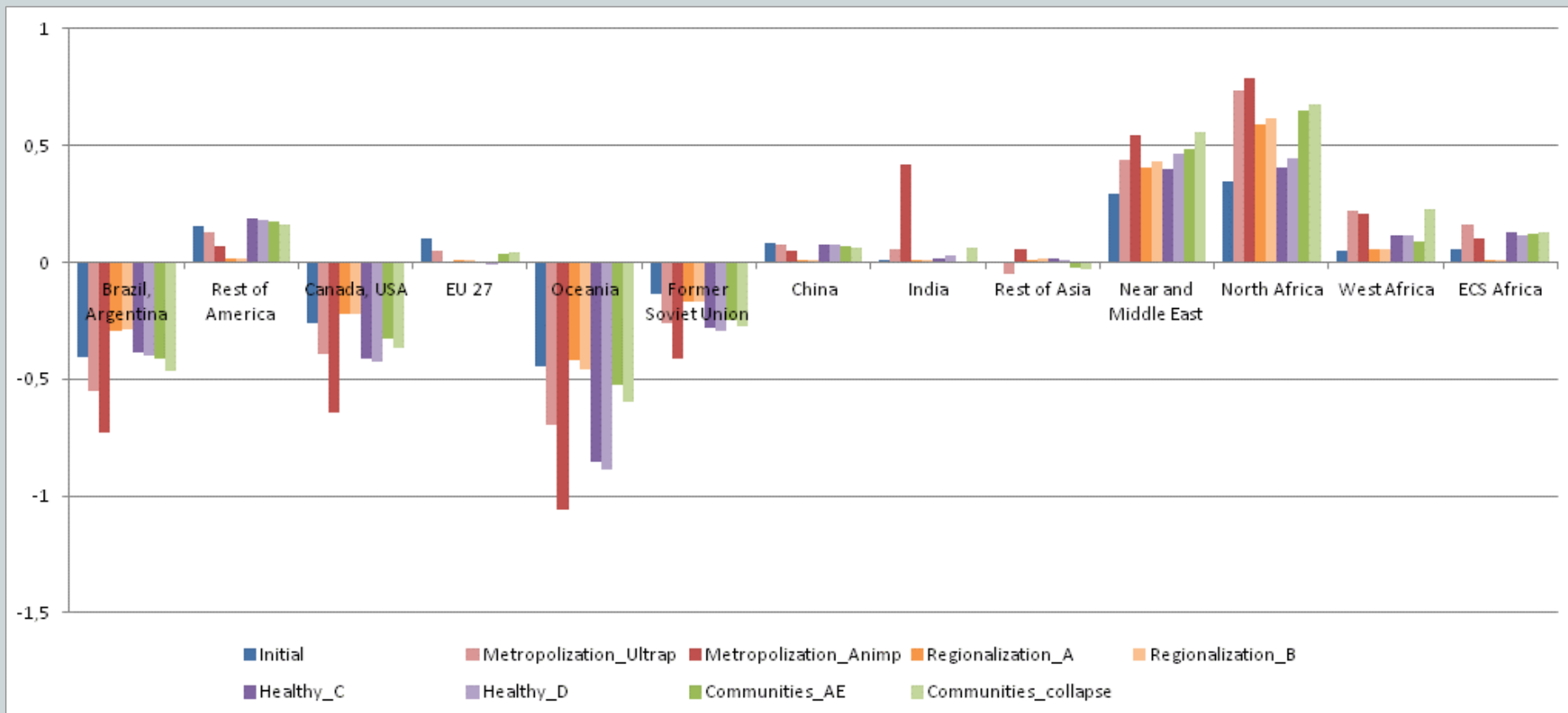
- The land area required to cover the world food needs in 2050 will depend closely from:
  - the future change of cropping systems in regions with increasing population and nearly reaching their max cultivable land, such as India
  - the future change of livestock systems in regions where they are currently 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:  $(\text{imports} - \text{exports}) / \text{total uses (kcal)}$



# 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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Agrimonde-Terra

Land use and global food security  
in 2050

A FORESIGHT EXERCISE



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