How do climate change and bio-energy alter the long-term outlook for food, agriculture and resource availability?

Günther Fischer,
Land Use Change and Agriculture Program,
IIASA, Laxenburg, Austria.

Expert Meeting "How to Feed the World in 2050?"
24-26 June 2009, FAO, Rome

Outline

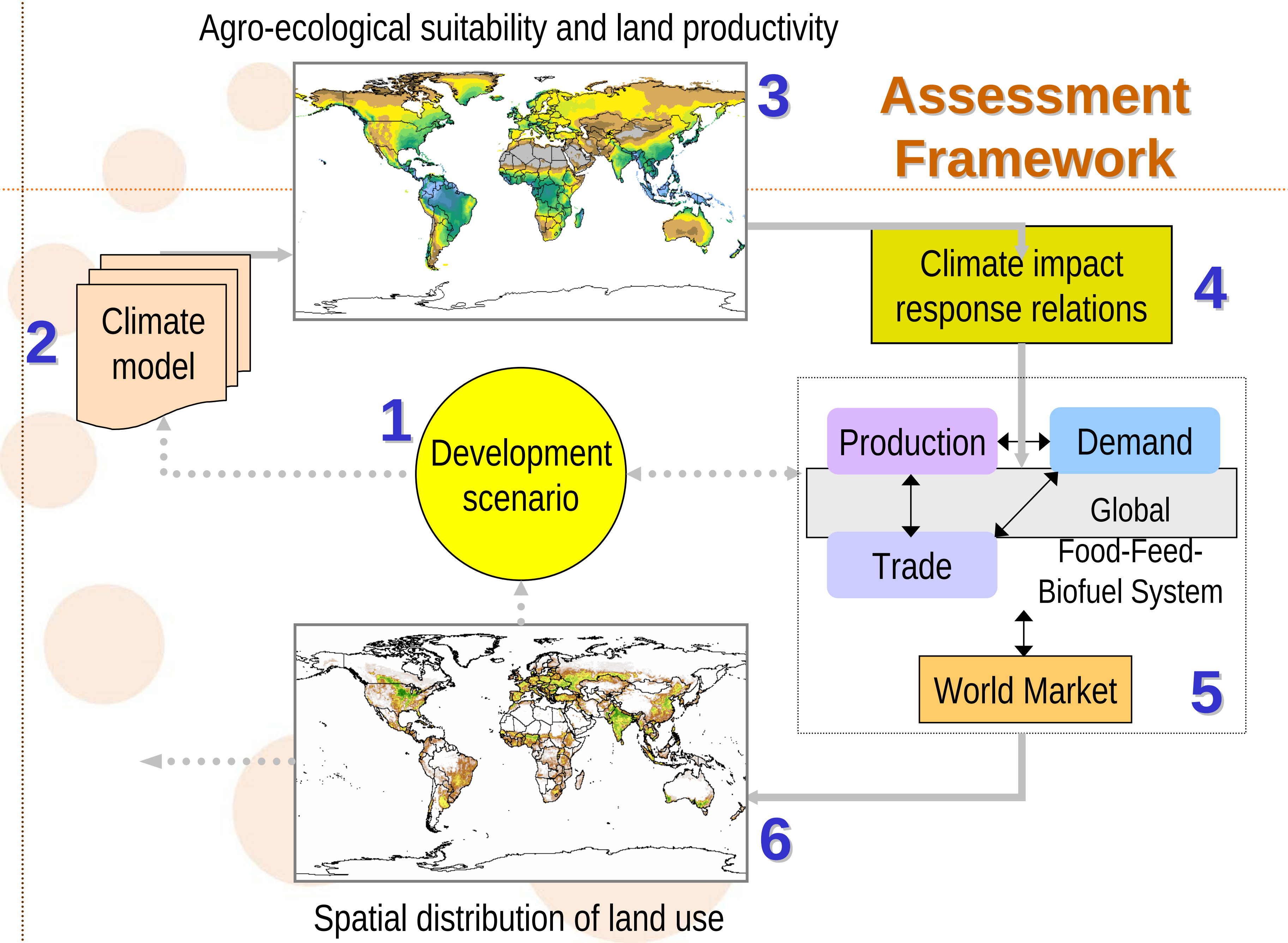
- Assessment framework of “Biofuels and Food Security” study
- Scenario assumptions
- Feedstock suitability assessment
- Impacts of biofuel expansion scenarios on food system indicators and resource use

“Biofuels and Food Security” Study

Mitigate Climate Change, Enhance Energy Security, Foster Rural Development

- Review of world-wide biofuels development and policy support
- Assessment of agro-ecological potential of 1st and 2nd generation biofuel feedstocks
- Scenarios of first and second generation targets to 2020 and 2030
- Impacts of biofuel expansion on food prices, agricultural value added, land use, GHG emissions.

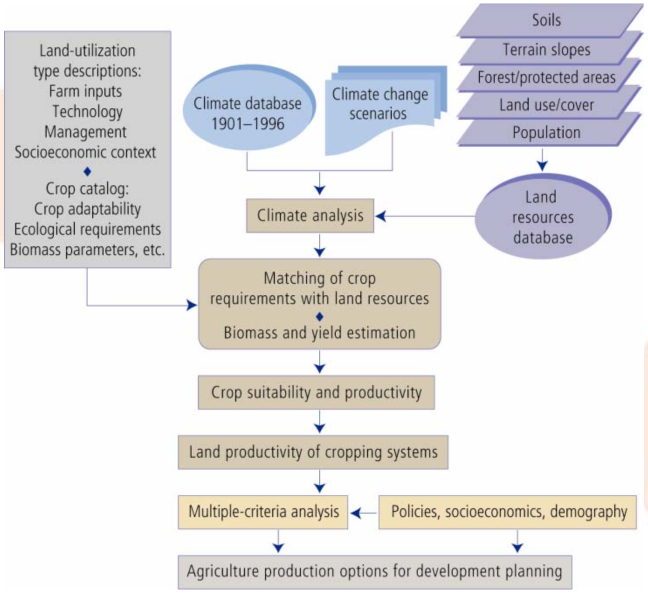
Assessment Framework

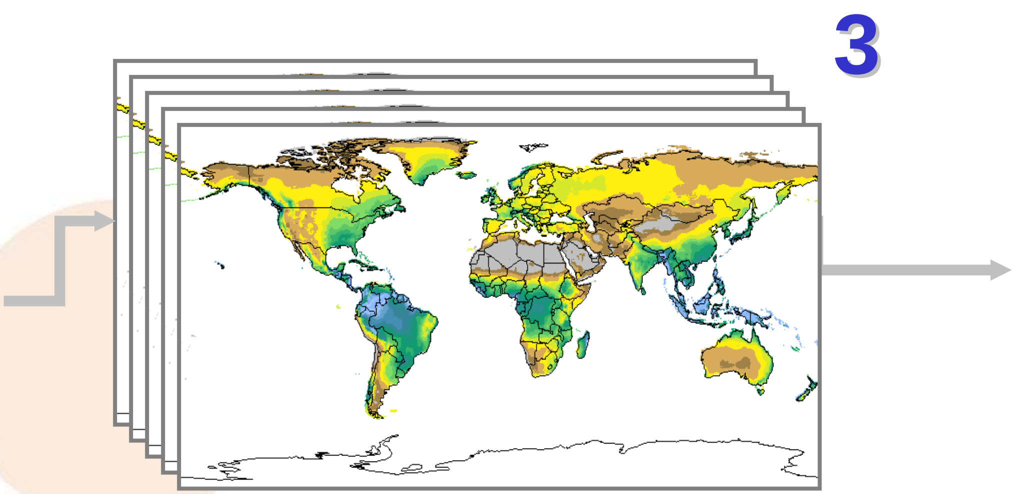


Global Agro-ecological Zones

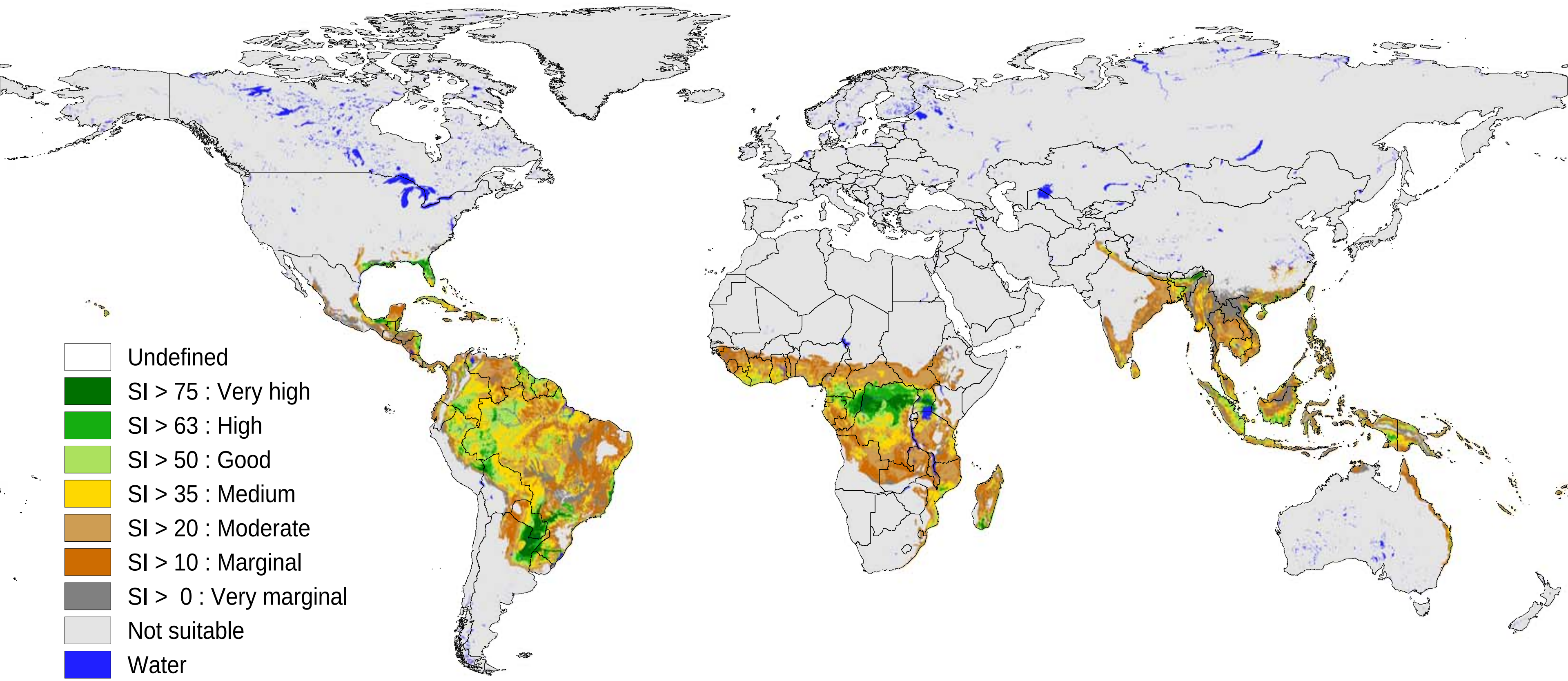
Environmental resources database
including climate, soil, terrain, land cover, population
comprising 2.2 million grid cells

Assessing the agricultural potential of
all major food, fiber, 1st and 2nd generation biofuel crops





Suitability for rain-fed
Sugar cane production, high input level



Potential VS and S Land

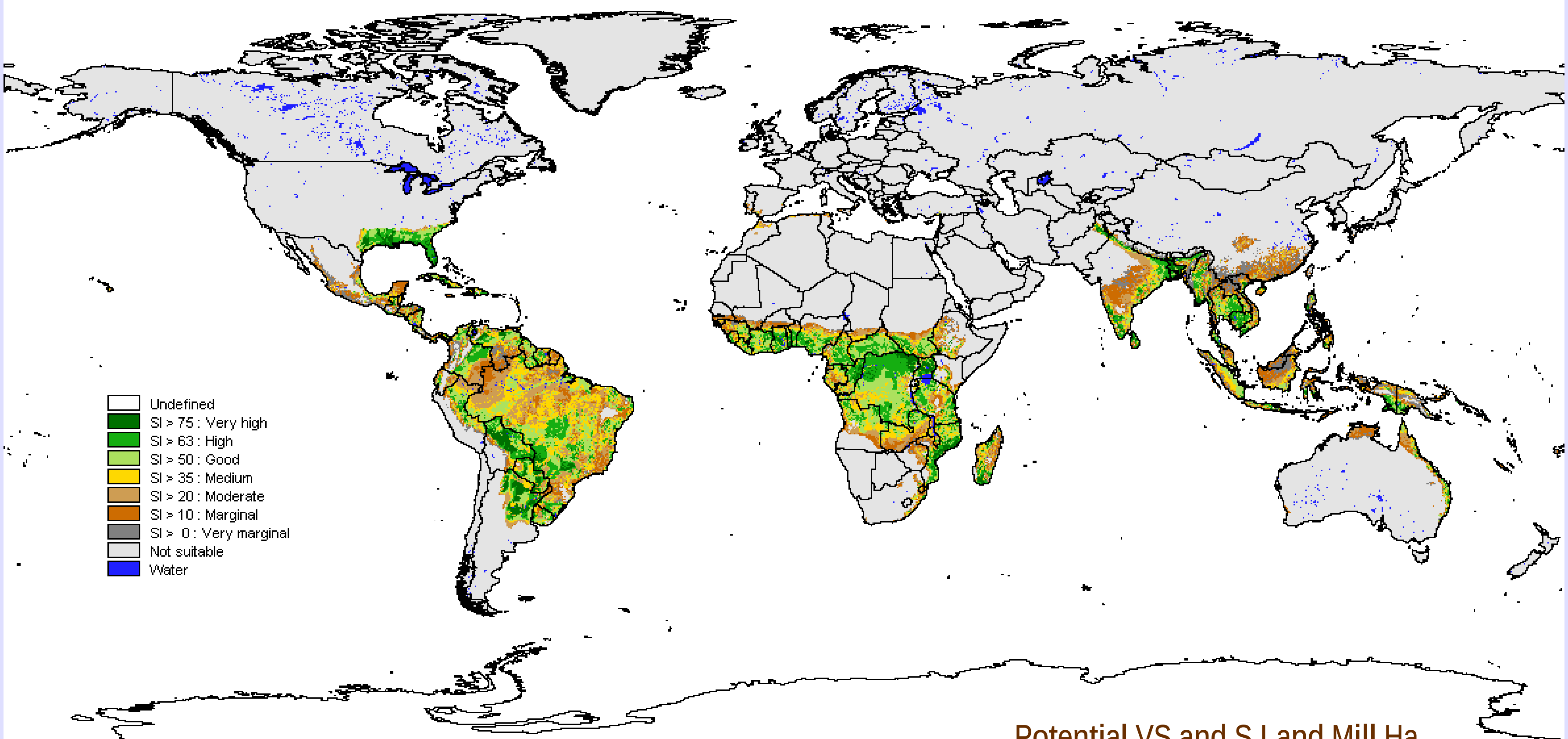
Current Land 135 Mill Ha

Forests 228 Mill Ha

Grasslands 87 Mill Ha

Current Sugarcane Land 22 mill Ha (Brazil + India 50%)

Suitability for rain-fed Jatropha production

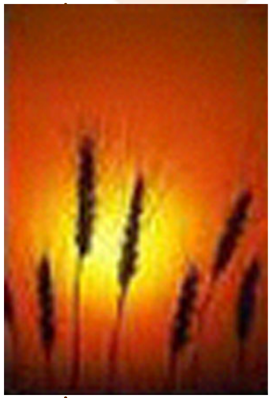


Potential VS and S Land Mill Ha

Jatropha	Developed	Developing
Current Land	17	286
Forests	28	348
Grasslands	6	264
Current Land	-	1.5

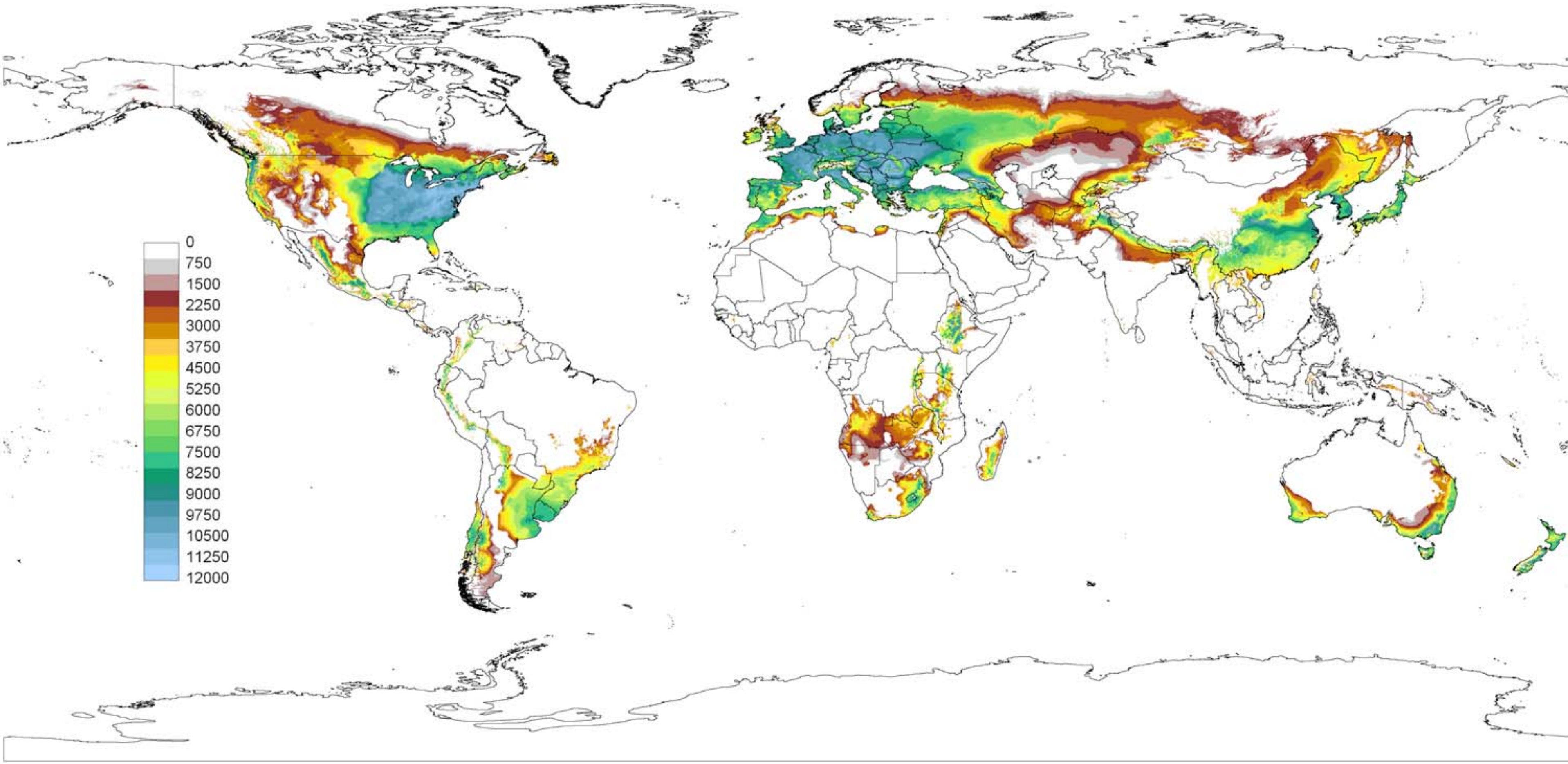
Sensitivity of Agro-ecosystems to Global Environmental Change

- Global warming **+/-**
  - + Removal of cold temperature limitations
  - + Longer growing season
  - • Faster growing period
  - • Exceedance of temperature thresholds
  - • Increased crop water requirements
  - • Increased incidence of pests and diseases
- Changes in composition of atmosphere **+**
  - + Yield increases due to CO_2 fertilization
  - + Increased water-use-efficiency
  - • Pollution (e.g. tropospheric ozone)
- Alterations in precipitation patterns, soil moisture conditions, surface runoff **+/-**
- Increased occurrence of extreme weather events **-**
- Increased climate variability **-**



Agro-climatically Attainable Yields

Rain-fed Wheat, Reference Climate

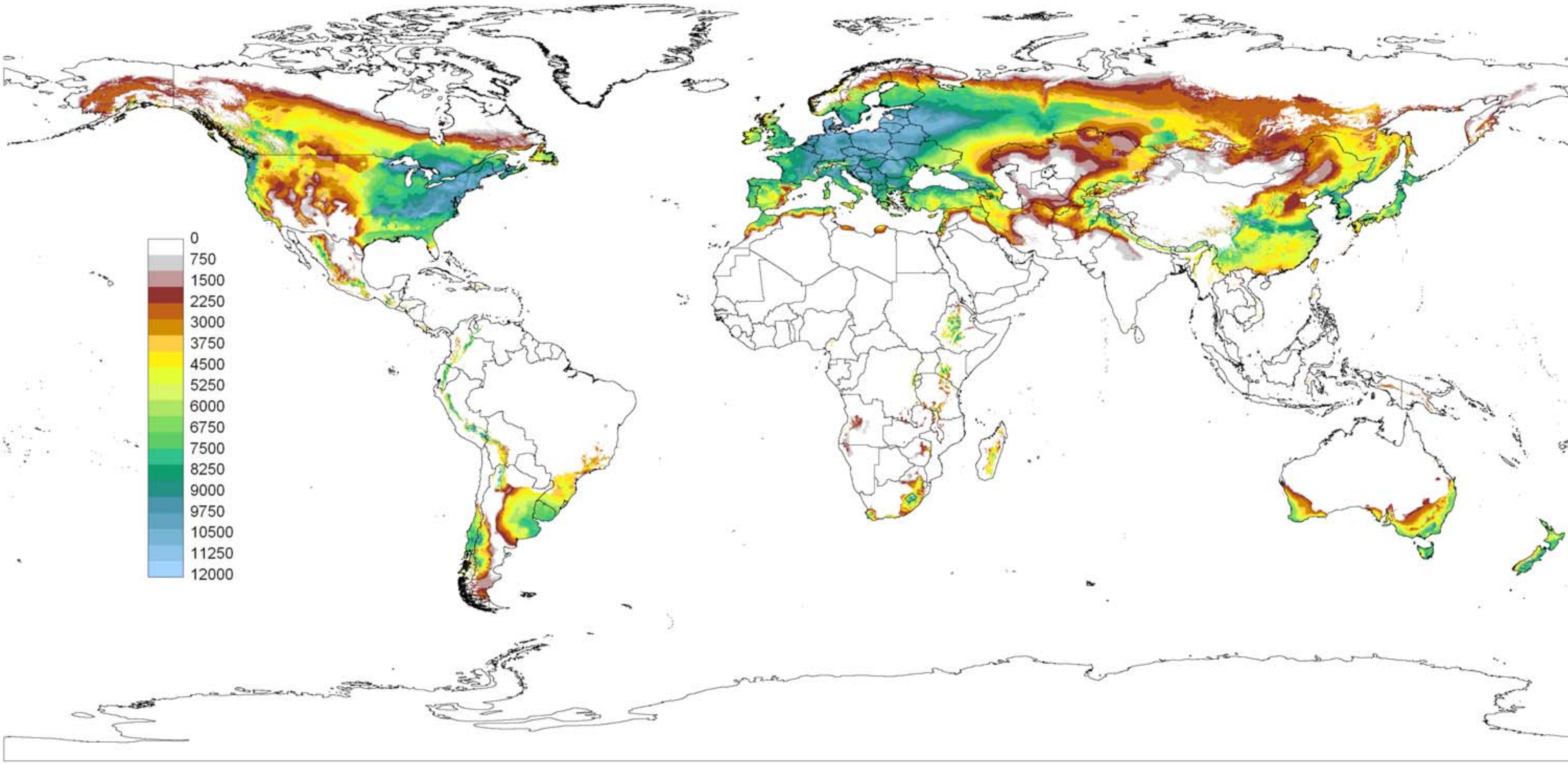


Source: Global AEZ 2007, FAO-IIASA

Note: Assuming good management and high input level

Agro-climatically Attainable Yields

Rain-fed Wheat, HadCM3-A2, 2050s



Source: Global AEZ 2007, FAO-IIASA

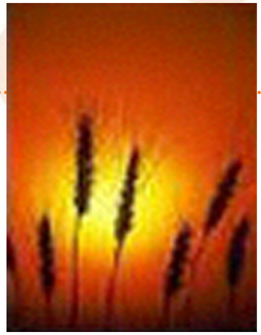
Note: Assuming good management and high input level

Impact of climate change on land suitability and potential production of cereals on current rainfed cultivated land

	Current climate			HadCM3 A2 2020s			HadCM3 A2 2050s			HadCM3 A2 2080s		
	Area	Prod	Yield	Area	Prod	Yield	Area	Prod	Yield	Area	Prod	Yield
	mln ha	mln tons	t/ha	% change			% change			% change		
North America	181	1053	5.8	2	-1	-4	2	-6	-7	2	-6	-7
Europe & Russia	237	1414	6.0	2	4	3	1	7	6	-1	2	3
South America	87	623	7.1	-1	1	2	-2	0	2	-11	-9	2
Sub-Saharan Africa	188	1142	6.1	-2	0	2	-4	-1	2	-8	-5	3
Southeast Asia	48	324	6.7	3	6	3	6	11	4	-1	-1	1
South Asia	107	705	6.6	1	3	2	0	0	0	-1	-5	-4
East Asia	66	391	5.9	2	5	3	1	13	12	-2	12	14
Developed	446	2586	5.8	2	2	0	3	3	0	1	-1	-1
Developing	559	3529	6.3	0	2	2	-1	2	3	-6	-5	2
World	1004	6116	6.1	1	2	1	0	2	2	-3	-3	0

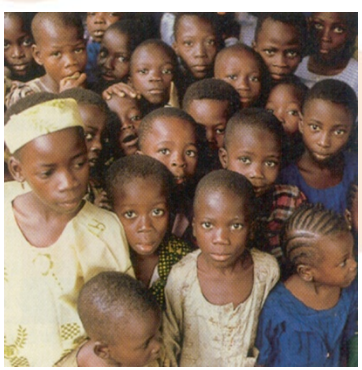
Note: Results include CO2 fertilization and assume rational adaptation and transfer of crop types and selection of best crop.

Impacts of Climate Change 1:



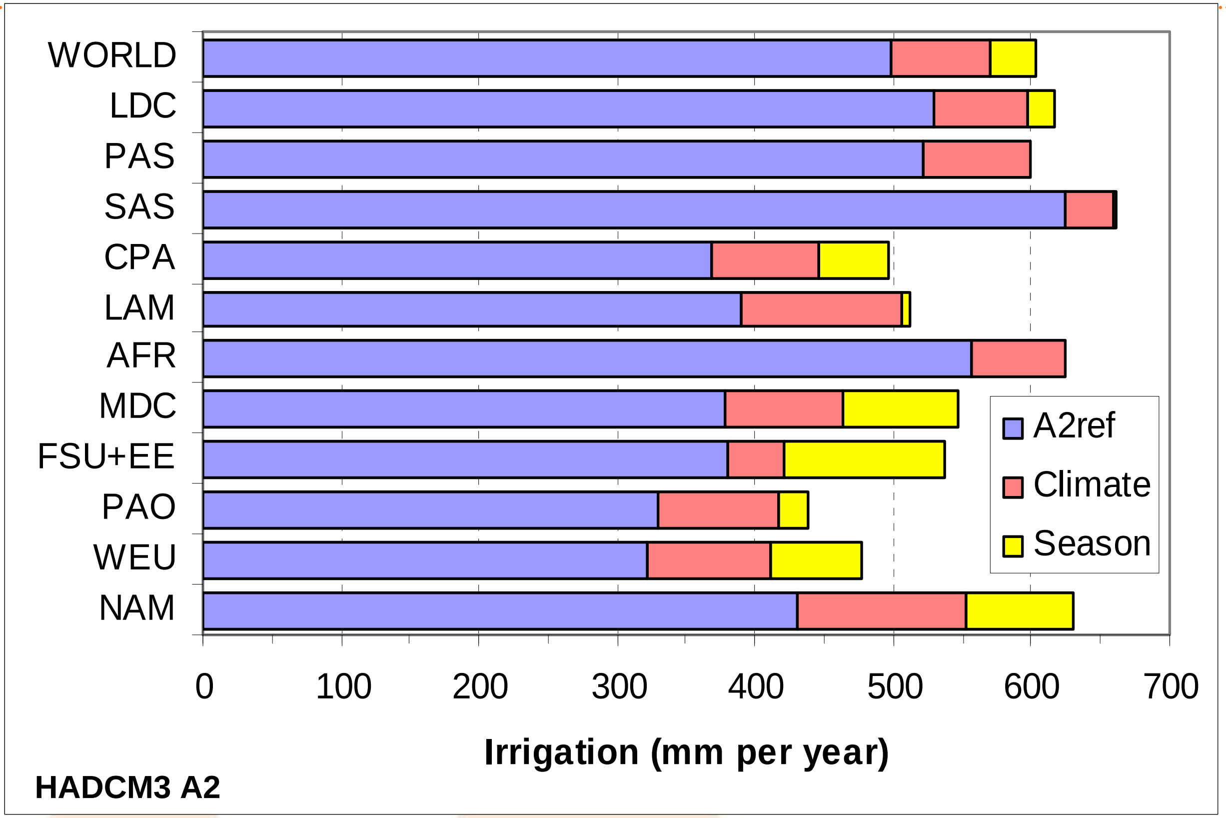
- The impacts of climate change on crop production are geographically very unevenly distributed and aggregate global figures reveal little.

- Autonomous adaptation (planting dates, cultivar changes, moisture conservation tillage, deploying irrigation where economical, switching crops) will offset some (gradual) warming (temperate climate +3-5°C, tropics +0-2°C).



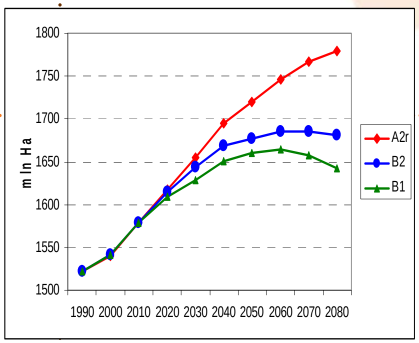
- Aggregate impacts of projected climate change on the global food system are relatively small. The global balance of food demand and supply is not likely to be challenged until middle of the century.

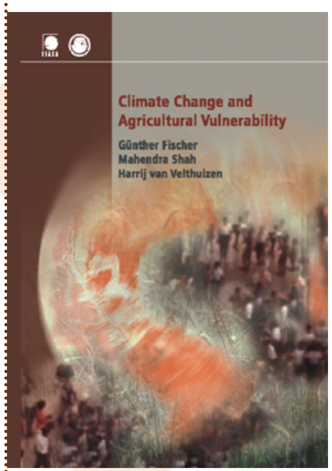
Impacts of climate change on regional net irrigation water requirements in 2080

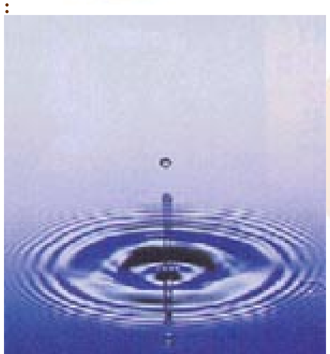


- 271 million ha irrigated out of total 1540 million ha cultivated (~ 18 %).
- Agriculture uses 2630 billion m³ out of 3816 billion m³ annual water withdrawals (~ 70%).
- On average, annual global crop water deficit is 500 mm (i.e., 1350 billion m³ in 2000); about 970 mm water per irrigated hectare were applied.

Impacts of Climate Change 2:





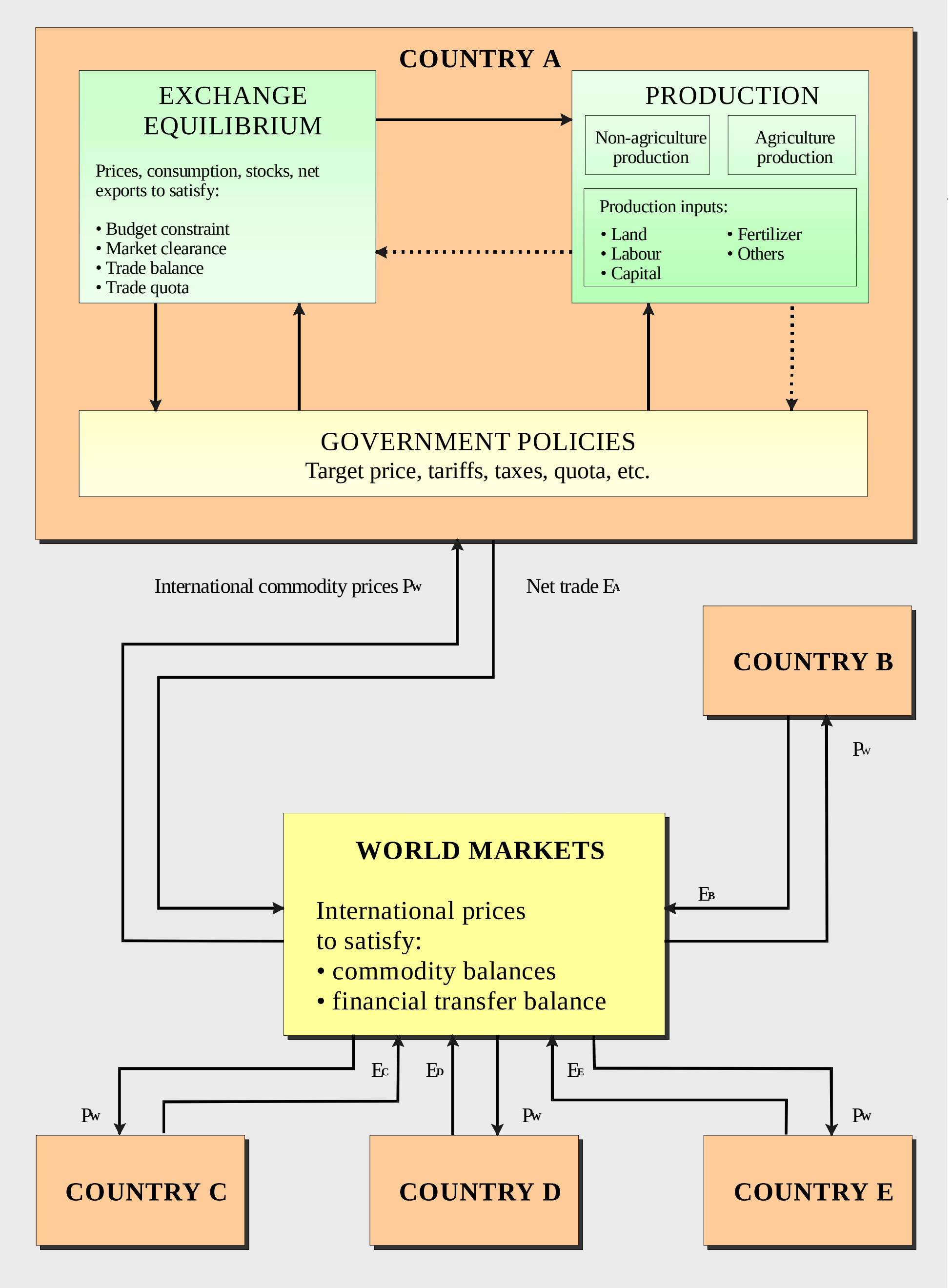


- While atmospheric changes (CO_2 fertilization) may initially increase productivity of current agricultural land, climate change, if not halted, will have a clearly negative impact in the second half of this century.
- Changes in frequencies of extreme events (droughts, heat waves, severe storms) are more troublesome in the near term than gradual changes in average conditions.
- Impacts of climate change on increasing net irrigation water demand could be as large as changes projected due to socio-economic development in 2000-2080.

World Food System Model (WFS)

- NATIONAL models
  - 18 single country (US, Australia, Brazil, China, …)
  - EU-15, EU-12, Rest of Europe
  - 13 regional aggregates (e.g., African oil exporters; Africa medium income food exporters,...)

- WORLD MARKET EXCHANGE MODULE: links national models through trade, world market price, and financial flows



World Food System Model

A) NATIONAL/REGIONAL models

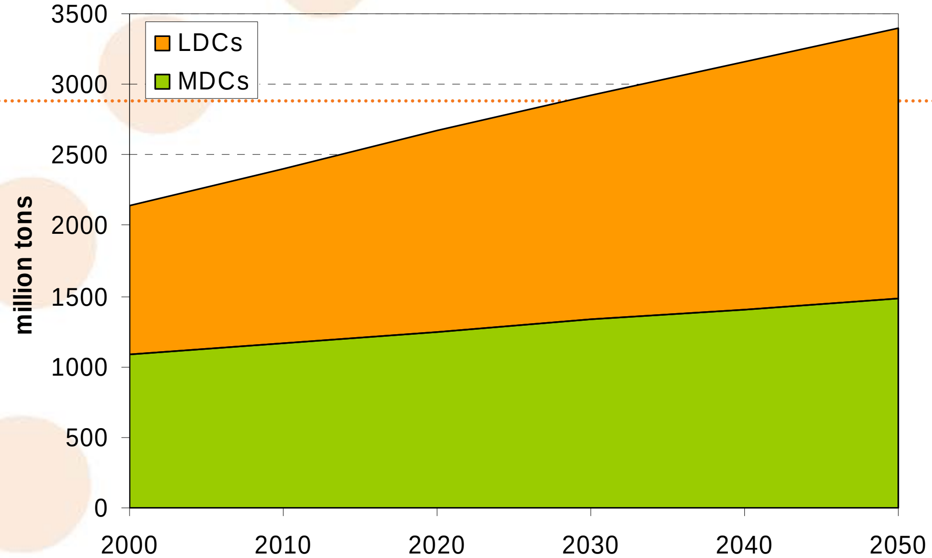
- Simulate behavior of producers, consumers, and 'government'
- Agriculture produces 10 -16 aggregate commodities
- Production depends on: prices, rational resource allocation (short term), investment , Pa/Pn, technology, land conversion (long term)
- Crop acreage and livestock require land, labor and capital
- Yields respond to fertilizer use and technical progress

B) WORLD MARKET links national exchange components

- Simulate supply, consumption, and net trade flows
- Clears markets and determines endogenous clearing prices for 9 agricultural sectors and one non-agricultural sector:
  Wheat, Rice, Coarse grain, Bovine & ovine meat, Other Meat & Fish, Dairy products, Protein Feed, Other food, Non-food agriculture

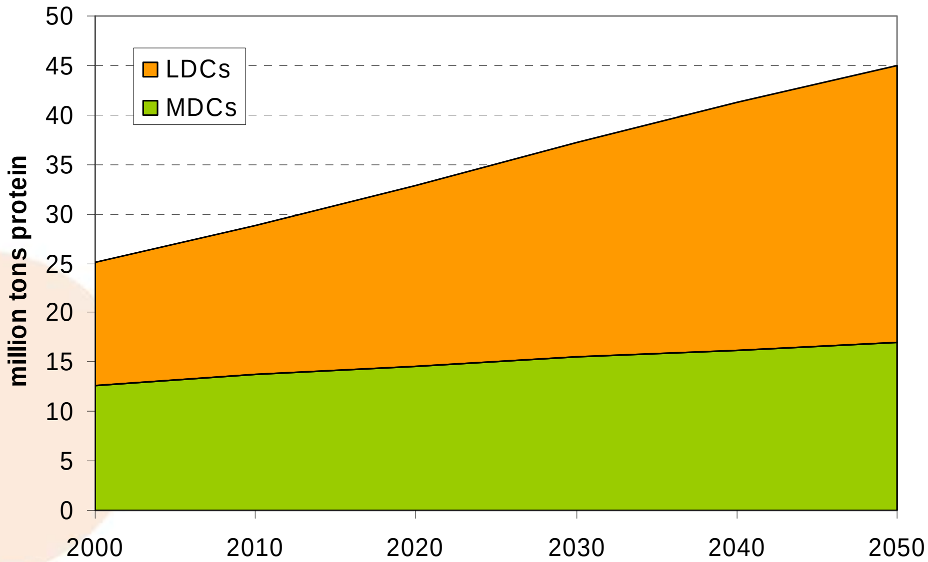
- Applied General Equilibrium model: recursive, dynamic

Food and Agriculture Outlook



1. Cereal production, 2000 to 2050

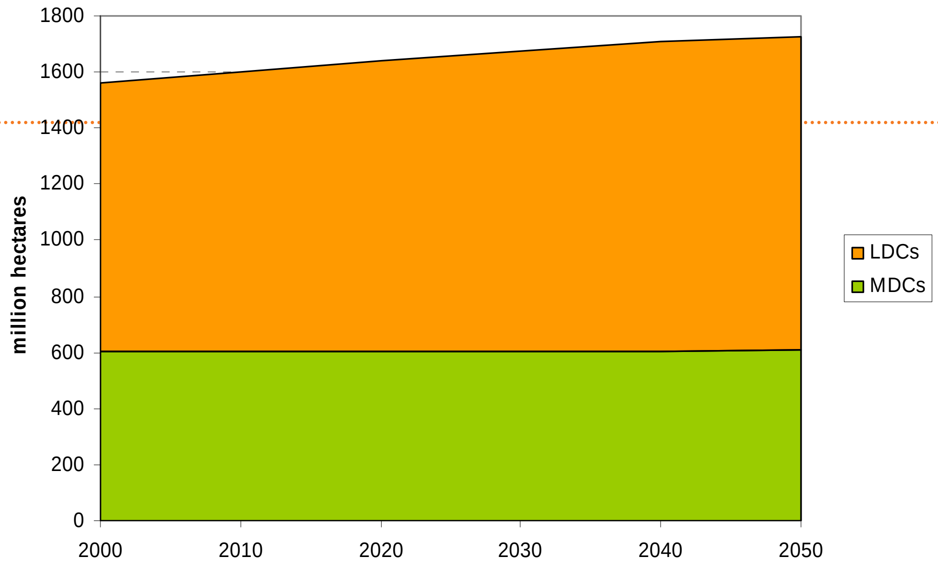
2. Pork & poultry production, 2000 to 2050



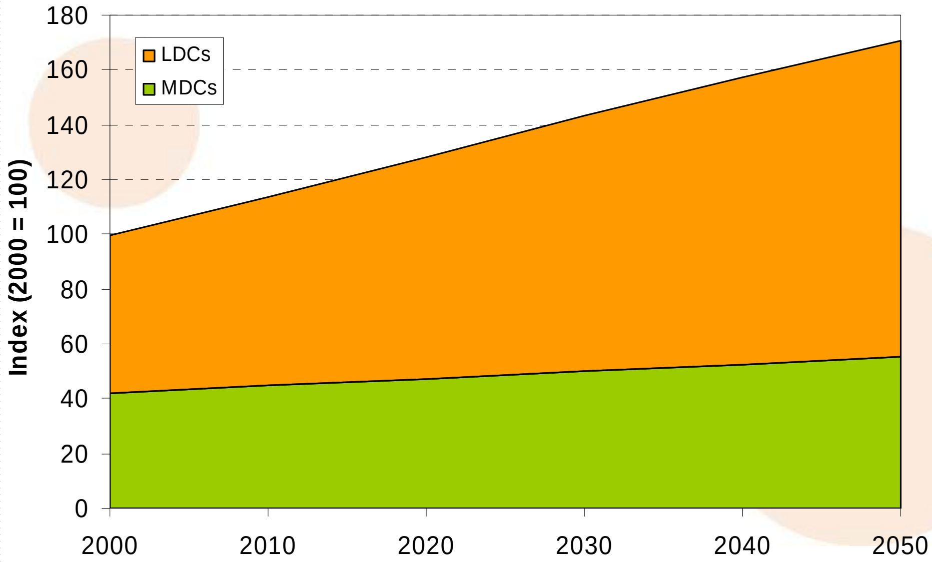
Source: LUC World food system simulations, IIASA (2009).

Food and Agriculture Outlook

Growth of:	2000-2050
Arable land	11%
Cereal production	59%
Ruminant meat	65%
Other meat	80%
Agriculture	71%



3. Cultivated land, 2000-2050



4. Index of agricultural production (2000=100), 2000-2050

Source: LUC World food system simulations, IIASA (2009).

WFS Simulations of Biofuel Scenarios

Supply representation:

- Conventional agricultural commodities (1st generation) to be used are wheat, coarse grains, other food (i.e., vegetable oil, sugar crops, root crops); -> conversion coefficients from WFS commodity to biofuel/energy equivalent;
- Production of co-products -> input to feed/other markets;
- Energy demand portfolio (ethanol vs. biodiesel; 1st vs 2nd generation) prescribed as scenarios;
- Impacts of biofuels on food and feed markets via competition for feedstocks and generation of co-products;

BIOFUELS SCENARIOS

Demography, Income

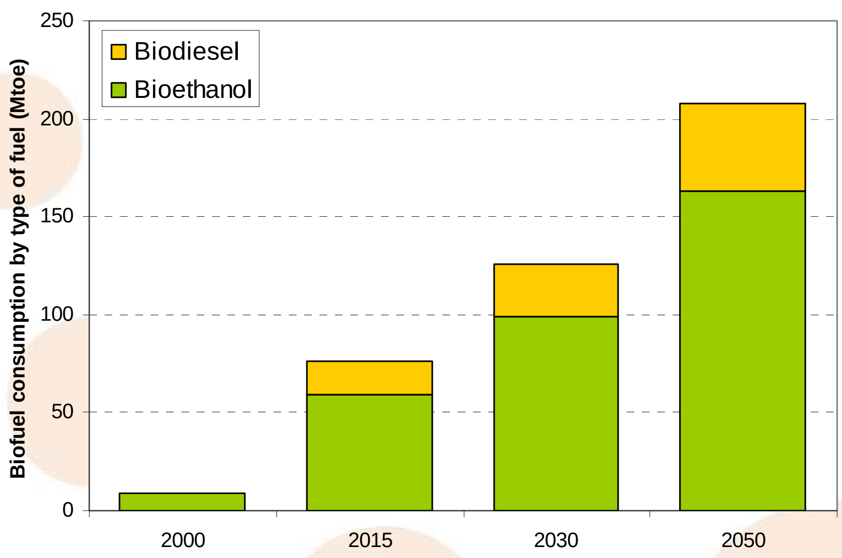
Transport fuel demand

Biofuel demand

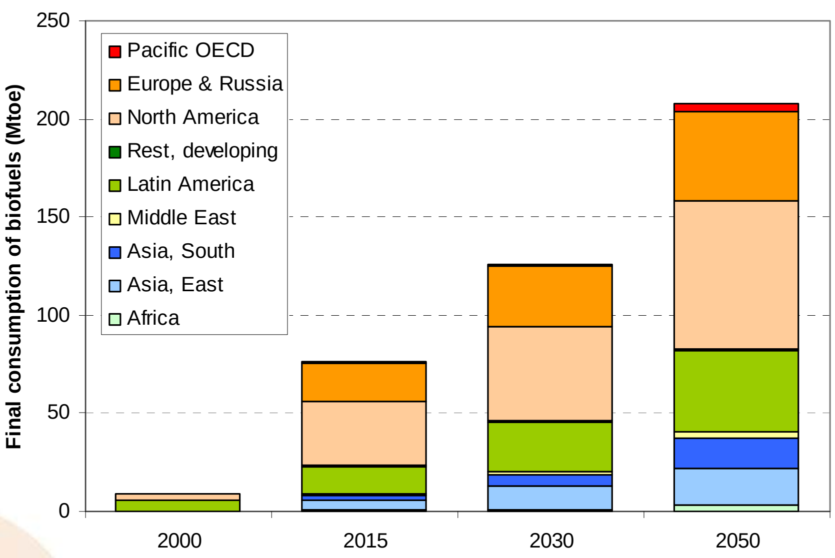



Final consumption of biofuels in the WEO scenario

a) Consumption by type of biofuel

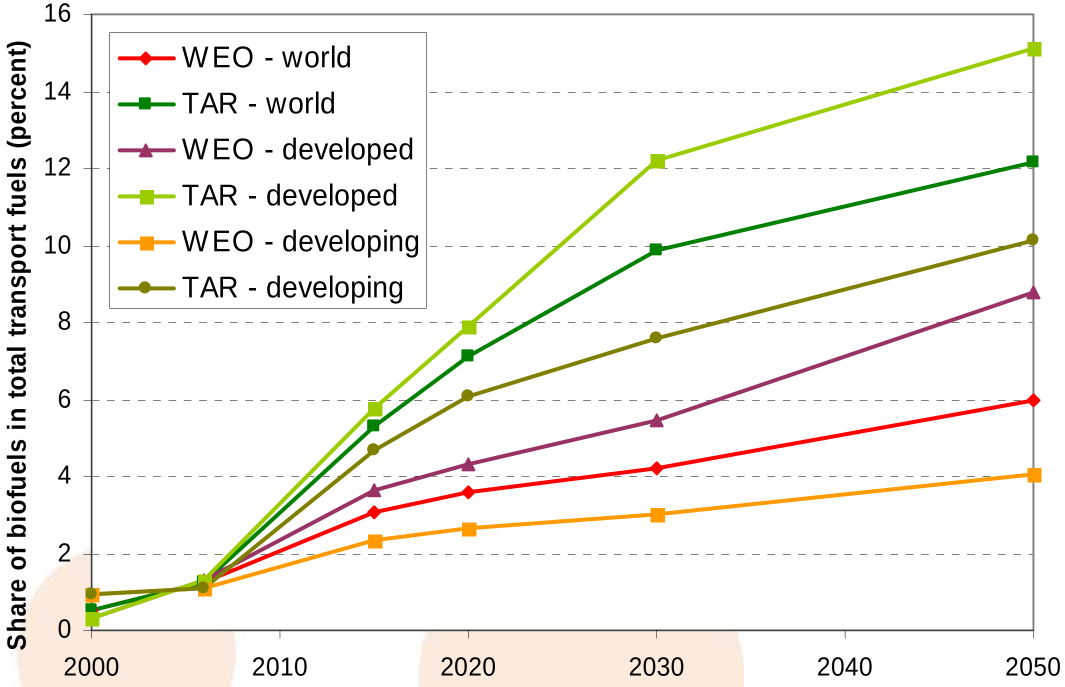


b) Consumption by region



Share of biofuels in final consumption of total transport fuels

Share of biofuels by scenario and region :



Biofuels in 2020 and 2030

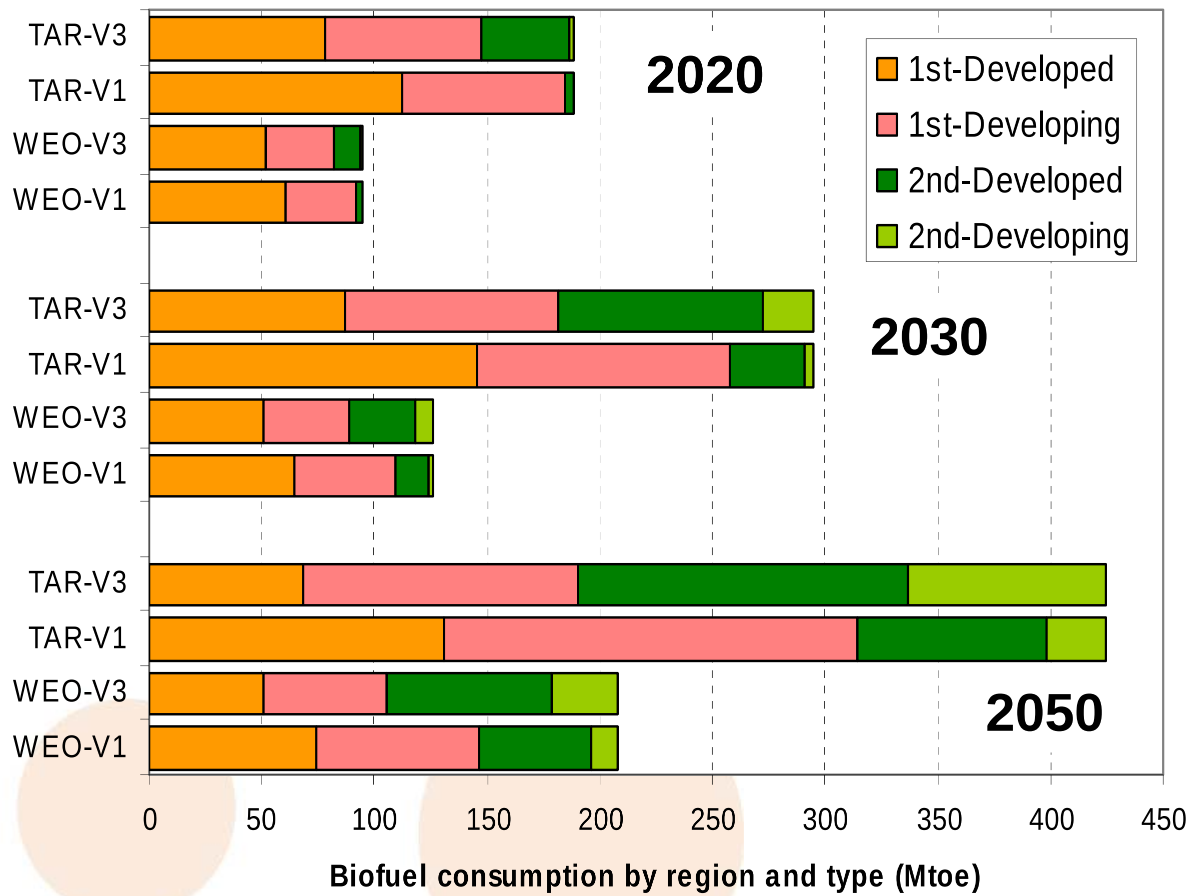
Million Tons Oil Equivalent

	TARGET V1		TARGET V3	
	2020	2030	2020	2030
Developed Countries				
Transport Fuels	1505	1486	1505	1486
1st Generation Biofuels	113	146	79	87
2nd Generation Biofuels	5	32	39	91
Biofuels in Transport Fuel	8%	12%	8%	12%
Developing Countries				
Transport fuels	1174	1529	1174	1529
1st Generation Biofuels	72	112	69	94
2nd Generation Biofuels	0	4	2	22
Biofuels in Transport Fuels	6%	9%	6%	9%

United States, European Union, Japan, Canada, Australia ...

Brazil, China, India, Indonesia, Thailand, South Africa ...

Biofuel scenarios by type of technology and by broad regions



Biofuel scenarios analyzed in "Biofuels and Food Security" study

Scenario acronym	**Scenario description**
REF-00	Starting in 1990, assumes a world without any agricultural crops used for biofuel production.
REF-01	Assumes historical biofuel development until 2008; biofuels feedstock demand is kept constant after 2008; used as a reference simulation to which alternative biofuel scenarios are compared for their impact.
REF-02	Assumes historical biofuel development until 2008; feedstock demand faded out linearly between 2008 and 2020; used to test a possible alternative future without first-generation biofuel feedstocks beyond 2020.
WEO-V1	Assumes transport energy demand and regional biofuel use as projected by International Energy Agency (IEA) in its WEO 2008 Reference Scenario. Second-generation conversion technologies become commercially available after 2015; deployment is gradual (see Table 3.3-2)
WEO-V2	Assumes transport energy demand and regional biofuel use as projected by IEA in its WEO 2008 Reference Scenario. Assumes that due to delayed arrival of second-generation conversion technologies all biofuel production until 2030 is based on first-generation feedstocks.
WEO-V3	Assumes transport energy demand and regional biofuel use as projected by IEA in its WEO 2008 Reference Scenario. Accelerated development of second-generation conversion technologies permits rapid deployment of second-generation biofuels; consequently, reduced competition with food/feed uses of agricultural crops.
TAR-V1	Assumes transport energy demand as projected by IEA in its WEO 2008 Reference Scenario. Assumes that mandatory, voluntary or indicative targets for biofuel use announced by major developed and developing countries will be implemented by 2020, resulting in about twice the biofuel consumption compared to WEO 2008. Second-generation conversion technologies become commercially available after 2015; deployment is gradual (percentage as in WEO-V1)
TAR-V2	Assumes transport energy demand as projected by IEA in its WEO 2008 Reference Scenario. Assumes that mandatory, voluntary or indicative targets for biofuel use announced by major developed and developing countries will be implemented by 2020. Assumes that due to delayed arrival of second-generation conversion technologies all biofuel production until 2030 is based on first-generation feedstocks.
TAR-V3	Assumes transport energy demand as projected by IEA in its WEO 2008 Reference Scenario. Assumes that mandatory, voluntary or indicative targets for biofuel use announced by major developed and developing countries will be implemented by 2020. Accelerated development of second-generation conversion technologies permits rapid deployment; 33% and 50% of biofuel use in developed countries from second-generation in 2020 and 2030 respectively.
SNS	Sensitivity scenarios assuming low (V1), intermediate (V2), high (V3), and very high (V4) share of first-generation biofuels in total transport fuels (see Table 3.3-3).

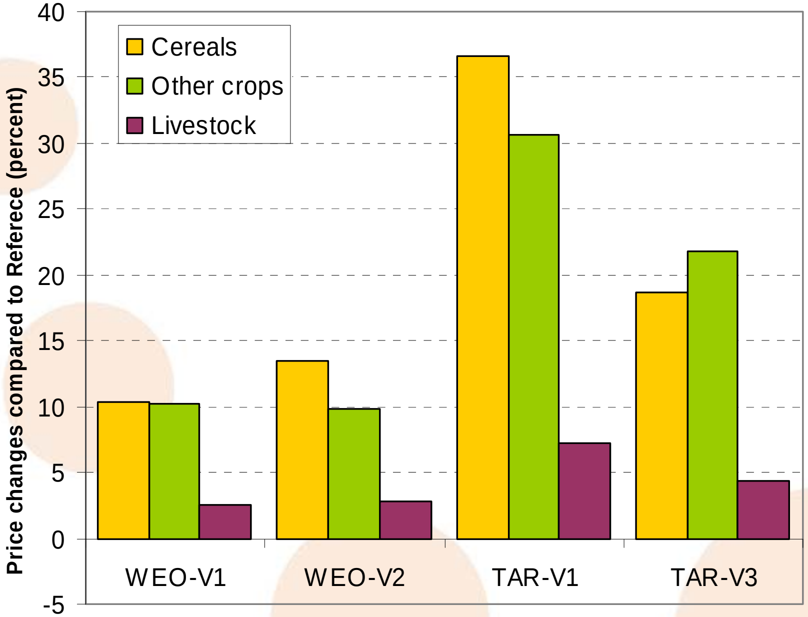
RESULTS

Social, environmental, economic impacts and implications of biofuels developments on transport fuel security, climate change mitigation, agricultural prices, food security, land use change and sustainable agricultural development

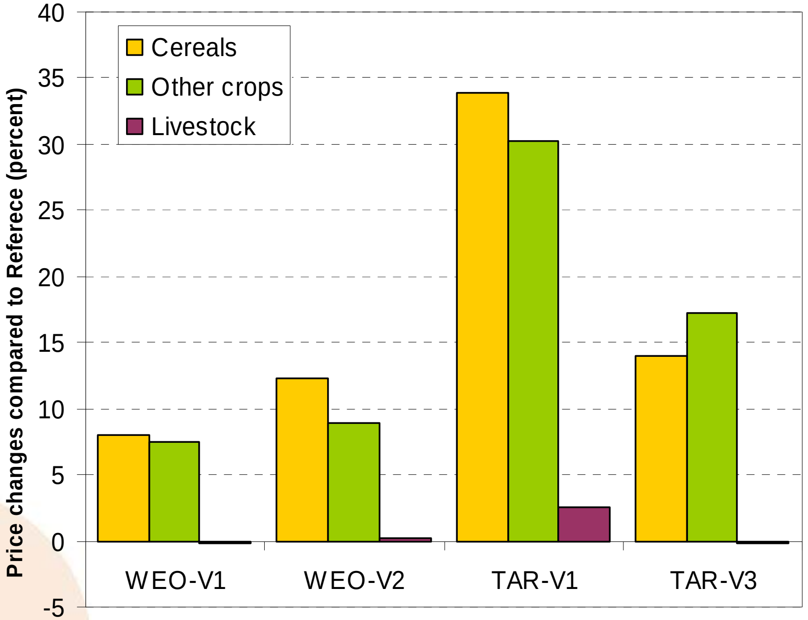



Impacts of first-generation biofuels on agricultural prices

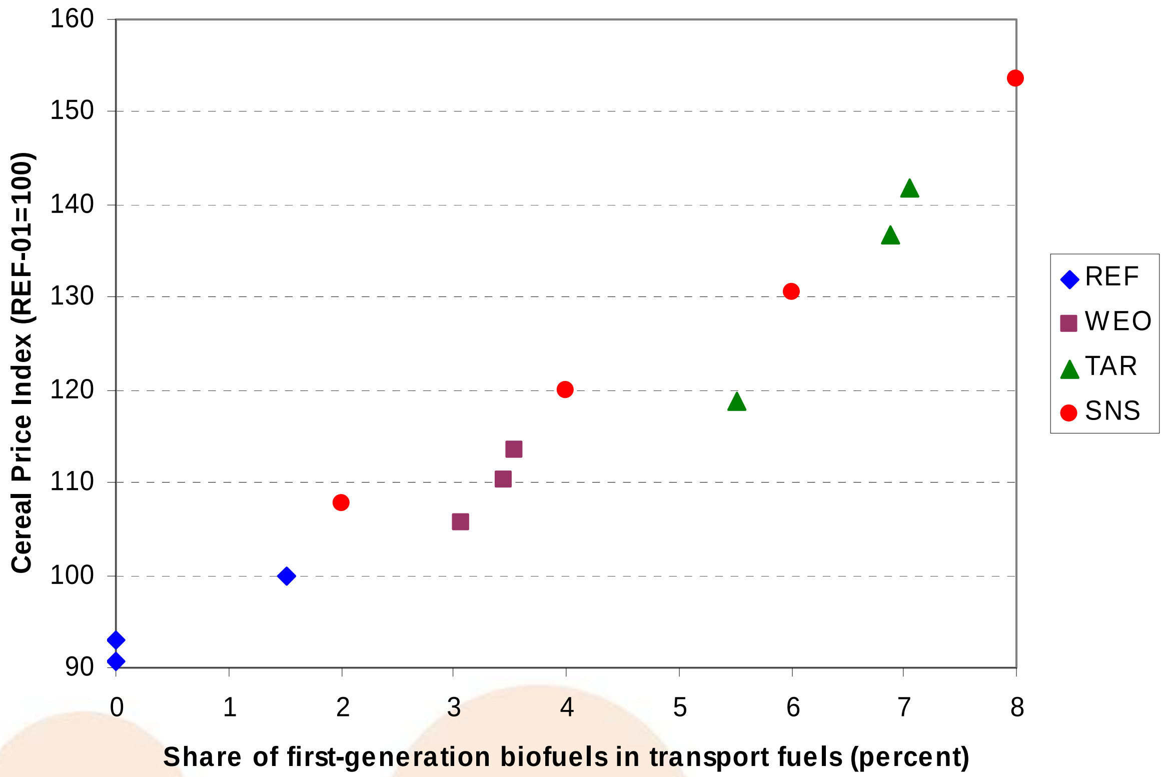
a) In 2020 (% change)



b) In 2030 (% change)



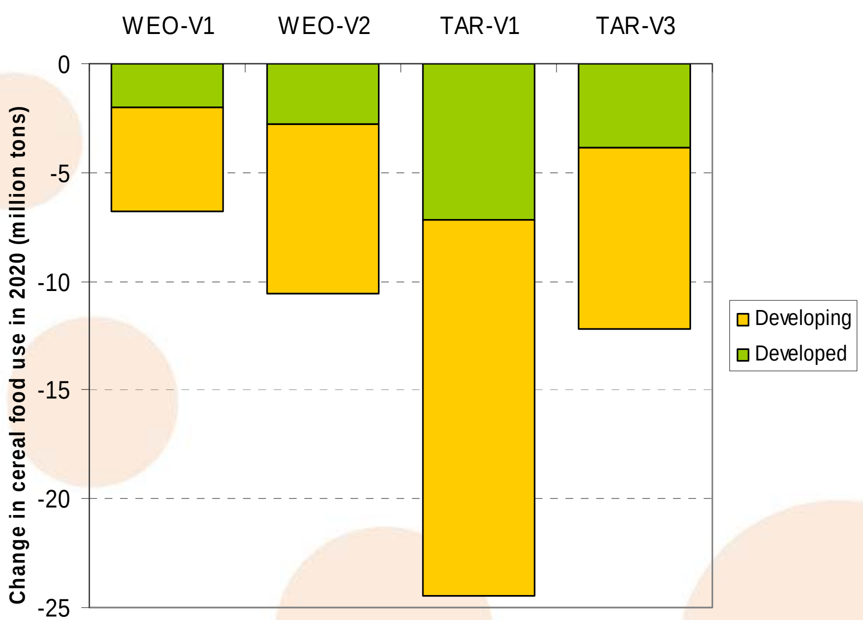
Cereal price index versus share of first-generation biofuels in transport fuels, in 2020



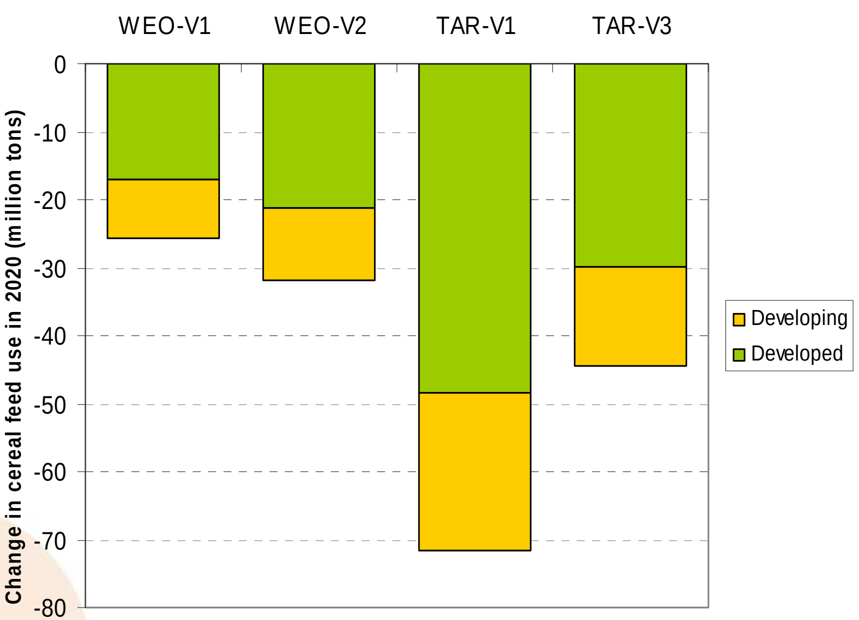
Note: SNS = sensitivity scenarios; TAR = scenario simulations based on mandates and indicative voluntary targets; WEO = simulations based on WEO 2008 projections of biofuel demand; REF = reference projections with constant, decreasing or no biofuel demand beyond 2008).

Change of cereal use relative to baseline REF-01, in 2020

a) Change in direct food use

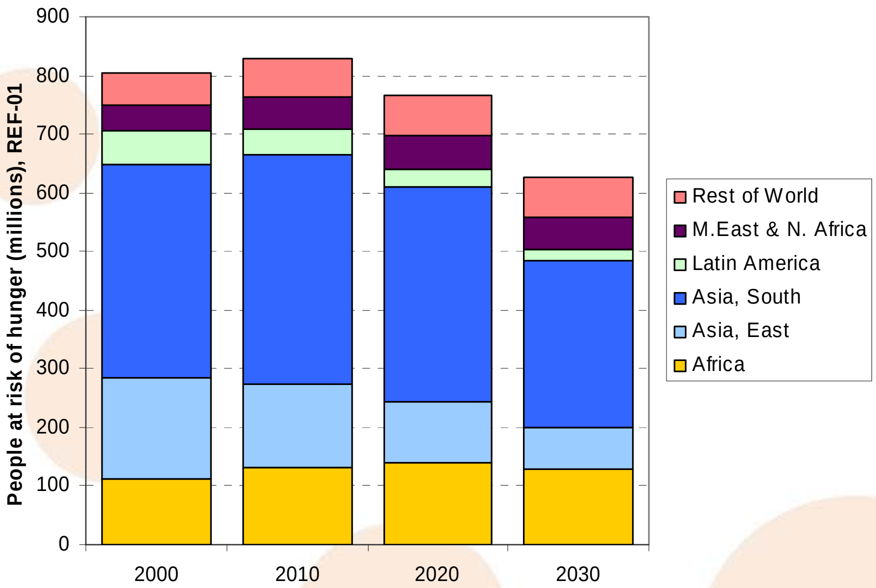


b) Change in feed use

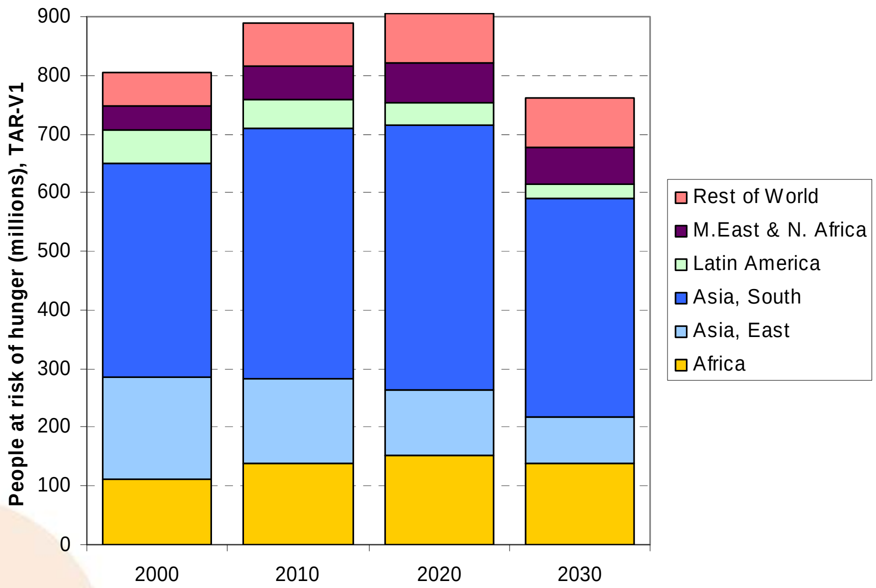


Risk of hunger in REF-01 and TAR-V1 scenarios

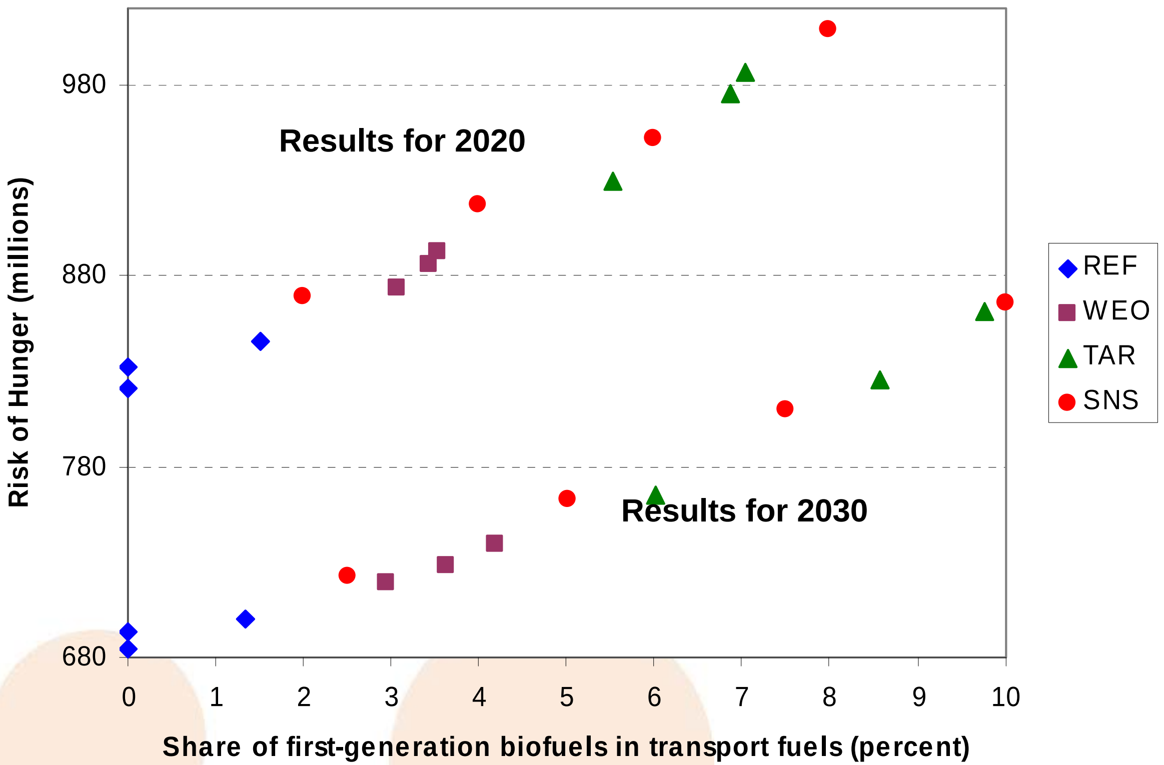
a) Scenario REF-01



b) Scenario TAR-V1

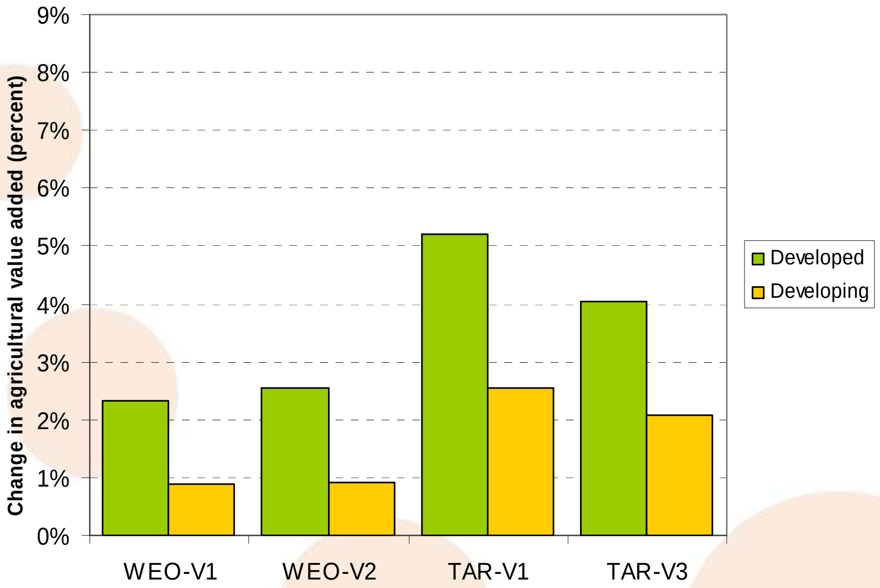


People at risk of hunger versus share of first-generation biofuels in total transport fuels

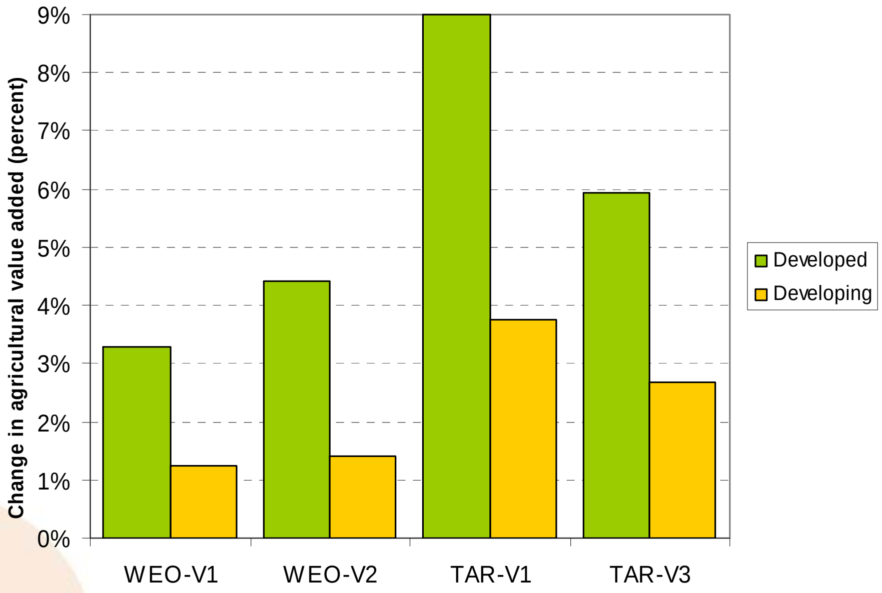


Change in agricultural value added relative to baseline REF-01

a) Percentage change in 2020

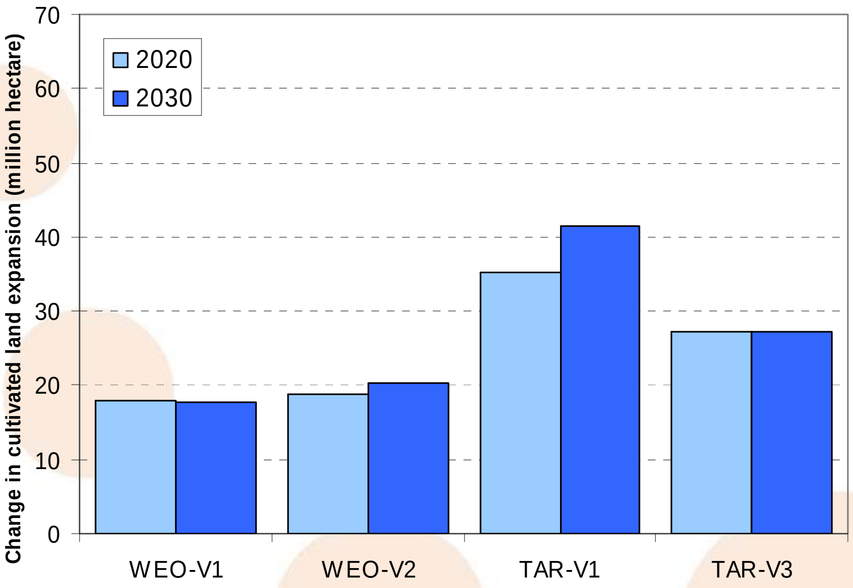


b) Percentage change in 2030

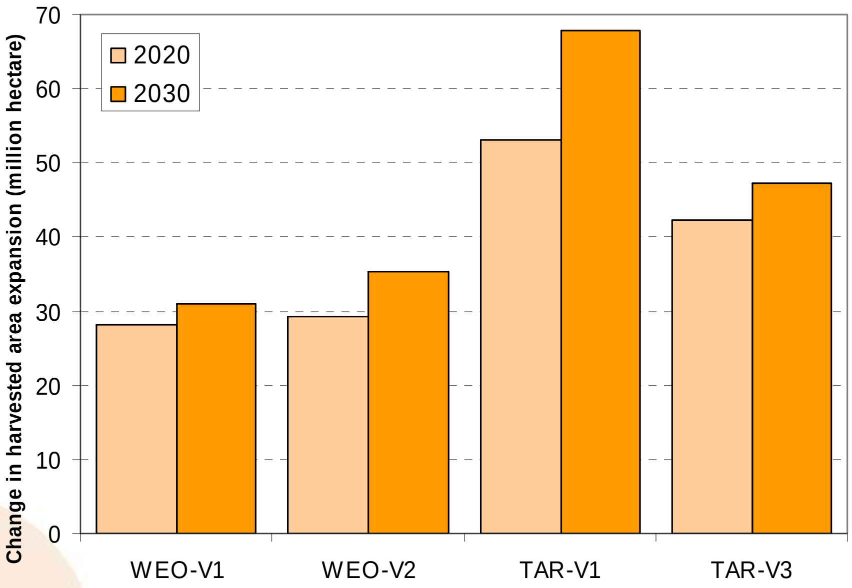


Additional use of cultivated land and harvested area in 2020 and 2030

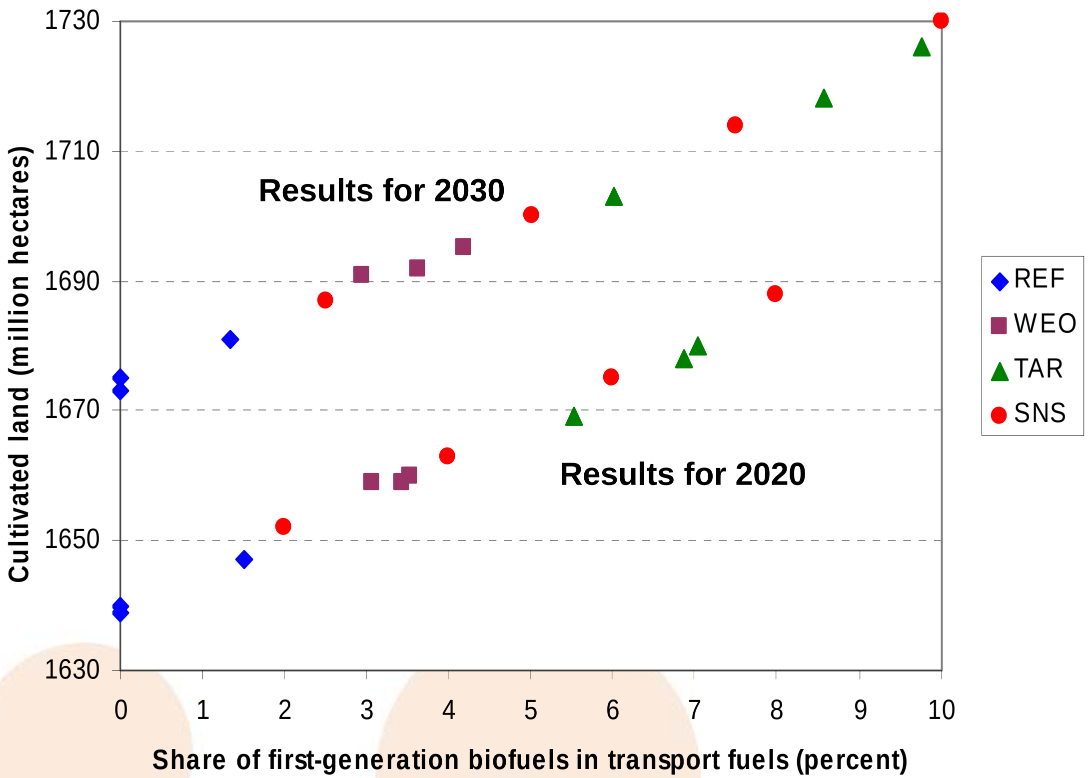
a) Additional cultivated land



b) Additional harvested area



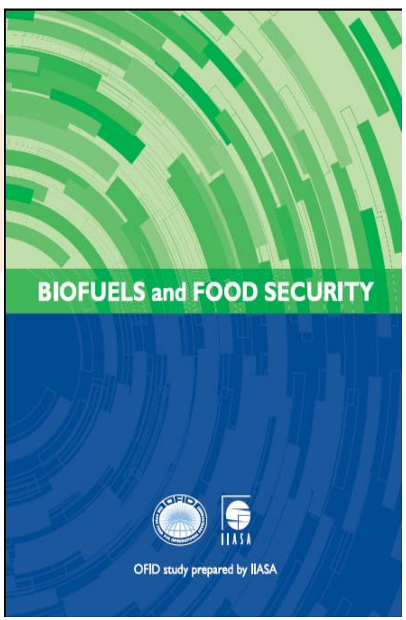
Cultivated land use versus share of first-generation biofuels in transport fuels

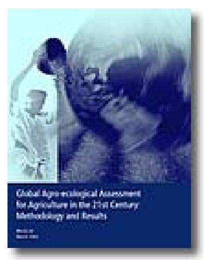


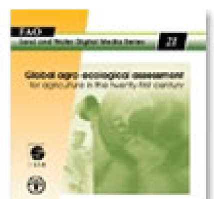
In summary …

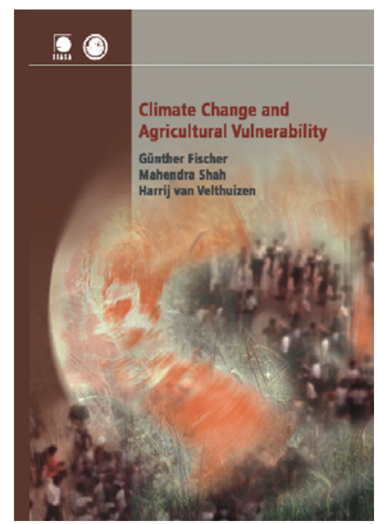
- Strong increases in global demand for agricultural products, about 70 percent in 2050 compared to 2000.
- Expected increasing integration of agriculture, forestry and energy sectors through land competition for biomass.
- Limited availability of additional high-quality land for 4F sectors; uncertainty regarding viability of using marginal land.
- Growing risks of yield damage due to extreme weather episodes; widespread negative climate change impacts after middle of century.

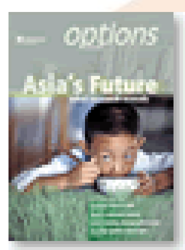
http://www.iiasa.ac.at/Research/LUC

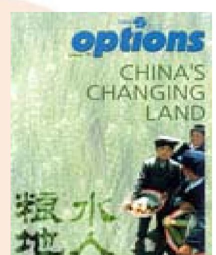






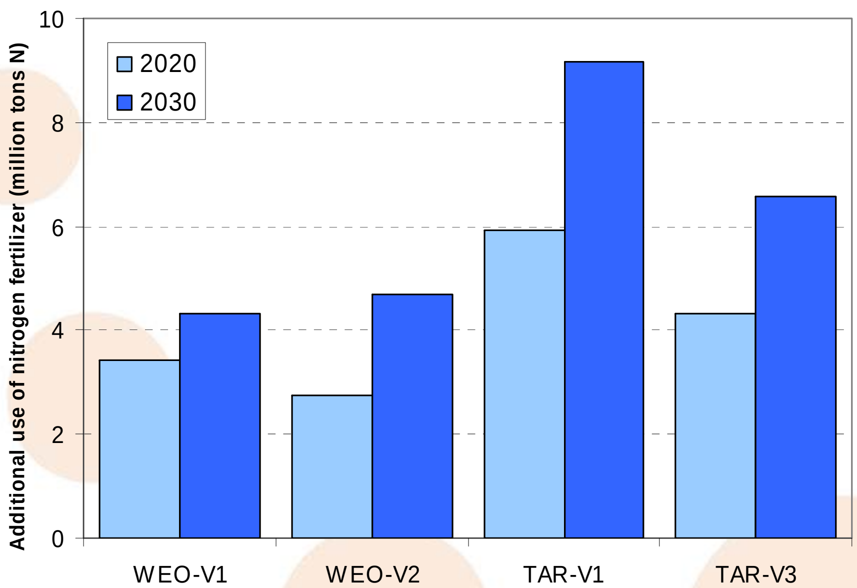






Nitrogen fertilizer use in biofuel scenarios

a) Additional use in 2020 and 2030



b) Fertilizer use vs. 1st generation biofuel share in transport