

Land use data

Integrating socio-economic and ecological data within the HANPP framework

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together with:

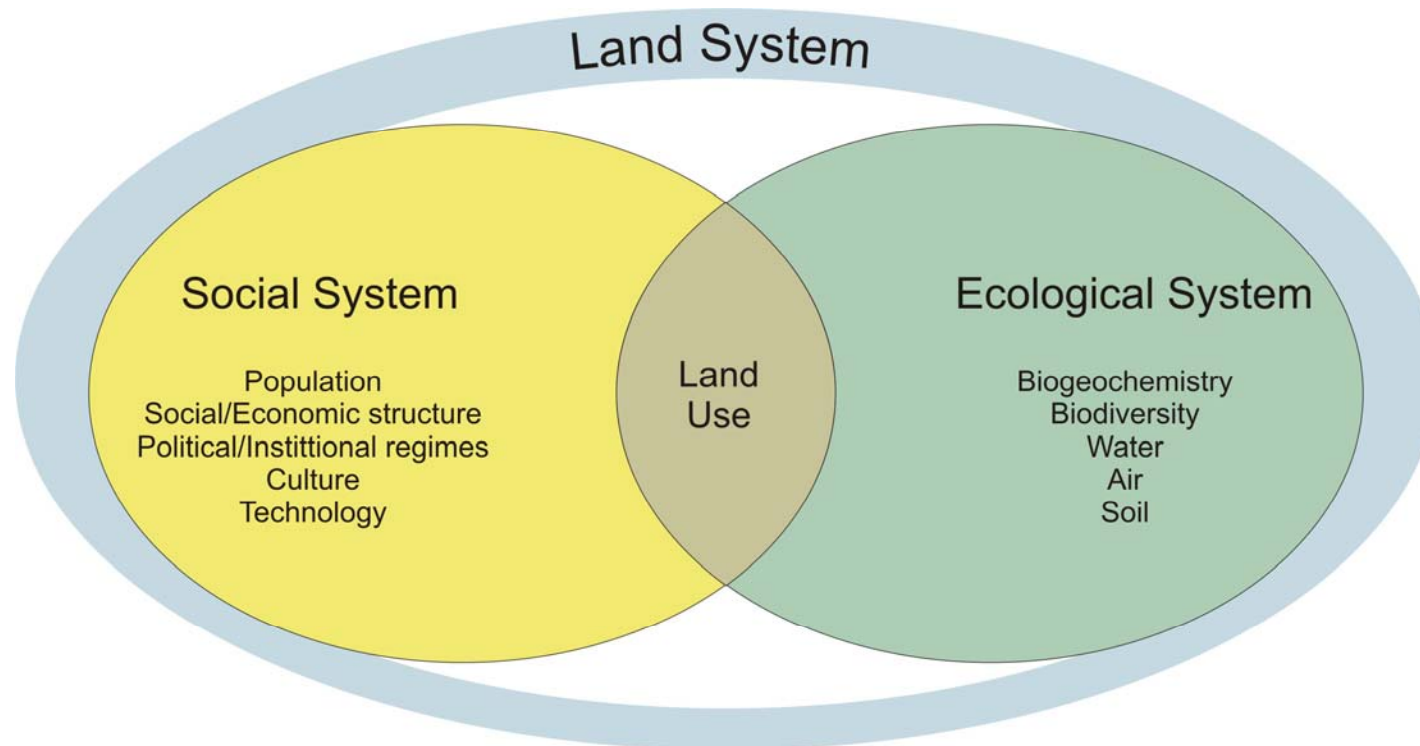
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Presentation at the GLP Workshop
'Data and model integration for coupled models of land use change'
17th – 19th July 2008

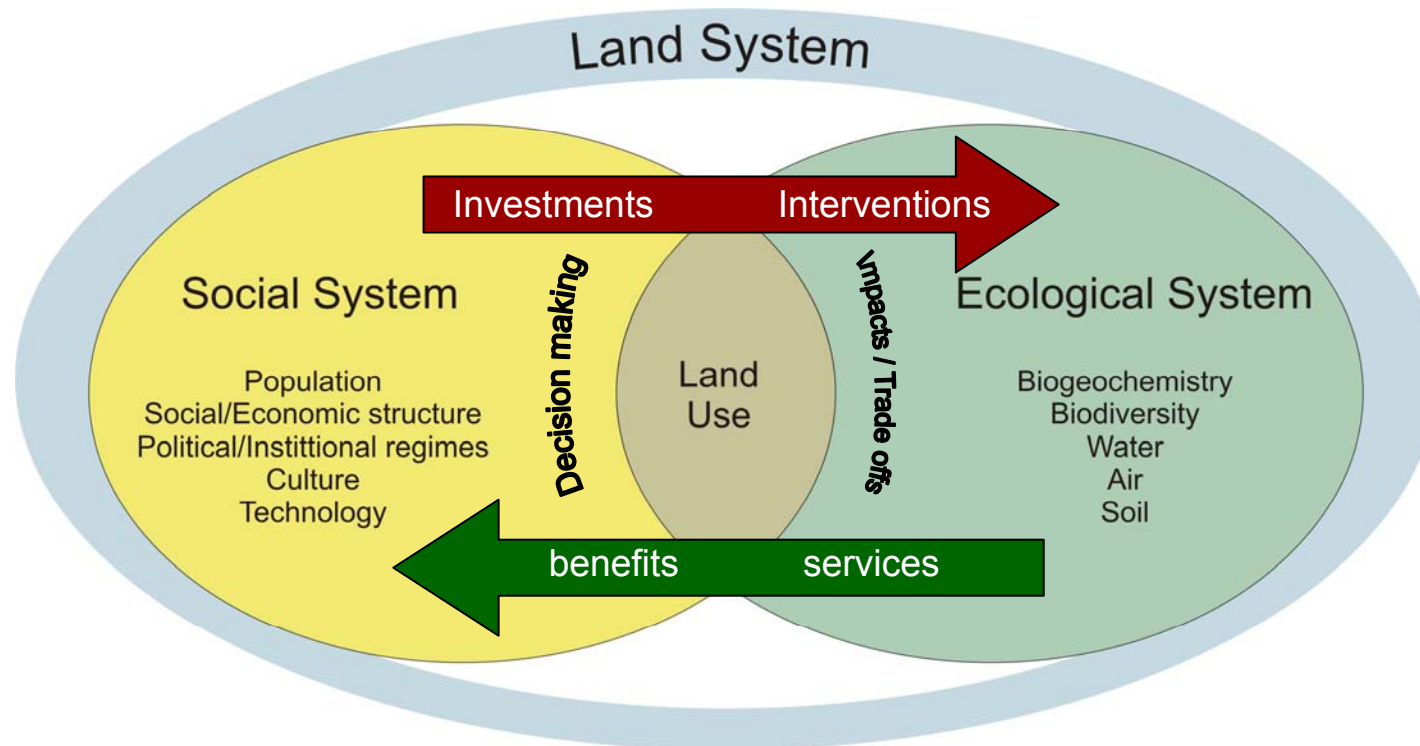
Overview

- Land as coupled socio-ecological system
- Concepts of society interaction: „socio-economic metabolism“, „colonization of natural processes“
- Biomass, carbon and the HANPP framework
- Data integration: global land use dataset – in particular: grazing
- Global results
- Conclusions

Starting point: Land, a socio-ecological system



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Data „families“

- **Socio-economic data:** demography, social structure, communication networks, literacy, economic structure & flows, cultural data
- **Ecosystem data:** biodiversity, biogeochemical flows, water balance, biomes, plant functional types, etc.
- **Interaction data:** socio-economic metabolism, land use
 - Ratios are important:
 - benefits per investment
 - alteration of ecosystem properties (and consequently, provision of services) per intervention
- Prerequisite for *sustainability science*: unambiguously linkable to socio-economic activities
- *Required for data integration*: **CONSISTENCY!**
 - Precondition: a systematic conceptual framework

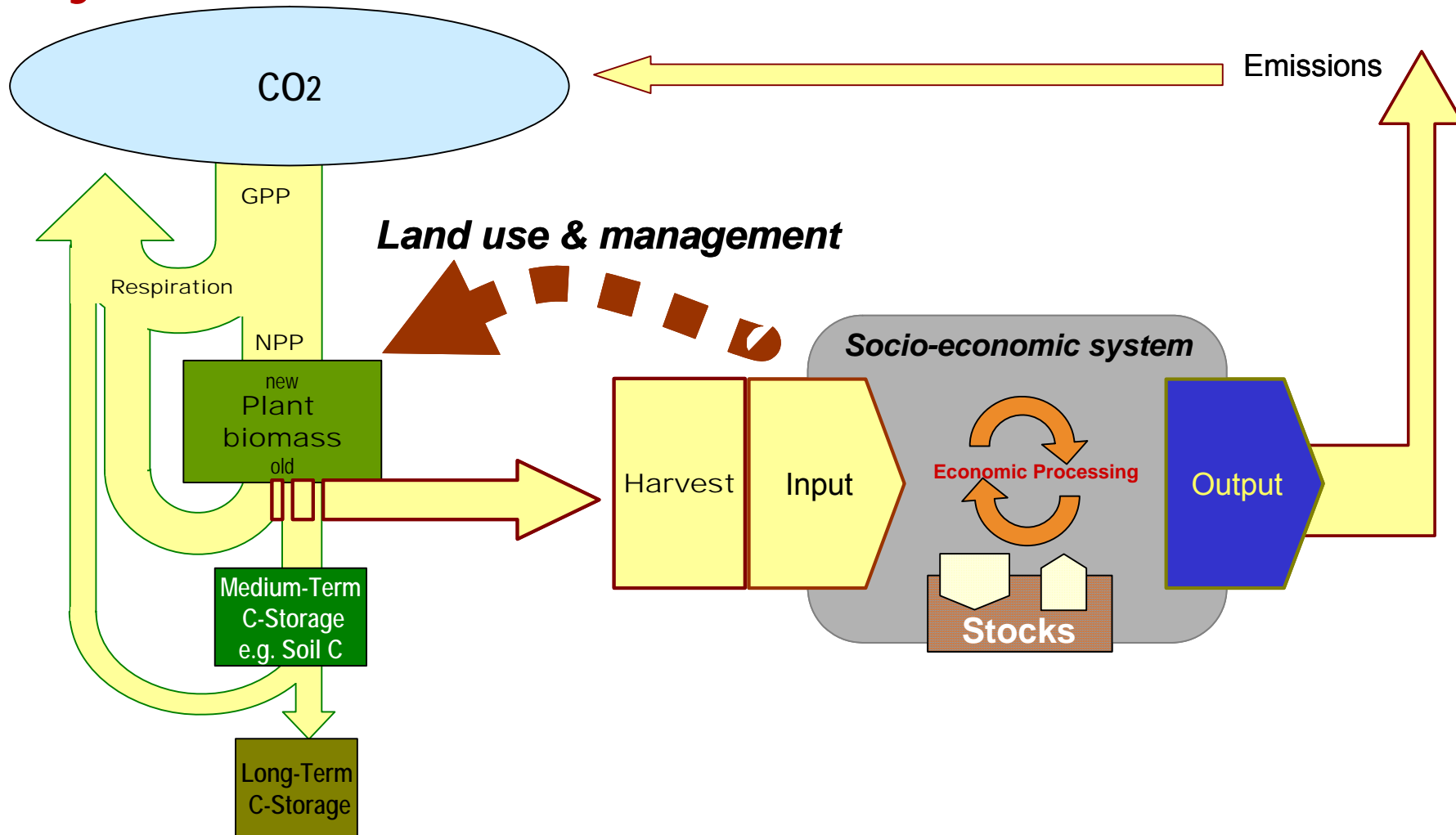
Concepts of Society-Nature Interactions

- **Socio-economic metabolism:** Input and output of material and energy of the socio-economic system.
Precondition: unambiguous definition of a system boundary between Society and Nature
- **‘Colonization’ of ecosystems:** purposive alteration of ecosystem processes (and patterns) in order to maximize the *useful* output.
 - ‘societal perspective’: investment per benefit, trade-offs (maximizing services at the expense of others), decision making
 - ‘ecosystem’ perspective: alterations, impacts on functions, consequences for other system components

Example: BIOMASS

- **Biomass:** the sum of organic, non-fossil material of biological origin; chemically stored solar energy (organic compounds) - closely linked to the global carbon cycle
- **Ecosystem functioning:** Biomass stocks and flows (NPP) are central parameters of ecosystem functioning: dynamics, patterns, trophic webs, turnover rates, etc.
- **Socio-economic material & energy flows:** Biomass is indispensable for the sustenance of humans and their domesticated animals (as food, feed, material and energy)
 - → Interconnected with land use and land use change: Humans interfere with (manage) ecosystem's energy flows. Aim: increase the output of *useful* products. Consequences: alterations of biogeochemical cycles, energy flows, patterns, dynamics, etc. Strongly related to biodiversity endangerment
 - → Humans compete with all other organisms for biomass

Example: the coupled socio-ecological System: C-flows



Global Carbon Cycle
Steffen et al. *Science* 1998

Social Metabolism
Matthews et al. *The Weight of Nations* 2000

HANPP

- **Aim**

- Assessments of human impacts on ecosystem functioning: land use & ecosystem service NPP (production, supporting service)
 - land use intensity

- **Rationale:**

- Land use has far-reaching effects on global bio-geochemical cycles: sustainability challenges
- Need to identify human activities and quantify impacts on natural systems, explore/analyse socioeconomic drivers

The HANPP framework

NPP₀



Annual energy flow of the potential vegetation (without human land use, e.g. Forests, Grasslands, Savannahs, etc.)

NPP_{act}



Annual energy flow of the actual vegetation, including secondary vegetation, fields, built-up areas, etc.

NPP_t



Energy flow available annually after the extraction of biomass through harvest

$$\Delta NPP_{LC}$$

$$NPP_h$$

HANPP

Spatially explicit modeling

Society and ecosystems are not uniformly distributed

	Spatially explicit	Census
AREA	GLC-2000 (JRC-GVM, [Joint Research Center 2002]) Forest Resource Assessment 2000 [FAO 1999] Cropland map (Ramankutty & Foley 1998) Global irrigation map [Siebert et al. 2005] GLASOD [Oldeman et al. 1990] Wilderness map [Sanderson et al. 2002]	Statistical data of FAO on cropland area, permanent pastures, permanent crops, forests and other land [34] Forest resource assessments [FAO 1998, FAO 2001, FAO 2006] Temperate and boreal forest resource assessment 2000 [UN 2000]



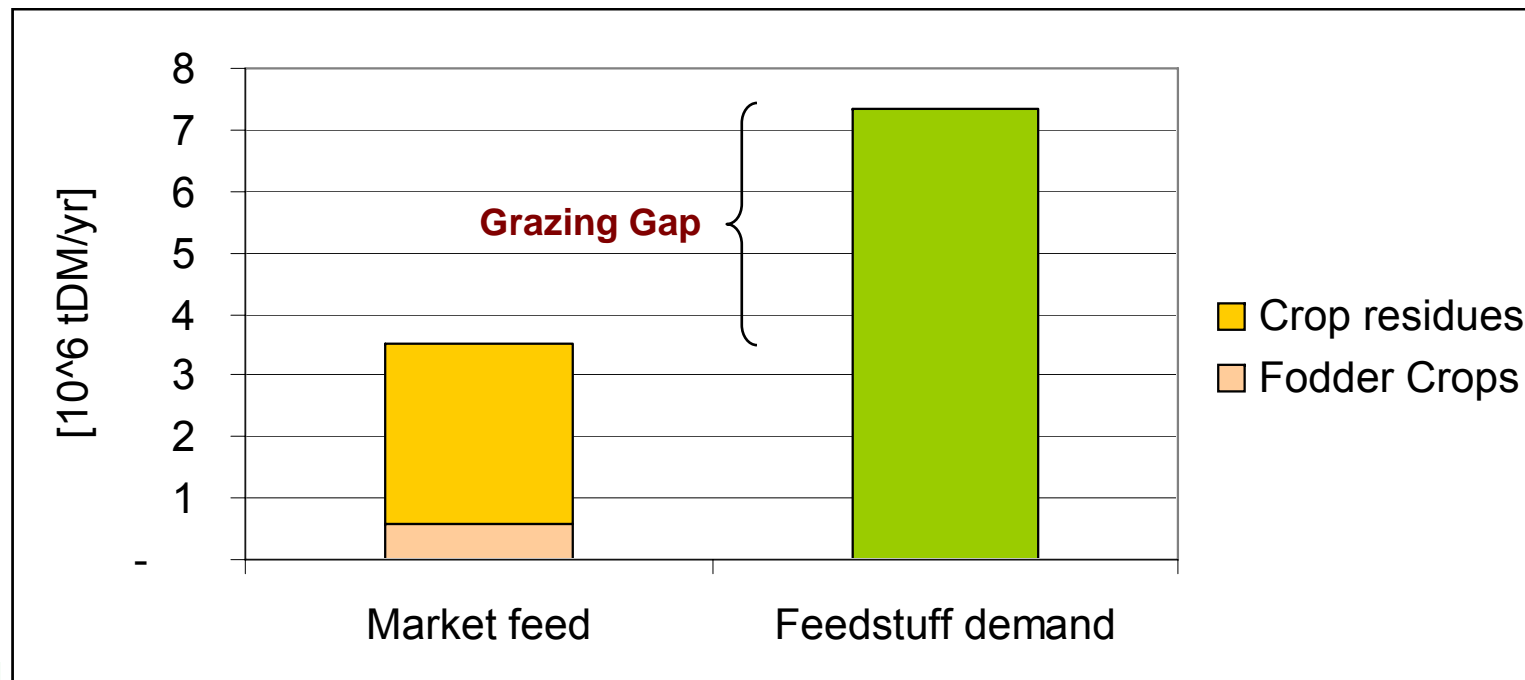
MATERIAL FLOWS	NPP₀ LPJ DGVM:	NPP_h Agricultural statistics (FAO): production, livestock, roundwood harvest Woodfuel statistics [FAO 1997, etc.] Energy statistics and balances [IEA 2004, UN 2004 and others]
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Requires consistent and comprehensive land use data

- **Consistent:** with metabolism-data: yields [=flow per area]
- **comprehensive:** 'relevant' land use types + non-land-use
- **Not straightforward:**
 - Most datasets refer to land cover – not consistent with census statistics (land use)
 - Data gap: infrastructure area (small extent, but far reaching land use type: alters land cover structure drastically; closely related to land use dynamics)

Grazing

- livestock grazing is the largest fraction of the global biomass harvest (32%), a major driver of the human transformation of terrestrial ecosystems
- Statistics comprise only market feed – no information on grazed biomass available. “Grazing Gap” must be modelled as difference between demand & market feed supply

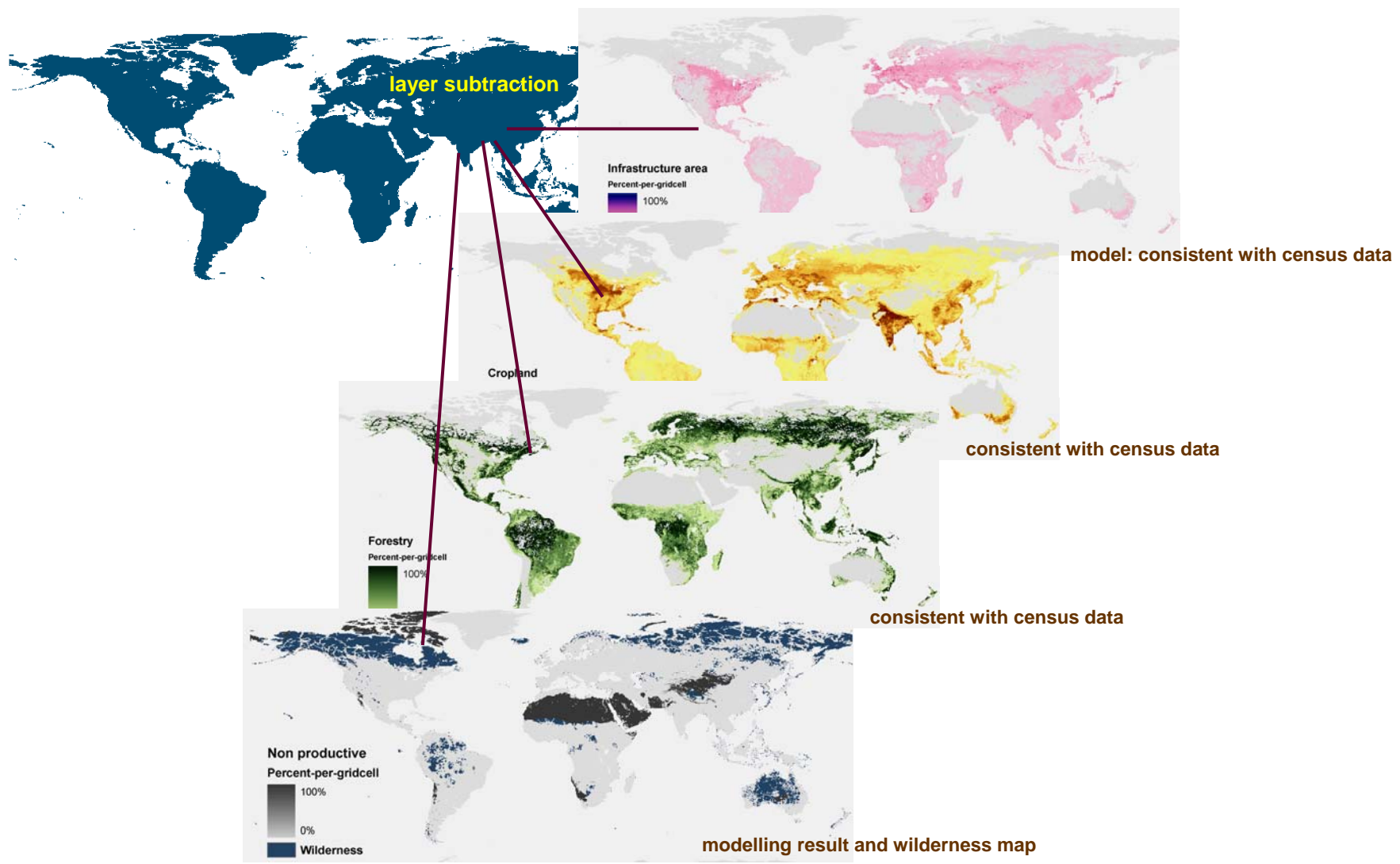


Source: Krausmann et al. *Ecological Economics* 2008

Grazing

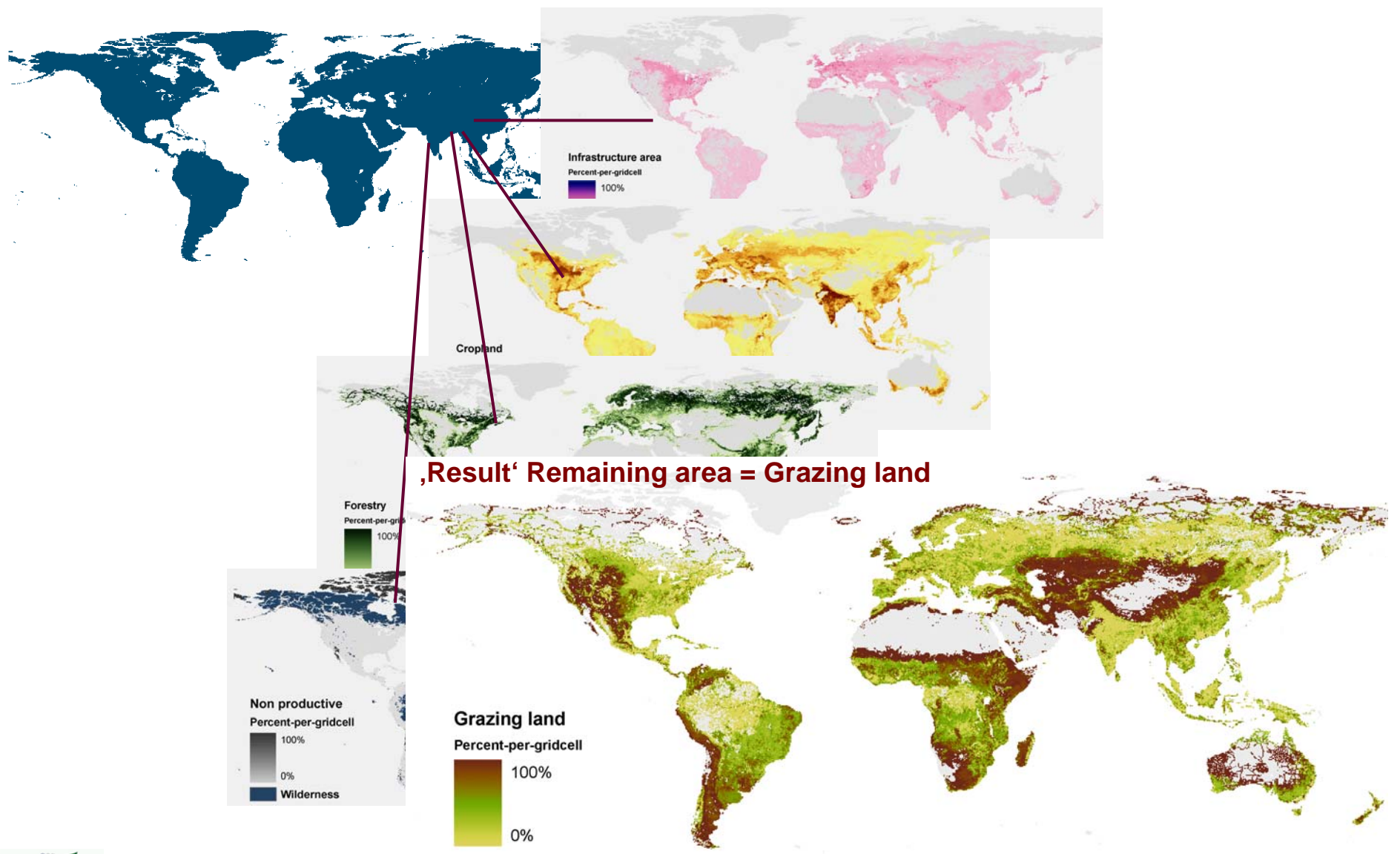
- livestock grazing is the largest fraction of the global biomass harvest (32%), a major driver of the human transformation of terrestrial ecosystems
- Statistics comprise only market feed – no information on grazed biomass available. “Grazing Gap” must be modelled as difference between demand & market feed supply
- very loose relation of land use and land cover (occurs in almost all ecosystems (hampers application of remote sensing techniques))
- Census statistics are of limited practicability, inconsistent, heterogenous definitions (e.g. artificial grasslands vs. natural grasslands)

Modelling Philosophy



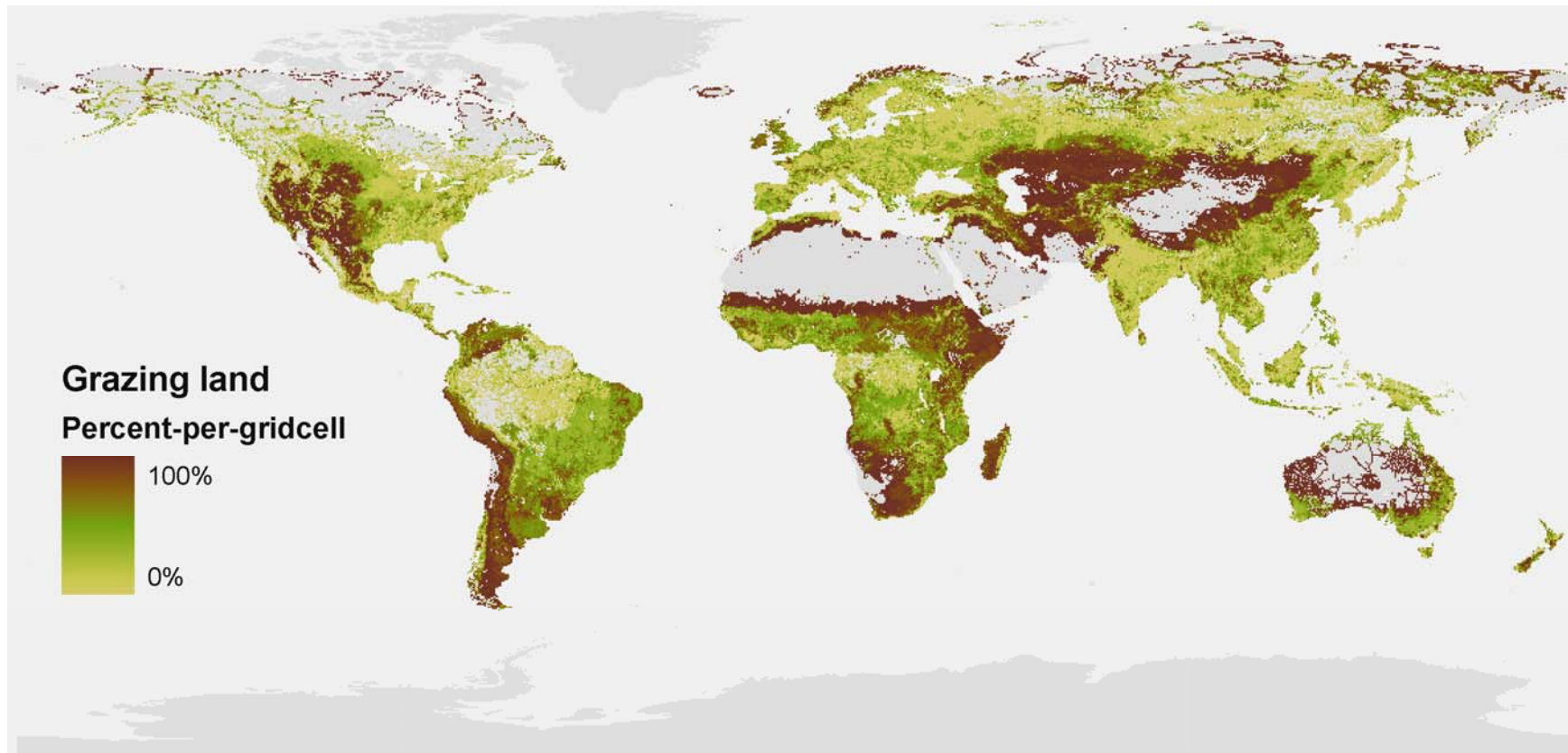
Source: Erb et al. JLUS 2007

Modelling Philosophy

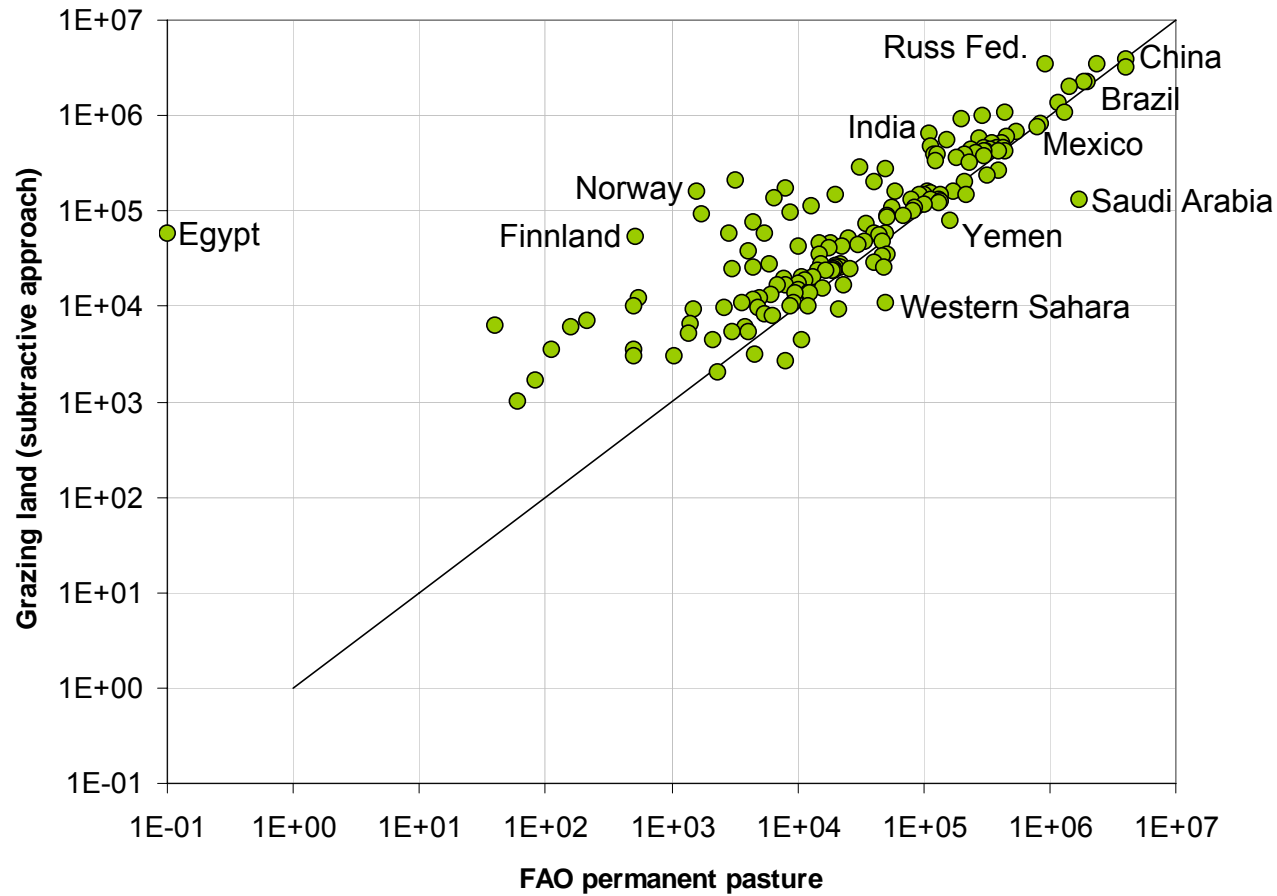


Source: Erb et al. JLUS 2007

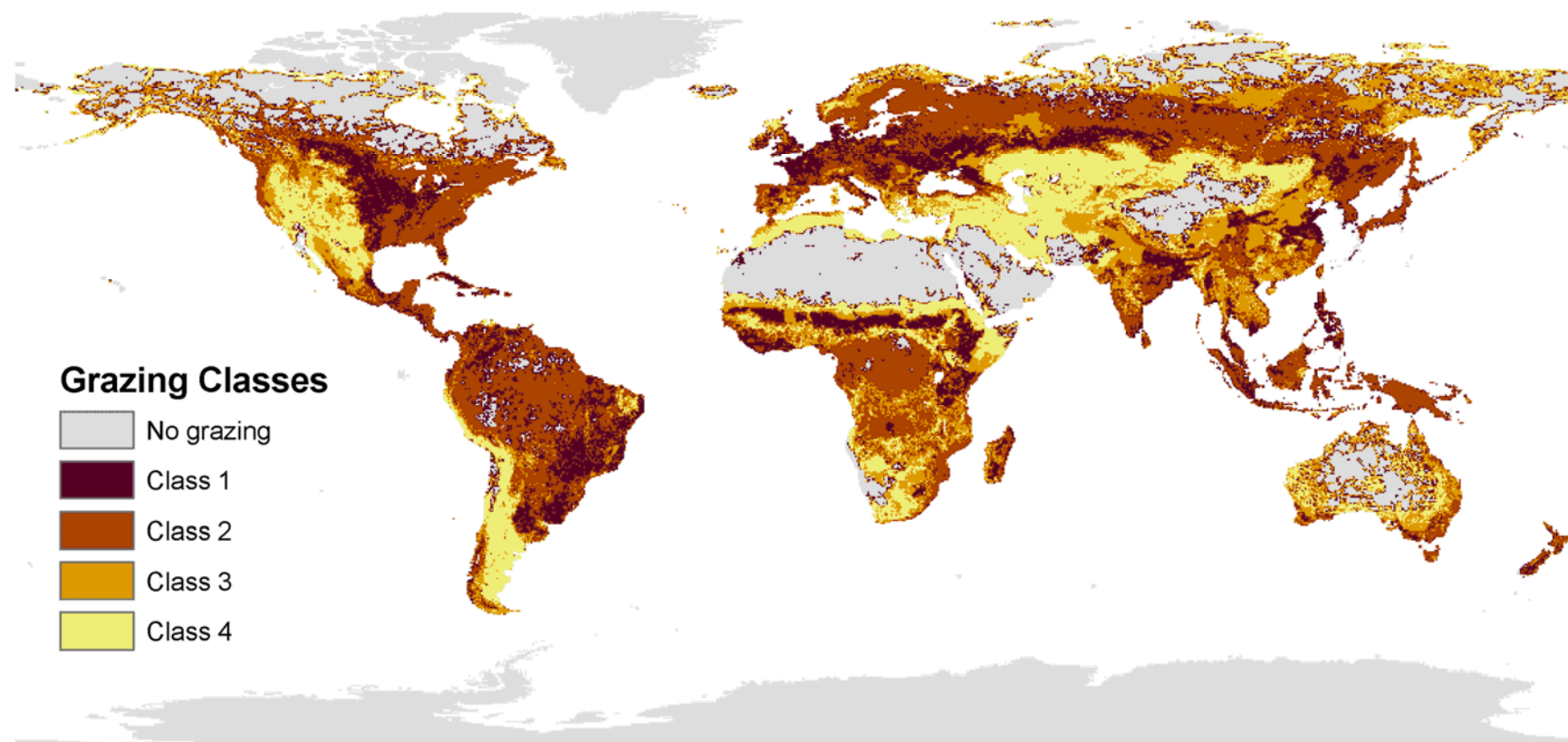
Grazing land



Grazing land

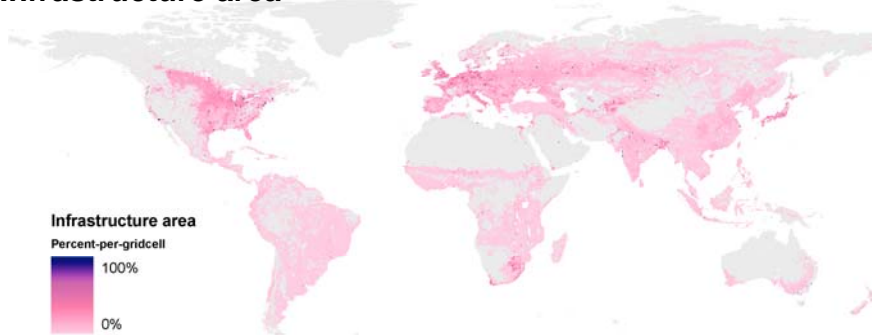


Grazing Land: suitability classes

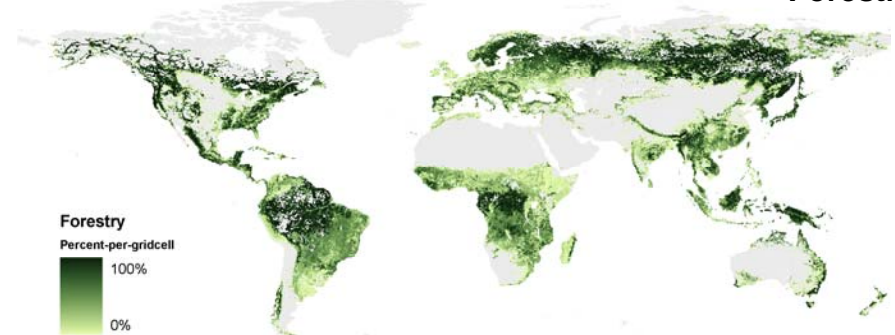


The land use data layers

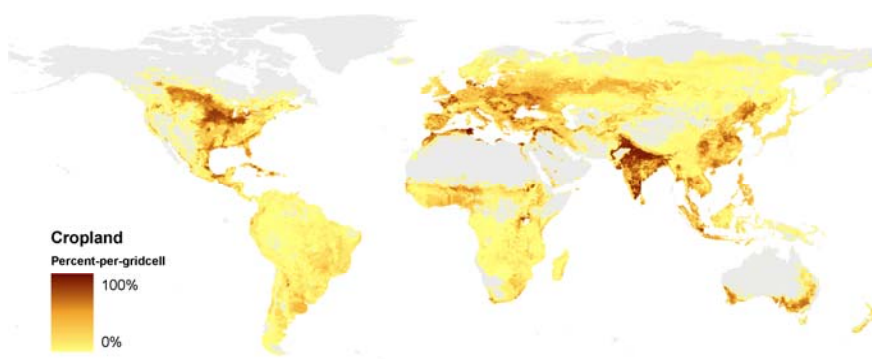
Infrastructure area



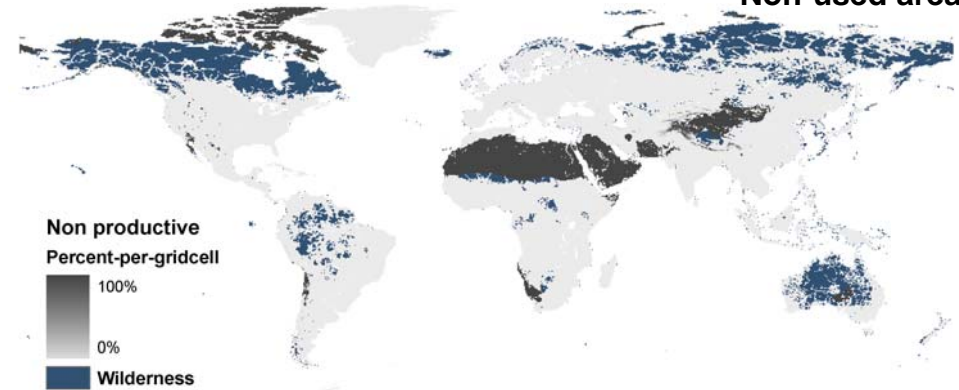
Forestry



Cropland



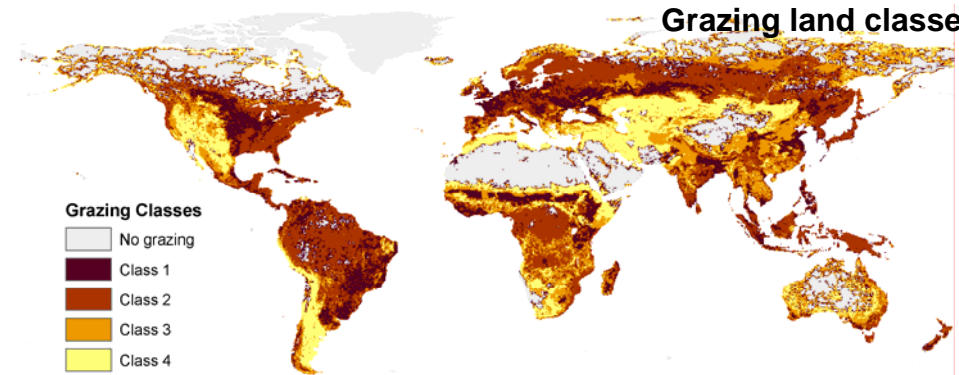
Non-used areas



Grazing land



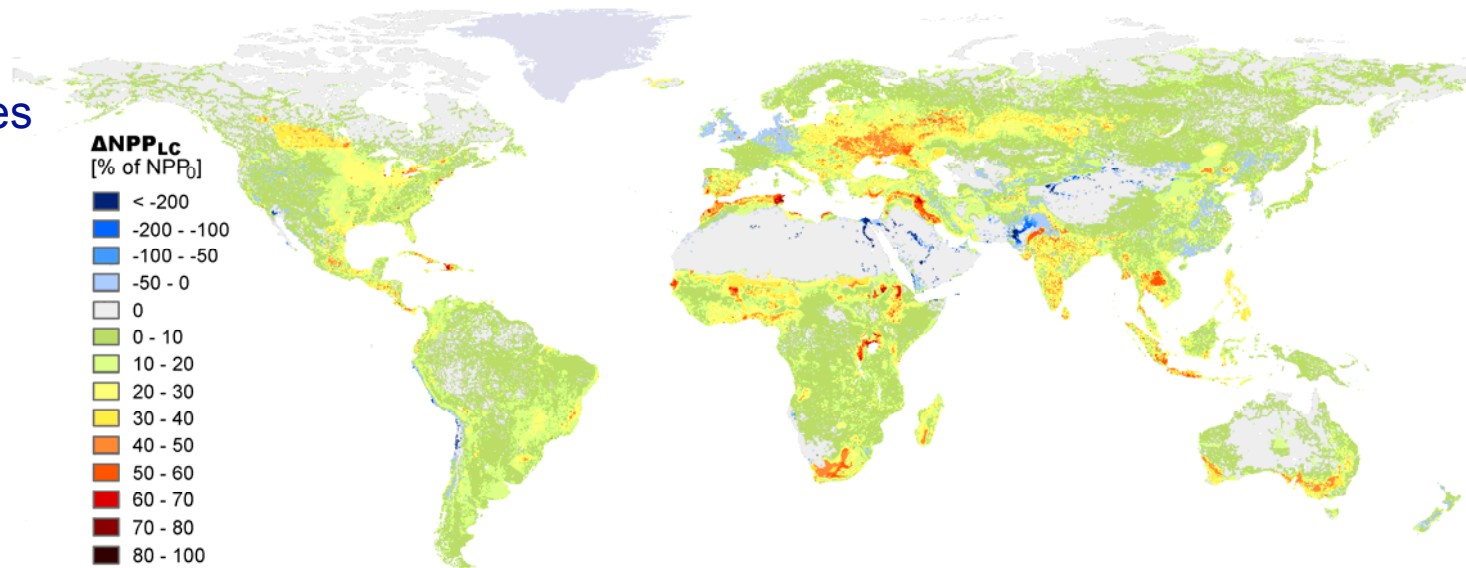
Grazing land classes



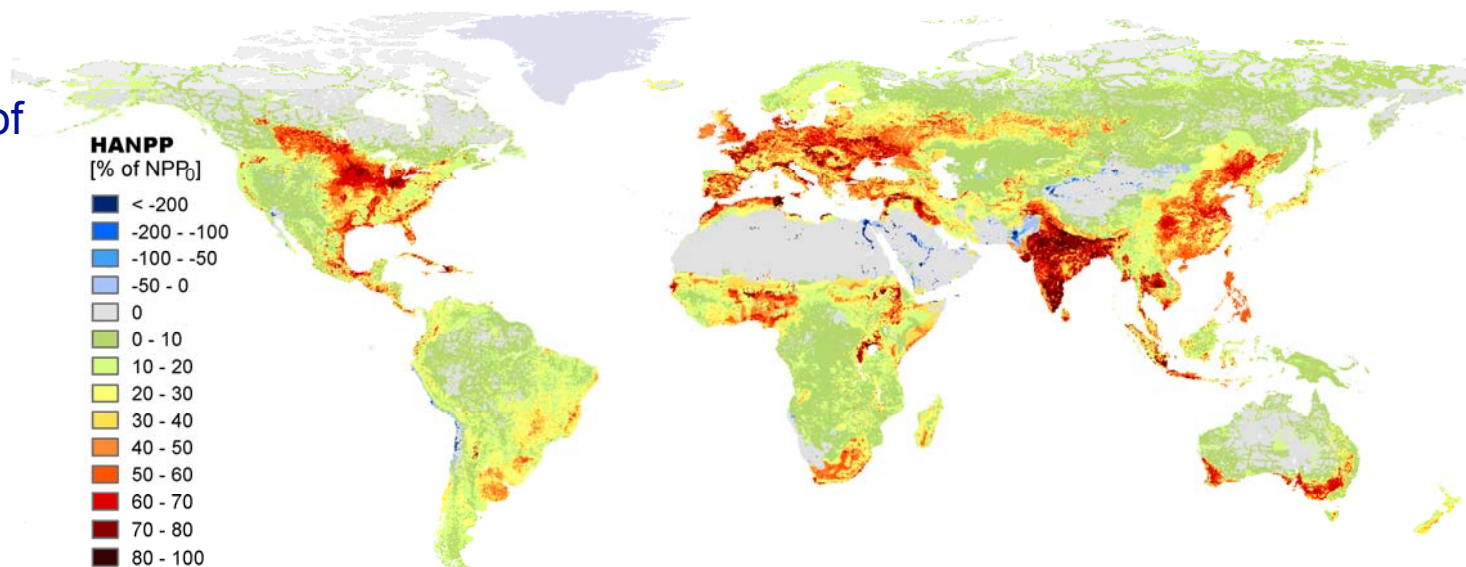
Dataset available at: <http://www.uni-klu.ac.at/socec>

Result: Global HANPP 2000

$\Delta NPP_{LC}\%$:
Productivity changes
due to land
conversions
<< 10% >>

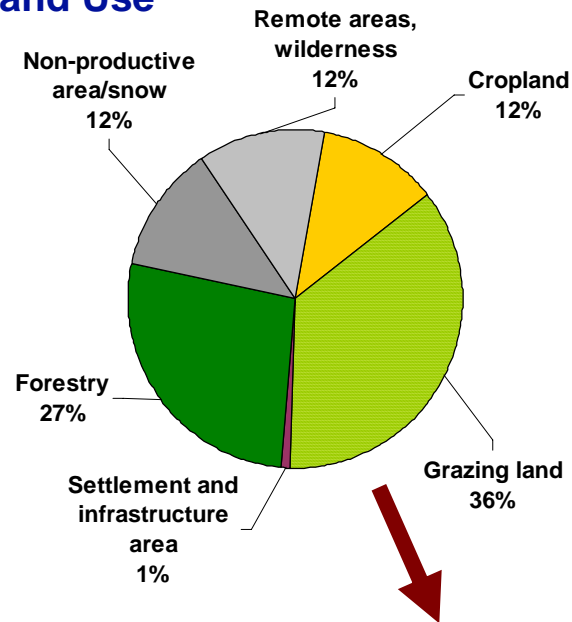


HANPP%:
Aggregated effect of
land use and
harvest
<< 24% >>

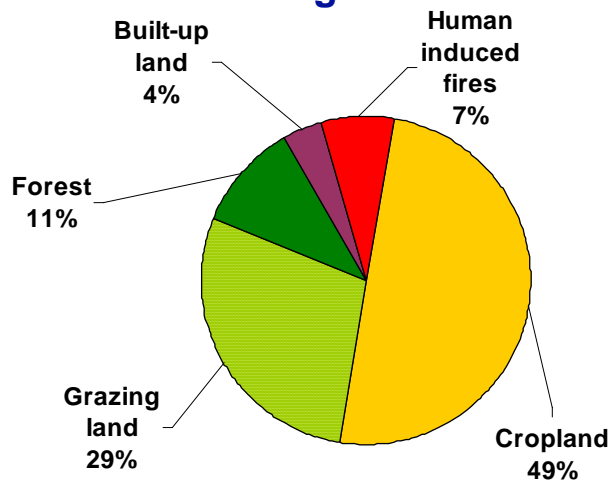


Result: Global HANPP 2000

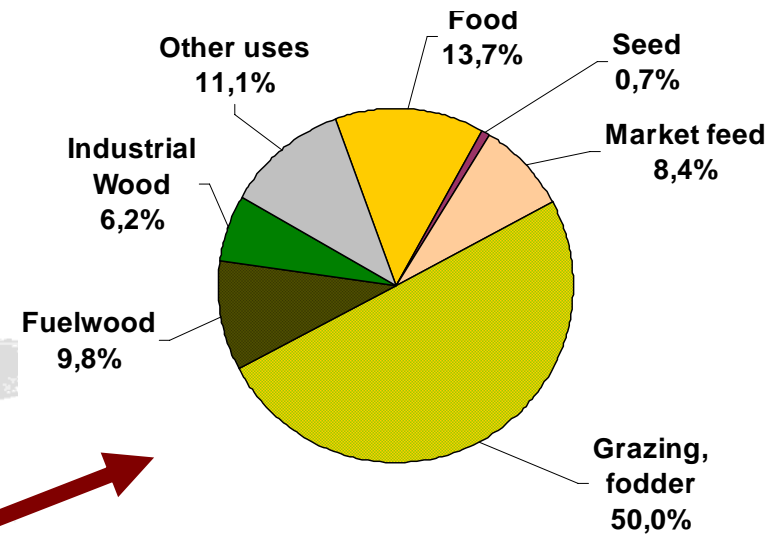
Land Use



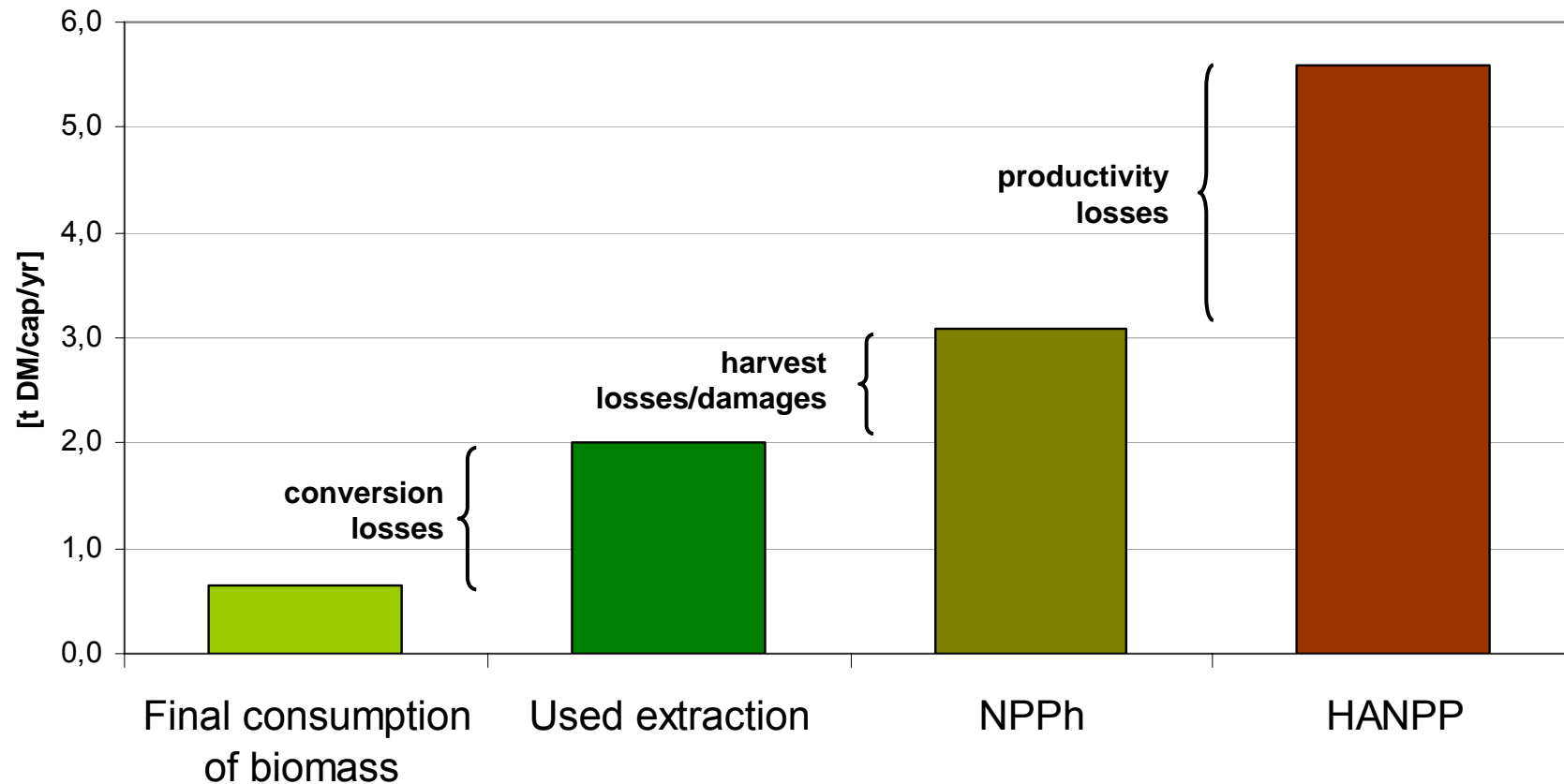
Activities contributing to HANPP



Use of harvested biomass



Material Flow Consistency

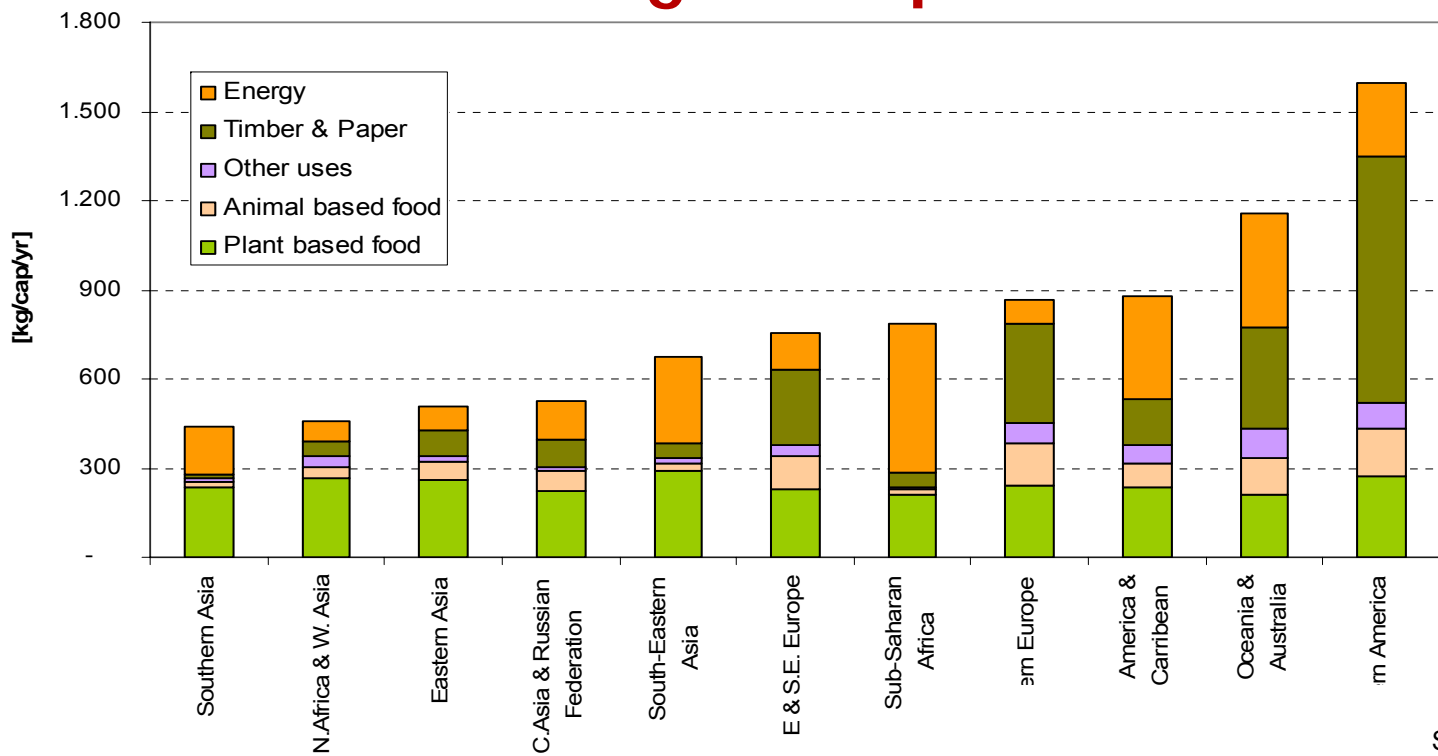


Social System

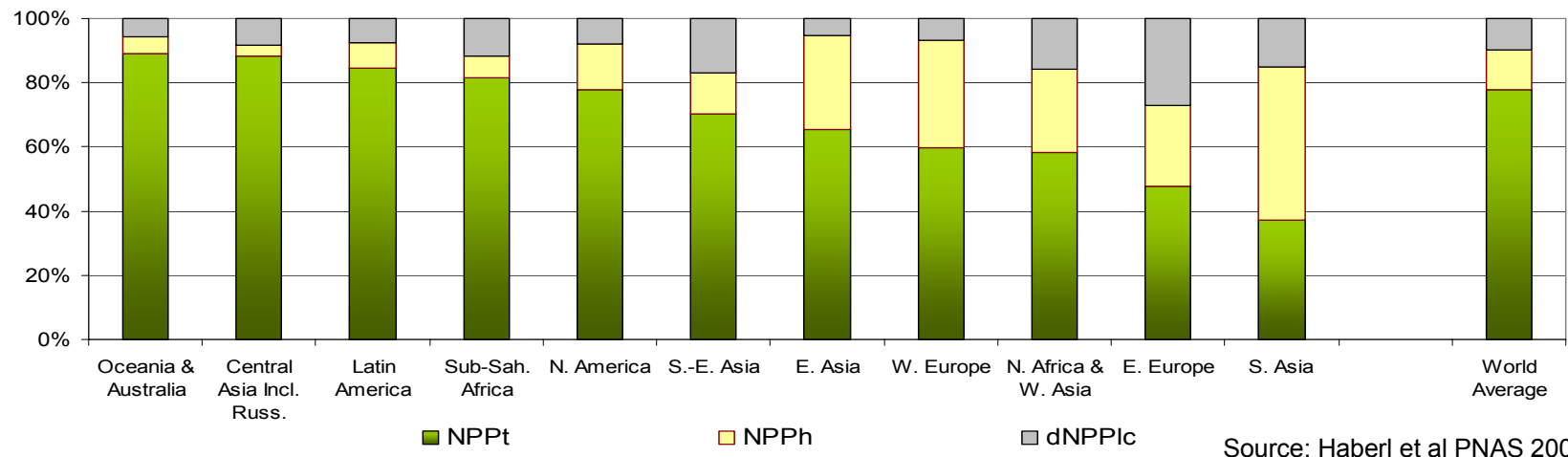


Ecosystem

Biomass flows - global patterns



Source: Krausmann et al. EE 2008

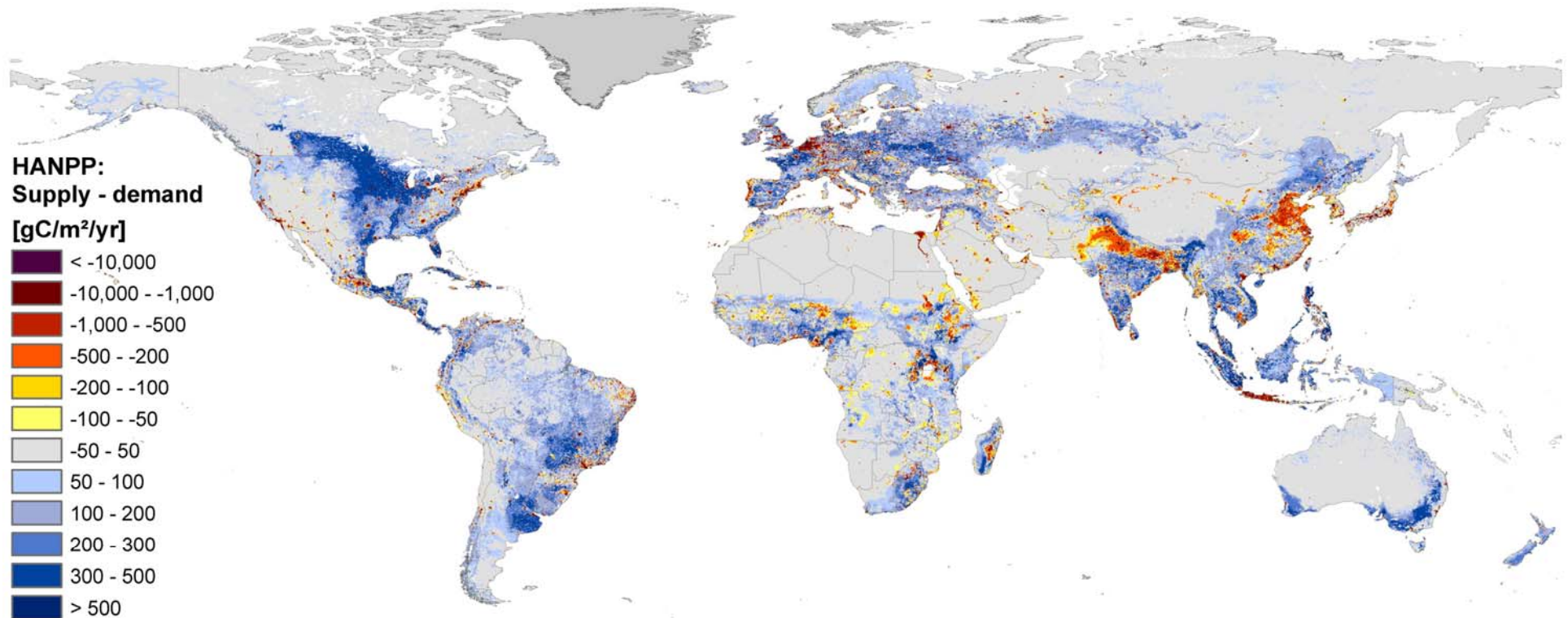


Source: Haberl et al PNAS 2007



Challenge: Spatial aspects

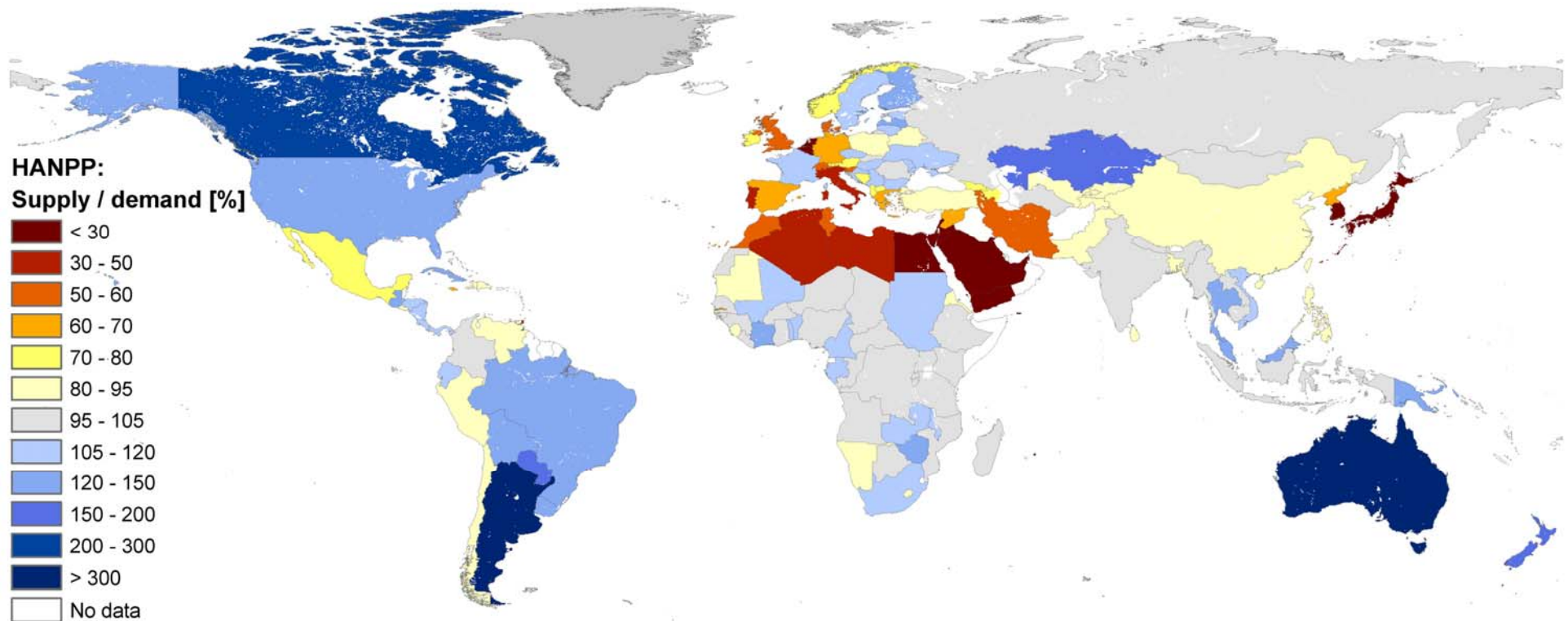
Spatial separation of „Production“ and „Consumtion“



Source: Erb et al. forthcoming

Challenge: Spatial aspects

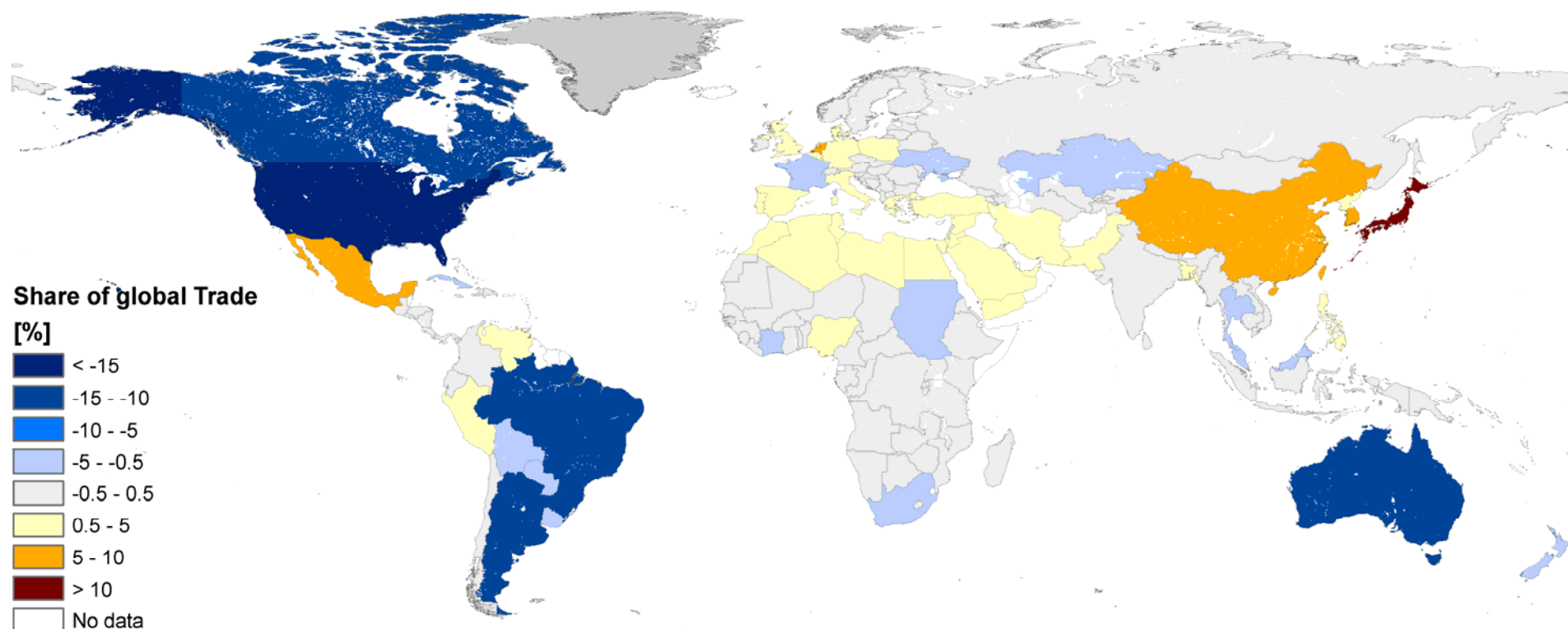
Spatial separation of „Production“ and „Consumption“



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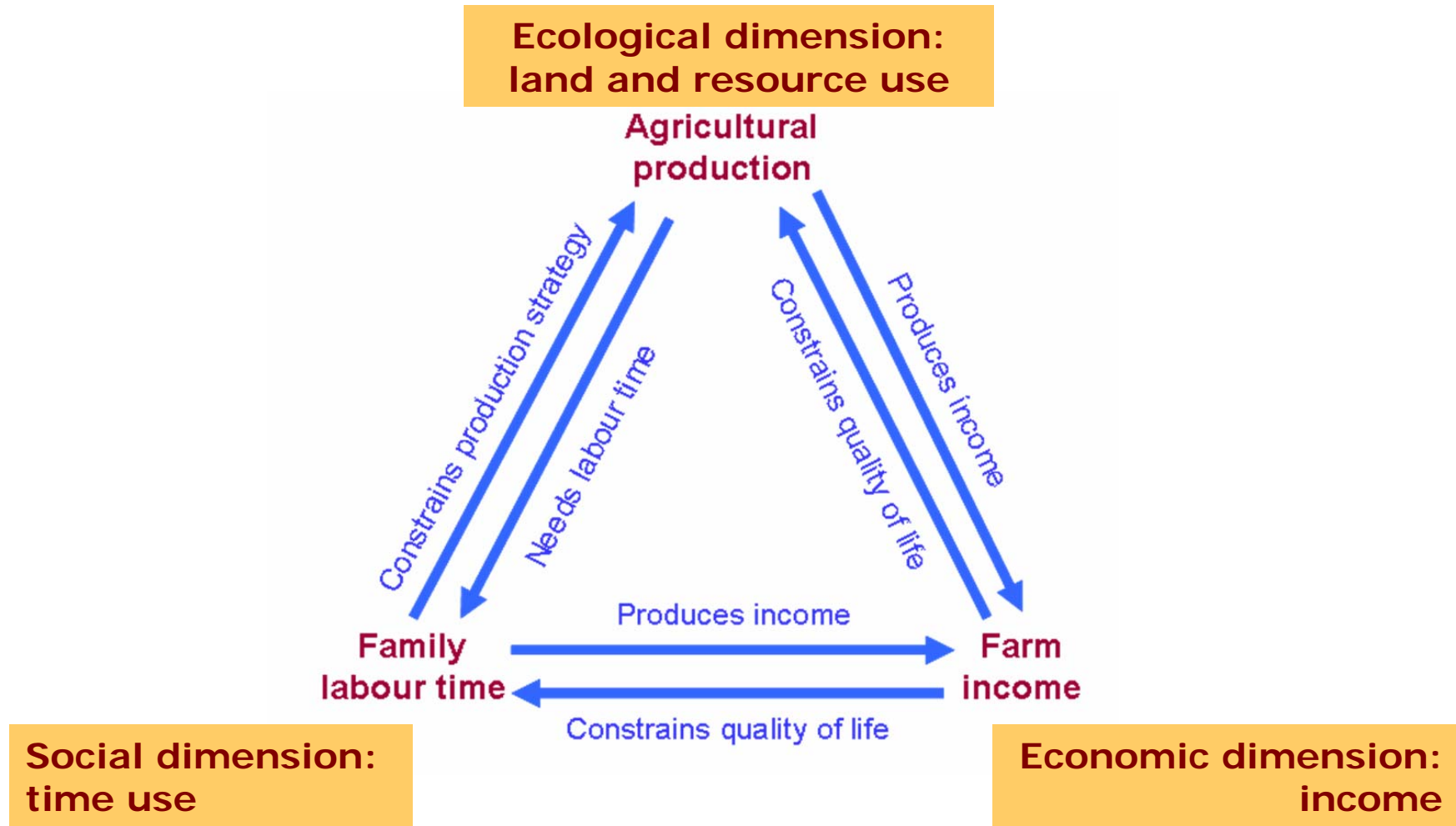
Challenge: Spatial aspects

Spatial separation of „Production“ and „Consumption“

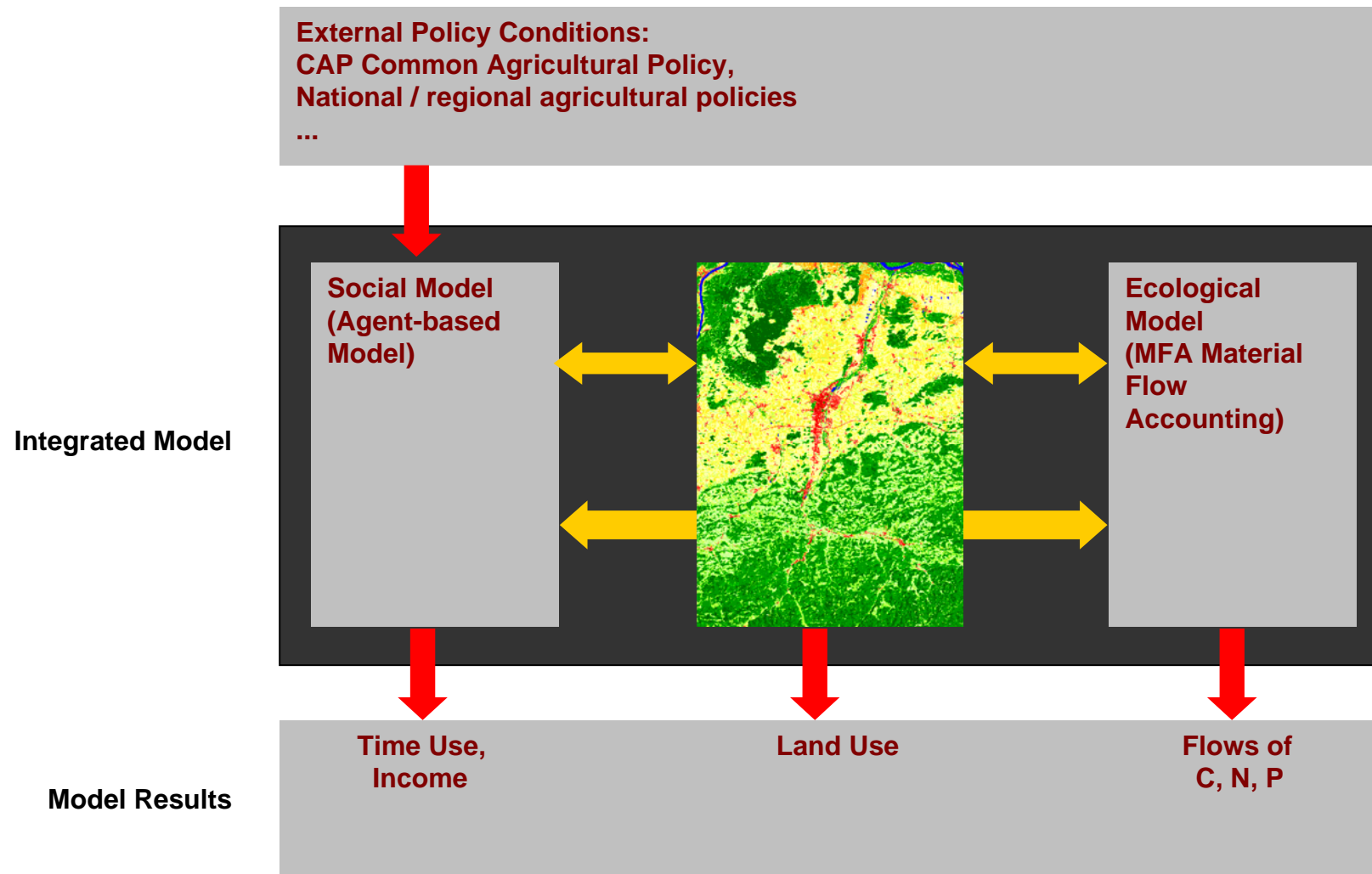


Source: Erb et al. forthcoming

Socioeconomic drivers of land use: Decision-making on the farmstead level

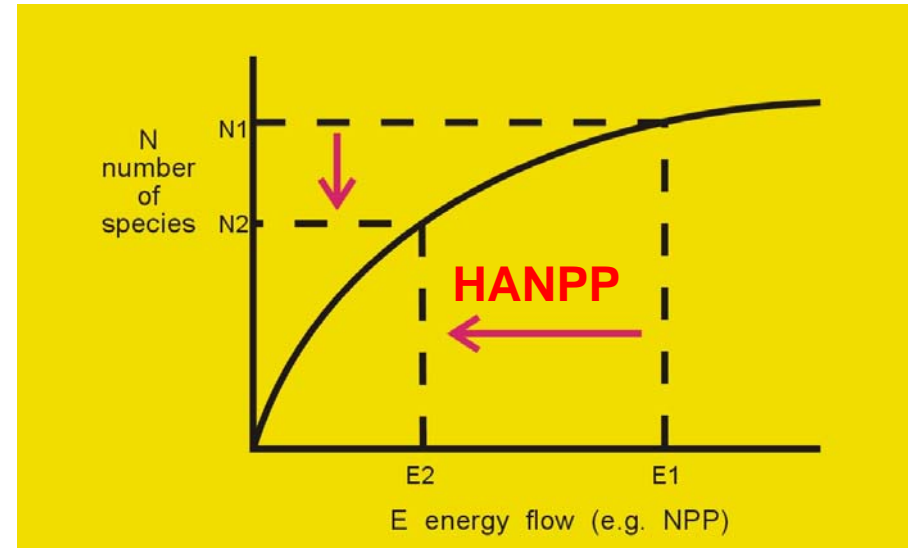


Integration in a conceptual model



Consequences of Land Use: HANPP and biodiversity

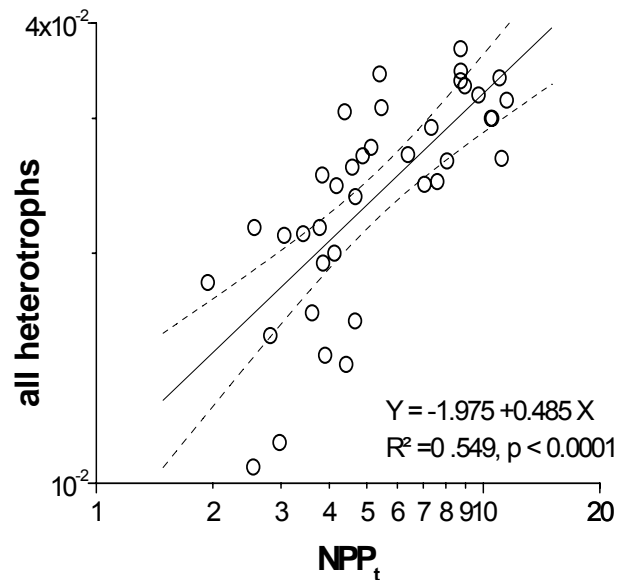
- **Basic claim:** The number of species is positively related to the flow of energy in an ecosystem.
- **Corollary:** If humans reduce energy flow (e.g., through HANPP), then species richness will decline.
- **Why is it relevant:** pressure indicator, unambiguously related to human activities. causal chain: drivers-pressures-states-impacts
- **Notes**
 - Can explain species diversity gradient from equator to poles.
 - Not undisputed. Competing (complementary) hypotheses exist (e.g., intermediate disturbance hypothesis).



- Brown, J.H. (1981) *Am. Zool.* **21**, 877-888.
Gaston, K.L. (2000) *Nature* **405**, 220-227.
Hutchinson, G.E. (1959) *Am. Nat.* **93**, 145-159.
Rapson, G.L. et al. (1997) *J. Ecol.* **85**, 99-100.
Waide, R.B. et al. (1999) *Ann. Rev. Ecol. Syst.* **30**, 257-300.
Wright, D.H. (1983) *Oikos* **41**, 495-506.
Wright, D.H. (1990) *Ambio* **19**, 189-194.

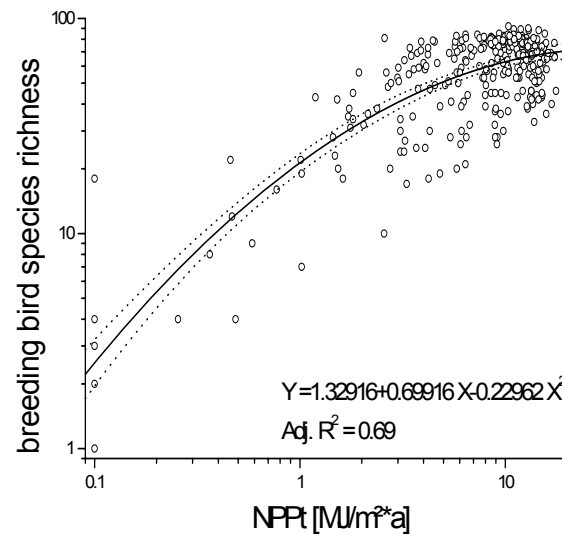
Consequences of land use: Biodiversity

Species richness is well correlated with NPP_t - indirect support for HANPP/biodiversity hypothesis



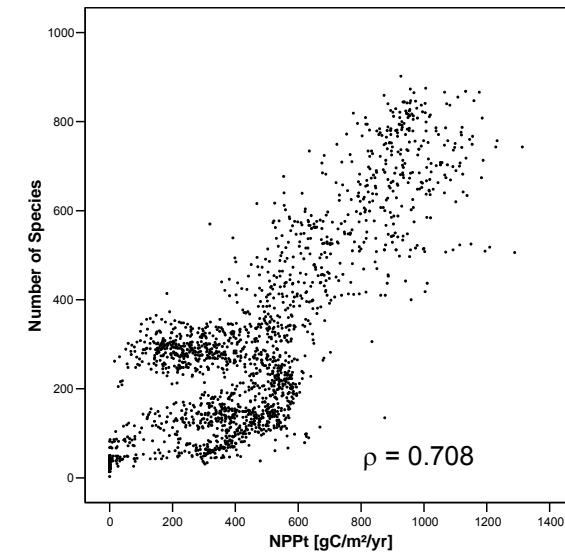
Case study 1: Correlation between NPP_t and autotroph species richness (5 taxa) on 38 plots sized 600x600 m, East Austria

Haberl et al., 2004, *Agric., Ecosyst. & Envir.* 102, p213ff



Case study 2: Correlation between NPP_t and breeding bird richness in Austria, 328 randomly chosen 1x1 km squares.

Haberl et al., 2005. *Agric., Ecosyst. & Envir.* 110, p119ff



Case study 3: Correlation between NPP_t and vertebrate richness in the Americas, 10,000 randomly chosen 5min gridcells

Haberl et al., forthcoming

Challenges

- Future biomass demand-supply: Options/potentials for sustainable biomass utilization are limited – requires integrated perspectives
- Spatial segregation between appropriation and consumption: Issues of scale, governance: drivers as well as consequences of land use are global. Important for the construction of causal chains
- Link land use – land cover is complex: local studies needed, no easy look-up table; in particular: longitudinal research
- Census statistics: definition, harmonization, extensions, etc...
- Data gaps: **Forestry** (used vs. unused forests), **grazing** (intensity, spatial pattern of grazing, biomass harvest through grazing; effects of grazing), **Soil/vegetation degradation** (where? how much? effects on NPP?), **Multifunctional land use** (how to operationalize?)

Conclusions

- **Purpose** determines data collection
 - in this case: analysing drivers, trajectories and consequences of land use
 - socioeconomic drivers and determinants in agriculture, food, and energy systems, distinction from natural drivers (e.g. climate change)
 - ecosystem services/functioning, interrelations with N-cycle, water cycle, etc.
- Data referring to the **interaction** of social and ecosystems are especially important
 - unambiguously linkable to socio-economic activities AND linkable to impacts: construction of causal chains
 - Land USE data are needed (land cover data is important, but something different)
- Basic requirement for data integration: **CONSISTENCY**
 - Prioritizing: correspondence of (national) land use census statistics and the (national) spatial extent more important than the accuracy of spatial information
 - caveat: census statistics may be flawed – how to overcome?
- Precondition: a systematic conceptual framework

The End

Thank you for your attention!

Further information/maps/data:
<http://www.uni-klu.ac.at/socec/>

