Scenarios and challenges for feeding the world in 2050

bruno.dorin@cirad.fr

sebastien.treyer@iddri.org

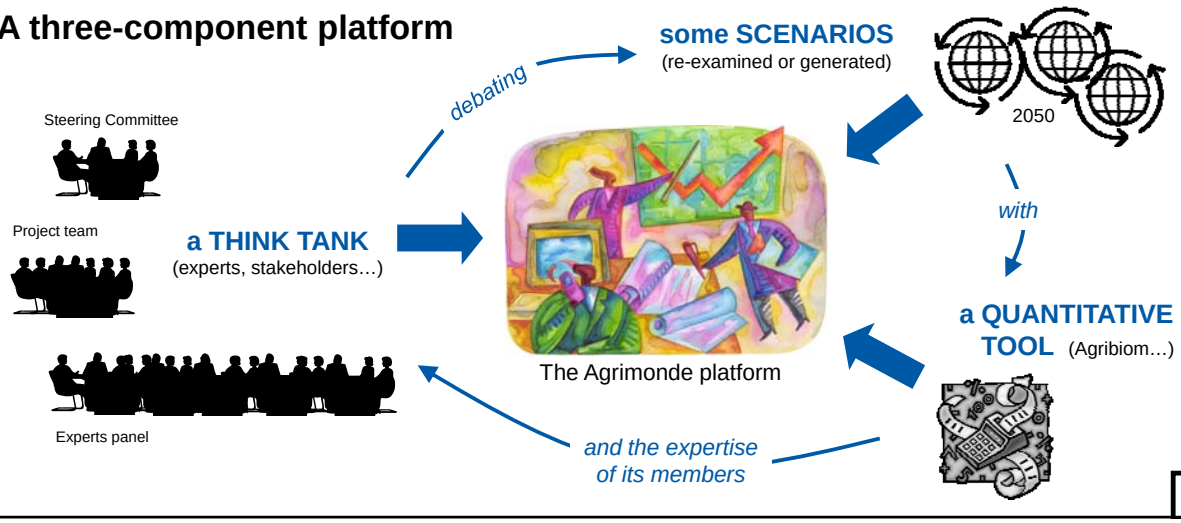
APF-GCARD workshop, CTA, Wageningen, 25 February 2010

The foresight exercise Agrimonde (introduction)

- **A joint INRA-CIRAD project** (2006-2008 = 1st phase)
  - French National Institute for Agricultural Research (www.inra.fr)
  - French Agricultural Research Centre for International Development (www.cirad.fr)
  - → under their common group **IFRAI** (French Initiative for International Agricultural Research)

- **Objectives**
  (1) to explore possible futures of food and farming systems up to 2050
  (2) to design and debate orientations and strategies for INRA - CIRAD research agendas
  (3) to contribute to international debates on food, agriculture and the environment

- **A three-component platform**



Part I

Aims & architecture of Agribiom

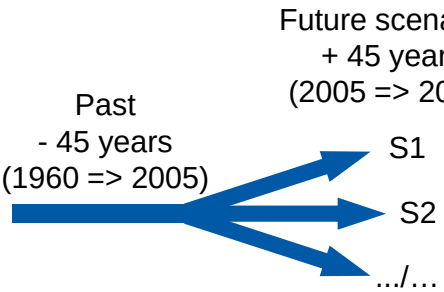
A quantitative module designed for facilitating
collective explorations and debates
as well as hybrid modeling
relating to global productions, trade and uses of biomasses

❶ The ambition for Agrimonde

Having a quantitative tool for :

(1) revisiting the past,
better understand it (with new estimates, new models…)

(2) debating the future
...from scenarios description (own or external qualitative conjectures)



reflected / summarized into
few quantitative parameters (populations, diets, non-food uses land uses, productivities…)

Global Consistency ?
(physical equilibrium between biomass uses & resources)

Impact of variants ?
(populations, composition of diets…)

Implications ? (international trade, energy & water consumptions…)

❷ The basic engine

S/U physical equilibriums of food biomasses
reconstituted (1961-2003, out of FAOSTAT commodity balances in metric tons)
and/or simulated (2030, 2050…)
on more than 97% of the world land surfaces (149 basic «regions»)

Food biomass RESSOURCES

some land & aquatic SPACES

crops, pastures…

rivers, oceans…

with some levels of PRODUCTIVITY

in calories
- vegetal
- aquatic
per hectare

Food biomass USES

some human POPULATIONS

Rural
Urban…

with some levels of FOOD intakes

in calories
- vegetal
- animal
- aquatic
per capita

Exports - Imports

SEED FEED

Non-Food Uses (biofuels…)

WASTES

some Food PRODUCTION

some Food CONSUMPTION

some co-products (straw…)
some "free" spaces

some non-food productions/potentials

some environmental impacts

some needs +/- satisfied

4

❸ The items

- 5 « compartments » of food biomasses (only…)
- Other productions (non-food…)
  Fibres, Tobacco, Rubber… Fodders …Wood

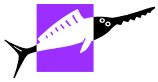
PLANTS (VEGE)

Cereals : wheat, rice, barley, maize…
Sugar crops : sugarcane, sugar beat…
Pulses : beans, peas…
Oilseeds : soybean, groundnut, coconut…
Roots & tubers : cassava, potato…
Fruits & vegetables : apple, onion…
Stimulants : cocoa, coffee, alcohol…

GRAZING ANIMALS (RUMI)
Meats : bovines, goat, mutton…
Milk, Butter, Animal fats…

Non-GRAZING ANIMALS (MONO)
Meats : poultry, pig…
Eggs…

FRESH WATER (AQUA)
Fishes…



MARINE (MARI)
Demersal & Pelagic fishes… Fats…

1961-2003 : 120 product lines of Faostat1 (SUA - *Commodity Balances*)

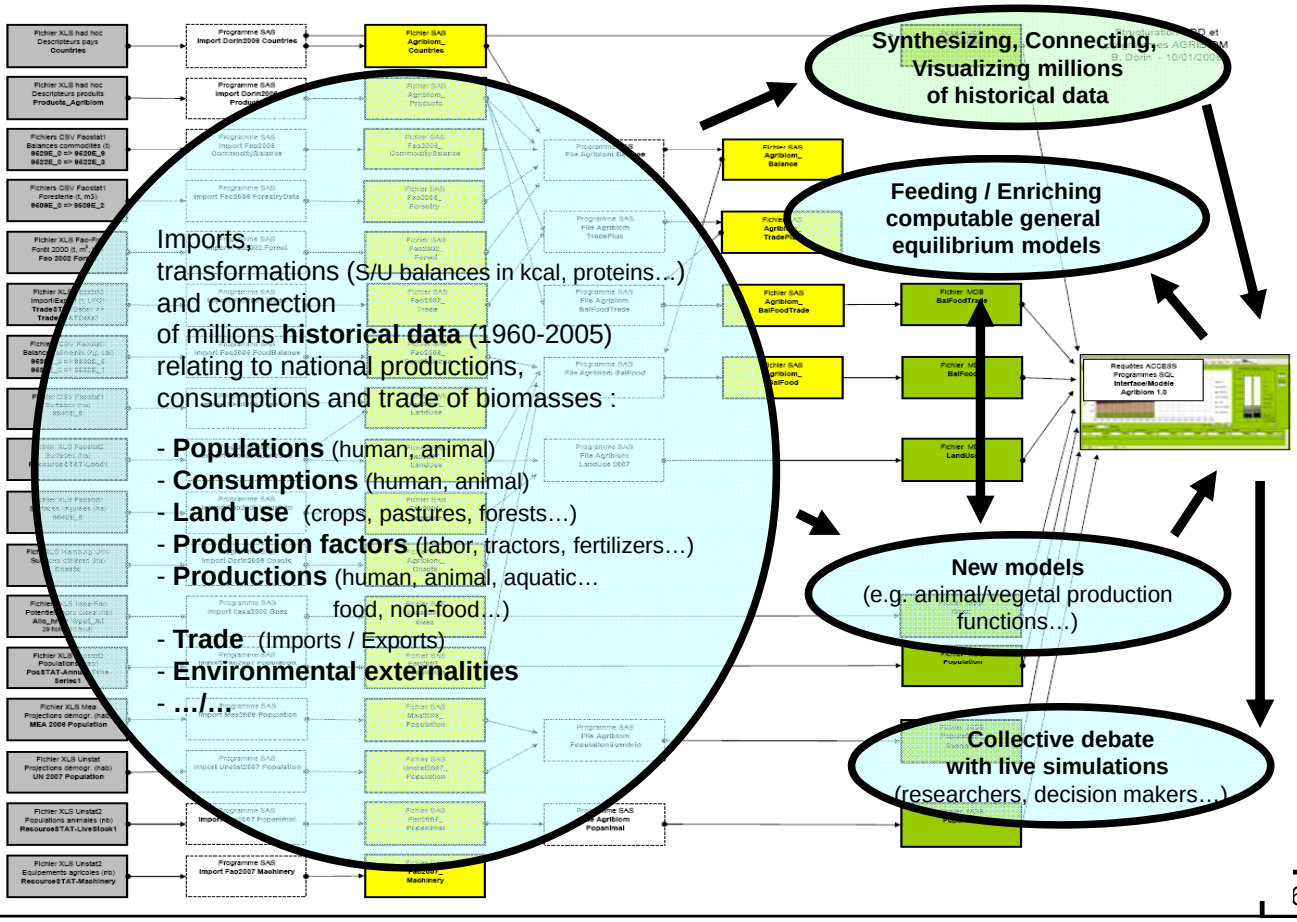
❹ The unit of account

- Food CALORIES
  (or equivalent for oilcakes, molasses…)

  Total Calories = Carbohydrates (4 kcal/g)
  + Proteins (4 kcal/g)
  + Fat (9 kcal/g)

- Tonnes (ou m^3) of DM
  - Fibres, rubber…
  - Crop residues…
  - Fodders…
  - Wood (fuel or industrial wood)

❺ A convergence on an interactive interface



❻ A 1st set of robust models

Cross-country animal production functions

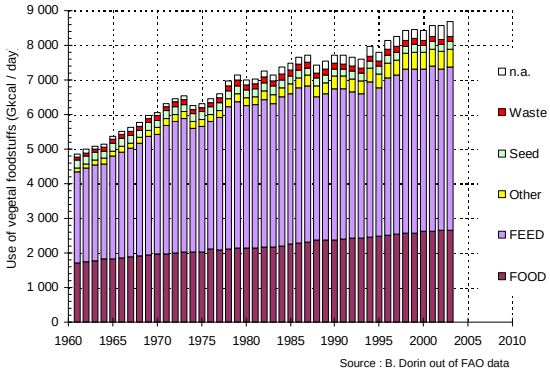
(B. Dorin + T. Le Cotty)

- A model with **2 interdependent functions**
  - Prod_Rumi (Gkcal) = f (x1,x2, x3…, Prod_Mono)
  - Prod_Mono (Gkcal) = f (x1,x2, x3…, Prod_Rumi)

- Key explaining factors (x1, x2, x3…) :
  - **Feed of vegetal origin** (Gkcal)
  - **Feed of animal origin** (Gkcal)
  - **Pasture area** (1 000 ha)
  - Agricultural active population (1,000 cap)
  - Tractors (units)
  - …/…

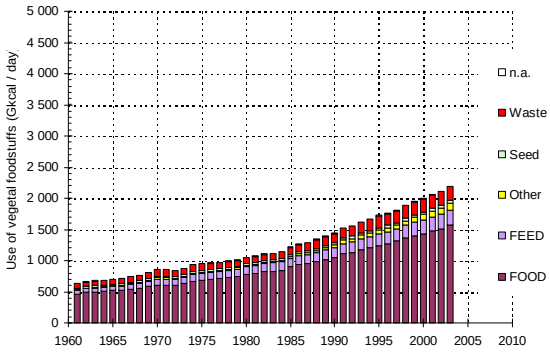
OECD

SSA
(Sub-Saharan Africa)



(in 2003, the OECD cattle ate 3 times as much foodstuff as the SSA human population did)

- Several models now available :
  - **linear** / quadratic
  - CalTot / **CalPro** (unit for the feed and for the outputs…)
  - with/**without «Dummies»** (region, years…)
  - with/**without «Trend»** (“technical progress”)
  - «**Region-based**» (MEA regions…) or «Type-based» (agricultural/industrial, extensive/intensive…)
  - …/…



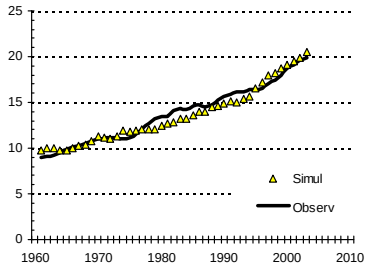
- Results :
  - replicate very-well the past 40-year of national/regional/global animal productions
  - “on-line” tests and modeling (choice of model, change of parameters/coefficients, simulations…)

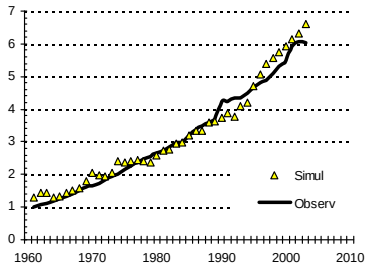
Rumi

Mono

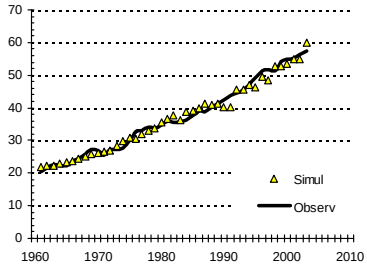
Gkcal of proteins / day

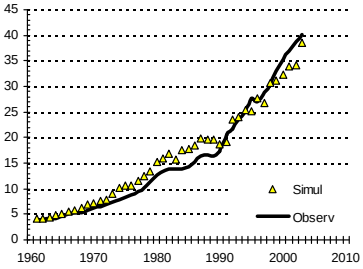
SSA
Sub-Saharan
Africa



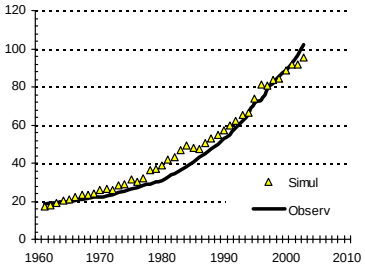


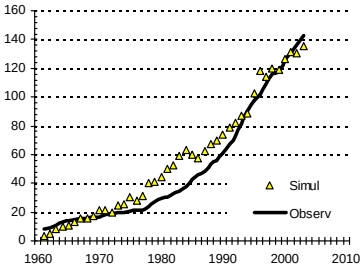
LAM
Latin
America





ASIA
Asia





8

❼ Annual R/U balances of food biomass reconstituted (1961-2003) ...or simulated

Param D6MEA AgM_R2V_00 2050

		Population (Kcap)	Rations (kcal/j/cap)		FOOD (Gkcal/j)	FEED	VANA	SEED	WAST	Residu	UTIL Total (Gkcal/j)	Surfaces (Kha)		Rendement (kcal/j/ha)	PROD Production (Gkcal/j)		EXIM Exp - Import (Gkcal/j)	Delta
1	OCDE 1990	1 066 211	2500	3	2 666	4 314	329	165	414	390	8 279	495 000	400 000	23600	9 449		1 161	0
			6	0	6	0	0	0	0	0	6	95 000	160 183	40	5		0	0
			43	0	46	32	15	0	0	-12	81	3 295 548	981 321	82	80		0	0
			251	0	268	81	142	0	5	59	554		576 226			984	430	0
			200		213	0	1	5	3	-30	193					455	262	0
2	Afrique Sub-Saharienne	1 662 000	2500	3	4 155	0	0	90	224	4	4 473	338 000	299 000	12400	3 708		-765	0
			4	0	7	0	0	0	0	0	7	39 000	65 352	100	7		0	0
			17	0	28	1	0	0	0	0	29	2 359 453	86 980	340	30		0	0
			129	0	214	1	7	0	0	1	225		692 000			21	-203	0
			350		582	0	0	0	0	3	585					-1	-585	0
3	EX-URSS	239 212	2500	3	598	3 586	184	90	230	-97	4 590	310 000	300 000	15300	4 590		0	0
			4	0	1	0	0	0	0	0	1	10 000	62 436	14,09	1		0	0
			33	0	8	2	0	0	0	-1	9	2 213 218	453 332	20	9		0	0
			251	0	60	34	21	0	7	-11	105		300 998			715	610	0
			212		51	0	0	0	0	-11	39					182	142	0
4	Asie	4 427 101	2500	3	11 068	1 939	596	298	744	232	14 877	559 000	539 000	27600	14 875		0	0
			12	0	53	0	5	0	0	-1	57	20 000	77 749	740	53		0	0
			76	0	336	32	3	0	0	-4	367	2 033 947	480 076	743	357		-11	0
			159	0	704	37	32	0	12	-34	751		512 000			401	-349	-1
			253		1 120	0	2	5	7	-20	1 114					528	-586	0
5	Amérique Latine	773 659	2500	3	1 934	3 386	248	124	310	197	6 200	310 000	250 000	24800	6 200		0	0
			3	0	2	0	0	0	0	0	2	60 000	26 431	90,222	2		0	0
			39	0	30	10	2	0	0	-7	35	2 039 563	283 809	161,427	46		11	0
			251	0	194	11	48	0	5	14	269		444 625			564	295	0
			207		160	0	0	2	3	-7	158					433	275	0
6	Moyen Orient et Afrique du Nor	631 964	2500	3	1 580	0	0	35	88	52	1 755	89 000	88 800	15300	1 359		-396	0
			4	0	3	0	0	0	0	0	3	200	14 757	150	2		0	0
			36	0	23	3	0	0	0	-1	25	1 136 711	69 672	350	24		0	0
			222	0	140	9	1	0	2	6	164		321 000			25	-139	0
			238		150	0	0	1	1	-1	151					-2	-154	0
	TOTAL Zone	8 800 147			22 000	13 225	1 358	802	2 010	778	40 173	2 101 000	1 676 800		40 173		0	0
					72	0	5	0	0	-1	76	224 200	426 910		76		0	0
					471	80	20	0	0	-25	546	13 076 440	2 355 190		546		0	0
					1 580	173	254	0	28	35	2 068	2 002	2 646 848			2 711	644	-1
					2 276	0	3	13	14	-67	2 239					1 595	-645	0

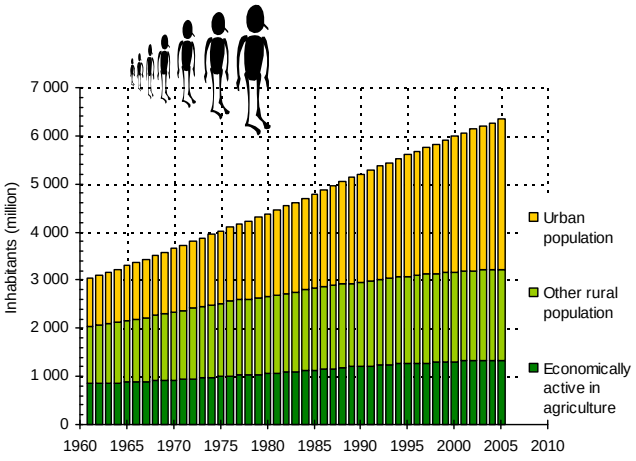
Part II

From past trends to scenarios

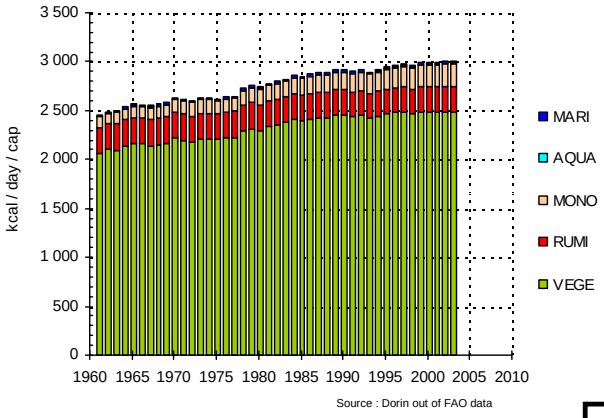
A 1961-2003 brief overview of the world food economy through Agribiom eyes…

❶ From average world increases…

- The population doubled



- The per-capita food availability increased too…

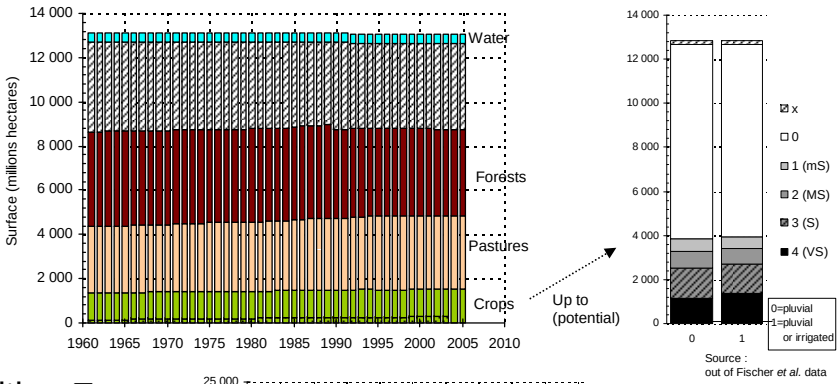


Source : Dorin out of FAO data

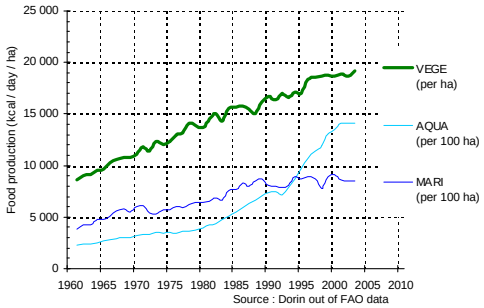
10

On the resources side:

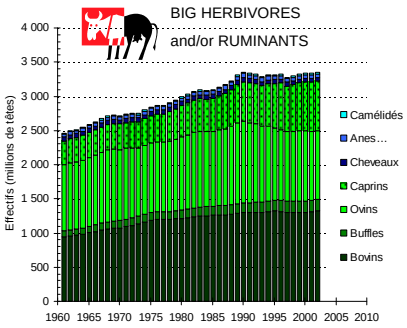
- Agricultural area ↗
  - Pastures : + 11%
  - Crops : + 13%

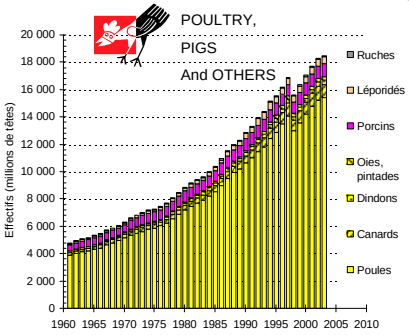


- Land and labour productivities ↗
  - Veg calories / cultivated ha : + 123%
  - Veg calories / farmer : + 53%

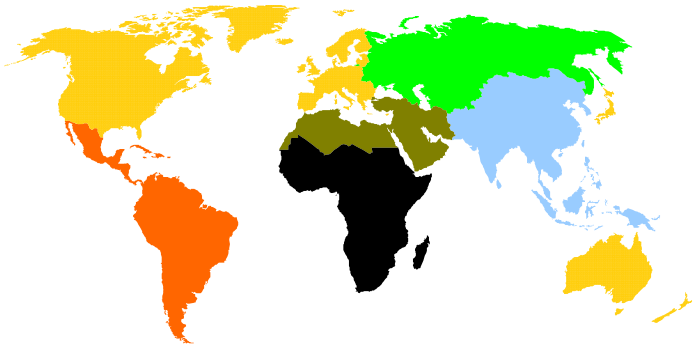


- Livestock ↗





❷ ...to regional disparities

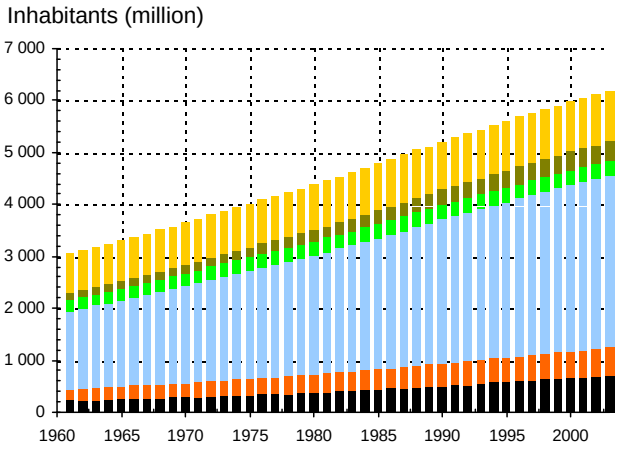


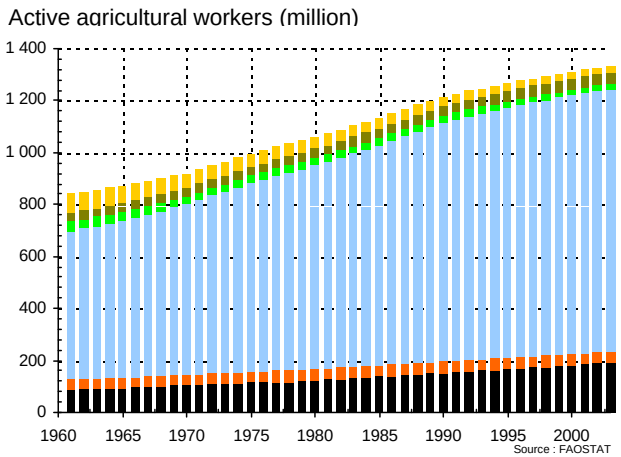
The 6 MEA regions

- OECD = Oecd-1990
- MENA = Middle East & North Africa
- FSU = Former USSR
- ASIA = Asia
- LAM = Latin America & the Caribbean
- SSA = Sub-Saharan Africa

■ Human populations

Farmers : highly and increasingly concentrated in Asia and Africa



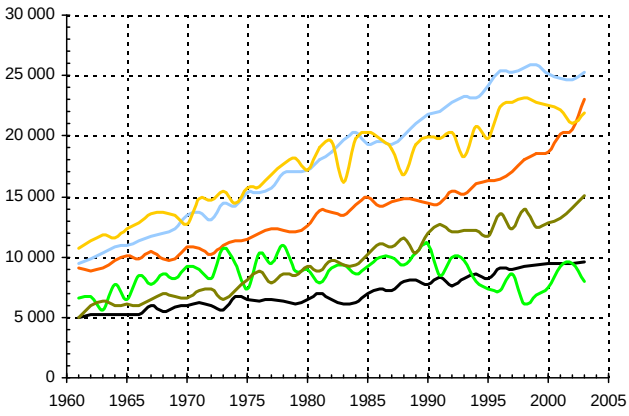


12

Highest land productivity in ASIA

Note : 10 000 kcal =
~ 2.4 kg of soybean
~ 2.8 kg of rice milled
~ 2.9 kg of pea
~ 3.0 kg of wheat
~ 15.0 kg of potato
~ 58.8 kg of tomato

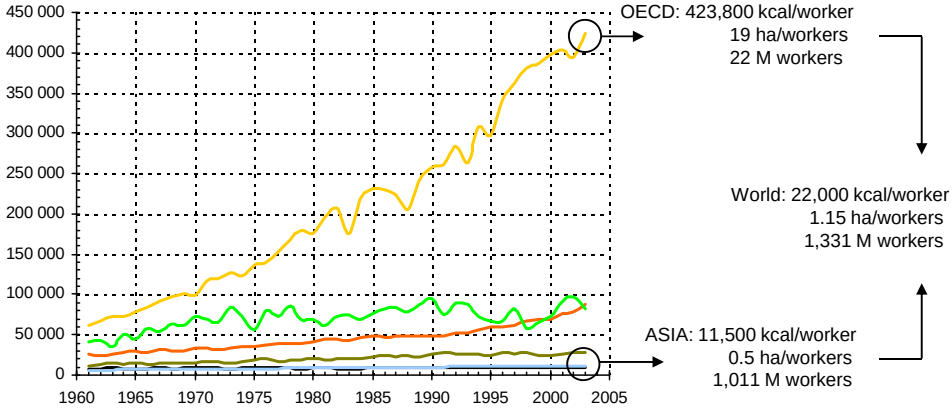
Vegetal kcal / day / cultivated hectare



Source : Dorin out of FAO data

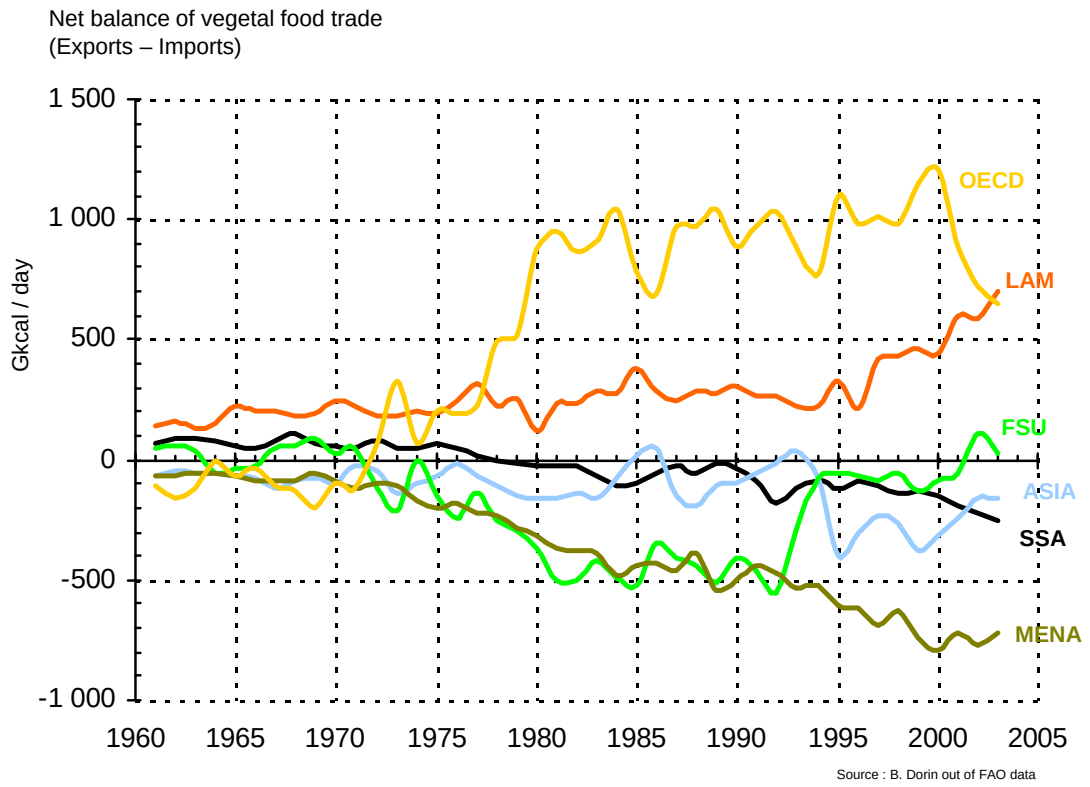
A labour productivity boom in OECD

Vegetal kcal / day / agricultural worker

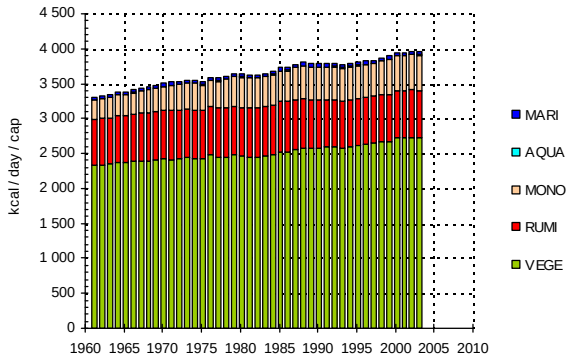


13

- A boom of food trade
  to clear surpluses and fill in deficits

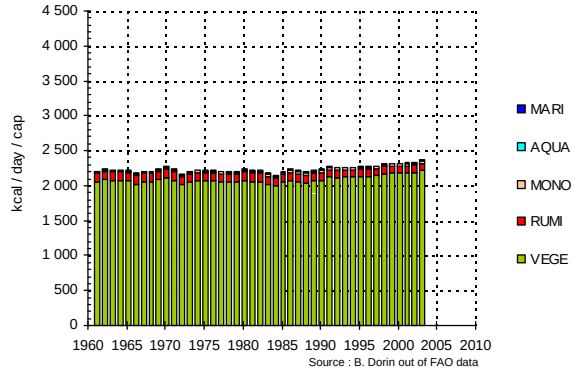


- But still very large disparities in per-capita food availabilities



OECD

- Animal proteins :
  71 g / day on 125 (60%)
- Animal fats :
  89 g / day on 165 (55%)



Source : B. Dorin out of FAO data

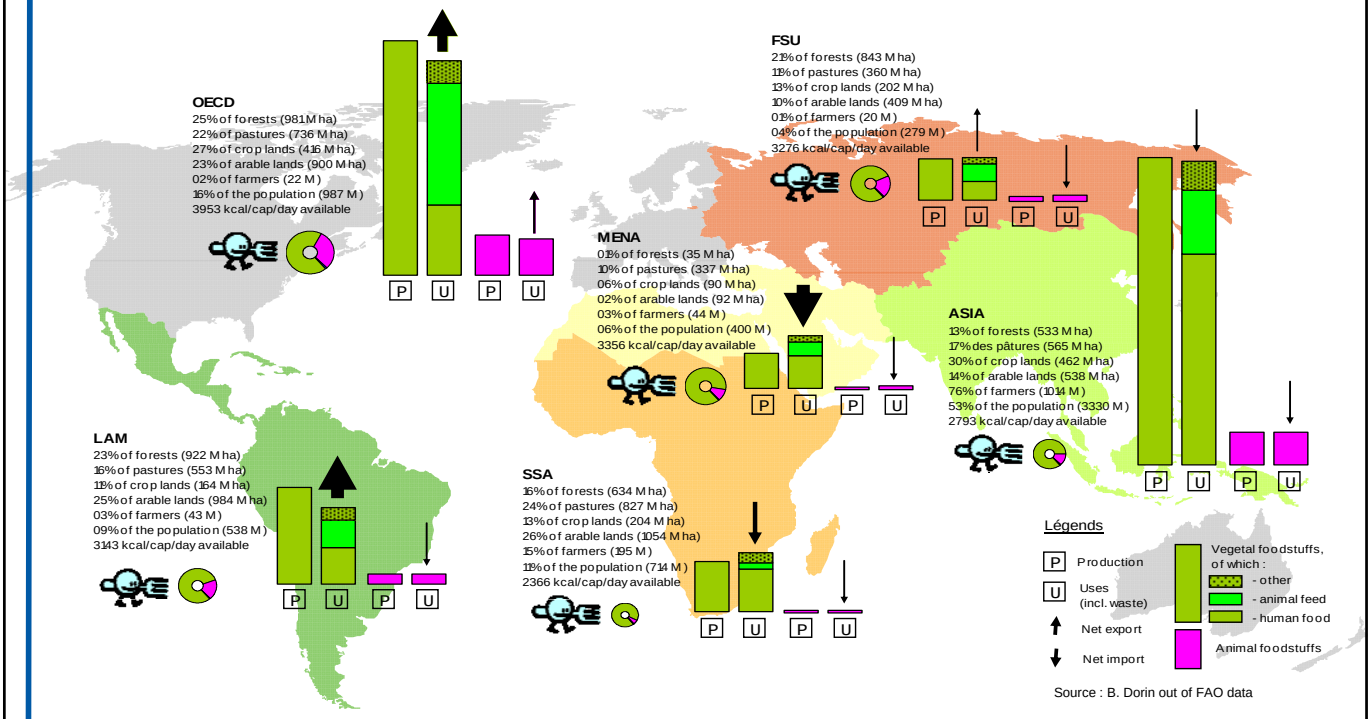
Sub-Saharan Africa

- Animal proteins :
  12 on 60 g / day (20%)
- Animal fats :
  10 on 48 g / jour (20%)

❸ Towards which new «equilibrium» in 2050 ?

Resources, productions, trade and uses of food biomasses (2003)

http://www.cirad.fr/upload/en/communique/Cirad-Inra-Agrimonde-GB.pdf



Source : B. Dorin out of FAO data

Scenarios, hypotheses, collective debates… (2050)

Agribiom simulations

Part III

Scenarios and challenges for feeding the world in 2050

First explorations by Agrimonde : the “AGO” and “AG1” worlds…

❶ Towards which new «equilibrium» in 2050 with…

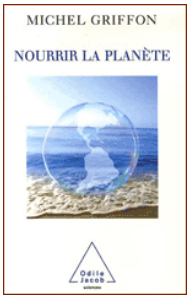
- +/- population growth (7-11 billions inhabitants in 2050) ?
- +/- incomes, incomes distribution and population migrations (regional opportunities of decent incomes, self-subsistence…) ?
- +/- change in food diets (vegetal/animal, macro/micro nutrients…) ?
- +/- demand in non-food products (bio-energies, bio-materials...) ?
- +/- economic liberalization and trust in international trade (“sovereignty” in cereals / other basic vegetal foodstuffs / feed for animal productions / animal foodstuffs…) ?
- +/- environmental regulations (forests, greenhouse gases, biodiversity…) ?
- +/- important crisis on present yield boosts (fossil fuels, water, pesticides, phosphates…) ?
- +/- climate change
- …/…

❷ The “AGO” and “AG1” worlds

- Two scenarios “reprocessed”

The *Doubly Green Revolution* scenario

Source: Griffon M., 2006. Nourrir la planète. Pour une Révolution doublement verte, Odile Jacob, Paris



The Green Revolution, which was introduced on a world scale after World War II, made it easy to ignore the threat of hunger. But the Green Revolution also encouraged overpopulation; it ravaged the environment in many places; it created inequalities in the sharing of the planet’s wealth, and these inequalities have made the threats we must face in the coming decades even greater than those the world had to confront in the early twentieth century.

Agrimonde platform

- The “Agrimonde 1” scenario (AG1)
- The “Agrimonde GO” scenario (AGO)

The *Millennium Ecosystem Assessment* scenarios

Source: MEA, 2005. Ecosystems and Human Well-being: Scenarios, The Millennium Ecosystem Assessment, Washington DC.

Globalization

Global Orchestration
A globally connected society that focuses on global trade and economic liberalization and takes a reactive approach to ecosystem problems but that also takes strong steps to reduce poverty and inequality and to invest in public goods such as infrastructure and education. Economic growth in this scenario is the highest of the four scenarios, while it is assumed to have the lowest population in 2050.

Techno-Garden
A globally connected world relying strongly on environmentally sound technology, using highly managed, often engineered, ecosystems to deliver ecosystem services, and taking a proactive approach to the management of ecosystems in an effort to avoid problems. Economic growth is relatively high and accelerates, while population in 2050 is in the midrange of the scenarios.

Reactivity — Proactivity

Order from Strength
A regionalized and fragmented world, concerned with security and protection, emphasizing primarily regional markets, paying little attention to public goods, and taking a reactive approach to ecosystem problems. Economic growth rates are the lowest of the scenarios (particularly low in developing countries) and decrease with time, while population growth is the highest.

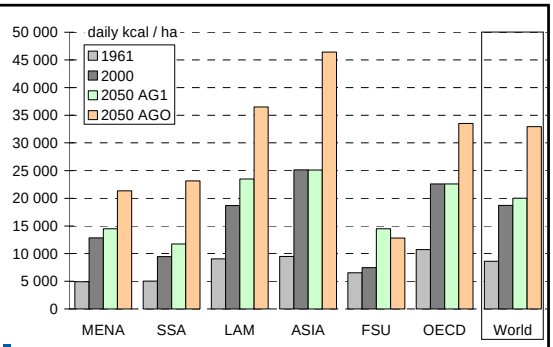
Adapting Mosaic
Regional watershed-scale ecosystems are the focus of political and economic activity. Local institutions are strengthened and local ecosystem management strategies are common; societies develop a strongly proactive approach to the management of ecosystems. Economic growth rates are somewhat low initially but increase with time, and population in 2050 is nearly as high as in Order from Strength.

Regionalization

Main quantitative assumptions

		2003	2050 - AG1	2050 - AGO
Uses	Population	6.2 Gcap	8.8 (+42%)	8.8 (+42%)
	Human food	3,000 kcal/day/cap 17% Non-Veg	**3,000** **17%** Non-Veg	**3,590** (+19%) **23%** Non-Veg
	Other uses	~14,440 Gkcal/day	Feed (Agribiom) + seed (3%) + waste (max 4%) + other (max 5%)	Feed (Agribiom) + seed (3%) + waste (max 4%) + other (max 5%)
Ressources	Food yields	~19,190 kcal/day/ha	~20,030 (**+4%**)	~32,940 (**+75%**)
	Crop land - for N-Food	~1,530 Mha neg.	~2,105 (**+38%**) 224 Mha	~1,860 (**+21%**) 217 Mha
	Pastures	~3,330 Mha	~2,845 (**–14%**)	~3,585 (**+8%**)
	Forest	~3,905 Mha	no change	no change

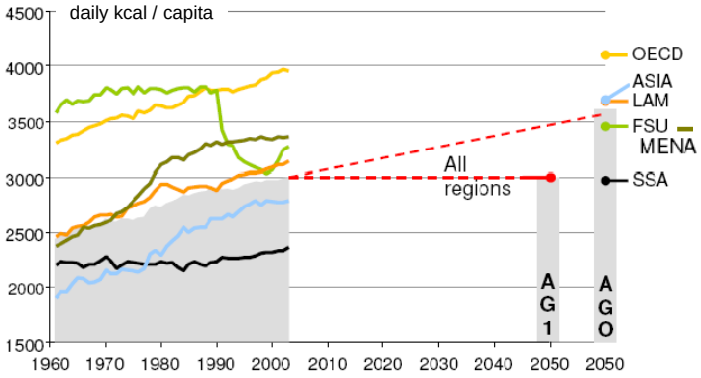
Trade : h01 : trade of plant food only (i.e. no trade of animal foodstuffs or by-products)
h02 : import of animal foodstuffs instead of import of plant feed

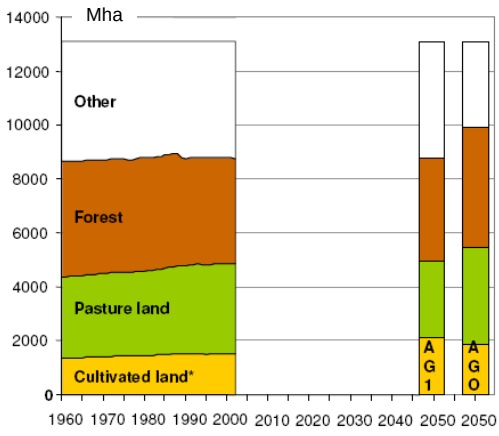


Yield

Land

Food

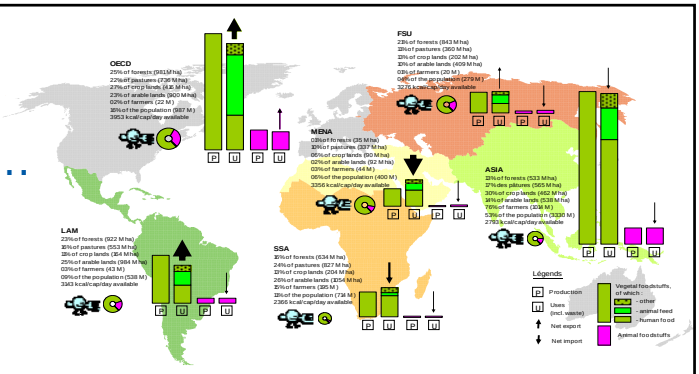


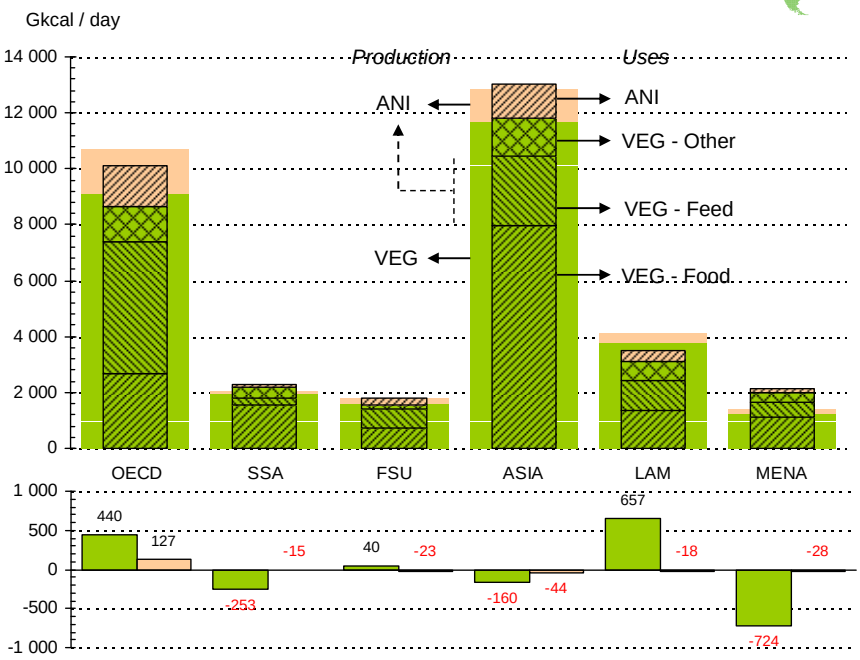


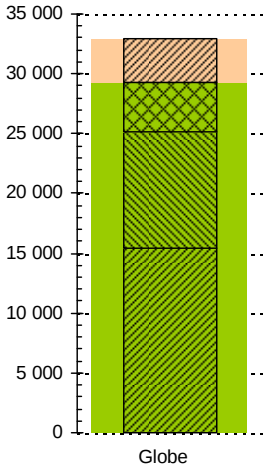
19

❸ Two new hypothetical equilibriums for 2050...

- Base 2003

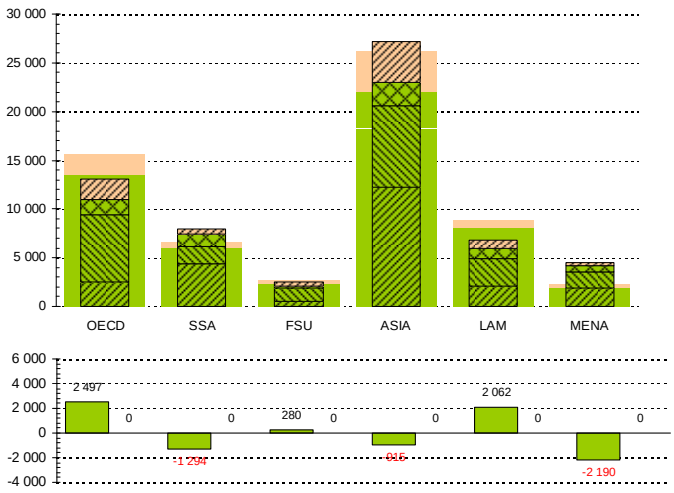


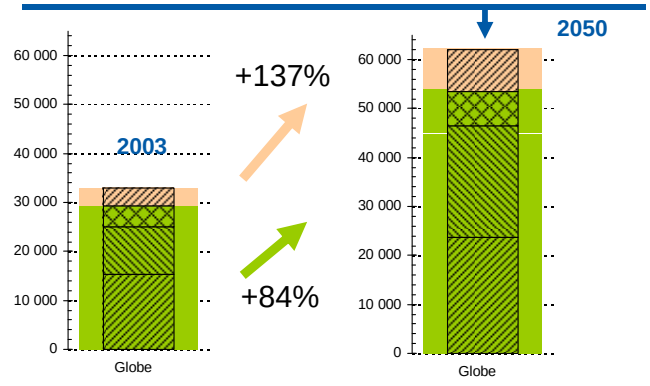




Scenario 2050 - AGO

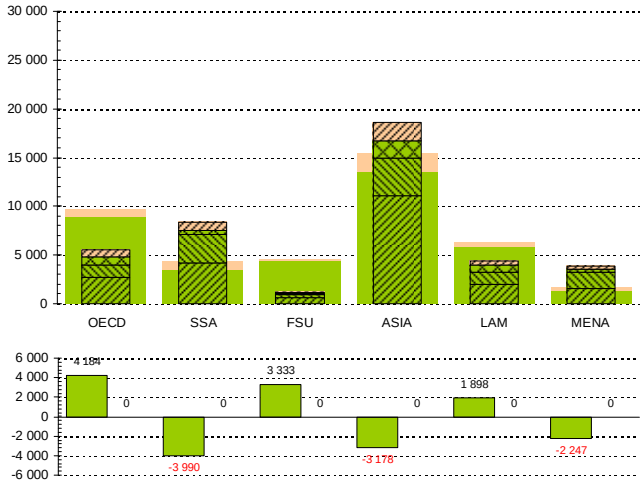
AGO.h01

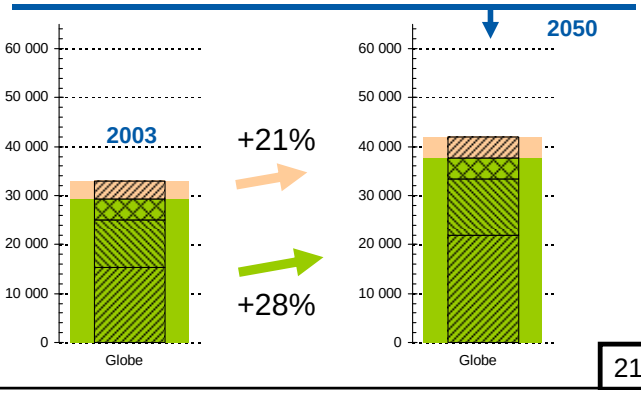




Scenario 2050 - AG1

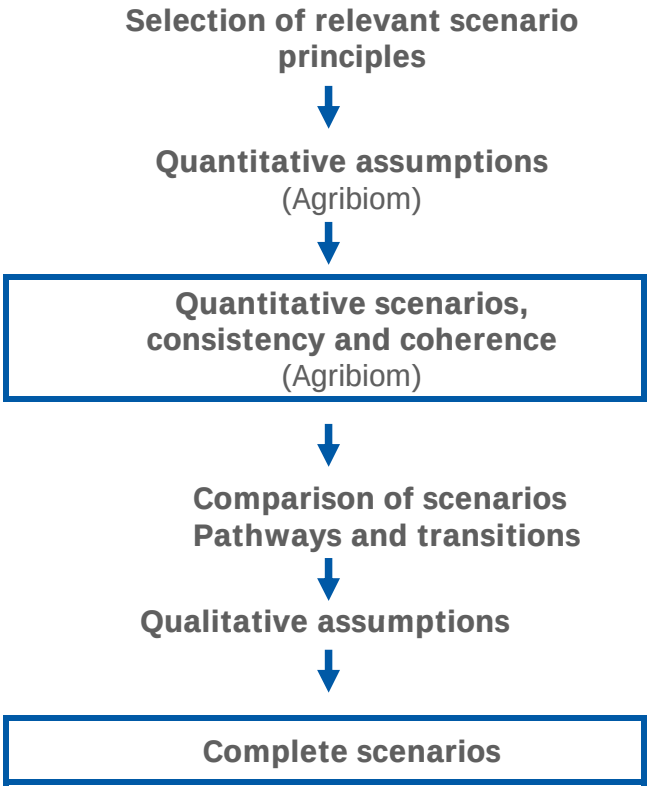
AG1.h01





21

❹ Possible narratives for each scenario



	Agrimonde GO ***Global economic growth to ensure food security***	**Agrimonde 1** ***Feeding the planet and/by preserving the ecosystems***
Growth, developt & migrations	Economic growth in LDC based on agricultural development	
	High level of global growth Acceleration of urbanization	Global growth based on deving countries Stabilization of urbanization
Regulations and governance	Massive north south transfers	
	Trade liberalisation	UNOFS : price distortions, volatility, temporary exceptions, envt protection Multi-functionnality
AKST-D	Massive public and private investment	
	Continuing the same technological pathway	Scientific innovation for ecological intensification : ▪ specific / generic ▪ interactive, mutualization
Energy	Massive investments	
	Rapid growth of energy demand Energy efficiency Biofuels	Demand management Energy efficiency, renewable energies Decentralized production Farm autonomy

23

❺ What lessons from the 2 scenarios ?

The planet can feed properly 9 billions people in 2050 but…

- What is in our plates (total calories, %Veg/Ani, macro/micro-nutrients…) is a key driver for:
  - preserving some ecosystem services (carbon sequestration, soil, water, pollination…) and/or saving the use of some agricultural inputs (water, fertilizers, pesticides…)
  - reducing some important human health problems (from under-nutrition to obesity)
  - opening larger opportunities for non-food productions (bio-energies, biomaterials…) and reducing substantially post-harvest losses and food wastes
  - maintaining a diversity of production systems, landscapes and environments

  There is no necessary convergence of world diets towards today's OECD mean diet.

- Food trade can secure some regional food needs and avoid huge migrations, provided the net-deficit regions/populations can:
  - pay for their food imports (local opportunities of incomes?)
  - rely on a fair and transparent international trade regulation system ...also aware of poor farmers incomes and environmental externalities

24

- Preserving or improving agricultural yields calls for breakthroughs:

(a) Need for much less polluting & less dangerous techniques (for workers, flora, fauna…)
founded on: - much better exploitation of ecosystem services
- new technologies (ITC, genetics, monitoring…)
- mobilizing jointly scientific & local knowledge (social learning processes)

and need for organizational breakthroughs (markets, regions, food chain, diversification of food systems…)

(b) Need to reframe the usual yield / area dilemma and production / protection divide :
- urban & peri-urban agriculture…
- agro-forestry, agro-ecology…
- complementarities between differentiated areas (…and not setting land aside)

(c) "Ecological intensification" might emerge as an interesting option
for sustainable biomass production and for food security of poor farming families,
provided institutional and technological lock-in situations can be overcome

25

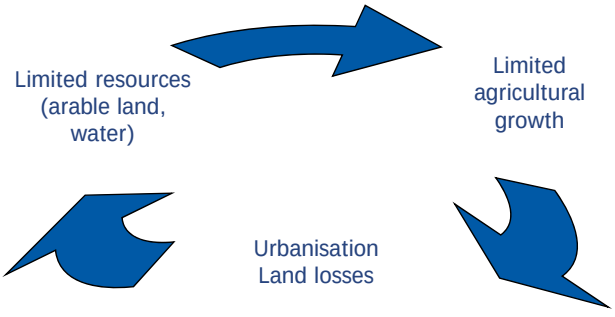
- Growth and development pathways in agriculture and rural areas

Sub saharan Africa

Some yield improvements seem very easy to gain through classical intensification :
Are they really accessible ?
What resilience to climate change of such a development pathway ?
Will it be possible to change for another pathway ?

Ecological intensification as a development pathway : high yield growth and resilience to climate change are needed !

MENA, Asia



To follow up...

- Need to involve a large set of actors, stakeholders and academic disciplines into food production, food security, food safety and food quality issues!
- Need to debate food and agriculture scenarios at various regional levels (…with various stakeholders)
- Need to better simulate (with Agribiom and other quantitative tools)
  - induced consumptions of fossil fuel and water
  - GHG emissions/sinks (C, CO_2, CH_4, N_2O…)
  - regional employments / incomes / migrations
  - …/… and biodiversity ?
- Some other themes for further scenarios/research:
  - think outside conventional boundaries
    (urban/peri-urban agriculture, agroforestry, agroecology…)
  - the importance of livestock systems & their diversity

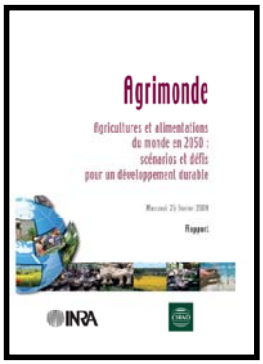
Agrimonde materials available on the web & elsewhere

http://www.inra.fr/l_institut/prospective/agrimonde
http://www.cirad.fr/actualites/toutes-les-actualites/articles/2009/science/resultats-de-la-prospective-agrimonde

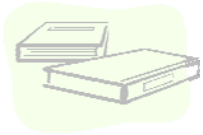
Preliminary results
8 pages brochure
May 2008

FR & EN

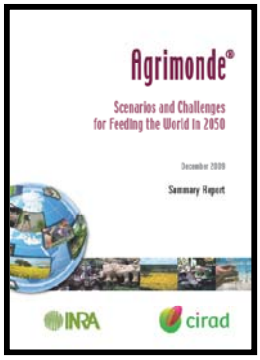
REPORT
200 pages
Feb. 2009



Coming soon…
BOOKS (FR & EN)
2010



SUMMARY REPORT
32 pages
June 2009



FR & EN
Updated versions
December 2009

BROCHURE
12 pages
Oct 2009

Coming soon…
EN version

VIDEOS
Presentations & debates
Feb-Oct 2009

FR only

thanks you for your attention!