Biomass, bio-energy and terrestrial ecosystems: a global perspective

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Workshop "Land Use Changes Due to Bioenergy",
Helsinki, 30 March – 1 April 2009

Global LAND Project

MATISSE

Global Energy Assessment

FWF Der Wissenschaftsfonds.

International Institute for Applied Systems Analysis IIASA www.iiasa.ac.at

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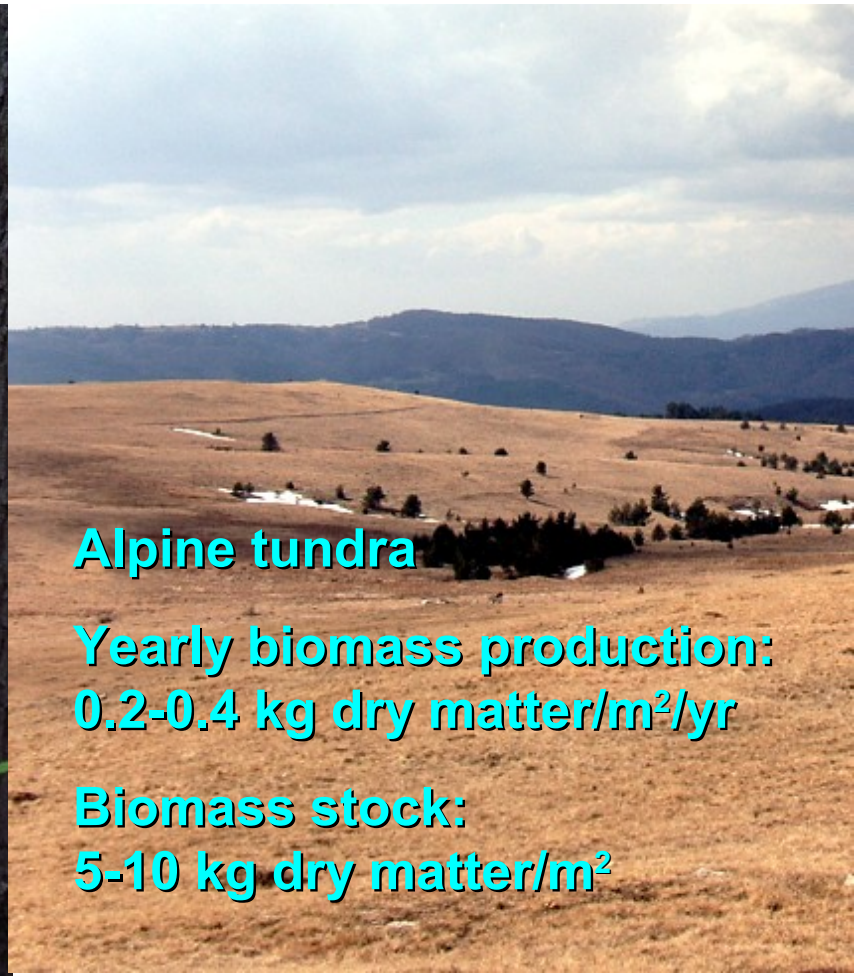
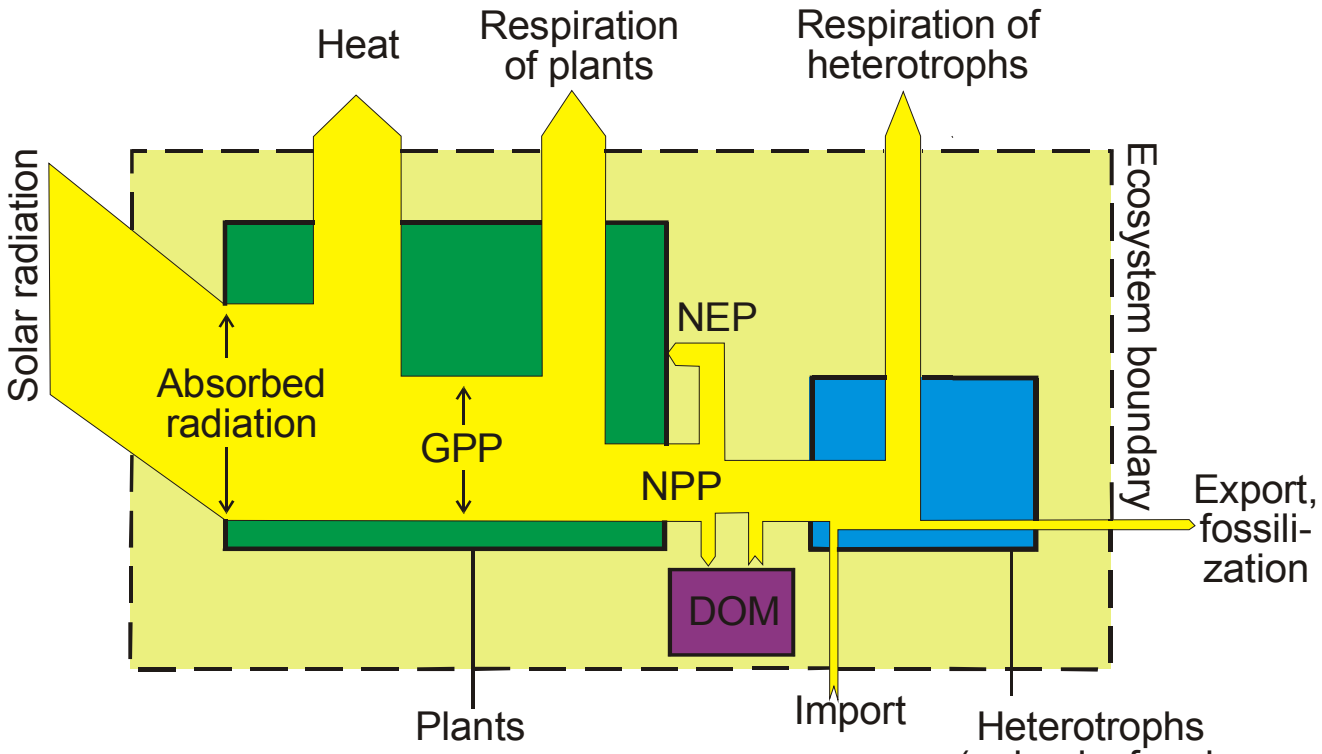
Overview

- Biomass: ecological and socioeconomic perspectives
- HANPP: an integrated socio-ecological view on global biomass flows
- Embodied HANPP: Tracing biomass flows from extraction to final use
- Socio-ecological optimization of bio-energy use
- Implications

Biomass stocks and flows in ecosystems



Ecological energy flows – the trophic-dynamic perspective [Lindemann 1942]



GPP … gross primary production
NPP … net primary production
NEP … net ecosystem production
DOM … dead organic matter

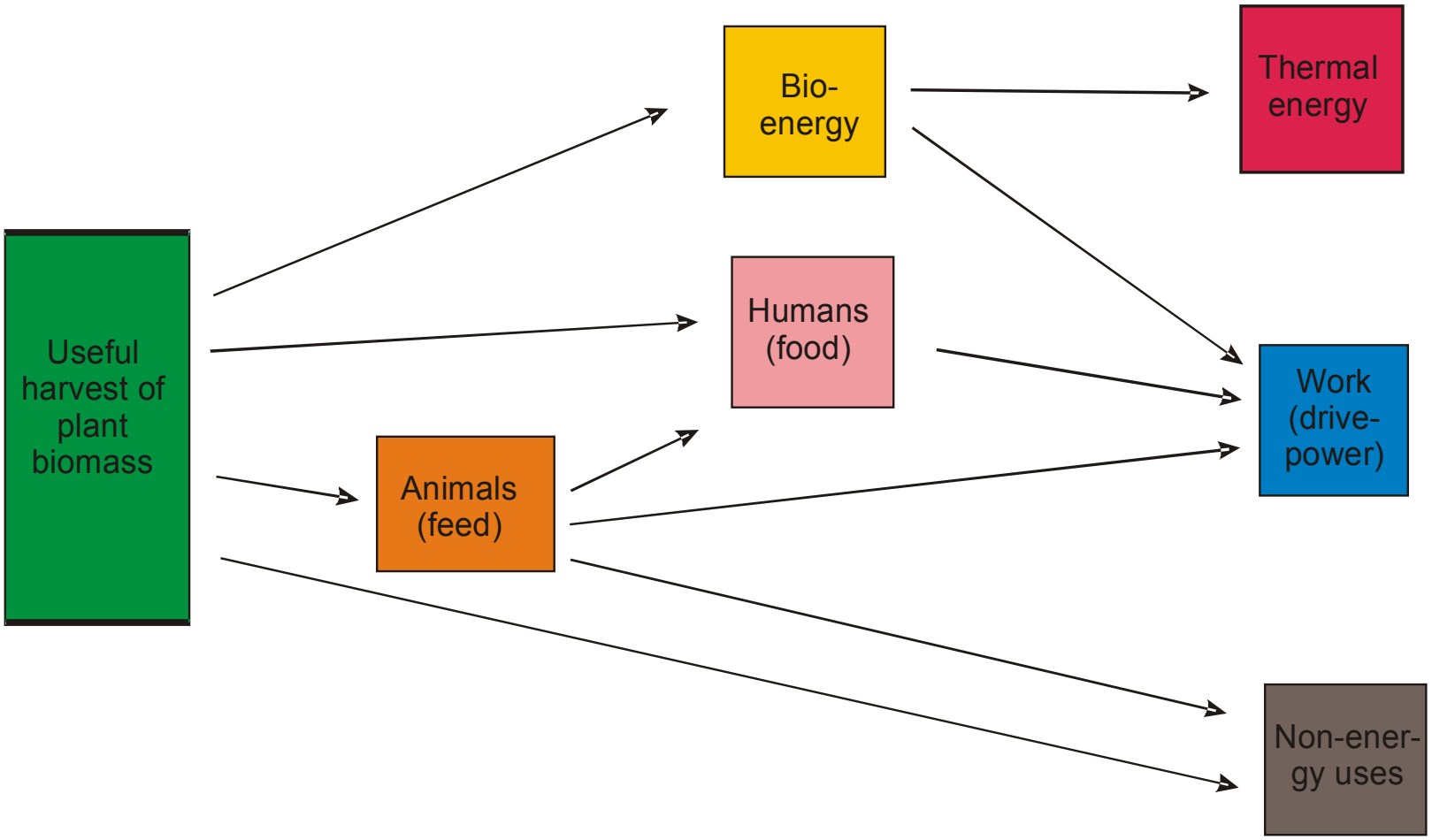
Melander family, Germany: 500 USD

Peter Menzel: Hungry Planet: What the World Eats

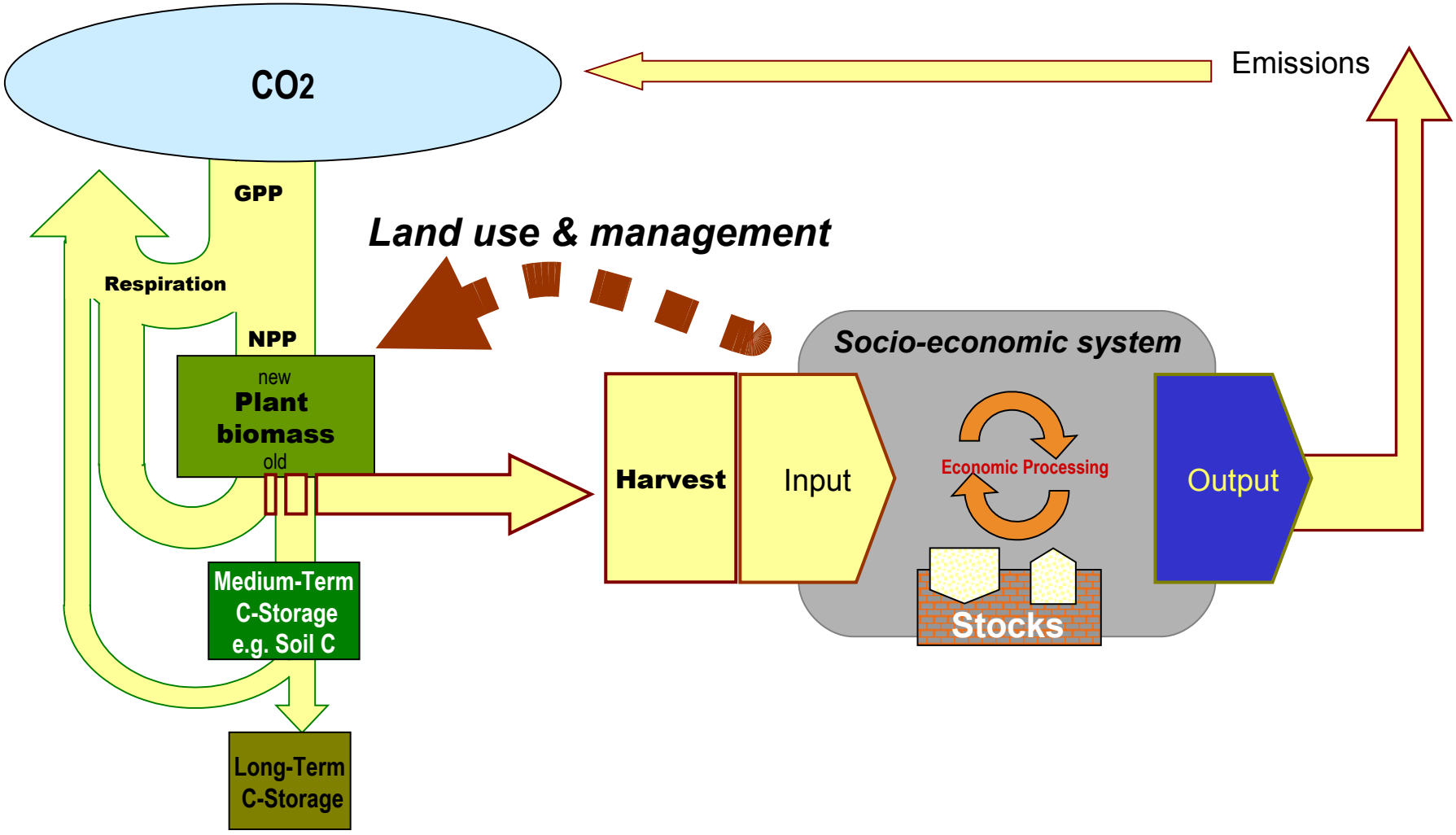
Ayme Family, Ecuador: 31 USD

Peter Menzel: Hungry Planet: What the World Eats

Principal socioeconomic biomass flows

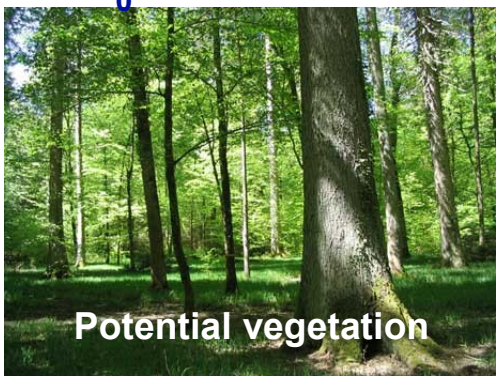


The integrated picture



An integrated socio-ecological perspective on global biomass flows: The HANPP approach

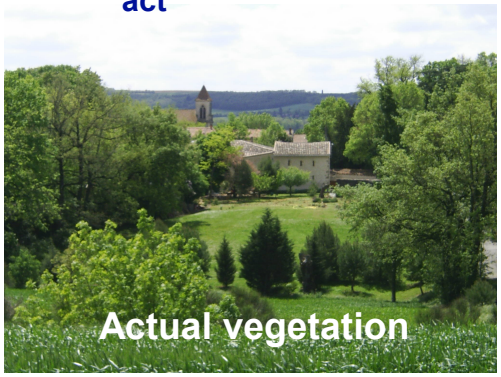
NPP_0



Productivity of potential vegetation

(hypothetical vegetation assumed to prevail in the absence of land use; e.g., forests, grasslands, savannahs, deserts, shrubs, etc.

NPP_{act}



Productivity of actual vegetation

(including croplands, grasslands, built-up area, etc.

NPP_t

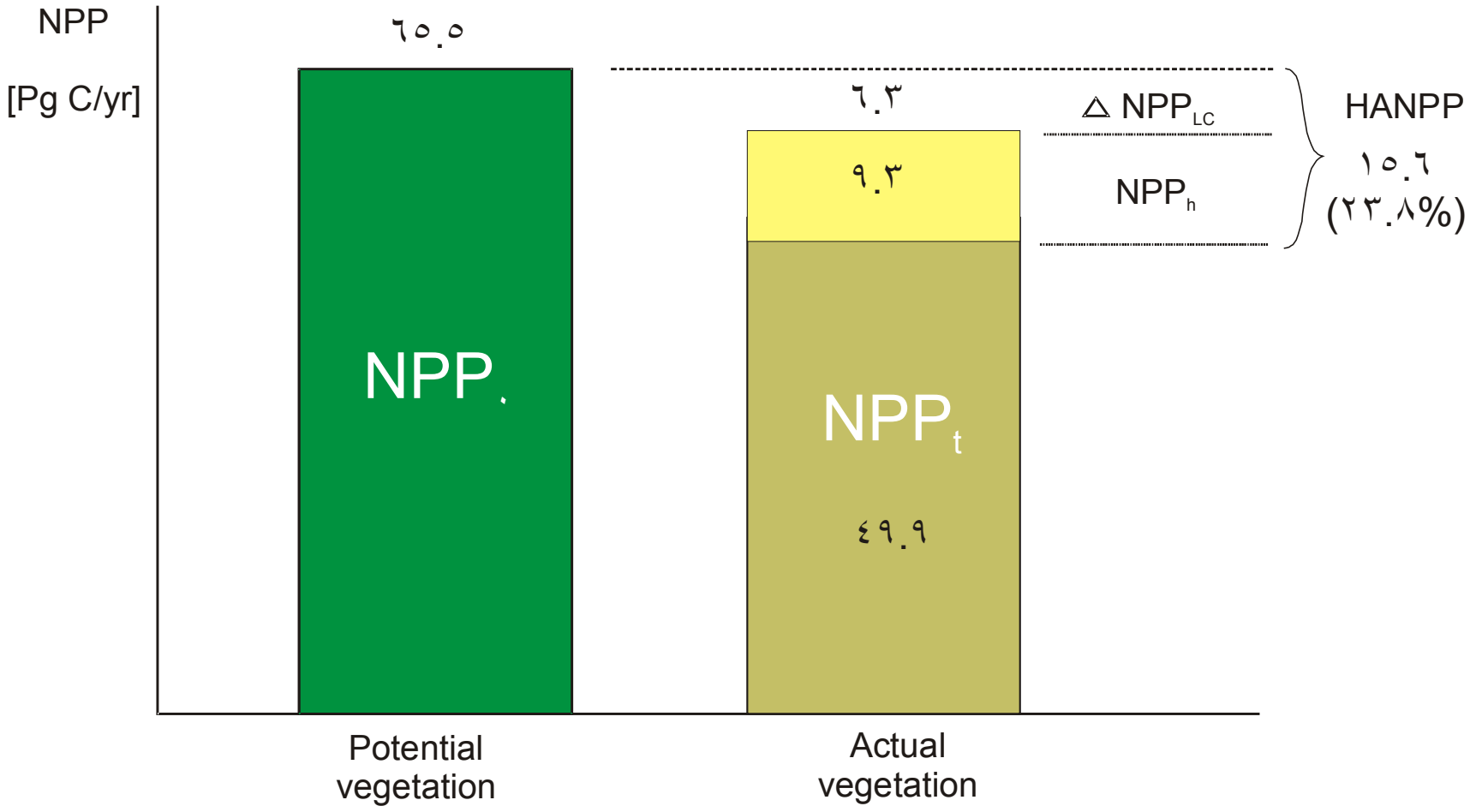
Energy remaining in the ecosystem after harvest

Productivity change

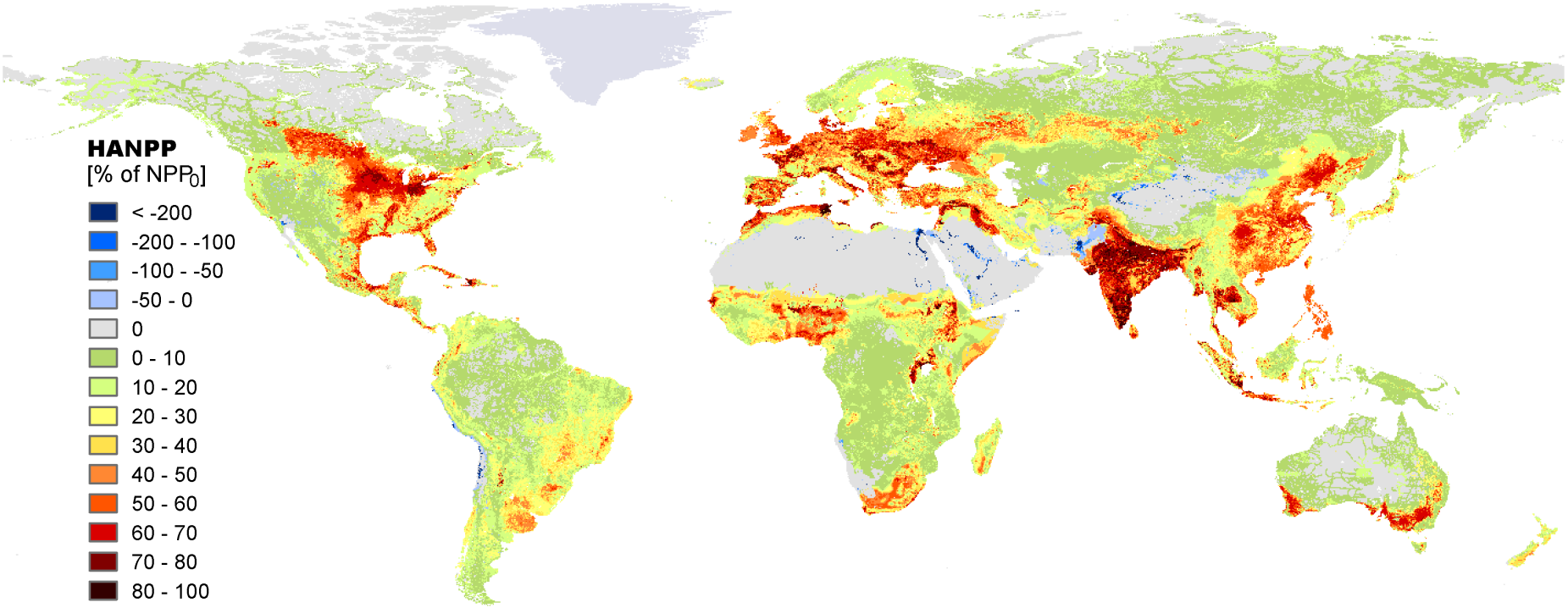
Harvest (NPPh)

- **Indicator of land-use intensity**
- **‚Pressure' indicator, useful to analyze drivers of land use**

Aggregate global HANPP (year 2000)



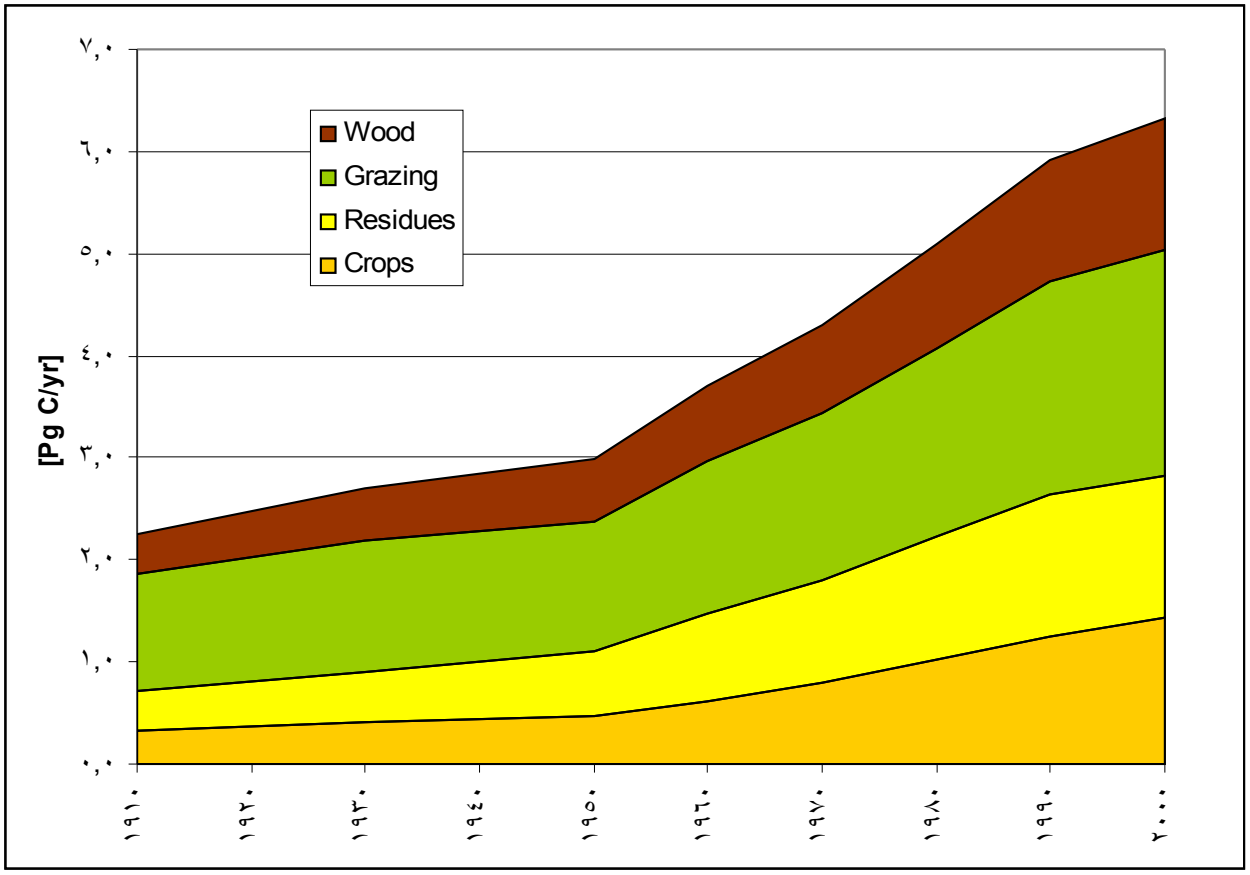
Spatial patterns of global HANPP



Aggregate HANPP (ΔNPP_{LC} plus harvest)

Haberl et al. 2007,
Proc. Natl. Acad. Sci.

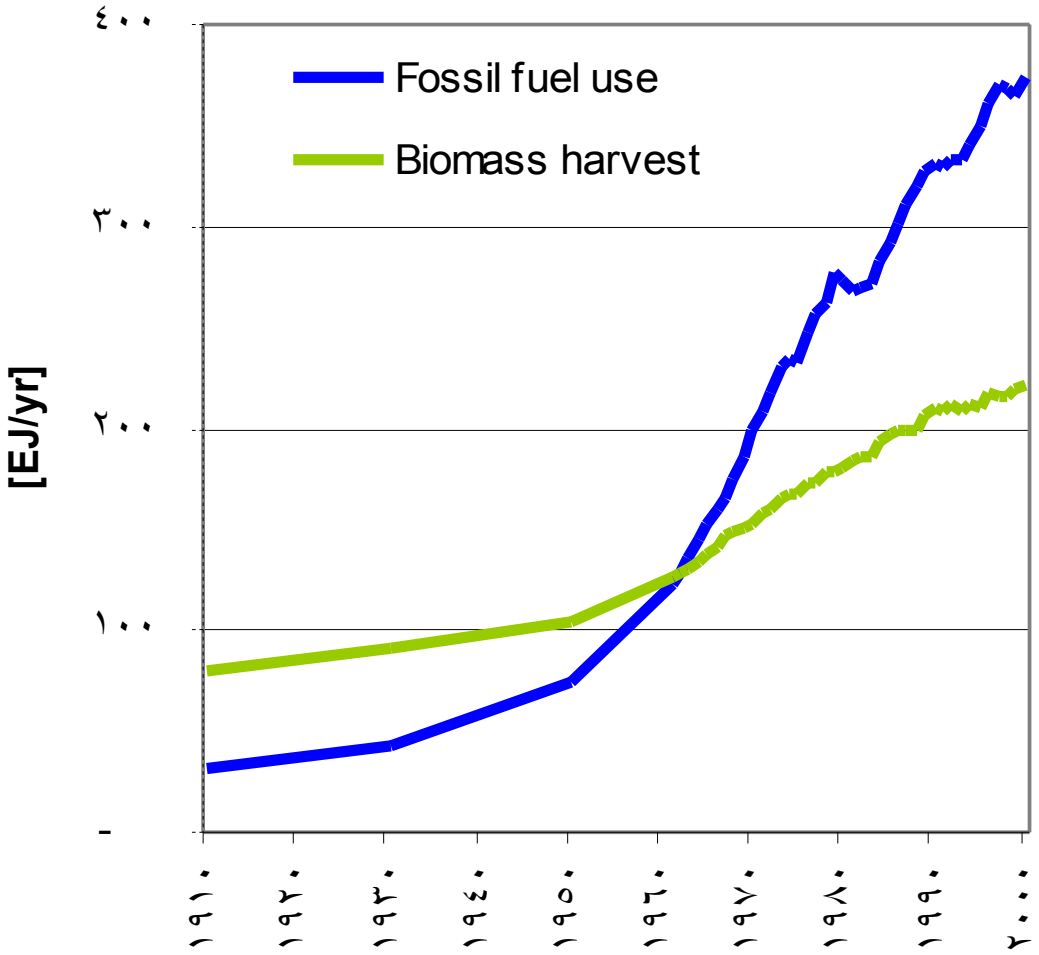
Global biomass harvest 1910-2000



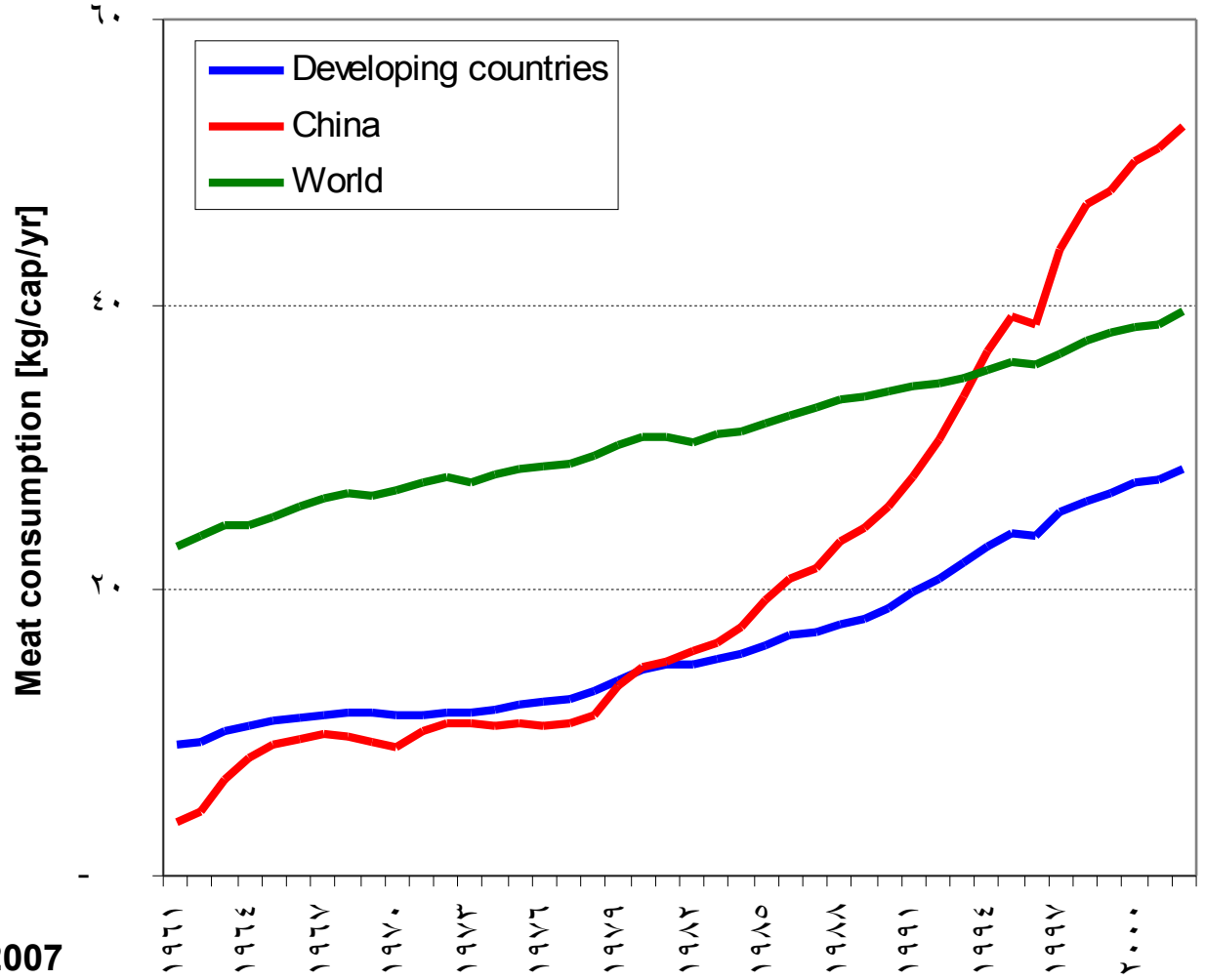
- Data sources: FAO, *Institute Internationale de Agriculture*
- Total biomass harvest grows by a factor of 2.8
- Crops grow fastest (factor 4.5), grazing most slowly (1.9)

Krausmann et al., *forthcoming.*

Biomass harvest and fossil energy use
1910 - 2000

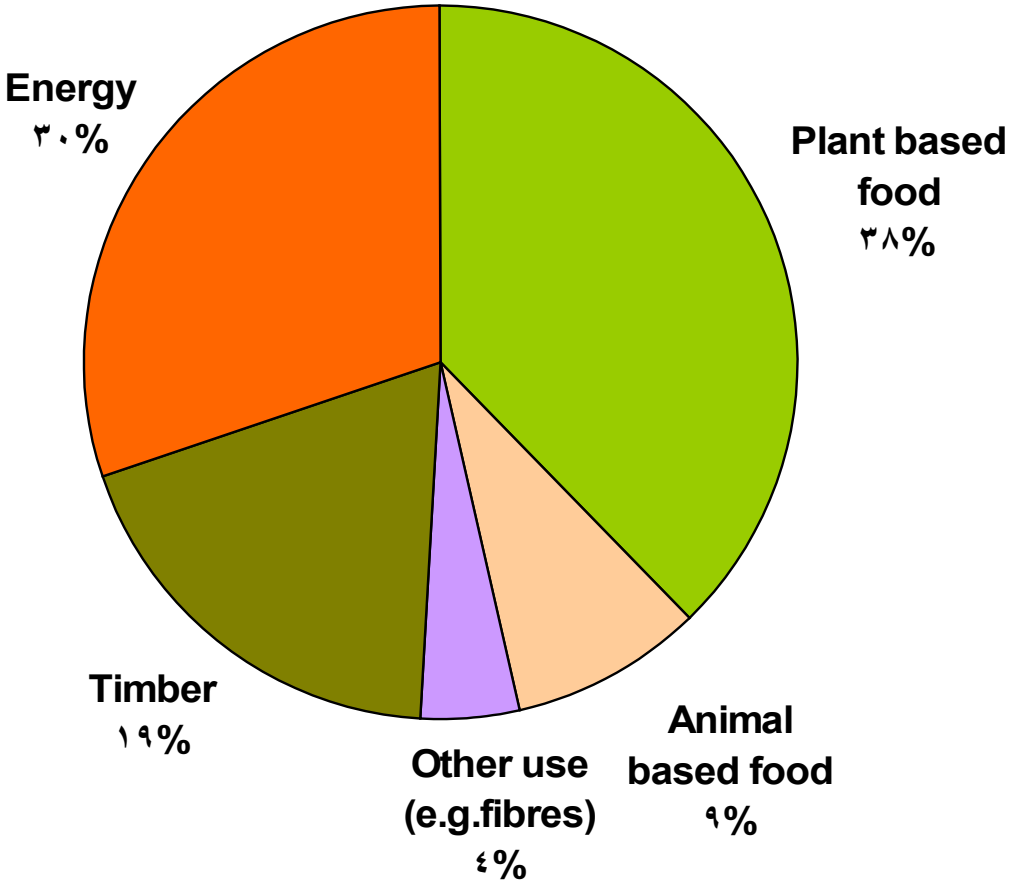


Changes in dietary patterns: Meat consumption



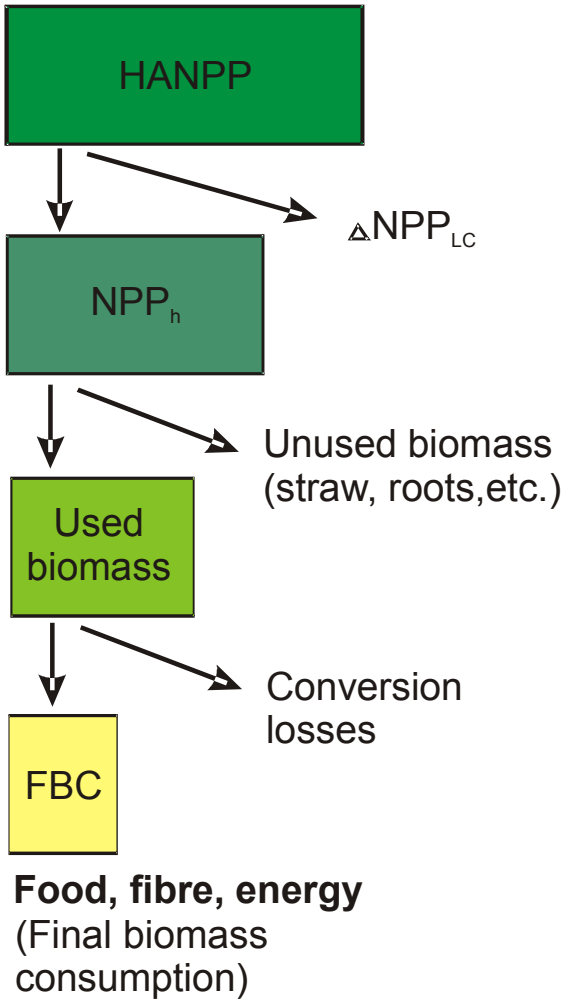
FAOSTAT 2007

Global final biomass demand : 650 kg per capita and year



Krausmann et al., 2008
Ecol Econ

Embodied HANPP of final biomass consumption (global average)



1 ton of dry-matter biomass (final use of food, fibre, timber, fuel)

implies (in the global average over all products and regions)

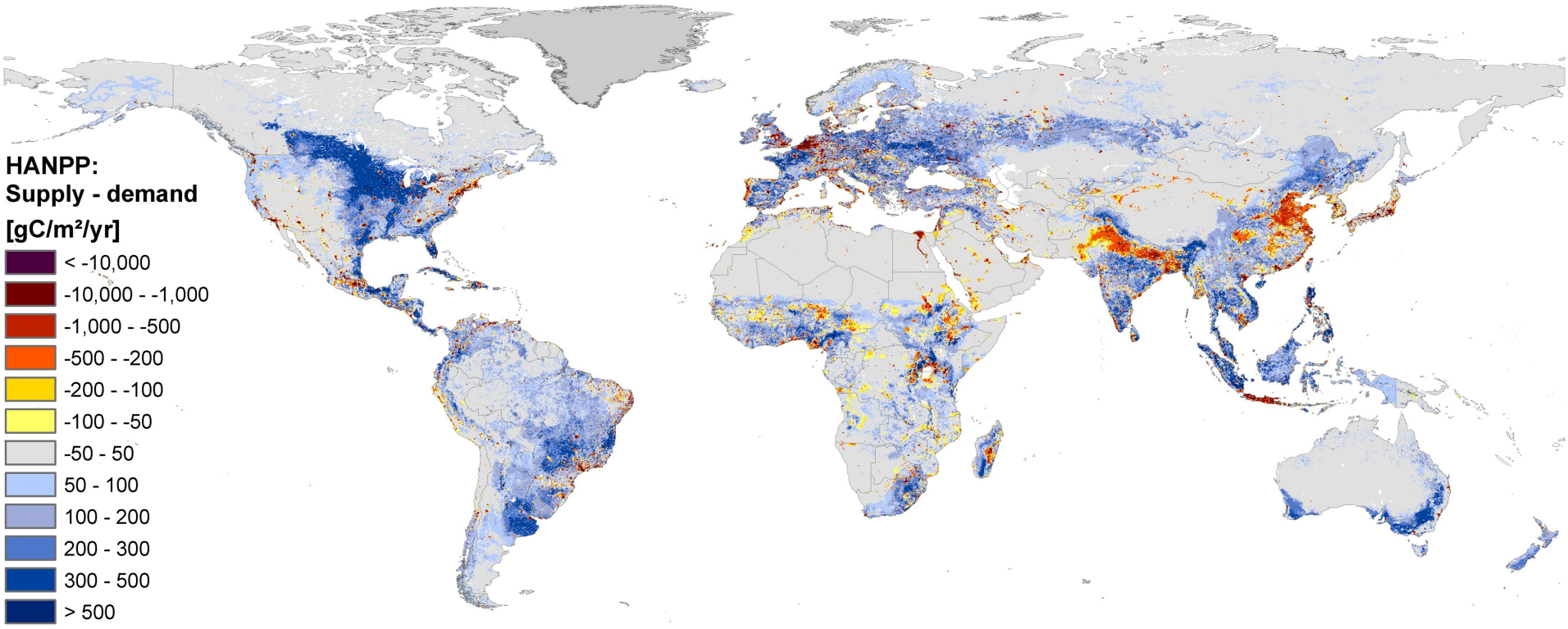
the harvest of **3.6 tons** of primary biomass (NPP$_h$)

a reduction of productivity of **2.4 tons** (△NPP$_{LC}$)

i.e. a total HANPP of **6 tons**

Krausmann et al., *Ecological Economics*, **65**:471-487 (2008).

Embodied HANPP:
„Supply“ and „Demand“ of HANPP



Erb, Krausmann et al.,
forthcoming

Embodied HANPP:
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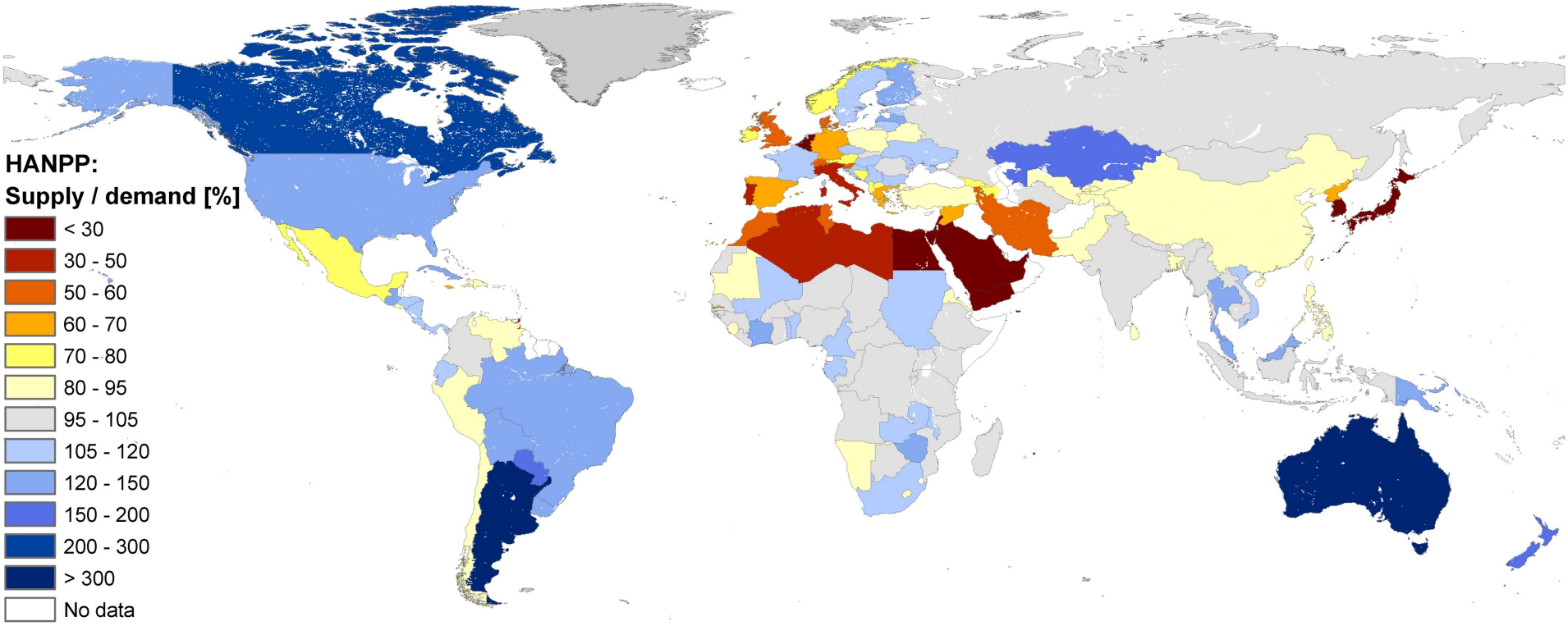
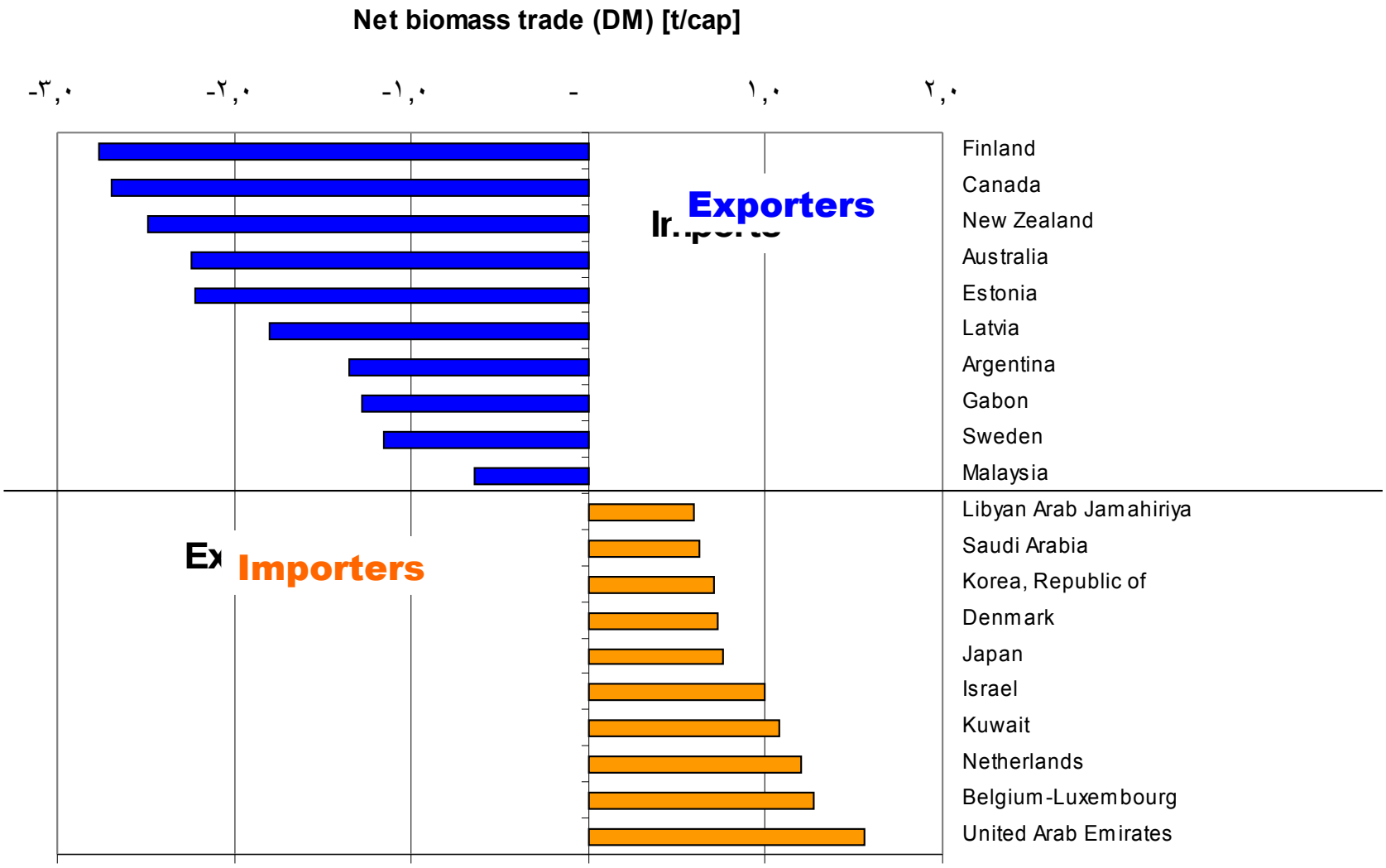
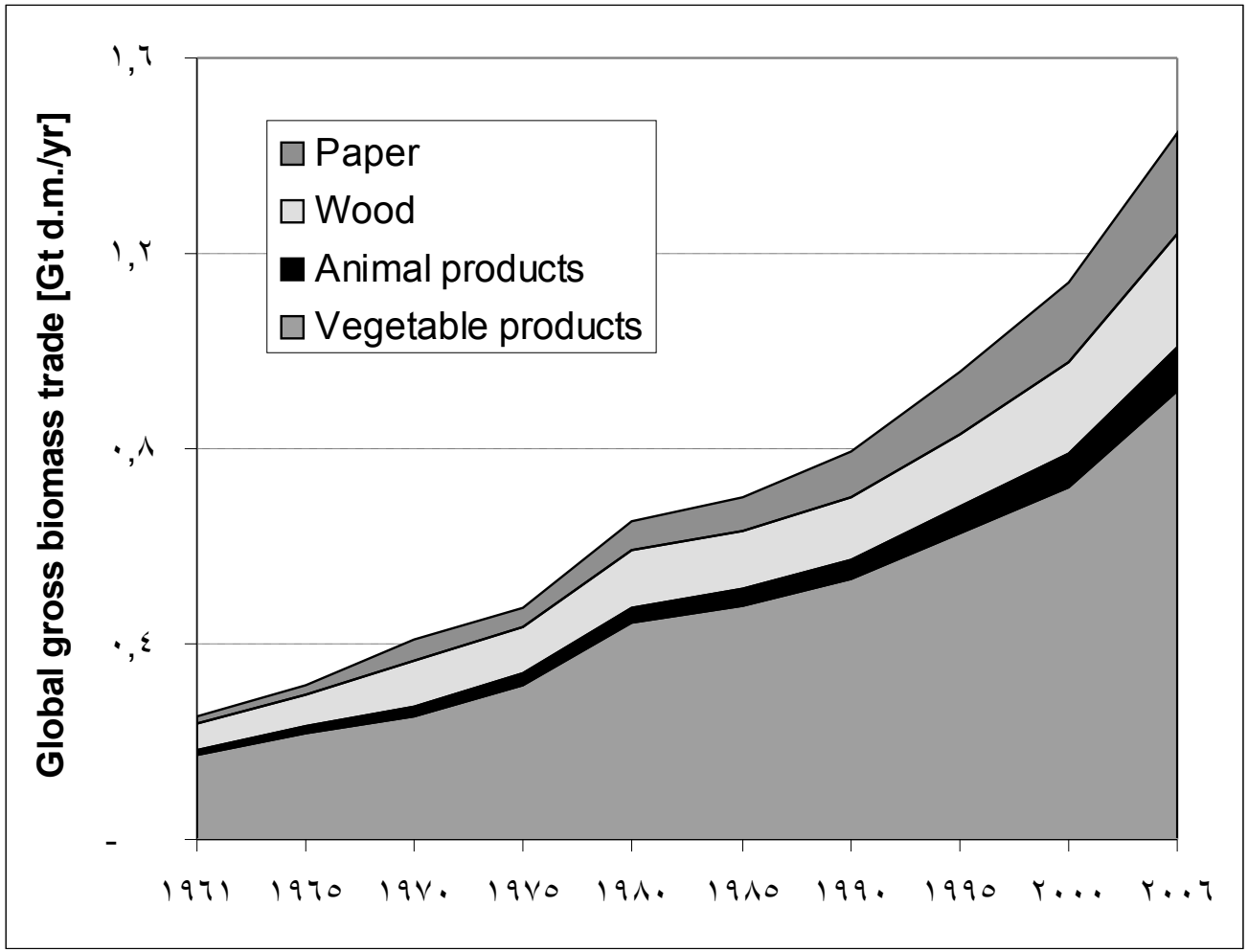


Erb, Krausmann et al.,
forthcoming

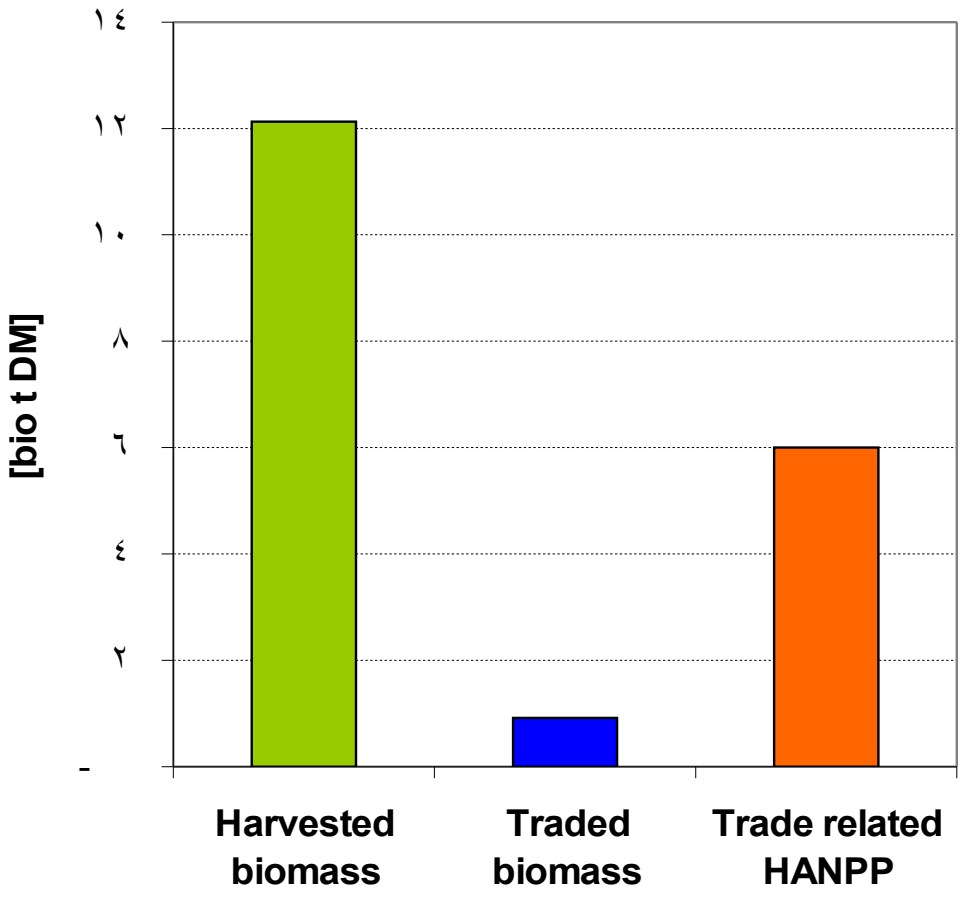
Physical net trade with biomass products: per capita flows



Global biomass trade 1962-2006



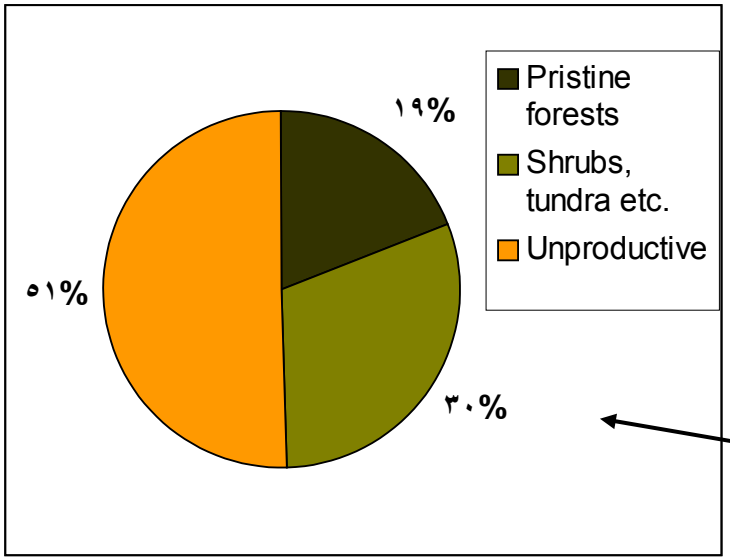
HANPP und international Trade

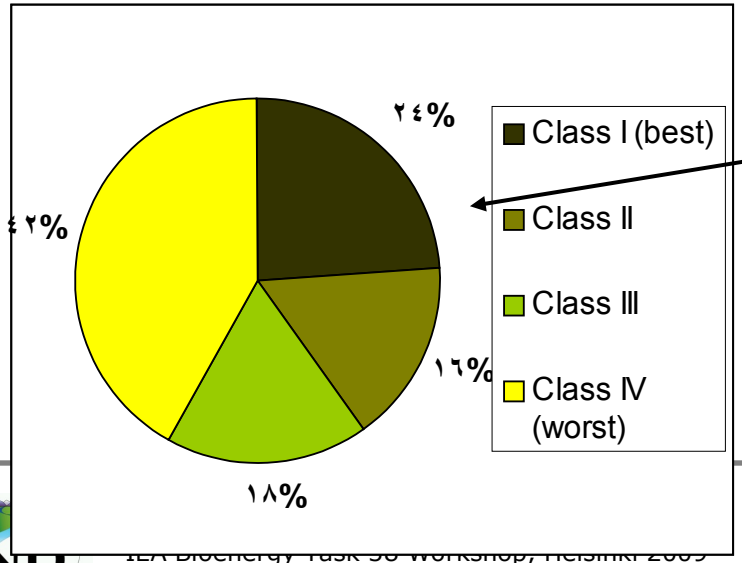


- Only 7% of used biomass extraction is traded (c.200 kg/cap/yr)
- But embodied HANPP of traded biomass is large (>20% of global HANPP)

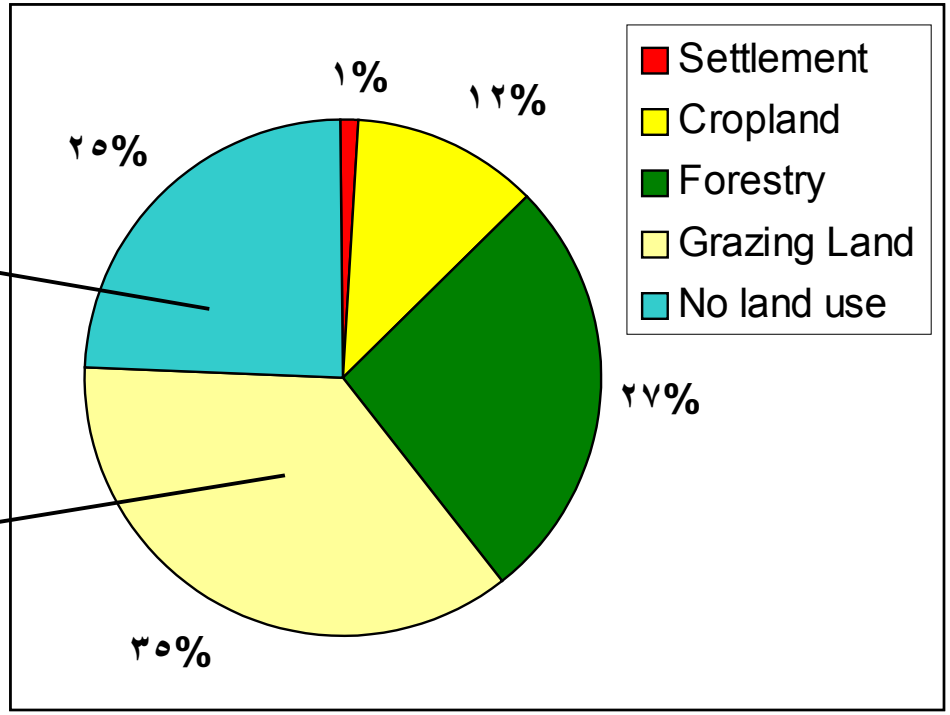
→ **Biomass and land use are globally connected systems**

There is practically no „unused land“





→ **Using more land for bio-energy will affect other land uses**



Erb et al., 2007 *J Land Use Sci.*

Some figures on current and projected future use of bio-energy

• Current global bio-energy production	48 EJ/yr (±10)
• Potential in 2050 according to the World Energy Assessment [2000]	280 EJ/yr
• World Energy Council/IIASA scenario for 2050	154 EJ/yr
• SRES-IPCC scenarios for 2050	193 EJ/yr
• Long-term potential estimates (various authors)	1 135 EJ/yr

For comparison:

• Current terrestrial NPP (above+belowground)	2 200 EJ/yr
• Current global human fossil fuel use (GCV, 2005)	390 EJ/yr
• Total current human harvest of biomass (NPP_h)	350 EJ/yr
• Total current used biomass harvest	224 EJ/yr

Embodied HANPP of bio-energy (rough estimates, should be improved)

„Energetic recycling“ of biomass wastes	No additional HANPP (but limited potential) **0 t HANPP per t of solid biofuel**
Integrated optimization of grain production for food & energy	Increases area-demand for grain production by c10% 50% of straw available for energetic use **0.2 t HANPP per t of solid biofuel**
Rape methyl ester (RME) as agro-fuel (diesel motors)	Assumtions: 0.13 kg RME per m^2 cropland and year HANPP per m^2 cropland and year 1.8 kg 50% of HANPP allocated to RME (remainder to feedstuff produced) **7 t HANPP per t of liquid biofuel (RME)**

Implications

- There is no „unused land“, except pristine forests and unproductive land. Using more land for bio-energy will impact other land uses, in particular extensive subsistence grazing.
- Land use effect of bio-energy interacts with production and consumption of all other biomass – cannot be determined on a product level (needs system-wide evaluation)
- HANPP efficiency (i.e. largely area-efficiency, i.e. energy yield per unit area and year) should be a highly important indicator for judging the ecological sustainability of bio-energy technologies. Liquid biofuels are much worse in that respect than other bio-energies.

⇒ Priority should be given to „cascade utilization“ of biomass and to solid bio-fuels with a high energy yield per unit area (and usually also a good EROI)

Download HANPP and land use data
http://www.uni-klu.ac.at/socec/inhalt/1088.htm