Global Development: Science and Policies for the Future

Expert Meeting on
Global Perspectives on Fuel and Food Security

FAO Headquarters,
Rome, 18-20 February, 2008

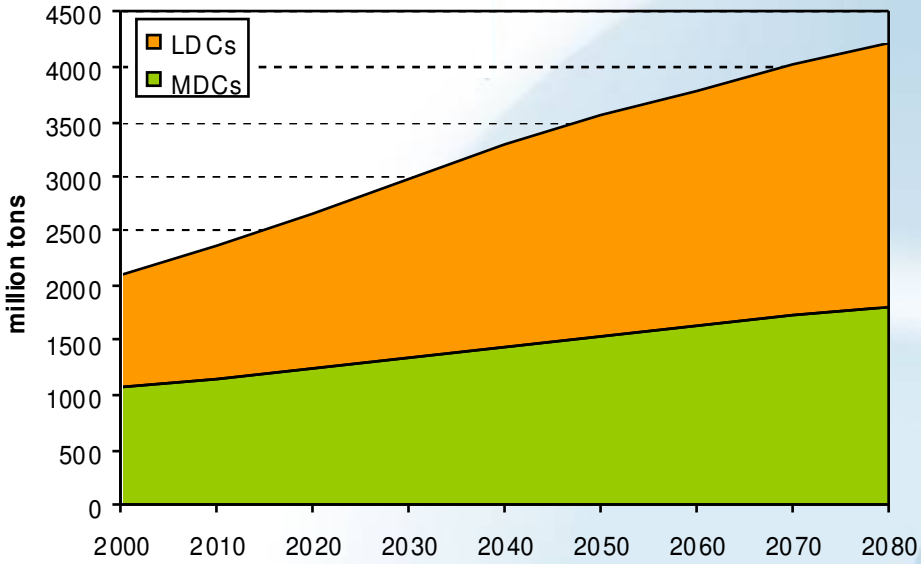
Implications for Land Use change

Günther Fischer
International Institute for Applied Systems Analysis, Laxenburg, Austria

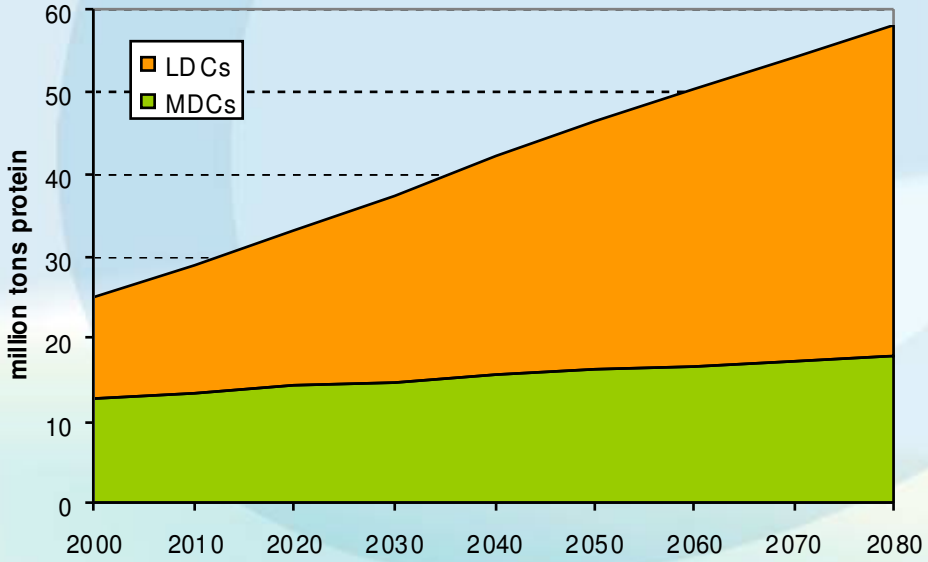
Overview

- Food and Agriculture outlook; land required
- Impacts of climate change on land
- Bioenergy feedstock production in agriculture and land competition
  - Land resources
  - First vs second generation feedstocks
  - How much land is available without compromising food and feed?

Food and Agriculture Outlook



1. Cereal production, scenario A2r, 2000 to 2080



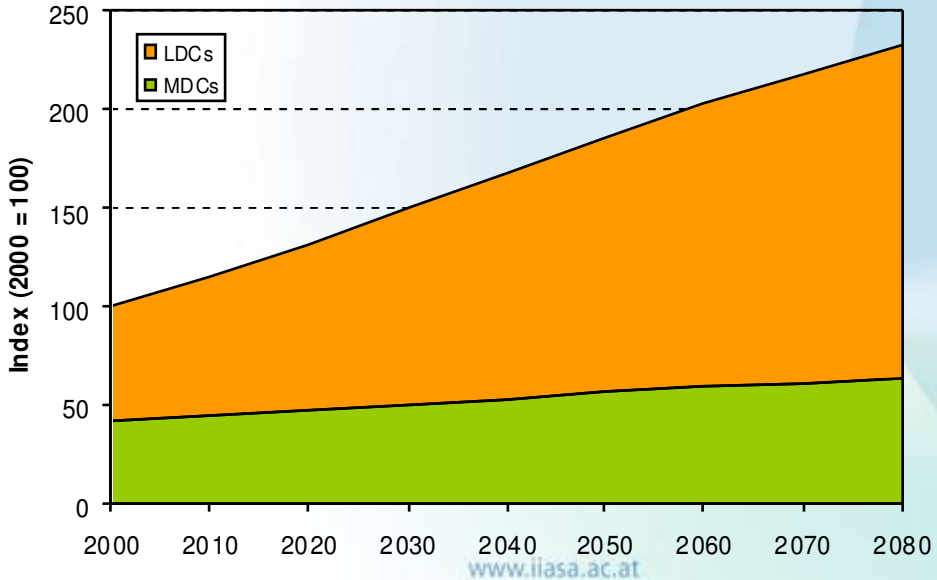
2. Pork & poultry production, scenario A2r, 2000 to 2080

Source: LUC World food system simulations of GGI scenarios, IIASA (2005).

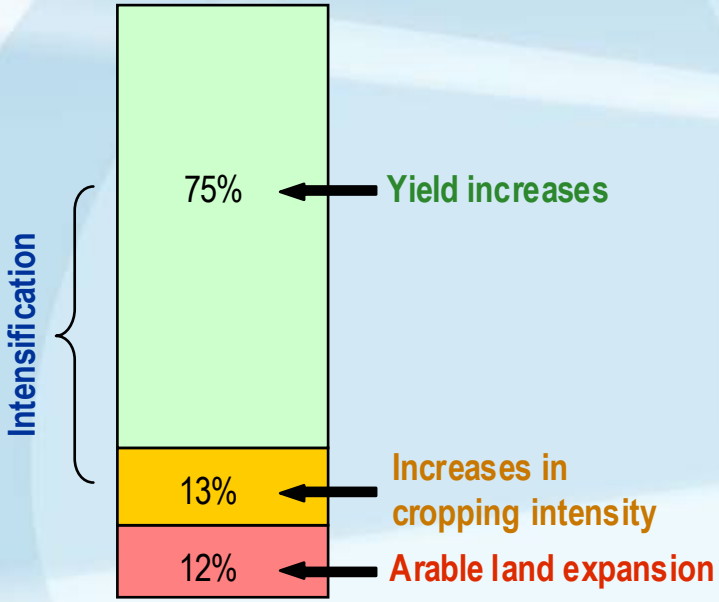
Food and Agriculture Outlook

Growth of:	2000-2050
Arable land	12%
Cereal production	69%
Ruminant meat	73%
Other meat	85%
Agriculture	86%

Index of agricultural production, IIASA A2r scenario, 2000-2080

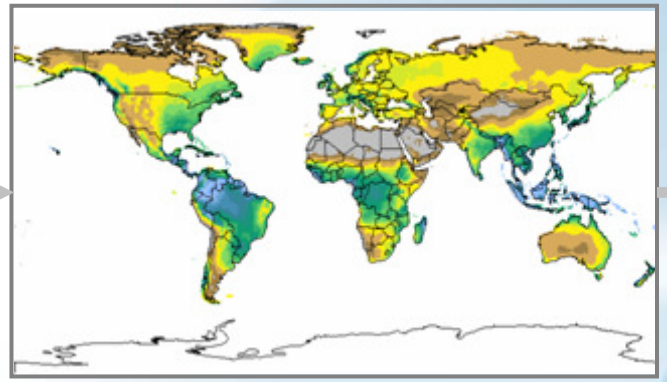


Sources of growth in agricultural production, Scenario A2r, 2000-2050



Source: World Food System simulations of IIASA GGI scenarios, Fischer et al. (2005).

Ecological-Economic Analysis



3

2

Climate model

1

Develop ment scenario

Climate impact response relations

4

Production

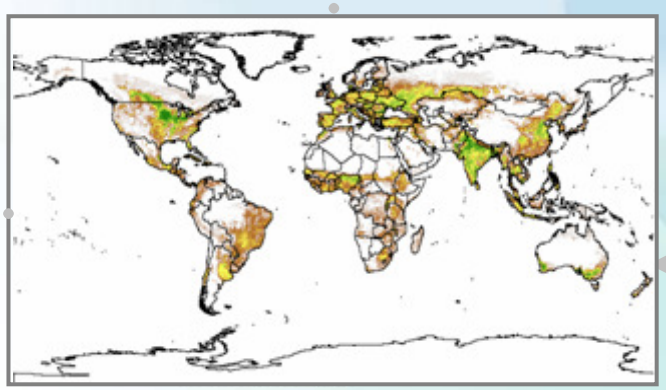
Demand

Trade

Global Food System

World Market

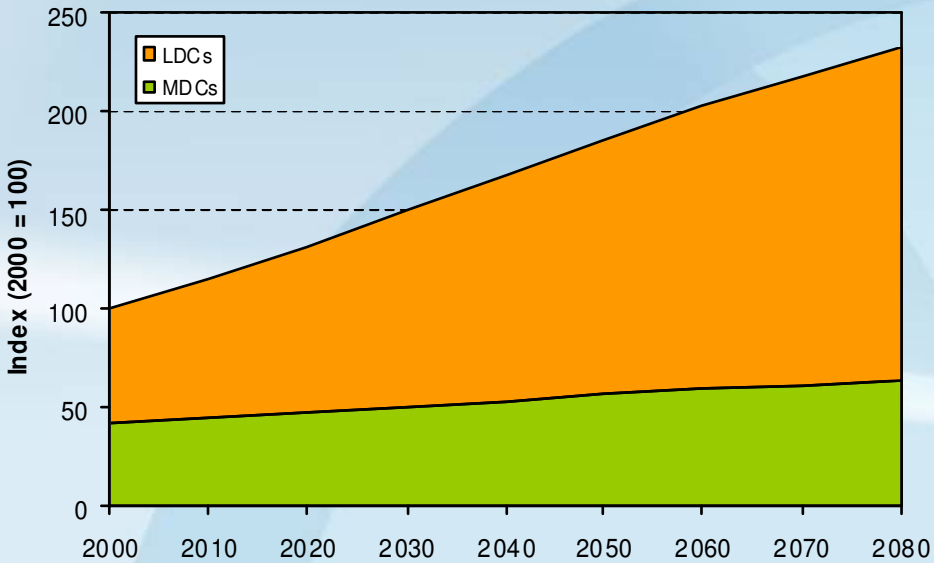
5

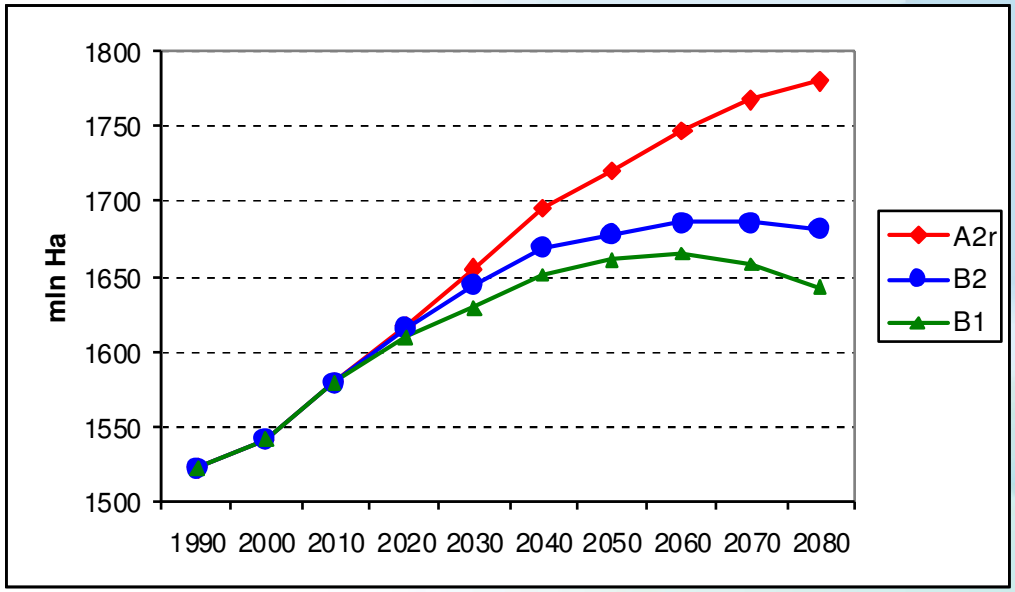


6

Food and Agriculture Outlook

3. Total agricultural production, revised A2r scenario, 2000 to 2080





4. Cultivated land, projected for different socioeconomic path-ways, 1990 to 2080

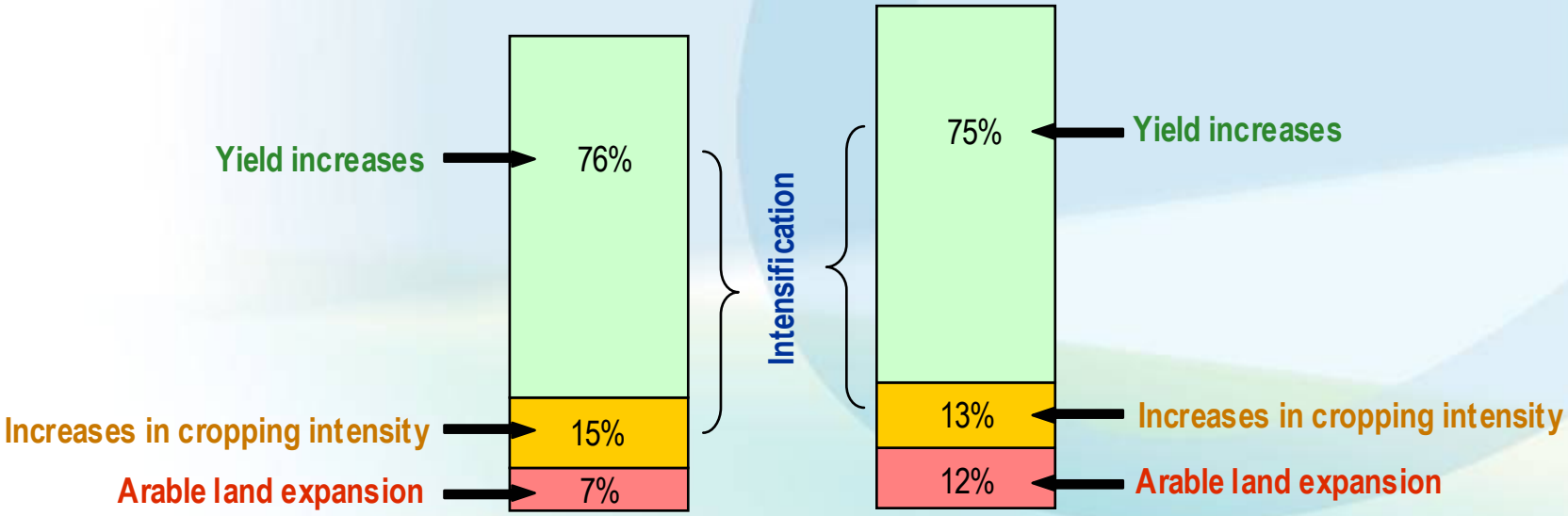
Source: LUC World food system simulations of GGI scenarios, IIASA (2005).

Food and Agriculture Outlook

Growth 2000-2050	Scenario B1	Scenario A2r
Arable land	7%	12%
Cereal production	62%	69%
Ruminant meat	68%	73%
Other meat	74%	85%
Agriculture	81%	86%

Source:
World Food System simulations of IIASA GGI scenarios, Fischer et al. (2005).

Sources of growth in agricultural production, 2000-2050



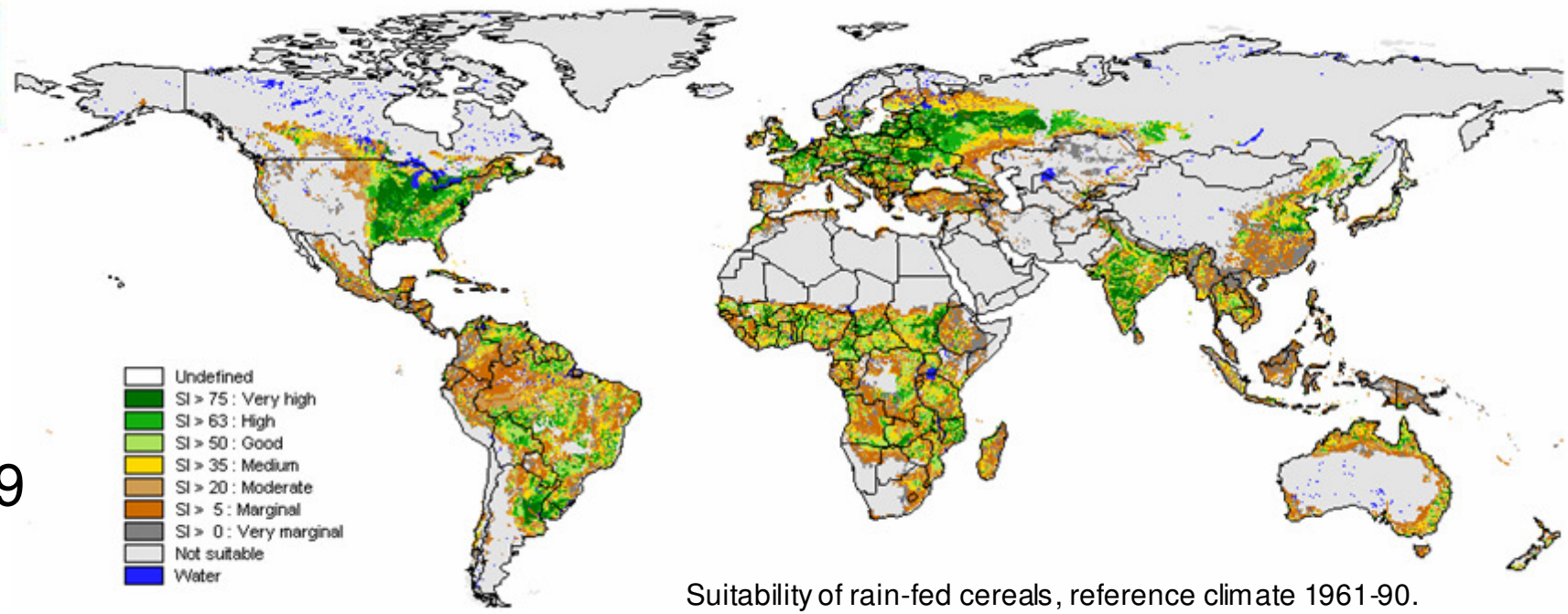
Message 1:

- While demographic growth flattens, land demand for food and feed (based on BAU assumptions) will continue to grow somewhat (100 – 250 mln ha depending on scenario assumptions).
- A substantial contribution of agricultural biomass to energy sources would require:

  (a) Focus on sustainable production increases on current agricultural land (beyond BAU);

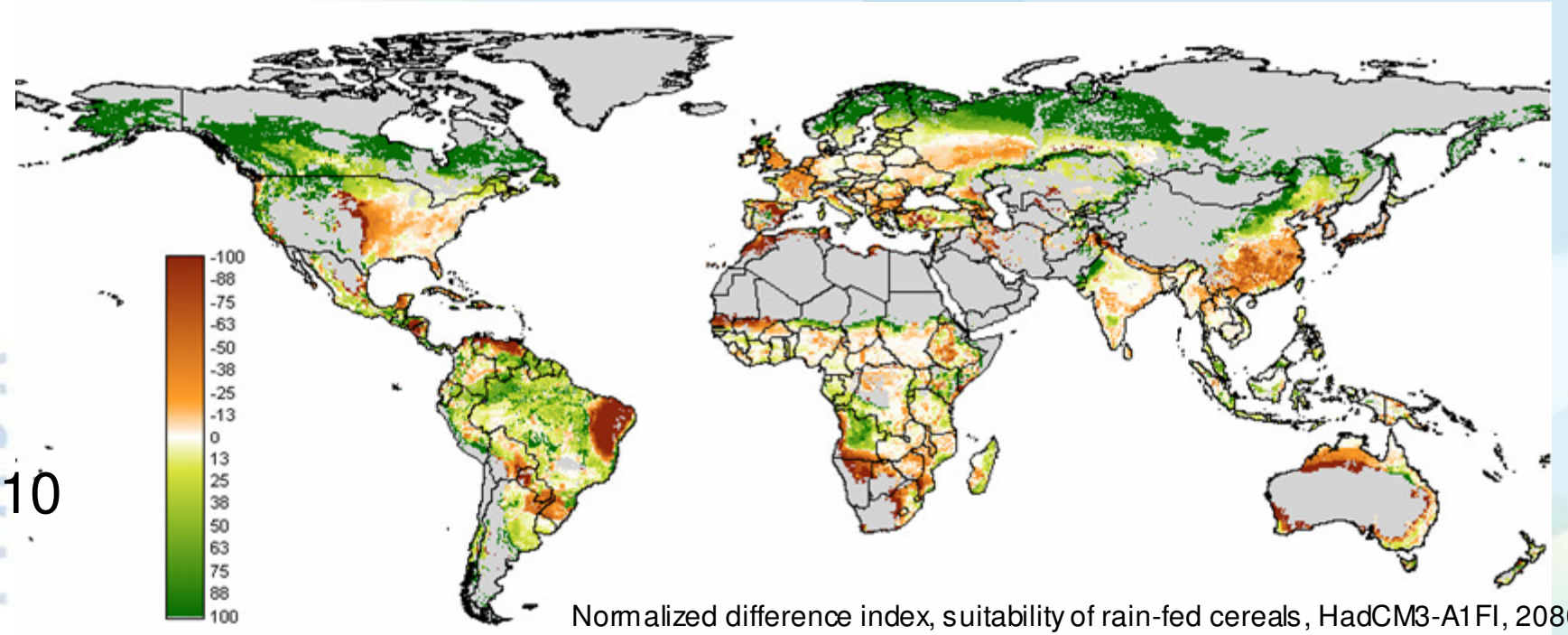
  (b) Tapping into land resources currently not or extensively used.

3.9



Suitability of rain-fed cereals, reference climate 1961-90.

3.10



Normalized difference index, suitability of rain-fed cereals, HadCM3-A1FI, 2080s.

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.

Message 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.
- 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 (~400 Gm_3 vs ~600 Gm_3, compared to 1350 Gm_3 in 2000).

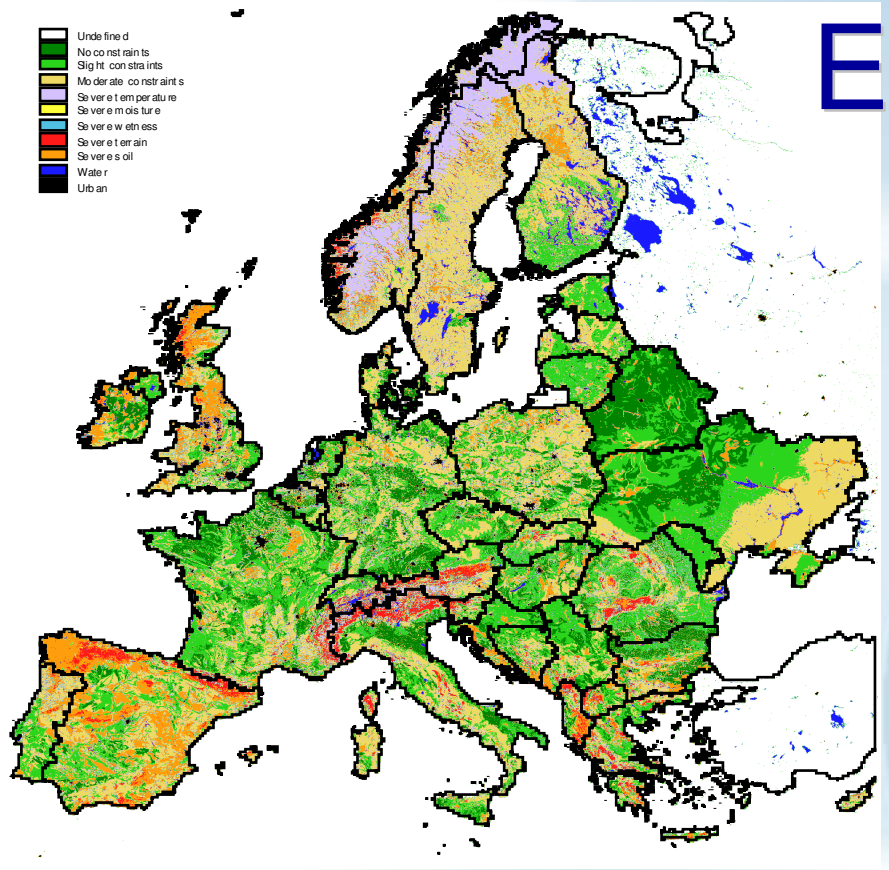
Bio-energy Production & Food Security & Land Competition:

- The role of bio-energy has been strongly enhanced by its consideration in the climate change debate, as well as opportunities it may create for rural development and improved energy security.
- Land use competition with food and feed production is considered a potential key barrier to exploiting the bio-energy production potential.

Current LUC projects:

- Global Assessment of Bio-energy Potentials
- Renewable Fuels for a Sustainable Europe (REFUEL)
- Effective and Low-disturbing Bio-fuel Policies (ELOBIO)

BIO-FUEL DEVELOPMENT EUROPE



- Feedstock potential
- Food/feed consumption
- Land use change
- Production costs
- Stakeholder needs/barriers
- Road map
- Policy recommendations

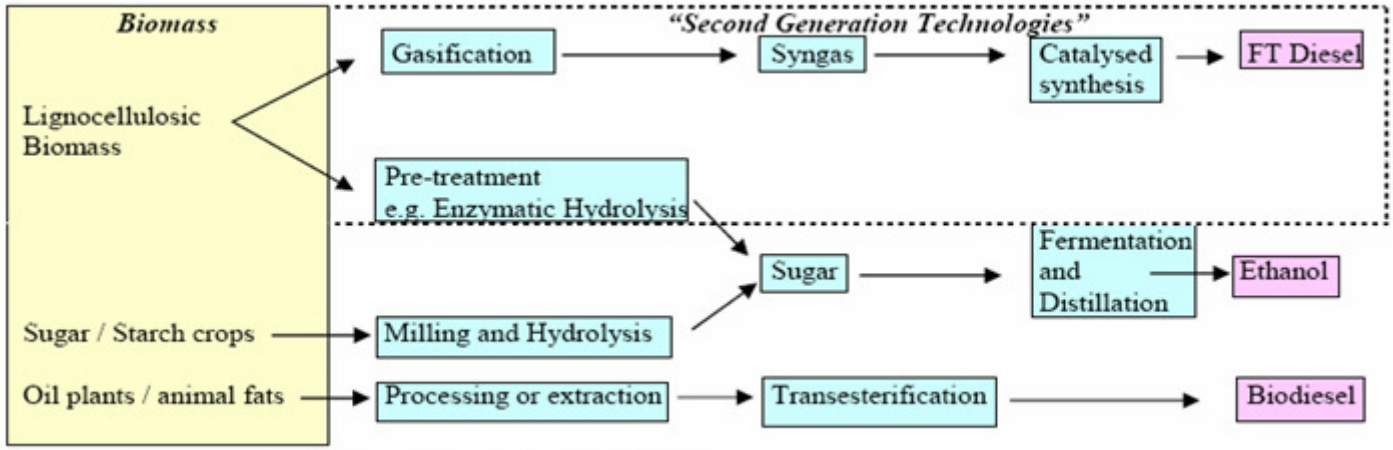
refuel

Bio-fuel Feedstocks

Feedstock groups:

- Oil crops
  Rapeseed; Sunflower; Soybean; Oilpalm; Jatropha
- Sugar crops
  Sugarcane; Sugar beet; Sweet sorghum
- Starch crops
  Wheat; Rye; Triticale; Maize; Sorghum; Cassava
- Herbaceous lignocellulosic plants
  Miscanthus; Switchgrass; Reed canary grass
- Woody lignocellulosic plants
  Poplar; Willow; Eucalyptus

Figure 1. Fuel production pathways



Source: adapted from BMU (2006) and Hamelinck and Faaij (2006)

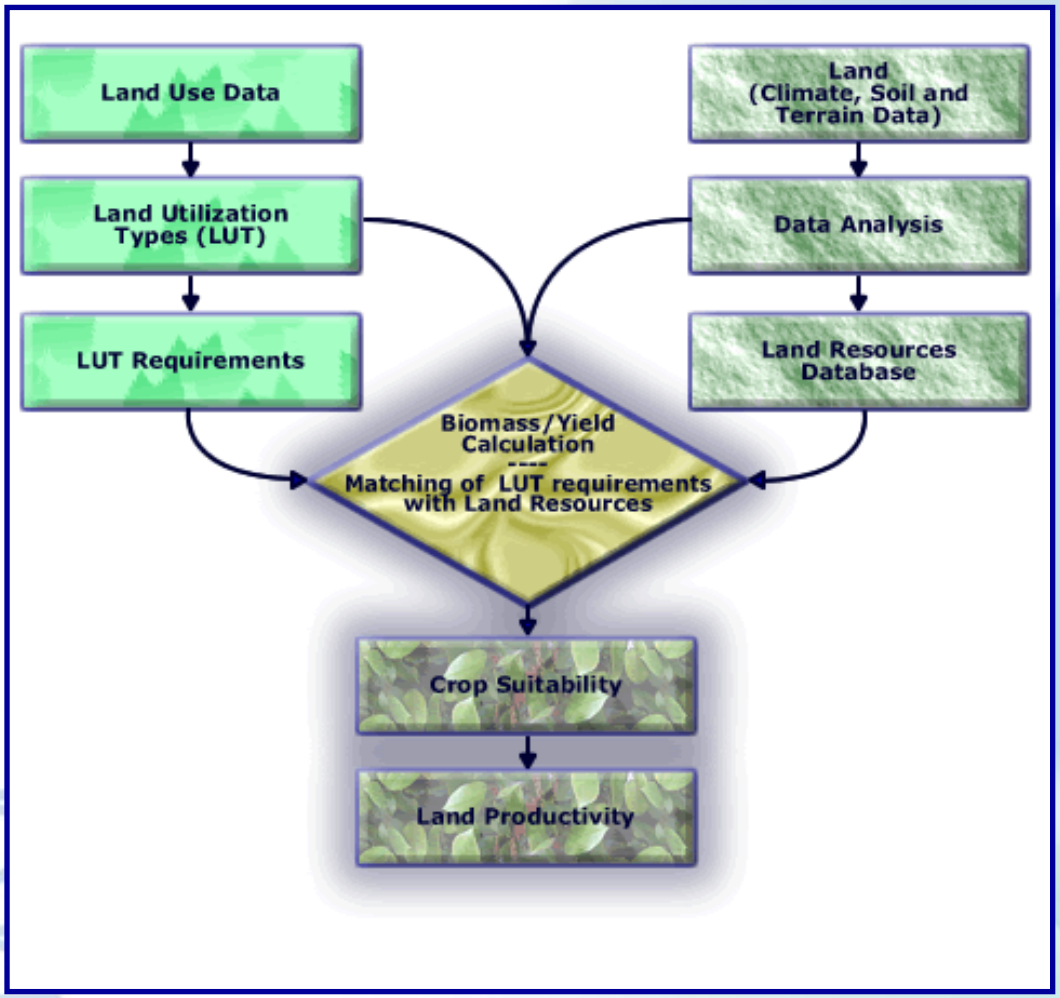
Land Resources & Agro-ecological Zoning:

- FAO and IIASA have developed a spatial analysis system that enables rational land-use planning on the basis of an inventory of land resources and evaluation of biophysical limitations and production potentials of land.
- The AEZ methodology follows an environmental approach; it provides a standardized framework for analyzing synergies and trade-offs of alternative uses of agro-resources (land, water, technology) for producing food and energy, while preserving environmental quality.

Current LUC projects:

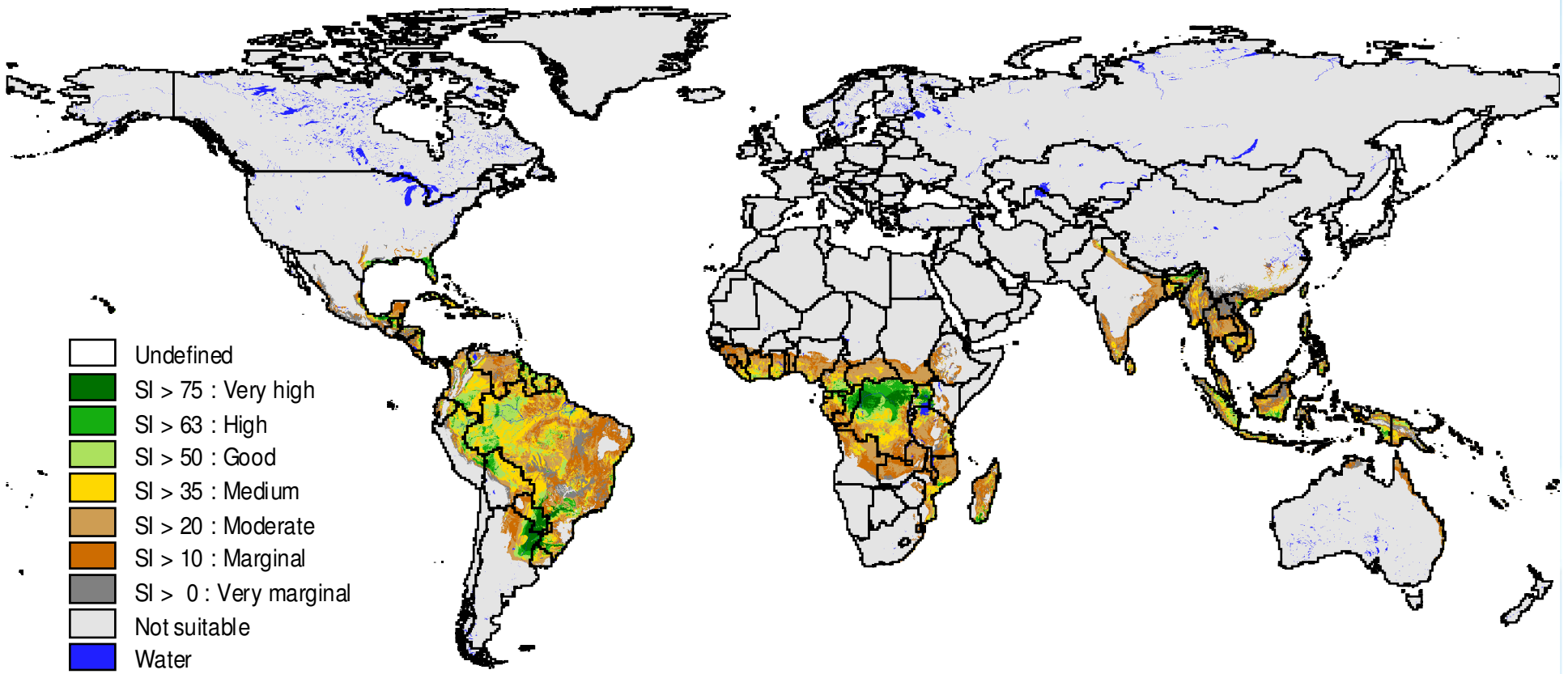
- Global Agricultural Zones Assessment (GAEZ 2007)
- Harmonized World Soil Database (HWSD)
- Exploiting Information on Global Environmental Risks – Agriculture (EIGER-Agri)

Global Agro-ecological Zones Methodology



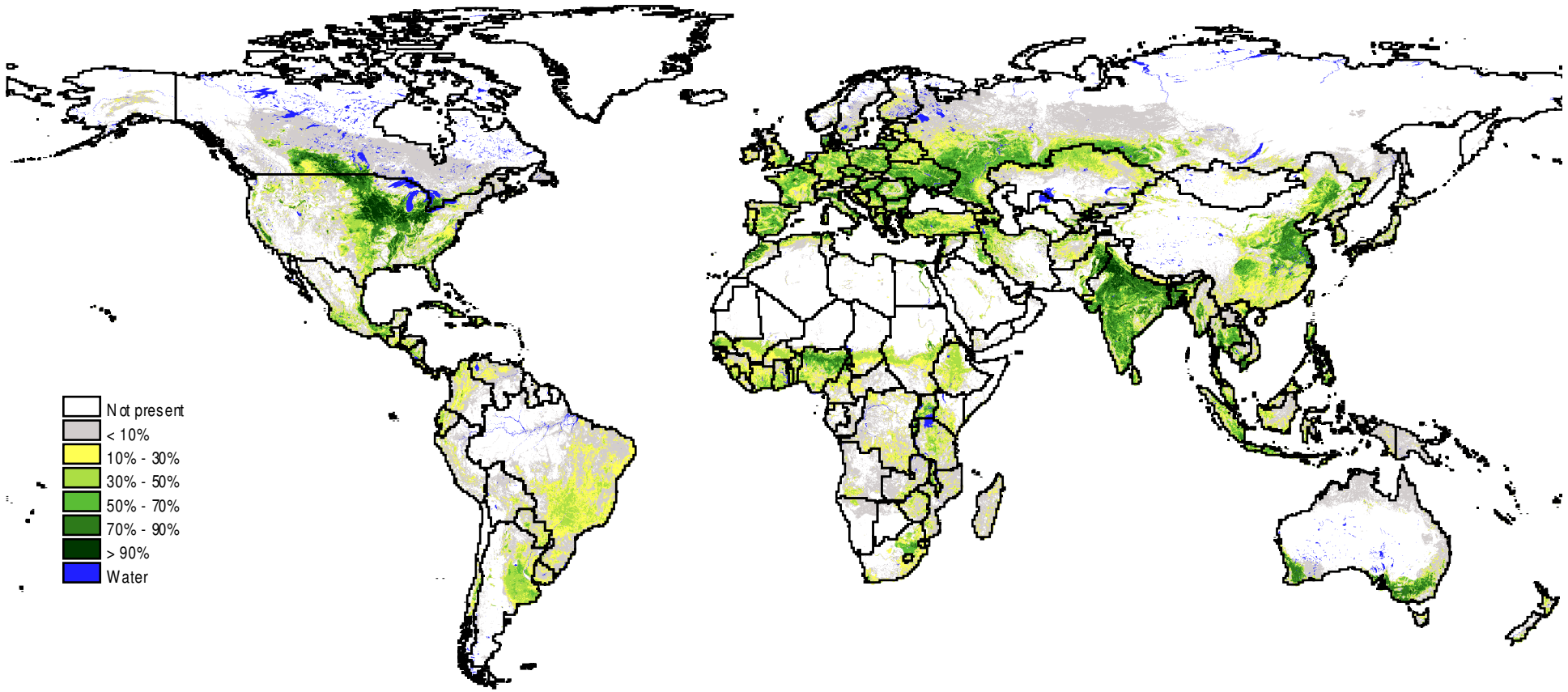
Environmental resources database including climate, soil, terrain, and land cover, comprising 2.2 million grid cells, assessing the agricultural potential of 28 crops at three levels of farming technology.

Suitability for rain-fed sugarcane production, high input level



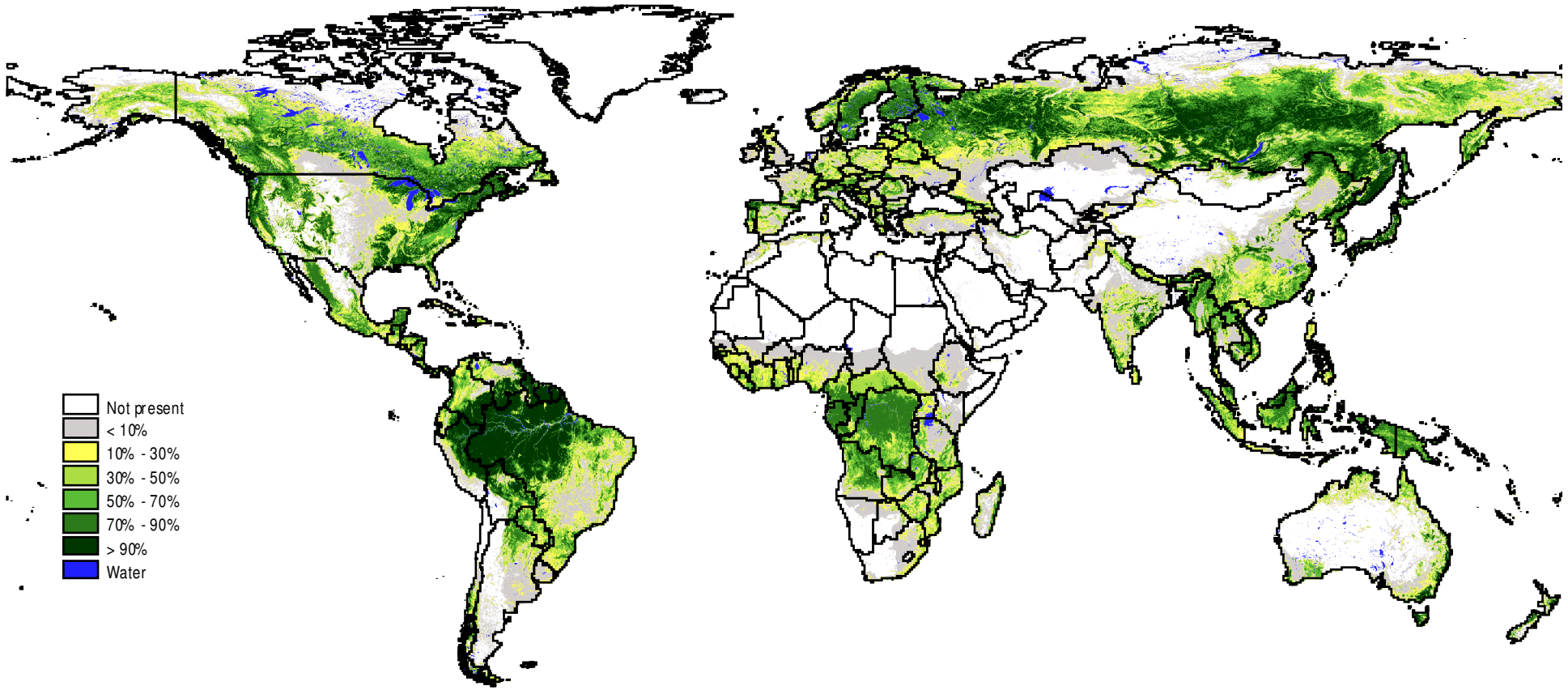
Source: GAEZ 2007, IIASA-LUC/FAO

Spatial Distribution and Intensity (percent) of Cultivated Land, year 2000



Note: calibration of GLC2000 class weights starts from estimated reference weights and is based on an iterative scheme to match national / sub-national statistics of year 2000 (FAO AT2015/2030 adjusted cultivated land).

Spatial Distribution and Intensity (percent) of Forests, year 2000



Note: calibration of GLC2000 class weights starts from estimated reference weights and is based on an iterative scheme to match national / sub-national statistics of year 2000 (FRA2000 and FRA2005).

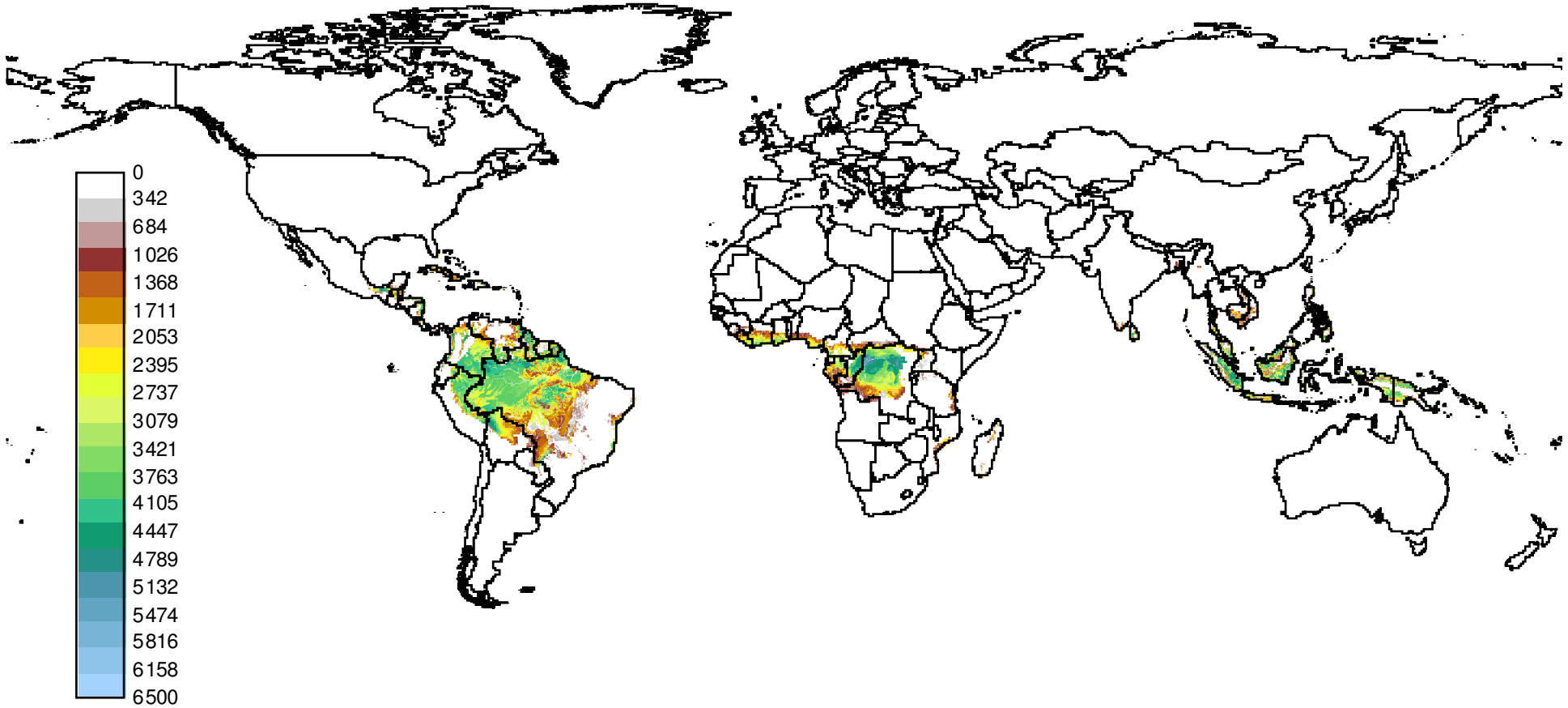
Where is the Land Suitable for Sugarcane?

Land cover	Total	of which	---------- VS+S ----------		
in 2000	Cultivated	VS+S	Forest	Wood/Grass	Other LC
	Land	mln ha	mln ha	mln ha	mln ha
World	1563	66	160	75	3
Developed	591	1	1	0	0
Developing	972	65	159	74	3
Centr. Amer&Carrib.	43	9	8	4	1
South America	129	22	67	37	1
Sub-Saharan Africa	225	17	77	29	1
Southeast Asia	98	11	4	2	0
South Asia	229	3	1	0	0
Other Developing	247	2	2	1	0

Source: GAEZ 2007, IIASA-LUC/FAO

Note: the table shows land assessed as very suitable or suitable for rainfed sugarcane cultivation in (i) current cultivated land and for land respectively classified as (ii) forest, (iii) woodland/scrubland/grassland, and (iv) other land cover. According to FAO there were about 20 mln ha under sugarcane in year 2003.

Suitability for rain-fed palm oil production, high input level



Source: GAEZ 2007, IIASA-LUC/FAO

Note: map shows potential palm oil production per unit area of 5' grid cell

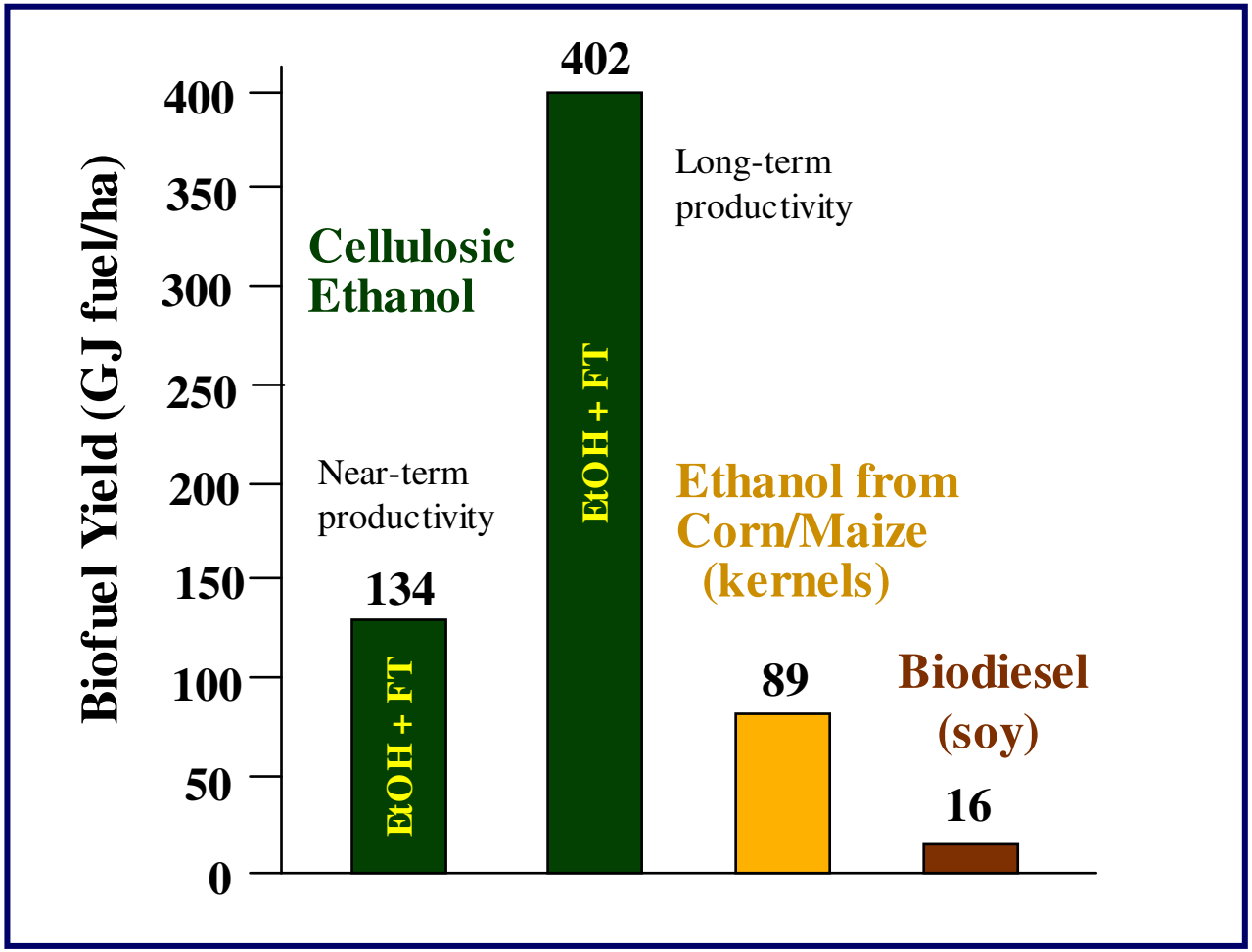
Where is the Land Suitable for Oilpalm?

Land cover	Total	of which	---------- VS+S ----------		
in 2000	Cultivated	VS+S	Forest	Wood/Grass	Other LC
	Land	mln ha	mln ha	mln ha	mln ha
World	1563	50	337	56	3
Developed	591	0	0	0	0
Developing	972	50	337	56	3
Centr. Amer&Carrib.	43	4	5	2	0
South America	129	5	227	22	1
Sub-Saharan Africa	225	8	68	17	0
Southeast Asia	98	31	28	12	1
South Asia	229	1	0	0	0
Other Developing	247	1	8	3	0

Source: GAEZ 2007, IIASA-LUC/FAO

Note: the table shows land assessed as very suitable or suitable for rainfed oilpalm cultivation in (i) current cultivated land and for land respectively classified as (ii) forest, (iii) woodland/scrubland/grassland, and (iv) other land cover. According to FAO there were about 11.4 mln ha under oil palm in year 2003 (of which 9.5 mln in three countries: Malaysia, Nigeria, Indonesia).

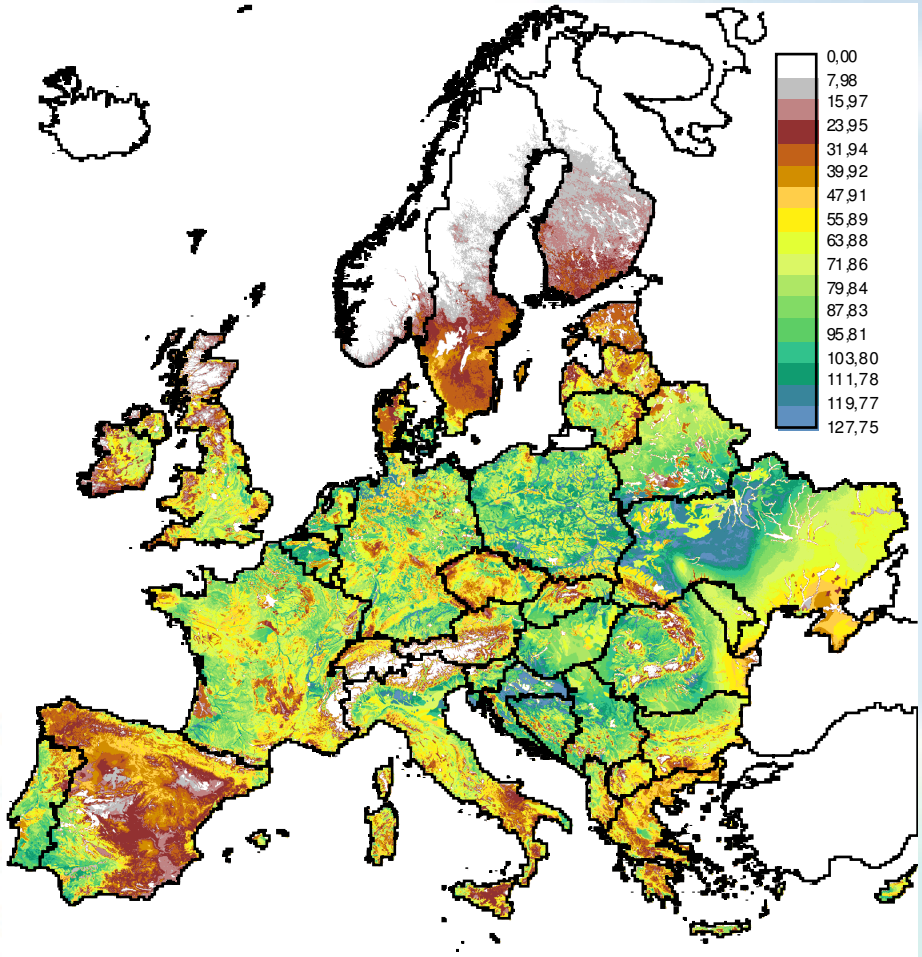
Comparative Land Productivity of Biofuel Options



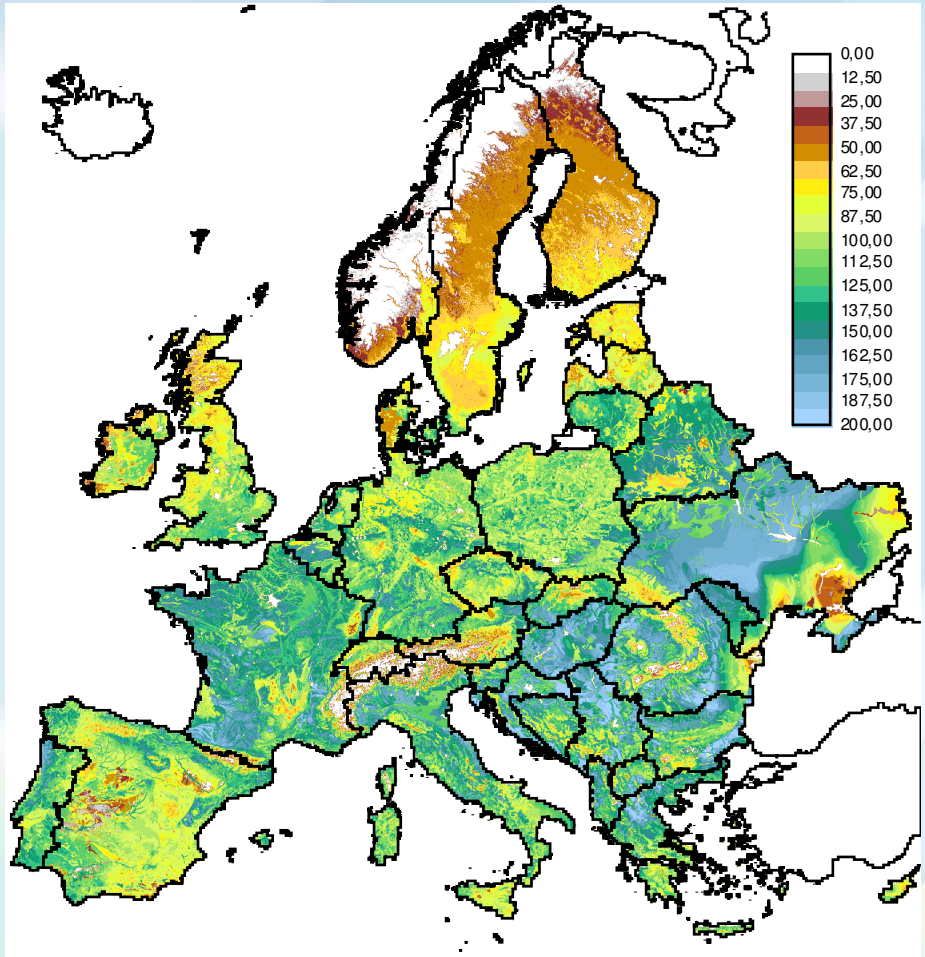
Crop Yields (U.S.)	Fuel Yields
Biomass yield: 5 dry ton/acre	Cellulosic ethanol from RBAEF
Corn yield: 160 bushel/acre	Corn ethanol: 2.8 gal/bushel
Soy yield: 42 bushel/acre	Soy oil: 18% of bean (dry basis)
	Biodiesel yield: 0.95 kg/kg soy oil

Bio-fuel Feedstock Yield Potential

(a) Attainable energy yields of (1st generation) starch crops, sugar crops and oil crops (GJ/ha, biofuel equiv.)



(b) Attainable energy yields of (2nd generation) woody and herbaceous lignocellulosic feedstocks (GJ/ha, biofuel equiv.)



Source: Land Use Change and Agriculture Program, 2007

GHG Avoidance

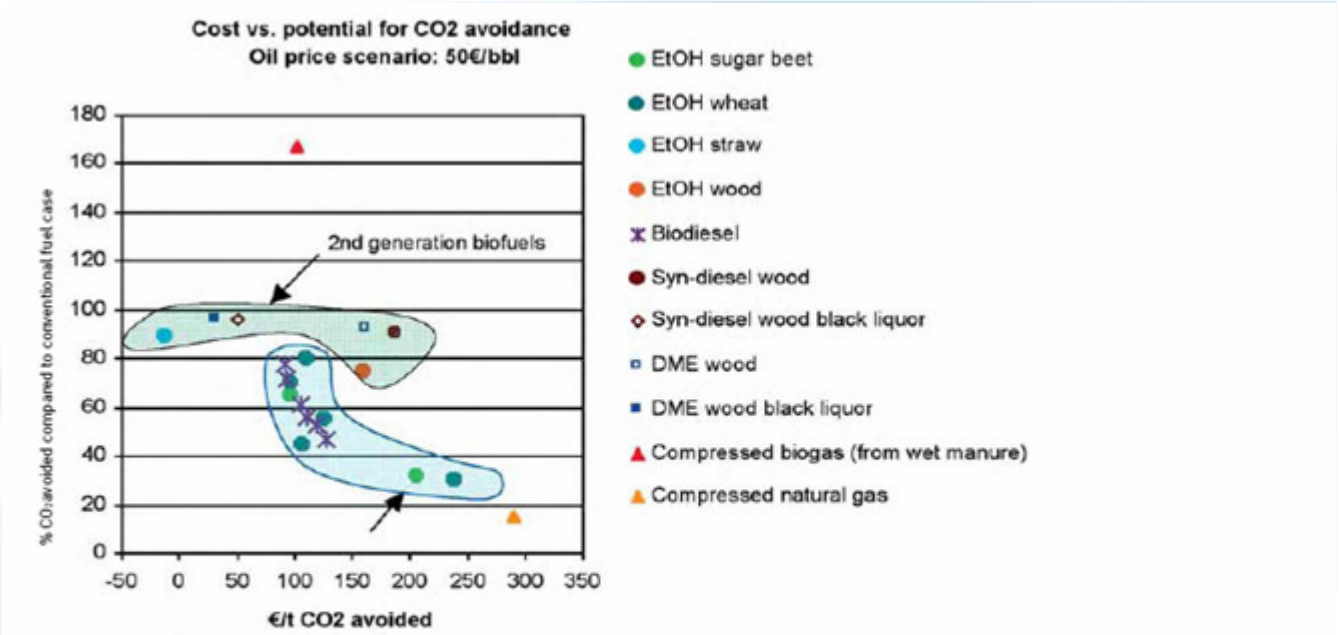
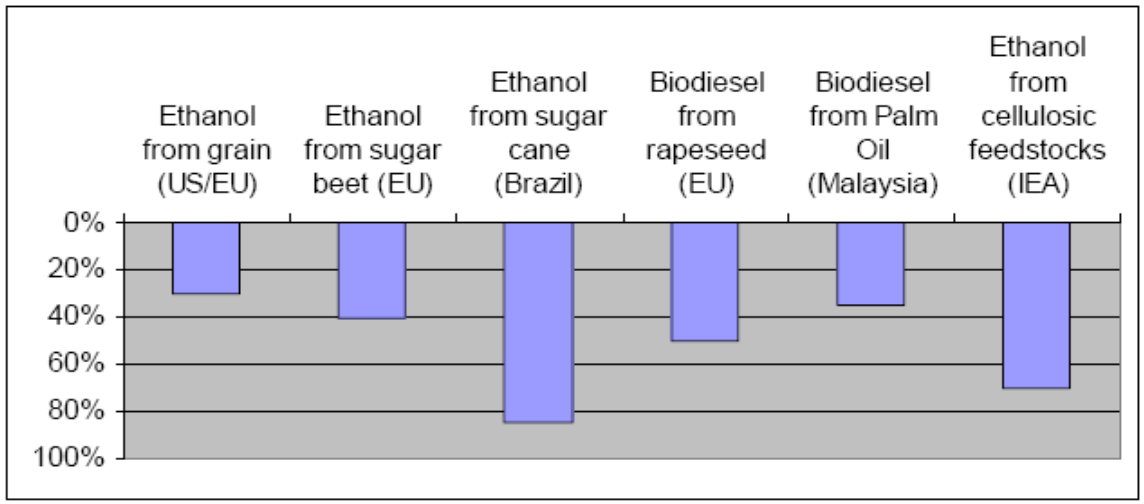


Figure 3.1: Indicative CO_2 reduction potential versus costs for CO_2 avoidance (source: WtW study, Eucar/Concawe 2005). Please note that the volumetric potential of the different fuel options is not taken into consideration. The higher than 100% CO_2 avoidance for biogas results from the reduction of methane emission through degradation of organic waste and manure in a controlled fermentation process where CO_2 is replacing methane (a much more powerful greenhouse gas).

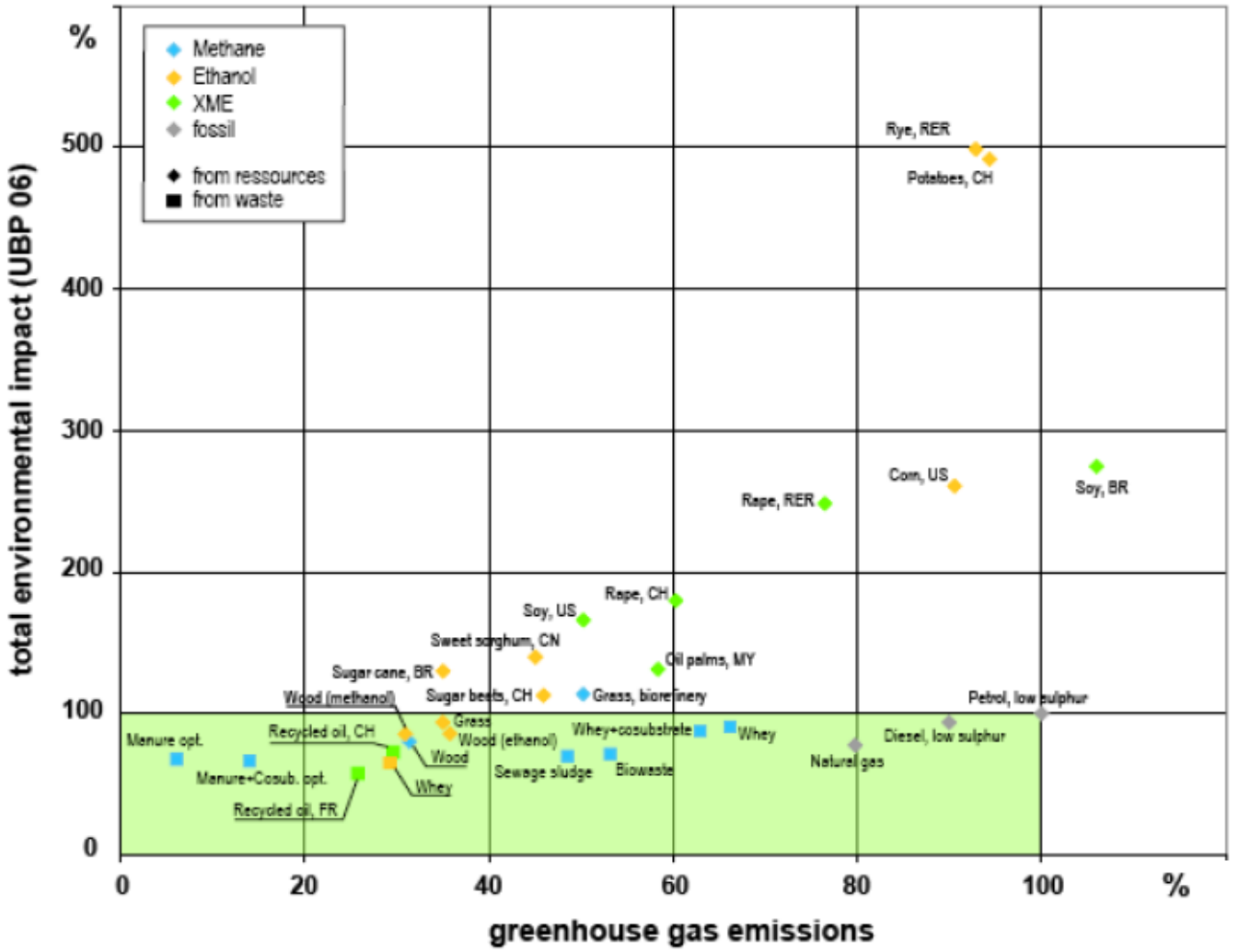
Figure 2. Range of estimated GHG Reductions from Biofuels compared with gasoline and mineral diesel



Source: IEA, 2005 and EMPA (biodiesel from Palm oil). Note: Reduction in well-to-wheels CO_2-equivalent GHG emissions per kilometre.

GHG Reduction and Environmental Impacts

Figure 8. GHG emissions of biofuels related to their gasoline or diesel alternatives and overall environmental impact assessment

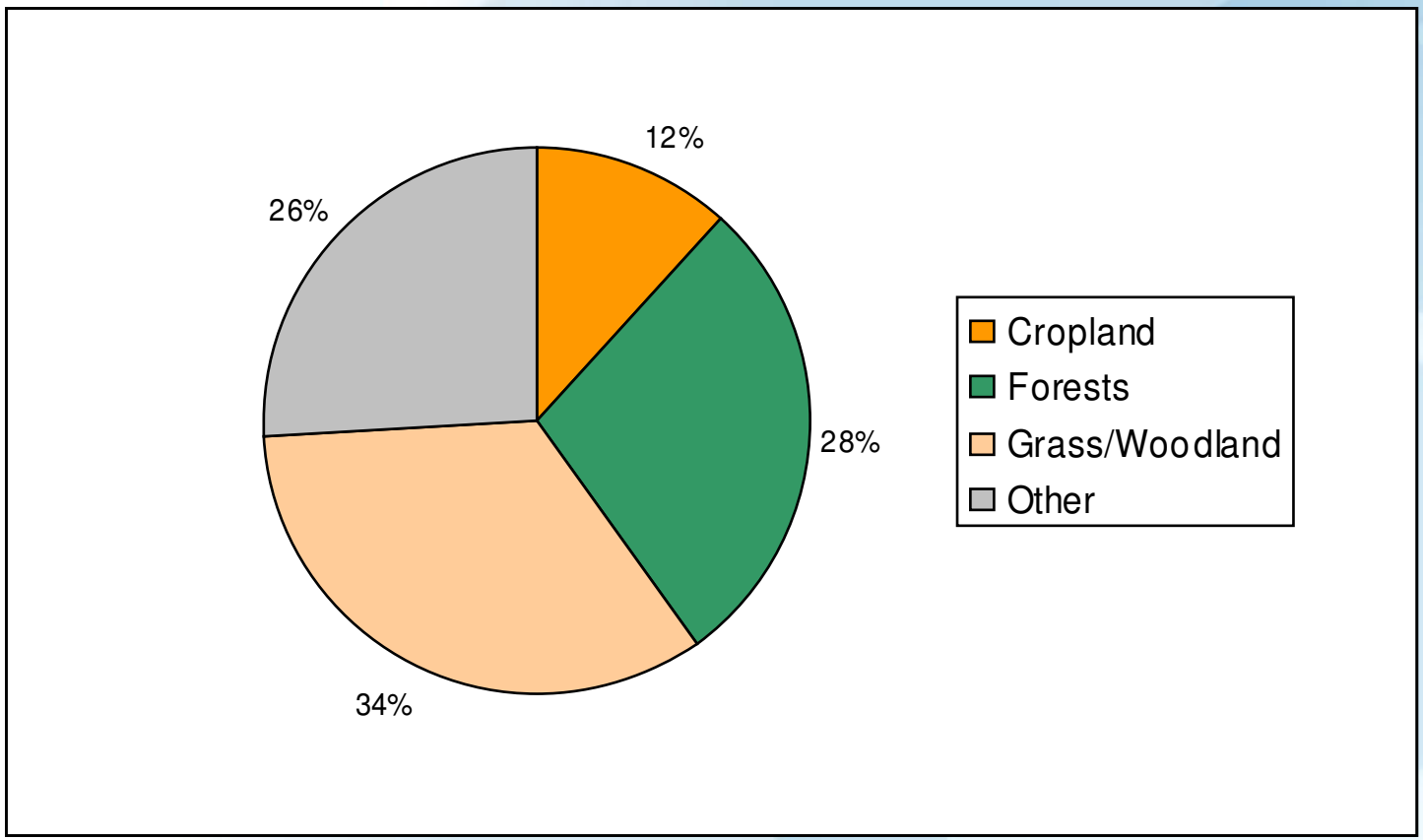


Source: Zah et al (2007a). Note : UBP stands for UmweltBelastungsPunkte : a Swiss indicator for the environmental impact .

Message 3:

- Conventional agricultural feedstocks perform inadequately for environmental criteria, especially if cultivation leads to additional conversion of grassland or forest.
- Only second generation ligno-cellulosic technologies (also recycling and using wastes) hold a promise of doing much better (both land use efficiency and GHG savings).

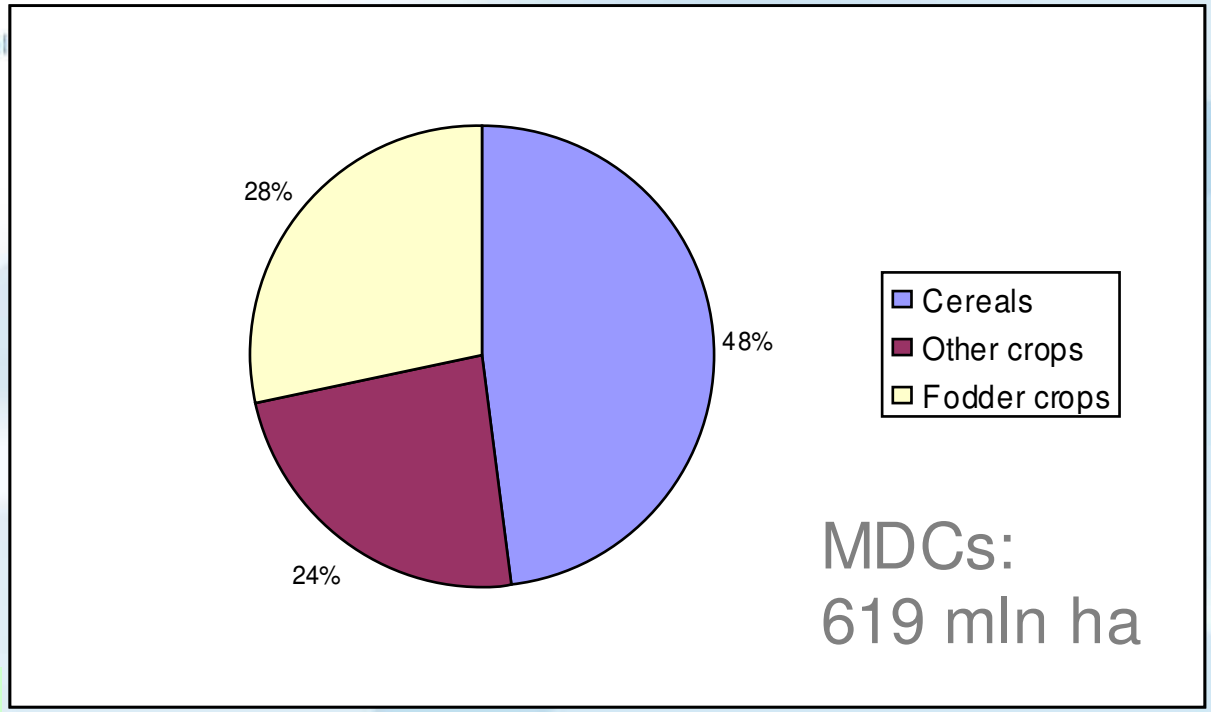
Estimated Use of Land (excl. Antarctica) in 2000

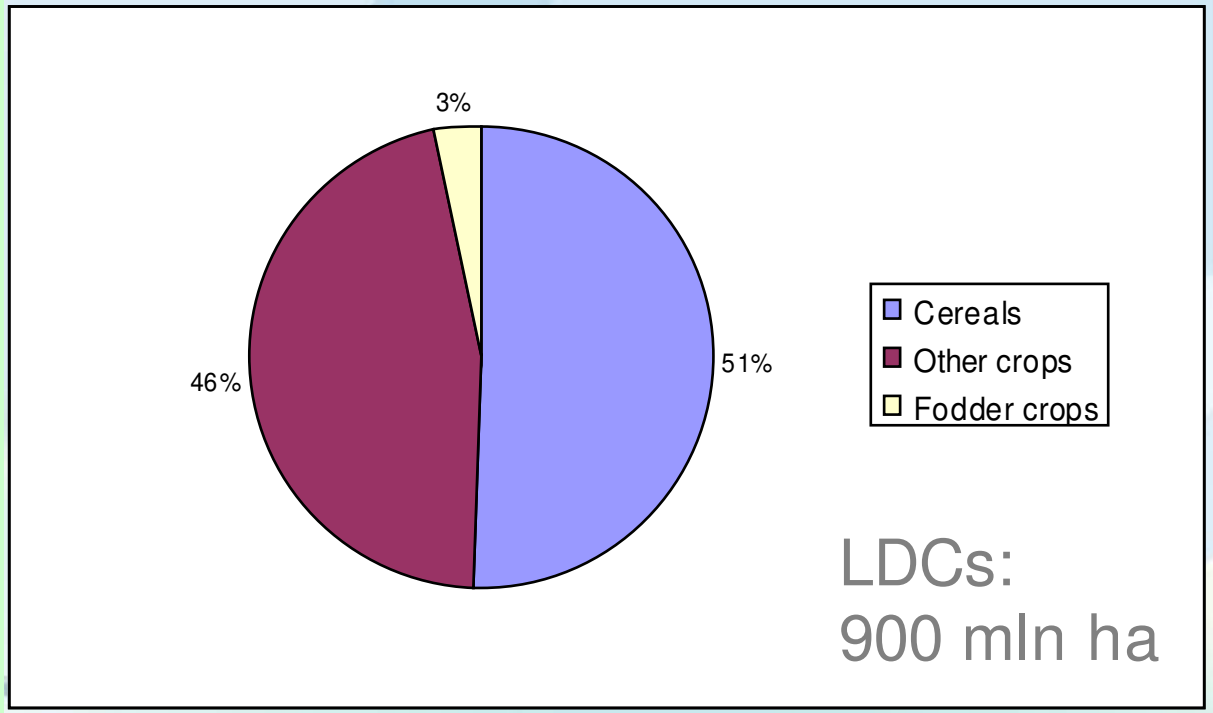


Cropland	1562 mln ha
Forests	3744 mln ha
Grass/woodland	4560 mln ha
Other land	3443 mln ha
TOTAL	13309 mln ha

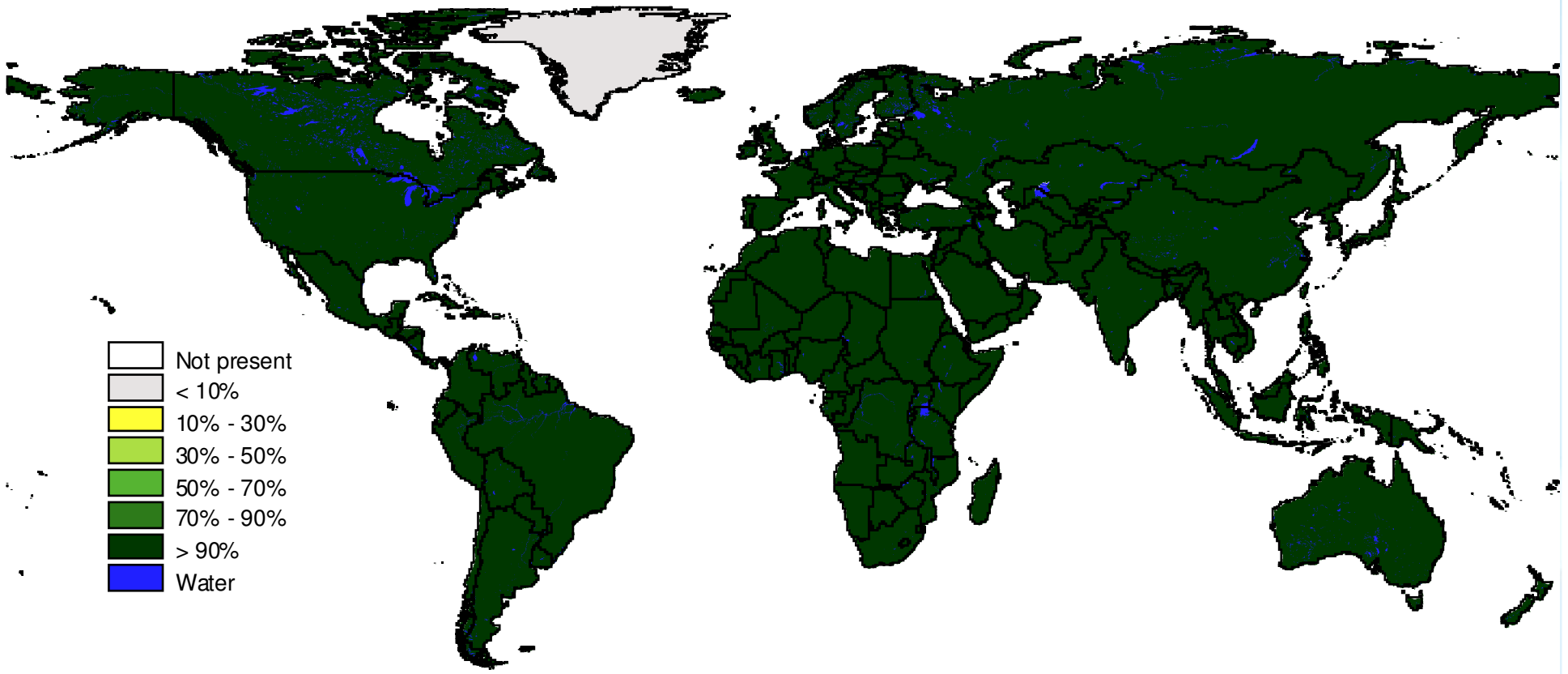
Global Use of Arable Land, year 2000

Land in consumption	World mln ha
Crops (excl feed)	1005.4
Cereals	536.9
Other crops	468.5
Feed use	514.1
Cereals	214.2
Other crops	94.4
Fodder crops	205.5
of which	
Ruminants	307.7
Other livestock	206.4





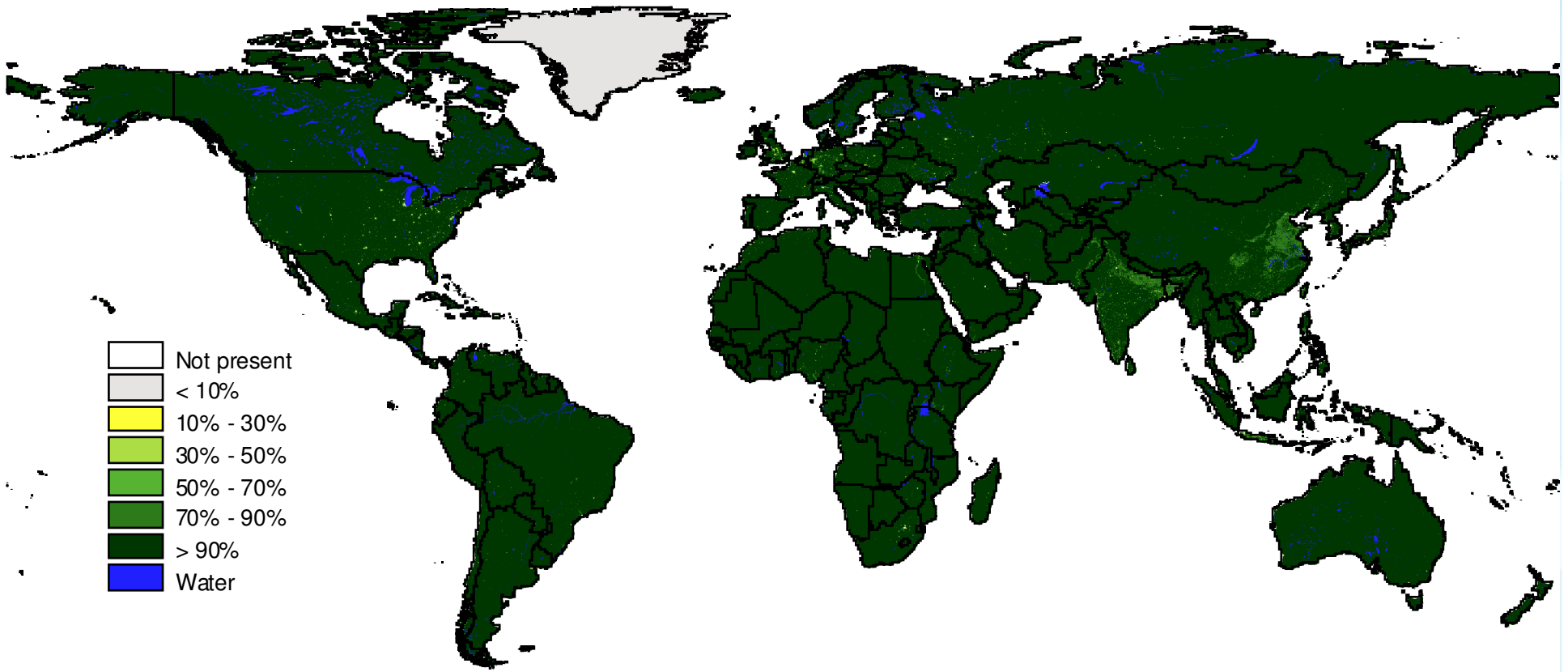
Total land ...



Note: The map indicates the share of each grid-cell that is available for use.

Source: GAEZ 2007, IIASA-LUC/FAO

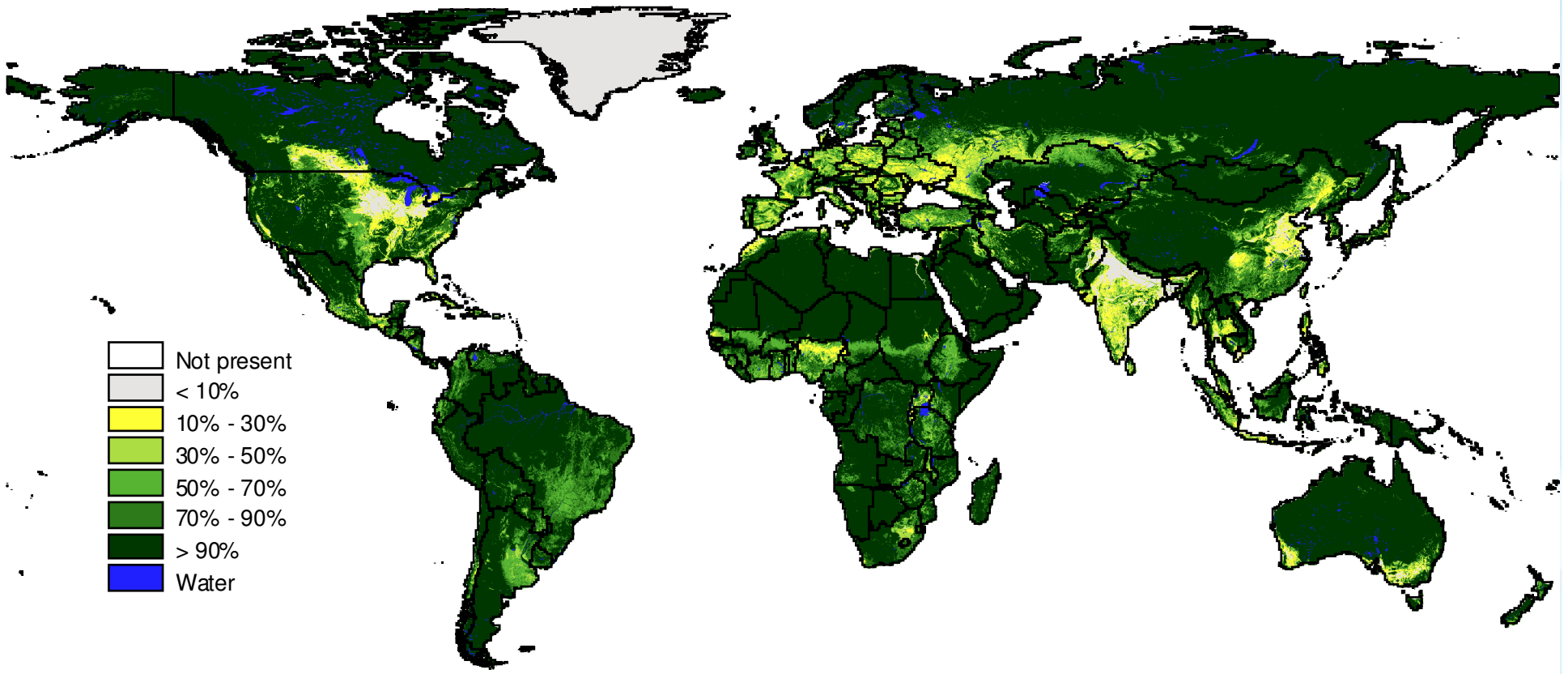
... subtracting built-up areas



Note: The map indicates the share of each grid-cell that is available for use.

Source: GAEZ 2007, IIASA-LUC/FAO

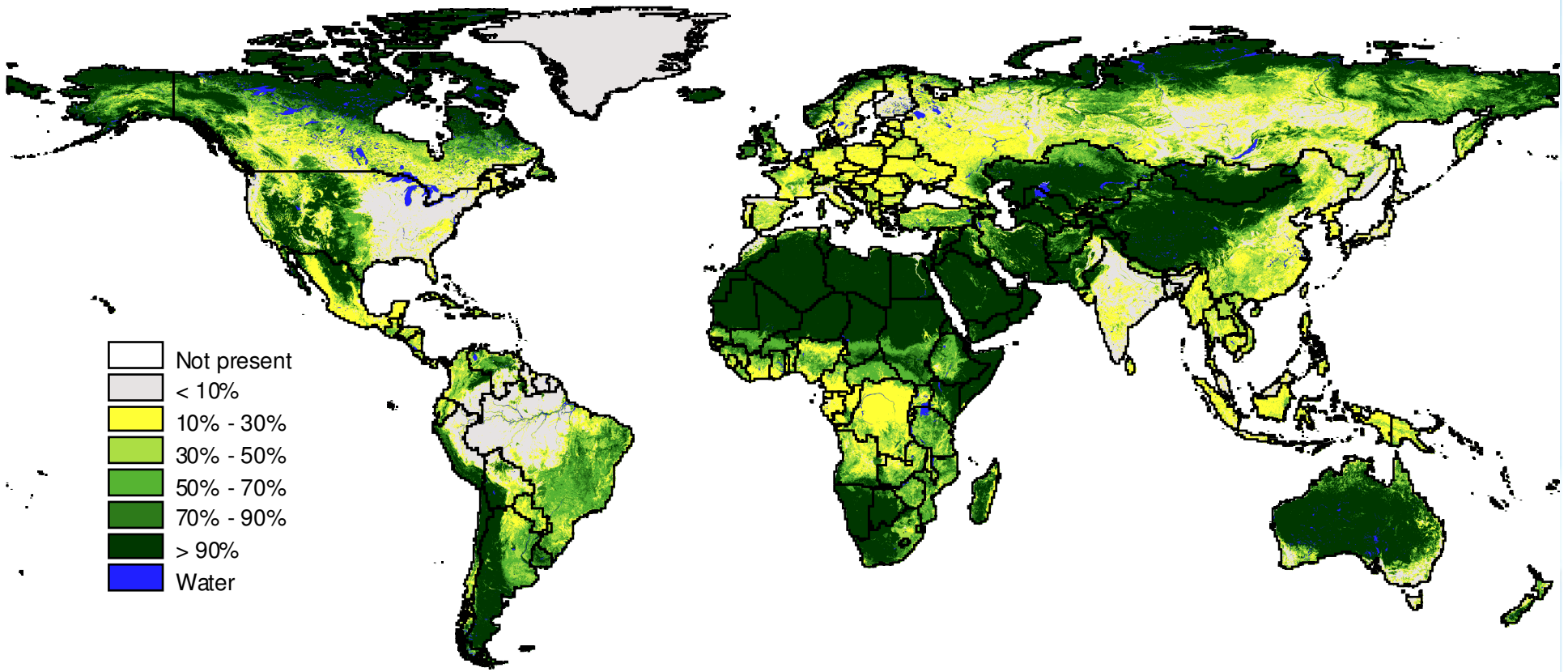
... subtracting cultivated land



Note: The map indicates the share of each grid-cell that is available for use.

Source: GAEZ 2007, IIASA-LUC/FAO

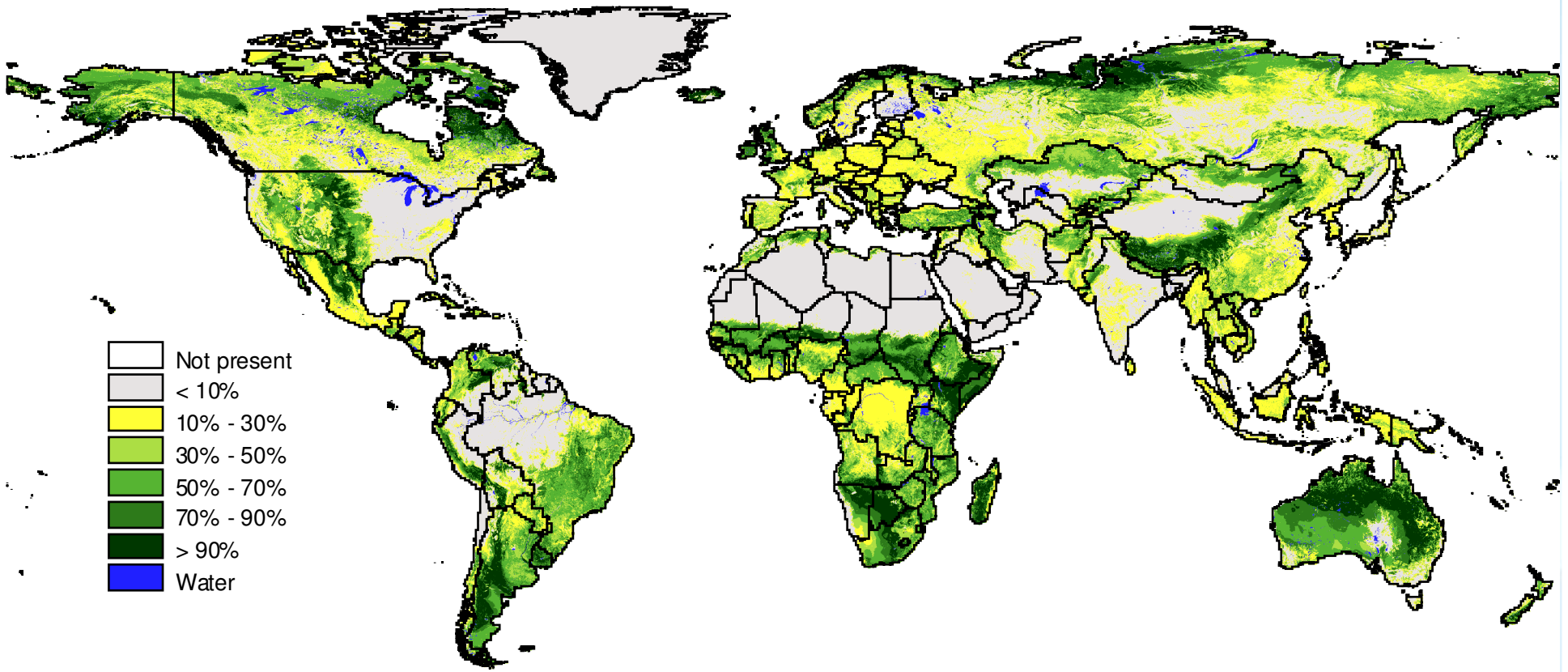
... subtracting forest areas



Note: The map indicates the share of each grid-cell that is available for use.

Source: GAEZ 2007, IIASA-LUC/FAO

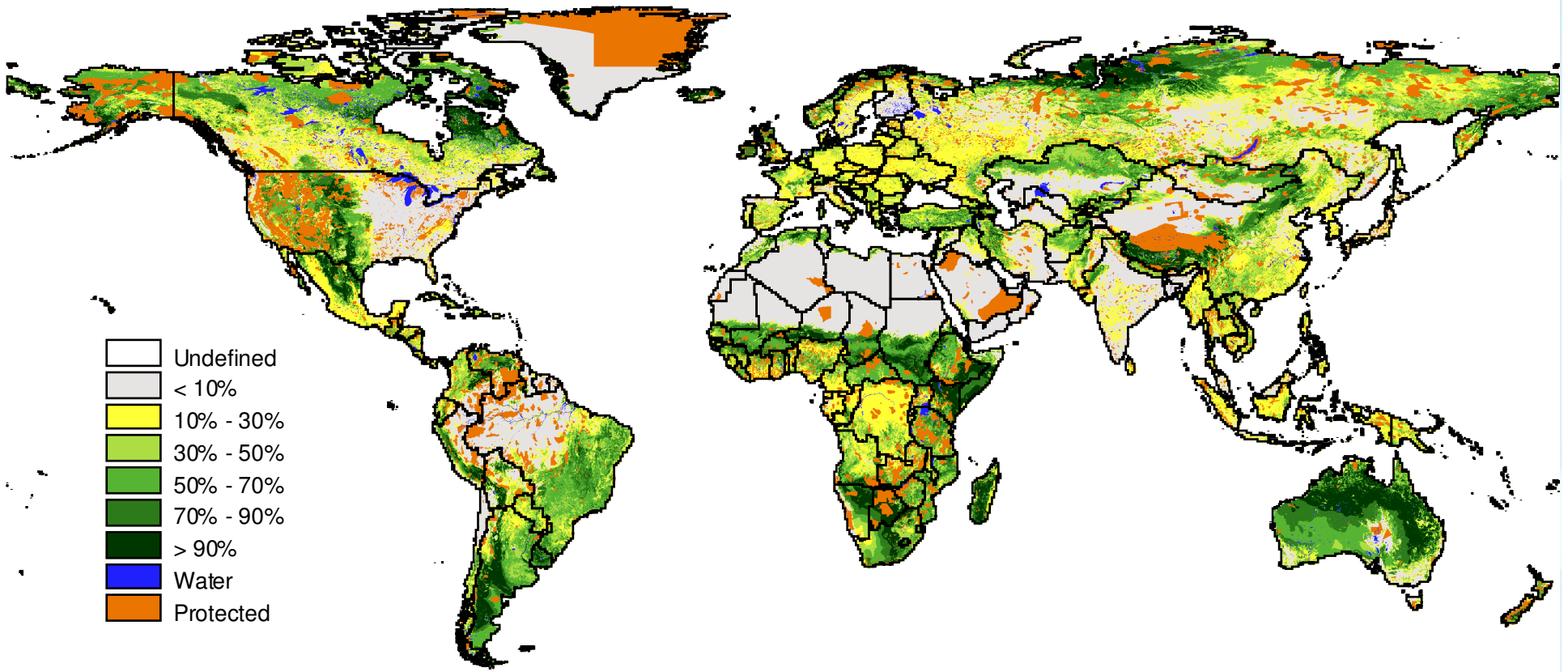
... excluding non-vegetated areas



Note: The map indicates the share of each grid-cell that is available for use.

Source: GAEZ 2007, IIASA-LUC/FAO

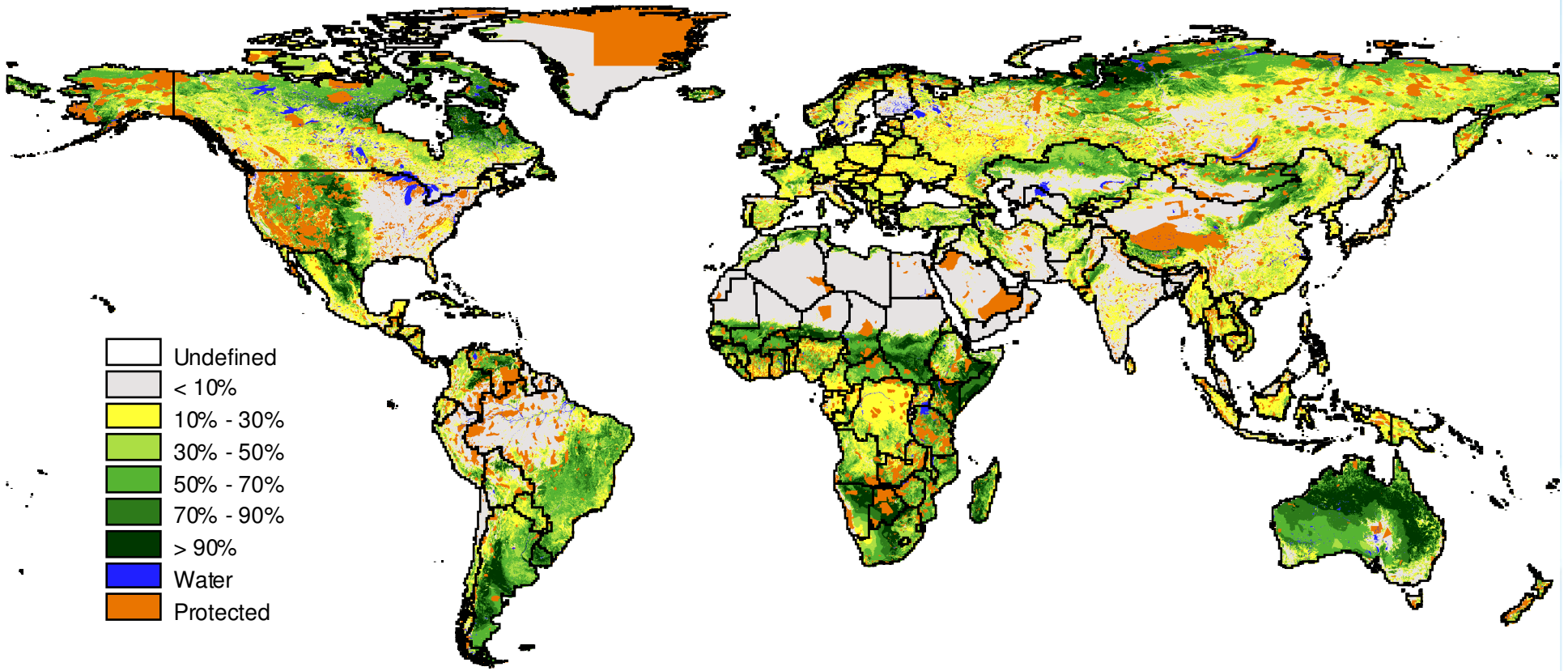
... excluding protected areas



Note: The map indicates the share of each grid-cell that is available for use.

Source: GAEZ 2007, IIASA-LUC/FAO

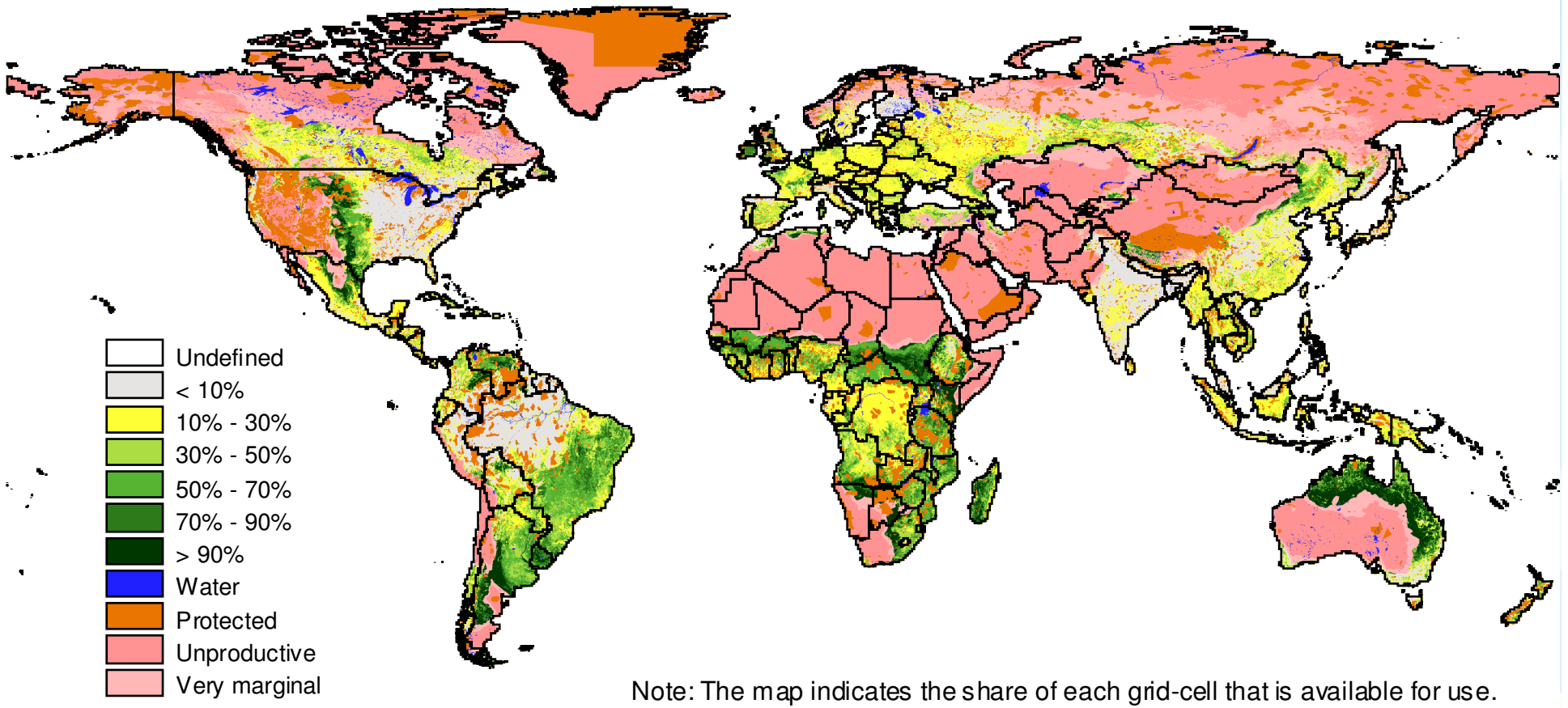
... subtracting land with steep slopes



Note: The map indicates the share of each grid-cell that is available for use.

Source: GAEZ 2007, IIASA-LUC/FAO

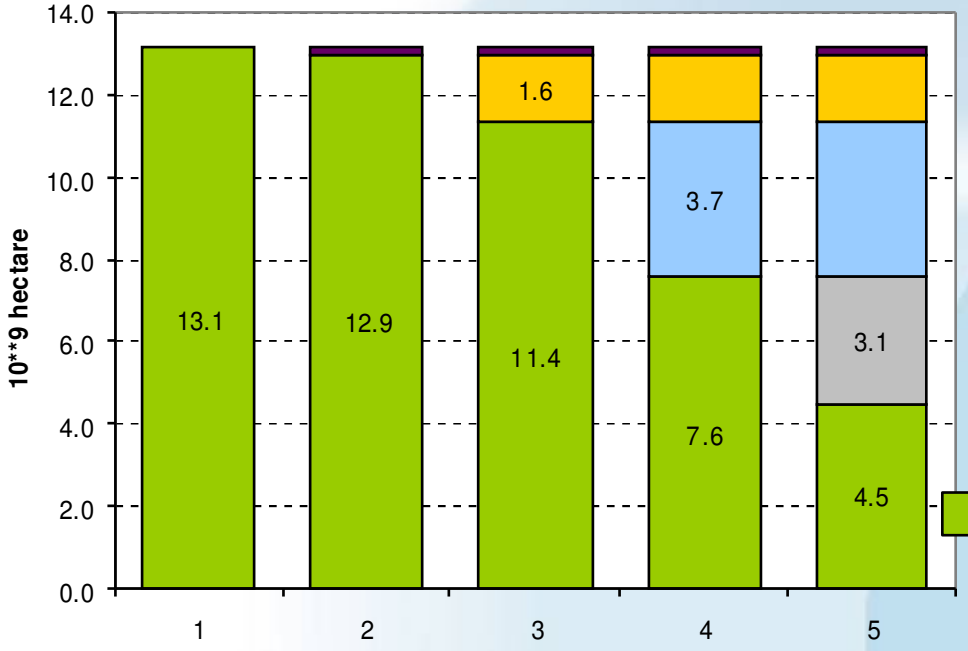
... excluding climatically unsuitable or very marginal areas

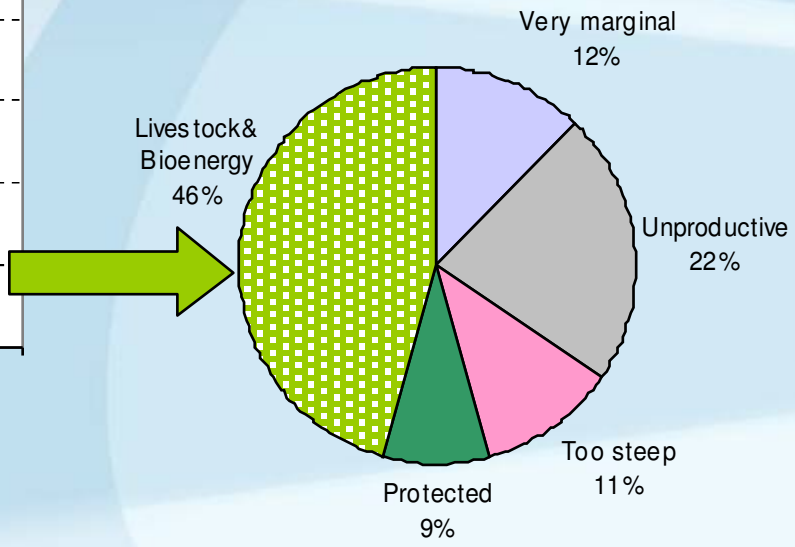


Note: The map indicates the share of each grid-cell that is available for use.

Source: GAEZ 2007, IIASA-LUC/FAO

How much land is available?

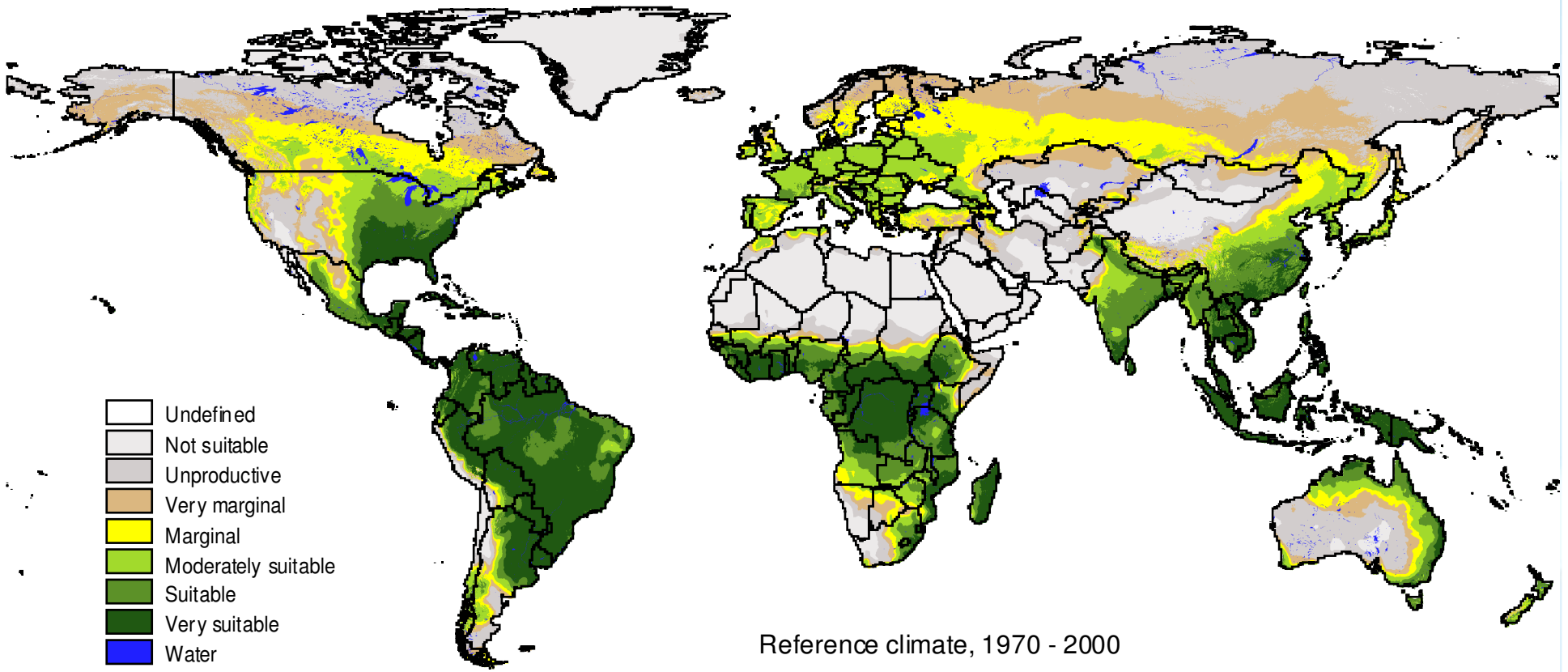




1 ... Total land (excl. Antarctica and Greenland)
2 ... excluding built-up land
3 ... excluding arable and perennial cropland
4 ... excluding forests
5 ... excluding barren land & water

Source: IIASA-LUC, 2007

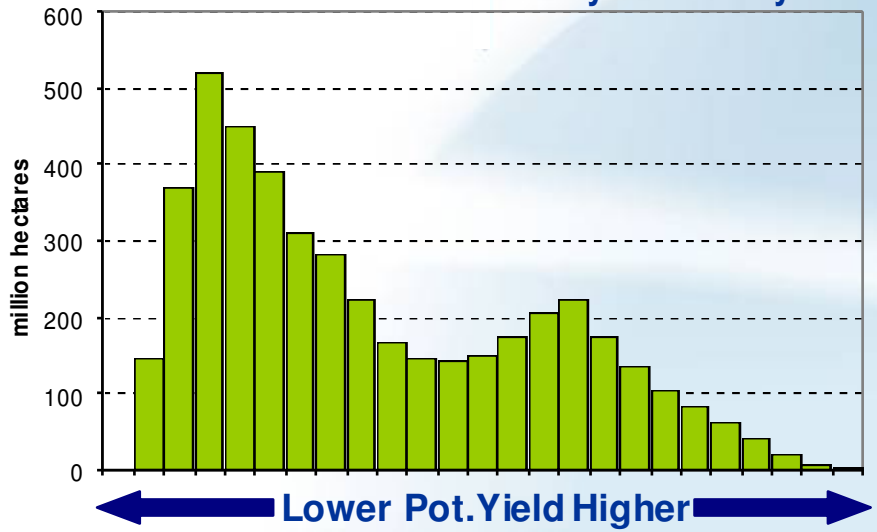
Climatic suitability for herbaceous and woody lignocellulosic plants



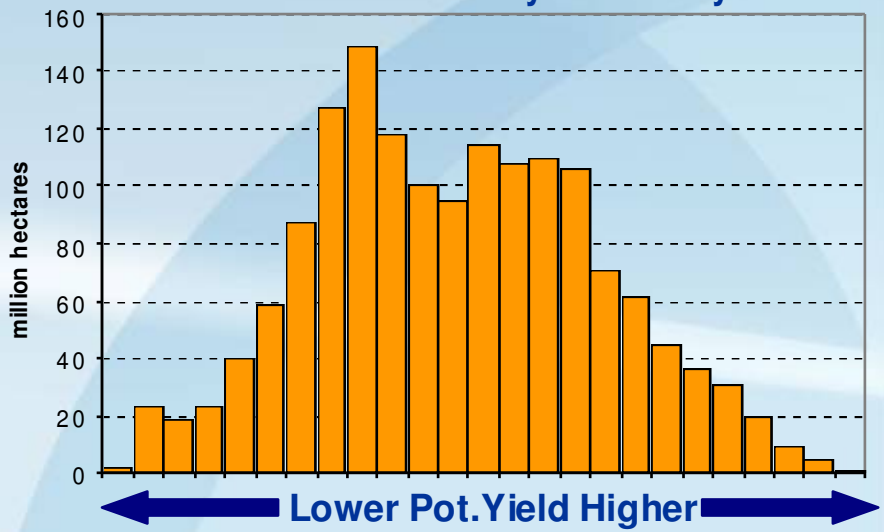
Reference climate, 1970 - 2000

Source: GAEZ 2007, IIASA-LUC/FAO

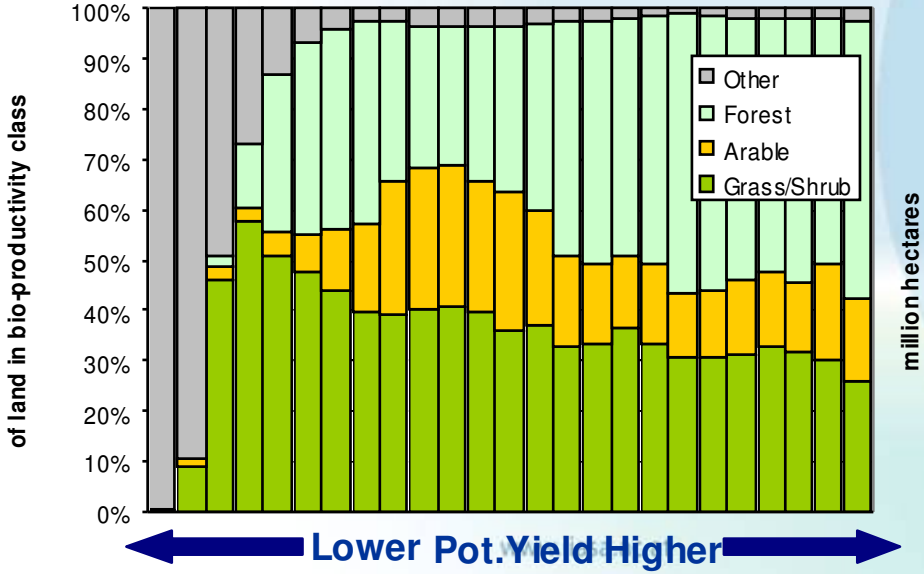
Distribution of Grass/Shrub/Woodland by Productivity Classes



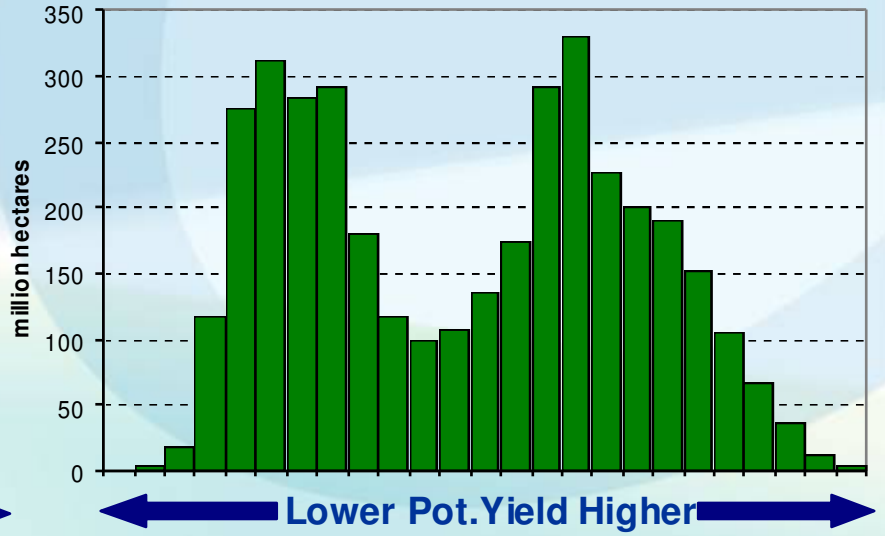
Distribution of Arable Land by Productivity Classes



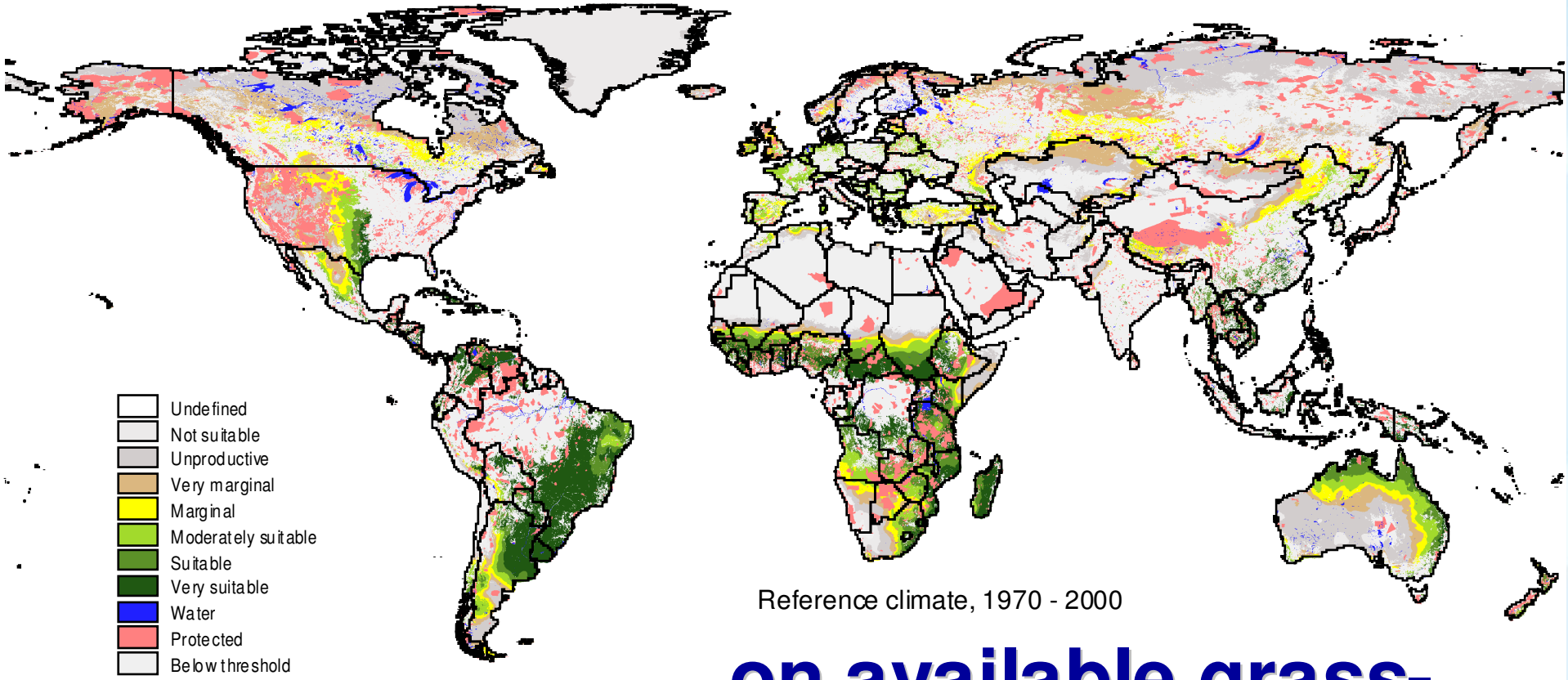
Distribution of Major Land Uses by Productivity Classes



Distribution of Forests by Land Productivity Classes



Climatic suitability for herbaceous and woody lignocellulosic plants …

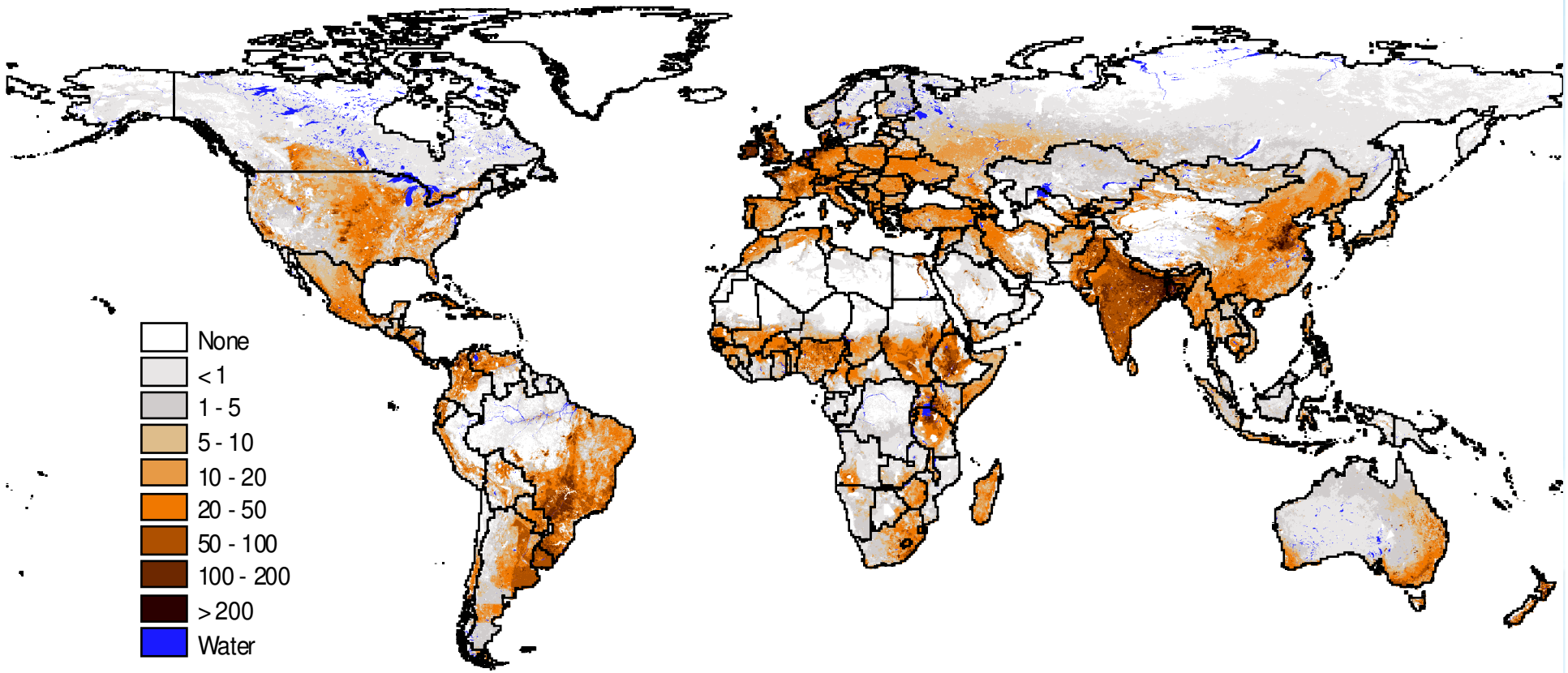


Reference climate, 1970 - 2000

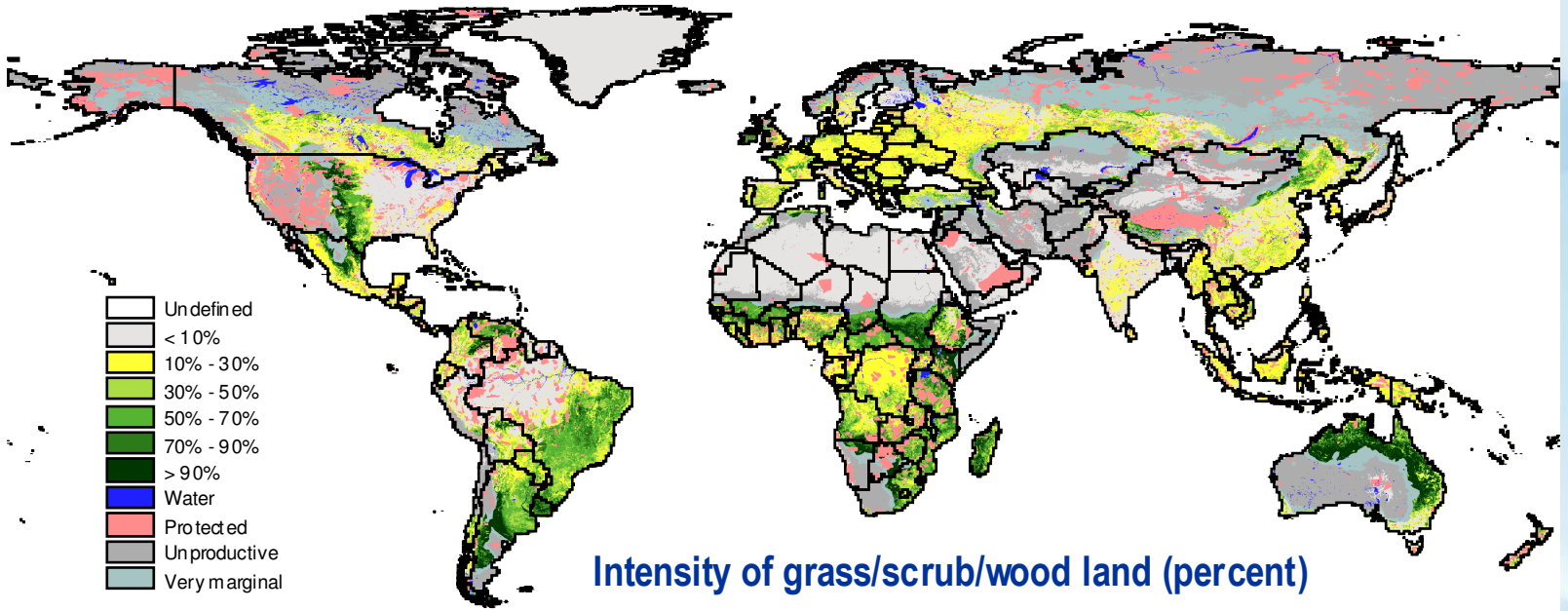
… on available grass-scrub-wood land

Source: GAEZ 2007, IIASA-LUC/FAO

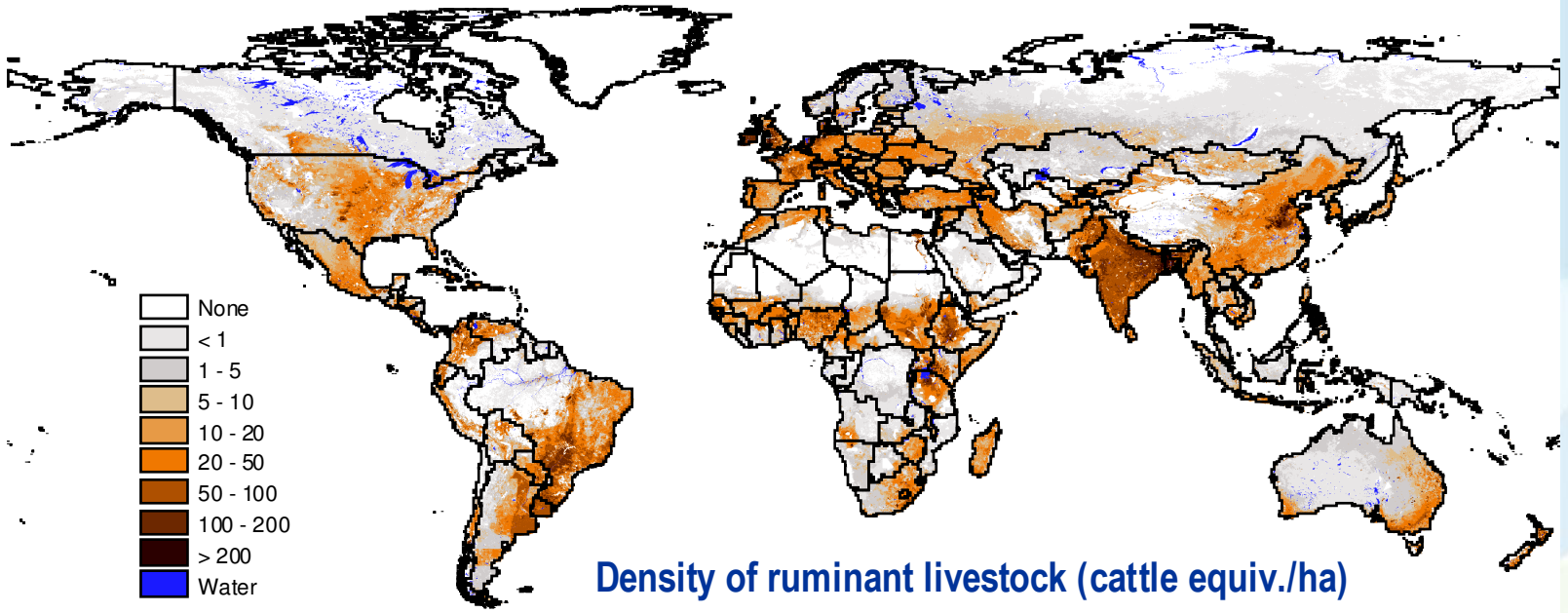
Distribution of ruminant livestock, year 2000 (cattle equiv. per km^2)



Source: FAO, 2005, modified by IIASA-LUC, 2007.
Note: Ruminants include cattle, sheep and goat. To calculate ruminant density, a weight of 1.0 was used for cattle and of 0.2 for aggregating sheep and goat.



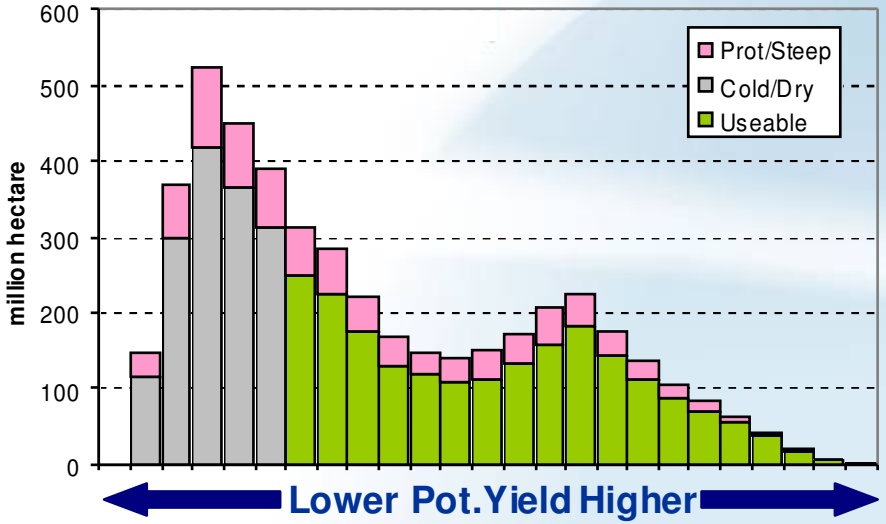
Intensity of grass/scrub/wood land (percent)



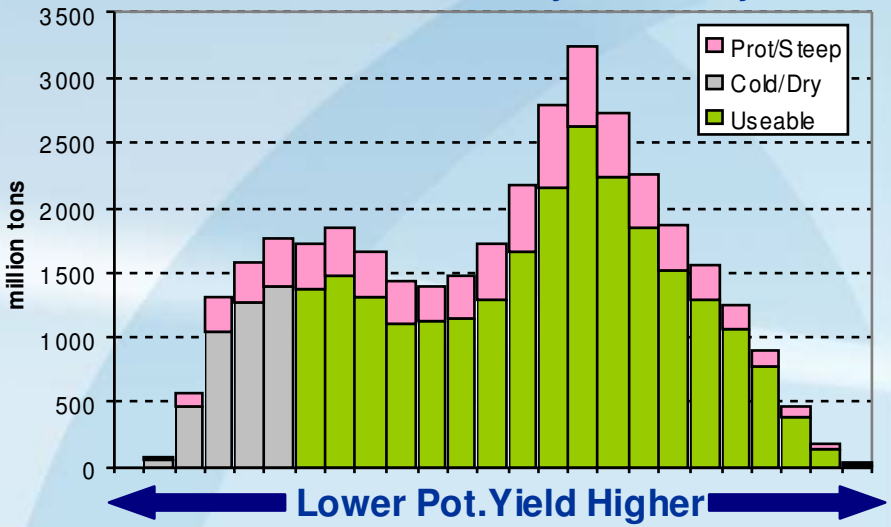
Density of ruminant livestock (cattle equiv./ha)

Source: GAEZ 2007, IIASA-LUC/FAO and FAO, 2005.

Distribution of Grass/Scrub/Woodland by Productivity Classes

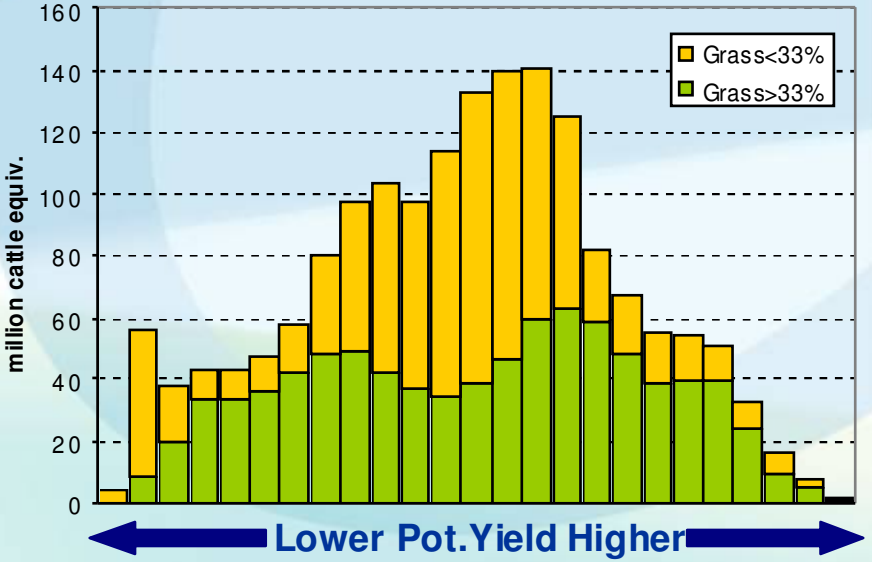


Distribution of Pot. Production by Productivity Classes



- The charts show the distribution of grass-scrub-wood-land areas and potential production by bio-productiviy class.
- Protected land and land with steep slopes is shown in red; Very low productive areas are indicated as grey.
- Number of cattle, sheep and goat is shown by bio-productivity class respectively for areas where grass/scrub/woodland cover exceeds 1/3 of total (green) and for less than 1/3 (yellow).

Distribution of Ruminants by Land Productivity Classes



Message 4:

How much land is available?

- Excluding from a total land area (excl. Antarctica & Greenland) of 13.1 billion hectares current cultivated land, forests, built-up land, water and unvegetated land (desert, rocks, etc,) results in some 4.5 billion hectare (35%).
- Excluding from these lands the very low and unproductive areas (e.g. tundra, arid land) a remaining area of 2.1 billion hectares is estimated (currently grassland & pastures, shrubs and woodland).
- Constructing detailed country-level livestock feed balances, we estimate that in year 2000 about 60-70 percent of the available biomass was used for animal feeding.
- Hence with current use, the land potentially available for bioenergy production is 600 – 800 million hectare, with a wide range of productivity.

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