Land Use, Biomass, Climate

A global perspective

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Biomasse Kaleidoskop, ÖAW, 9.Nov.2018

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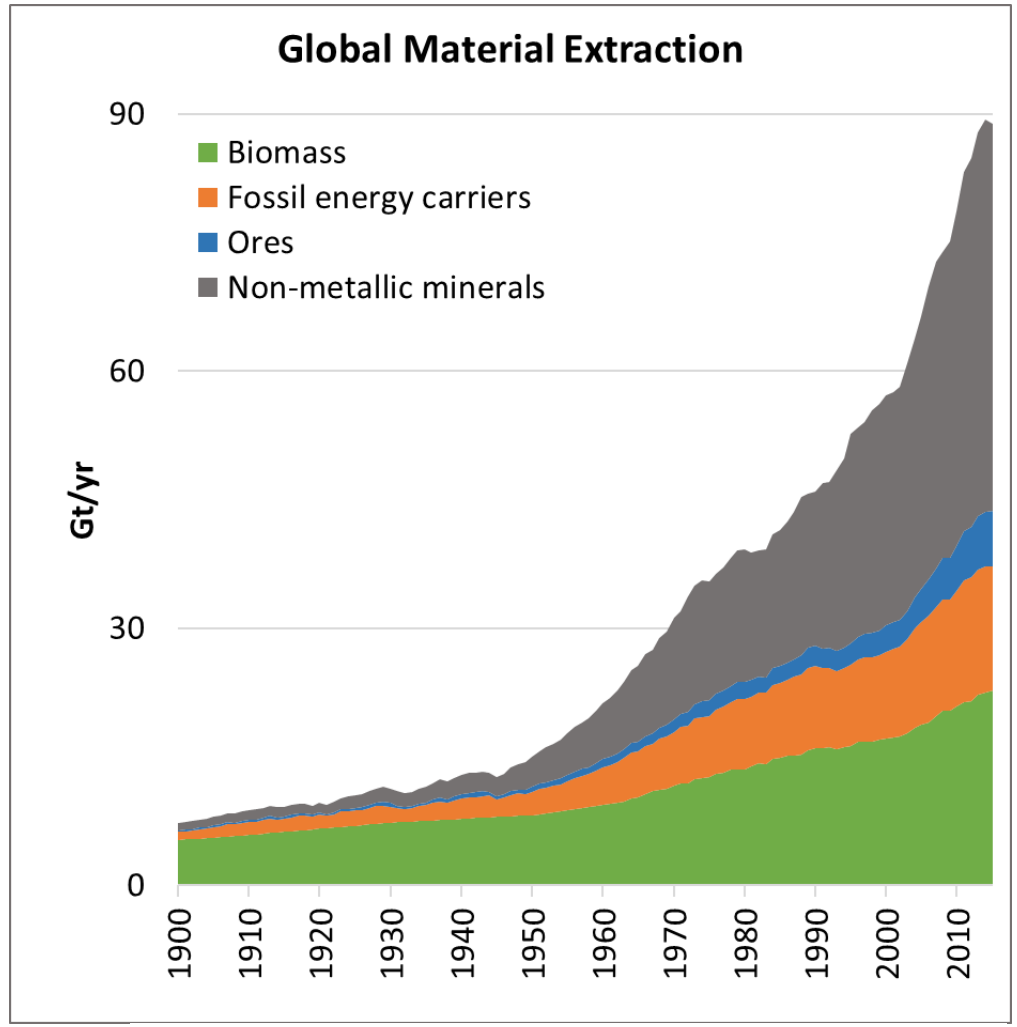
Biomass, a Key Socioeconomic Resource

- 1900: Biomass accounts for 72% of total global resource extraction
- 2010: 26% of resource extraction
- Increase in biomass extraction: factor 4.3
- Total extraction: increase factor 12 (fossil energy: 15, ores: 42, non-metallic minerals: 50)

- → no substitution of biomass as a resource
- → Biomass can not be substituted as a resource: food, animal feed

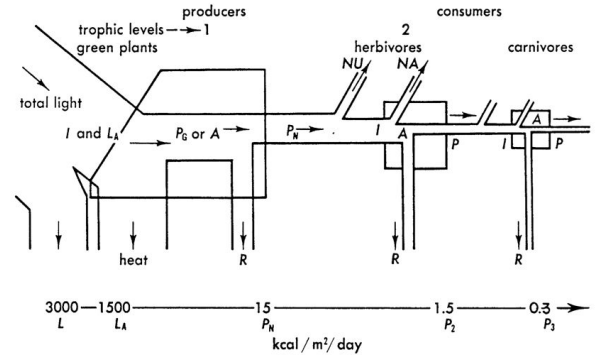


Krausmann et al., 2018 10.1016/j.gloenvcha.2018.07.003

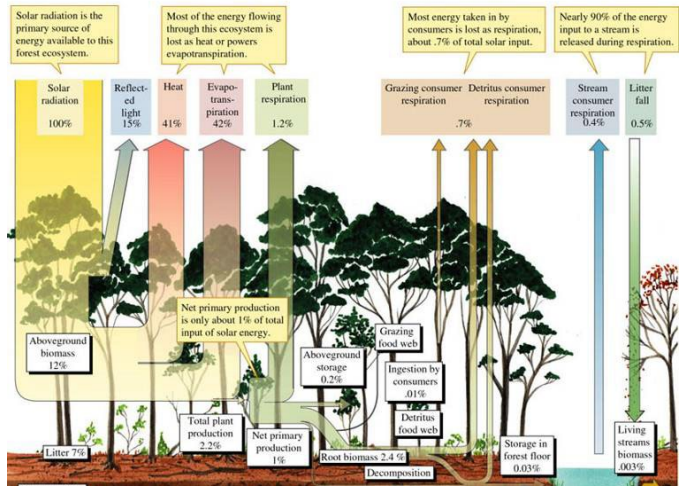
Biomass, a Key Ecological Resource

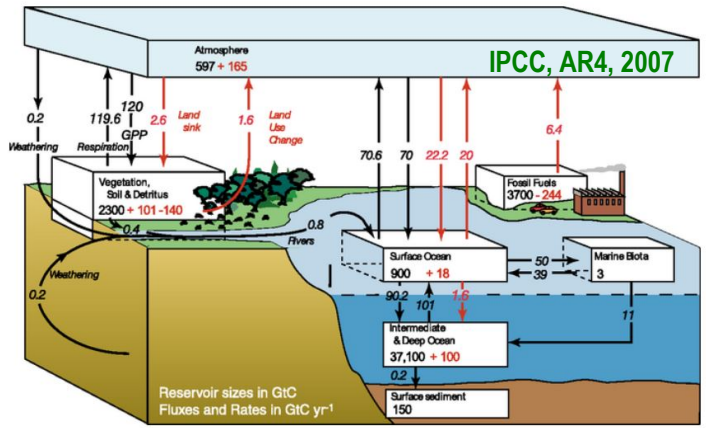
Biomasse is a key ecosystem component.

- It is directly related to the flow of energy, the "ecological currency" of ecosystems [Lindemann, Lotka, Odum, and others]
- Net primary production is essential for all heterotrophic species (including humans) → biodiversity
- Accumulated NPP: Standing crop of biomass - structure of ecosystems
- Central interface between biosphere and atmosphere: → Climate system, climate change

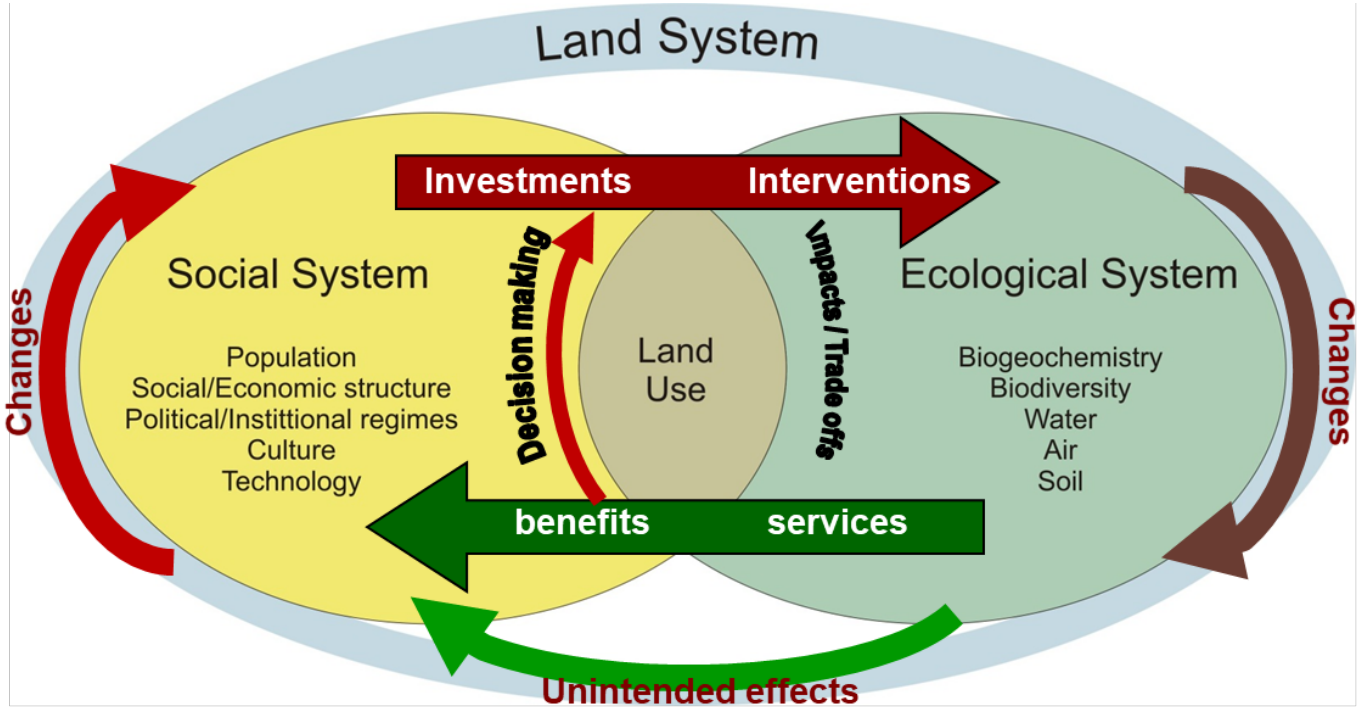


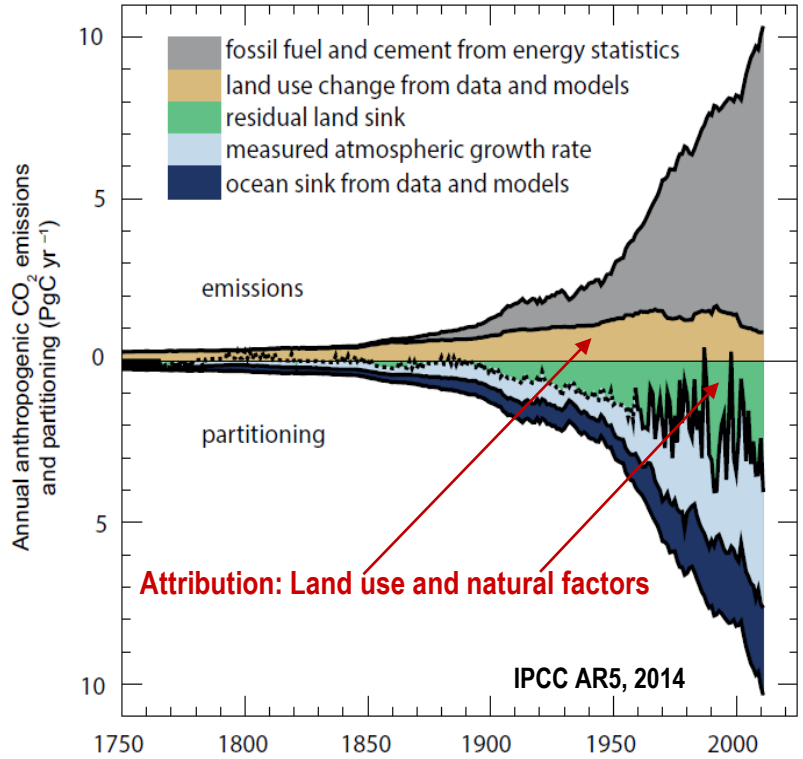
Source: Odum, E.P. (1971)



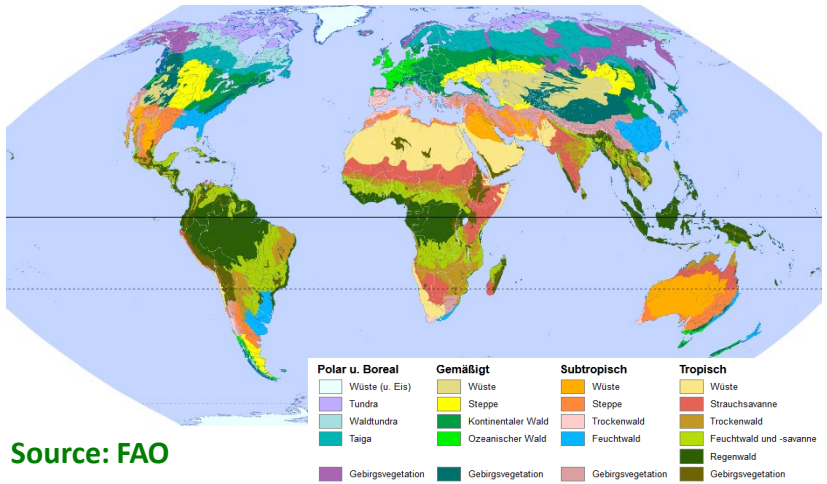


Land, a socio-ecological system



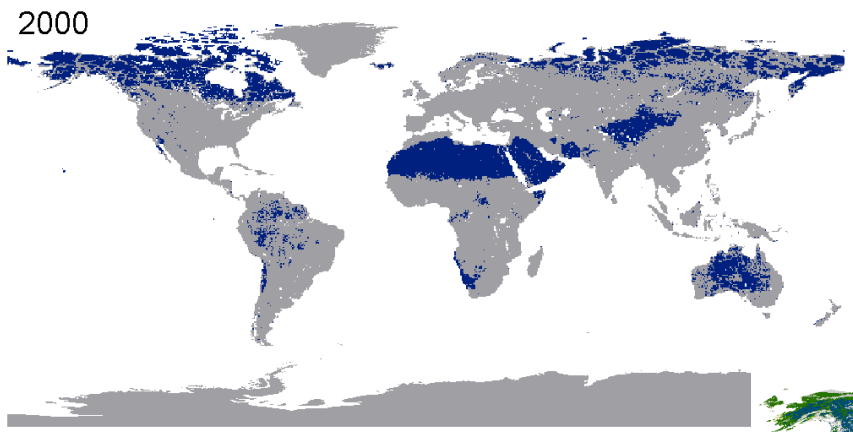


Global land use- from biomes to Anthromes

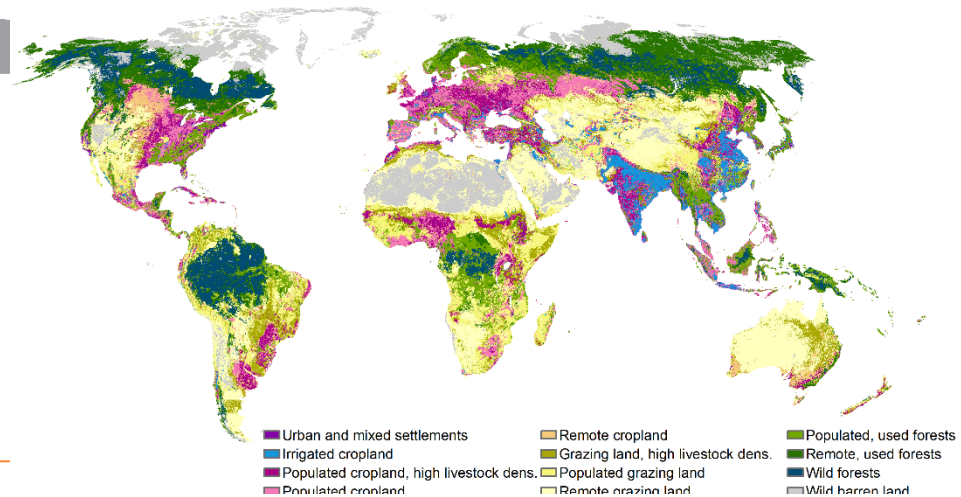


Source: FAO

Biomes



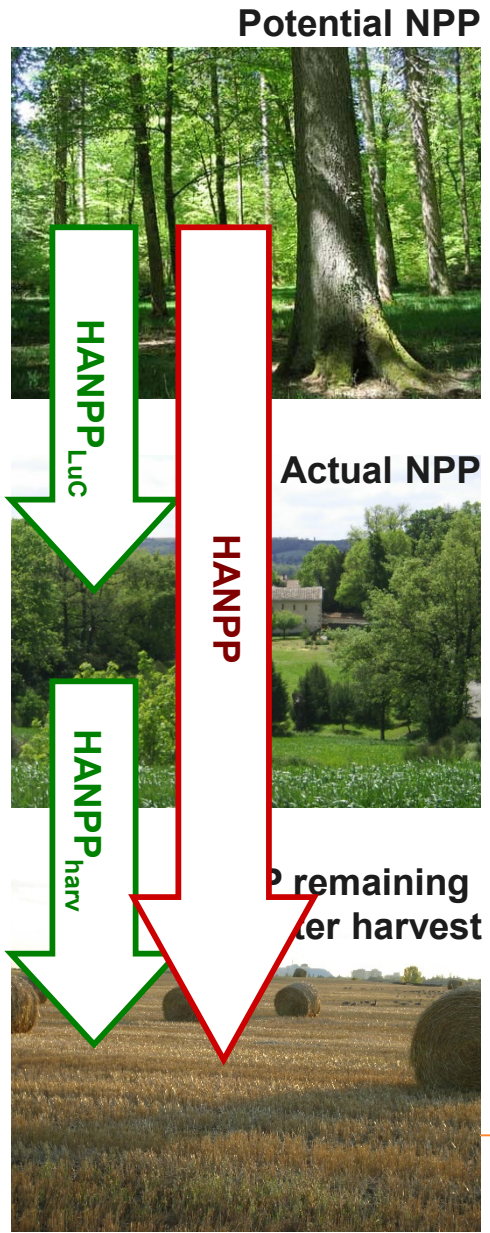
Anthromes

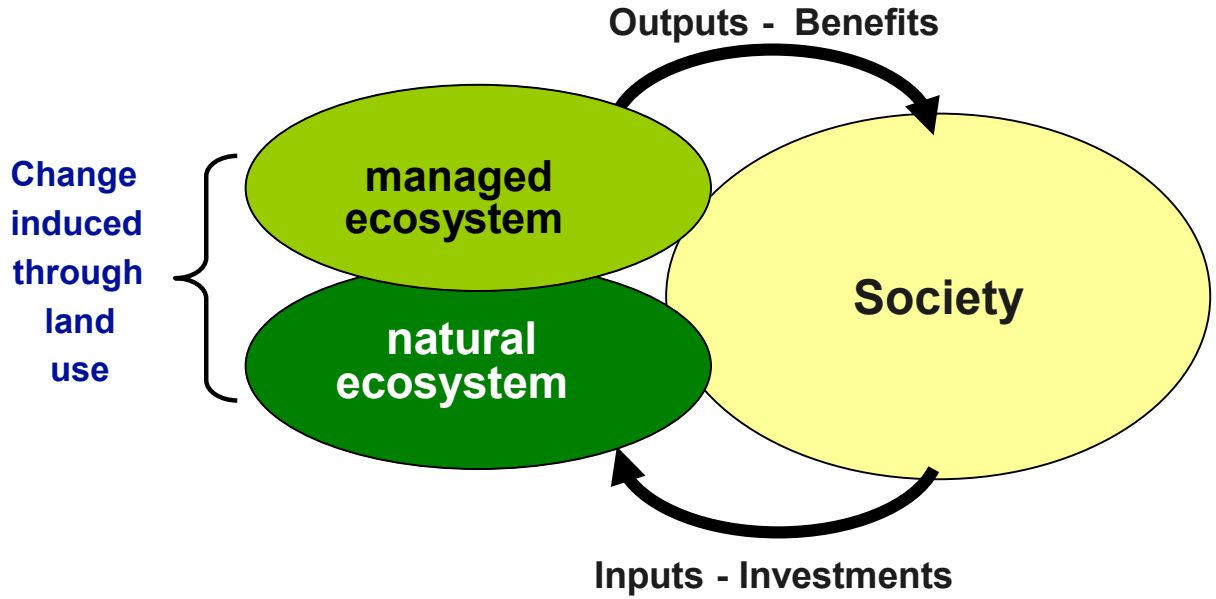


- 3/4 to 4/5 of the ice-free land today are under land use. Large unused areas are only occurring in regions that are:
  - too cold
  - too hot
  - too remote
- Great differences in the intensity of land use

Ellis et al., 2010 10.1111/j.1466-8238.2010.00540.x

HANPP – „human appropriation of net primary production“



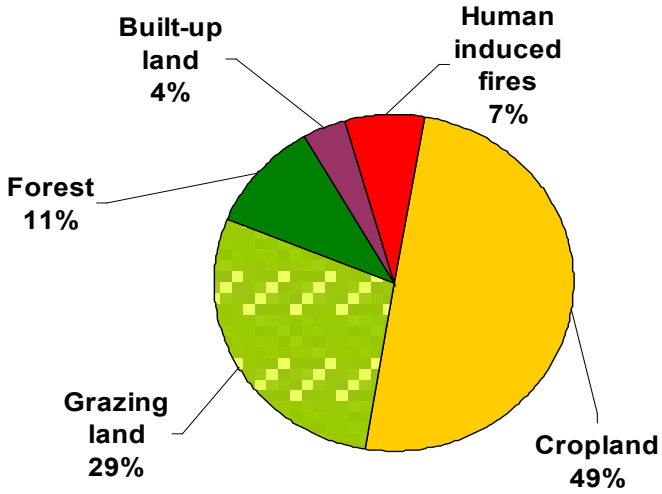


- NPP: net production of plants, Gross primay production minus plant respiration
- HANPP: A metric for the social intervention in ecological energy flows
- The sum of „forgone“ and harvested NPP

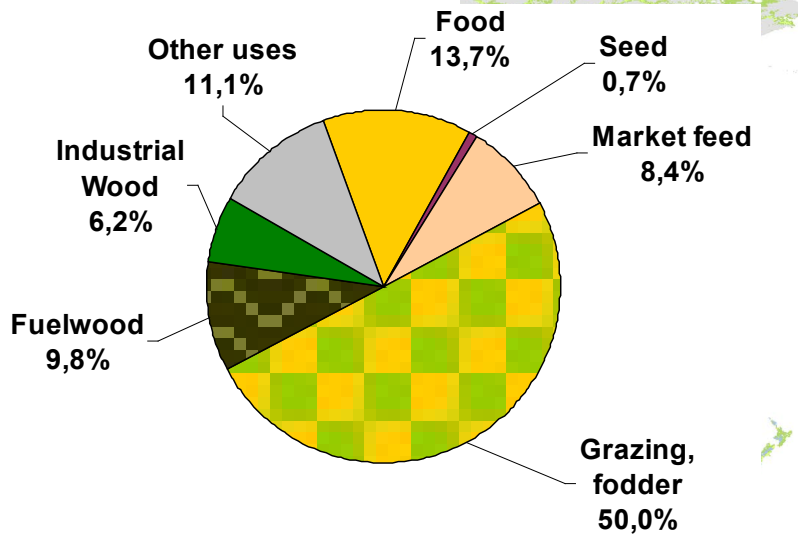
Global Human Appropriation of NPP in 2000

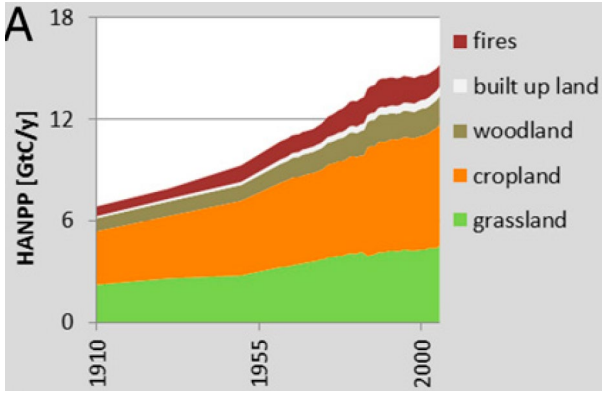
$HANPP_{LUC}$%: Productivity ch due to land coversions << -10% >>

HANPP



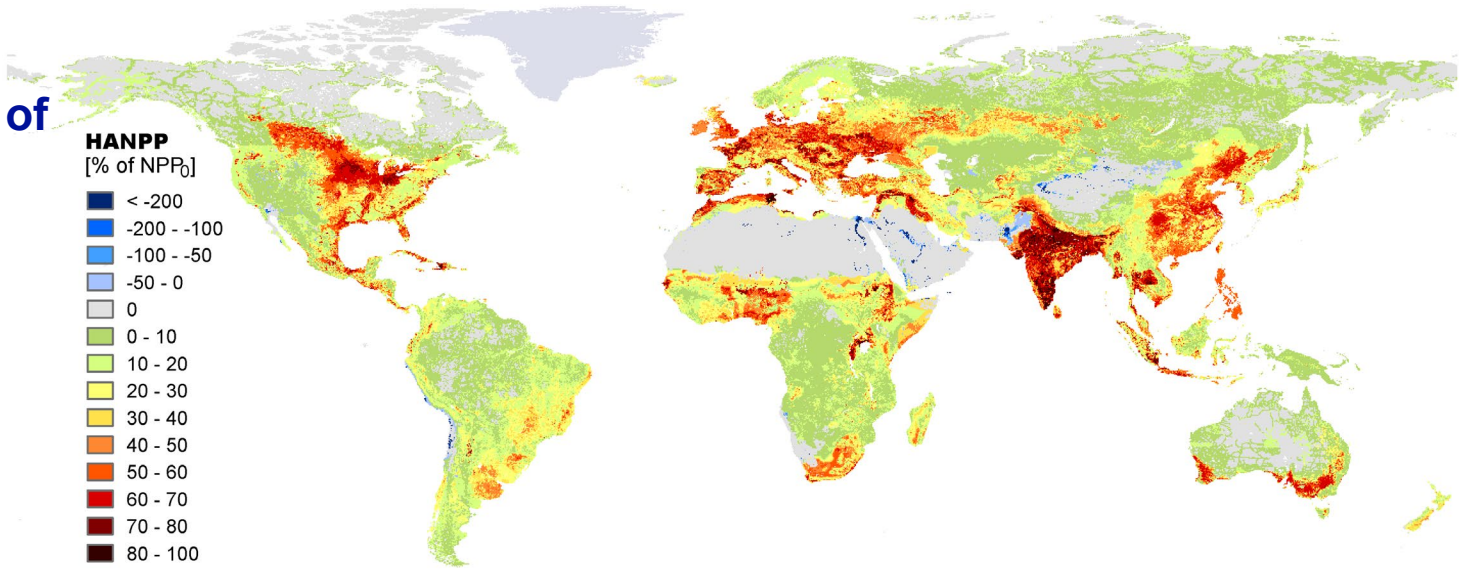
Consumption

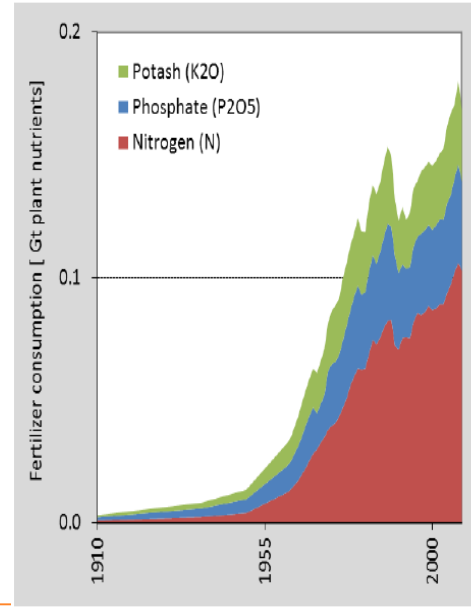




- 1910-2007: 13% → 25% factor 2
- Population: factor 4
- GDP: factor 17

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

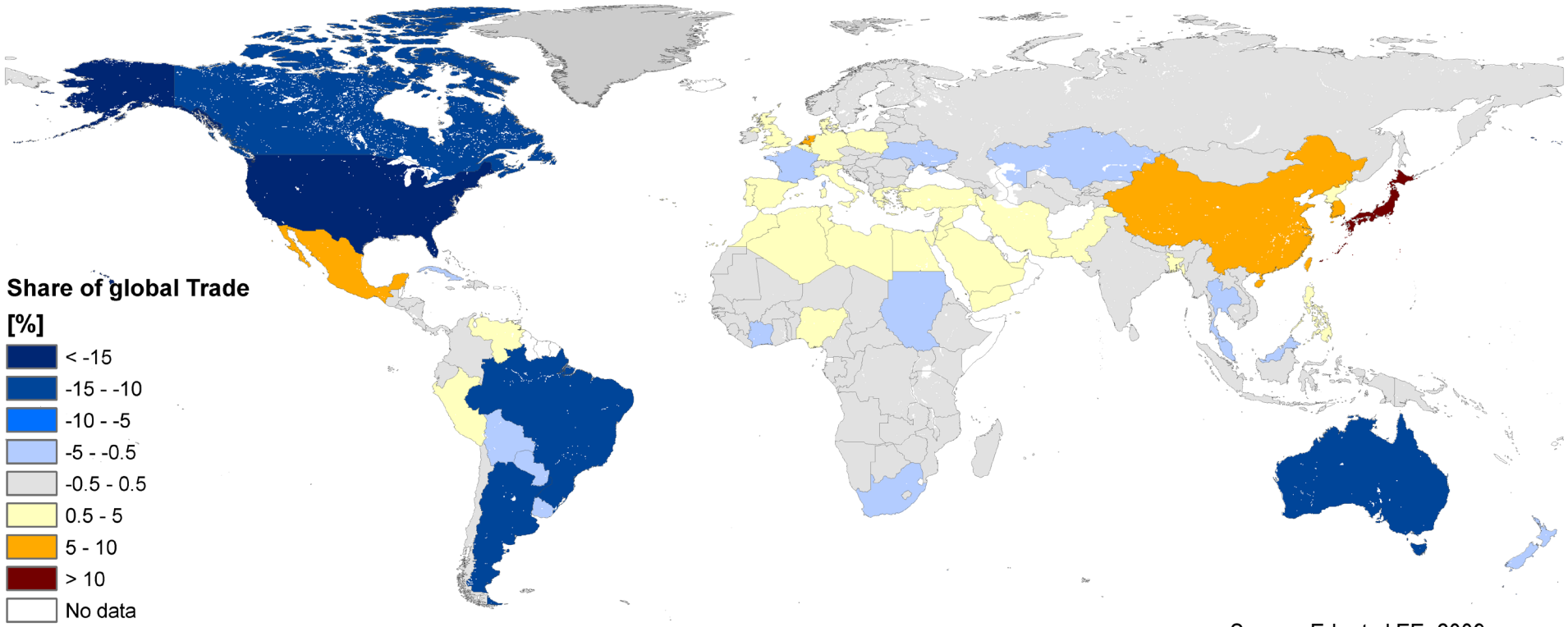




Haberl et al. 2007 10.1073/pnas.0704243104

Krausmann et al. 2011, 10.1073/pnas.1211349110

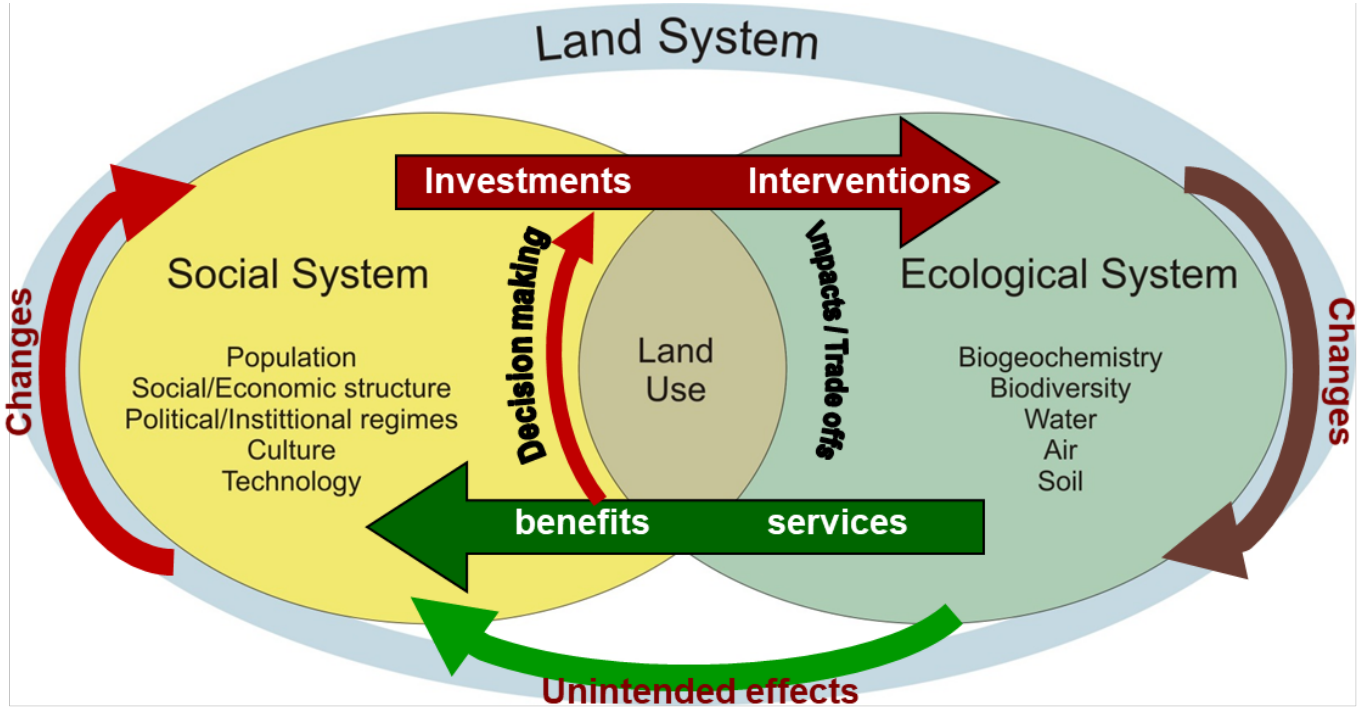
A key challenge: „Spatial disconnect“ between production and consumption

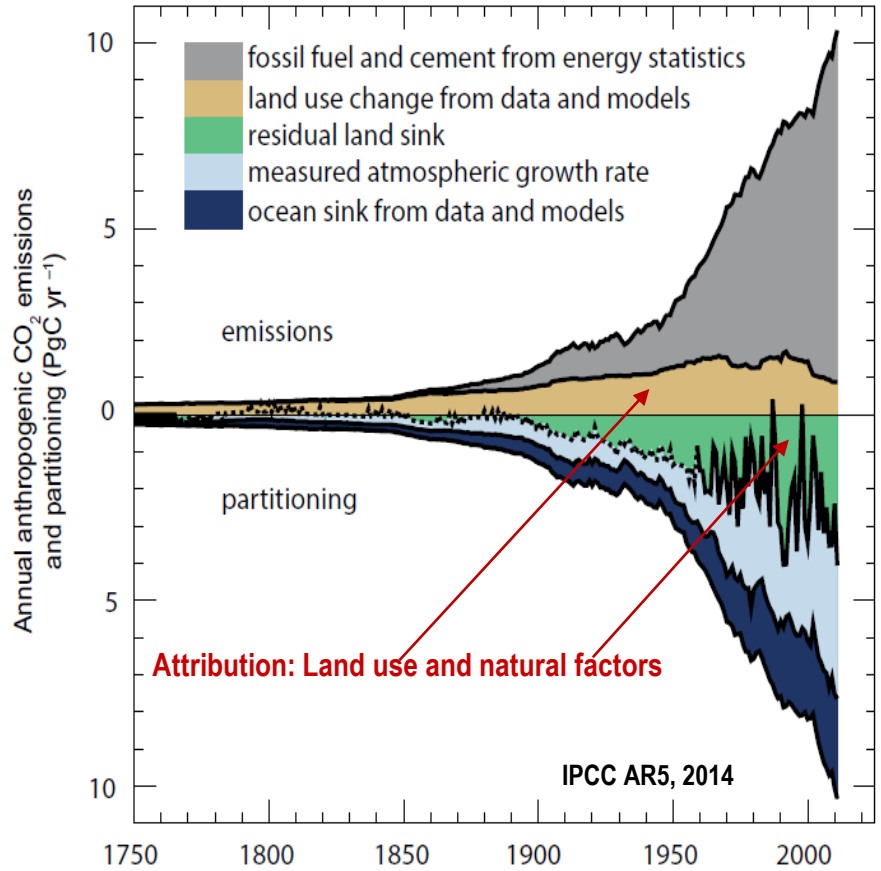


Source: Erb et al,EE 2009

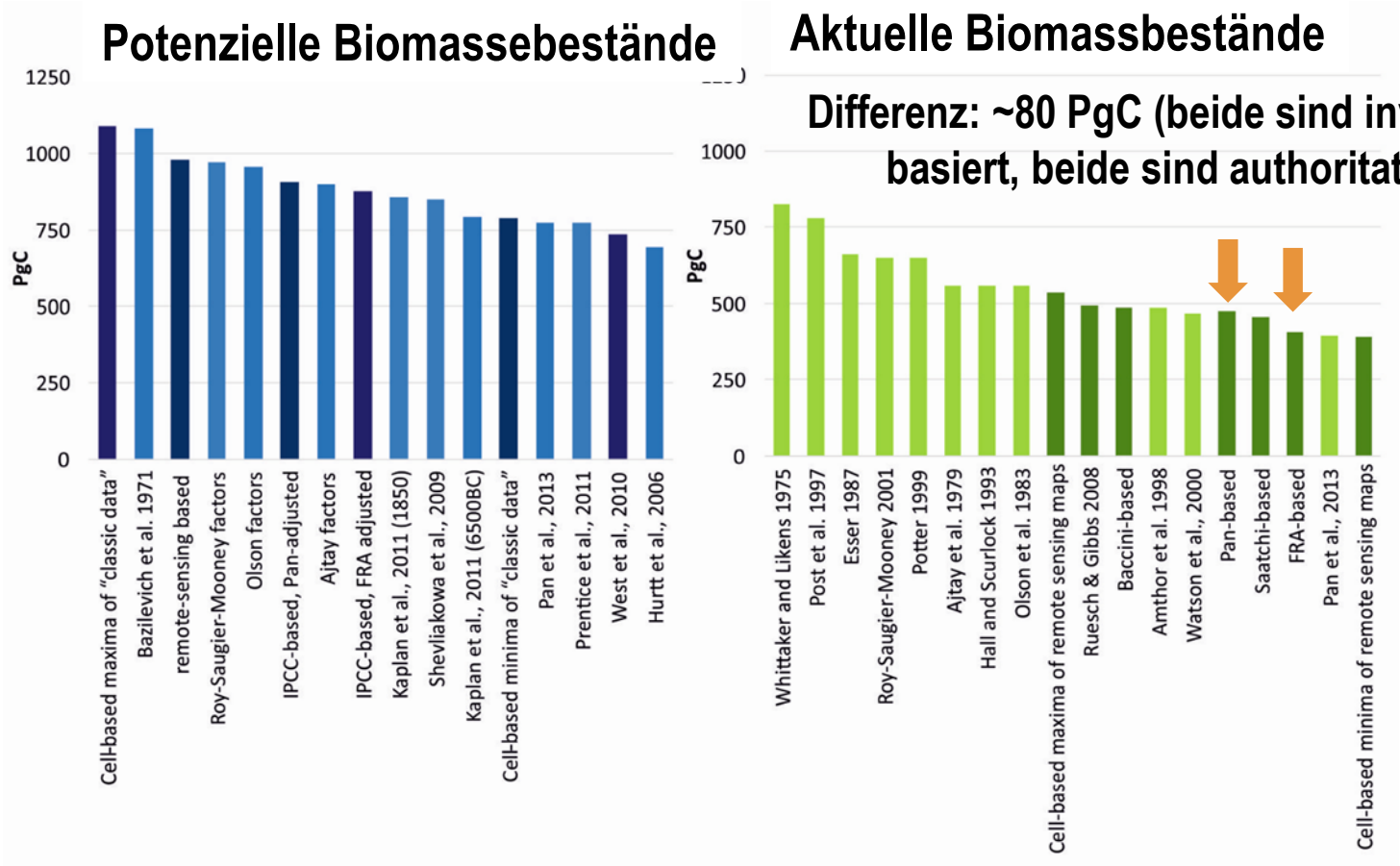
Difference of „production“ and „consumption“ of „embodied HANPP“

Stocks, not flows...





Biomass stocks: massive Uncertainties



Erb et al. 2018, doi:10.1038/nature25138

Seven maps of actual biomass stocks

Based on land-use data, bottom-up

A FRA-based
FRA: Forest Ressource Assessment

B Pan-based
Pan. Y. et al. A Large and Persistent Carbon Sink in the World's Forests. Science 333. 988–993 (2011).

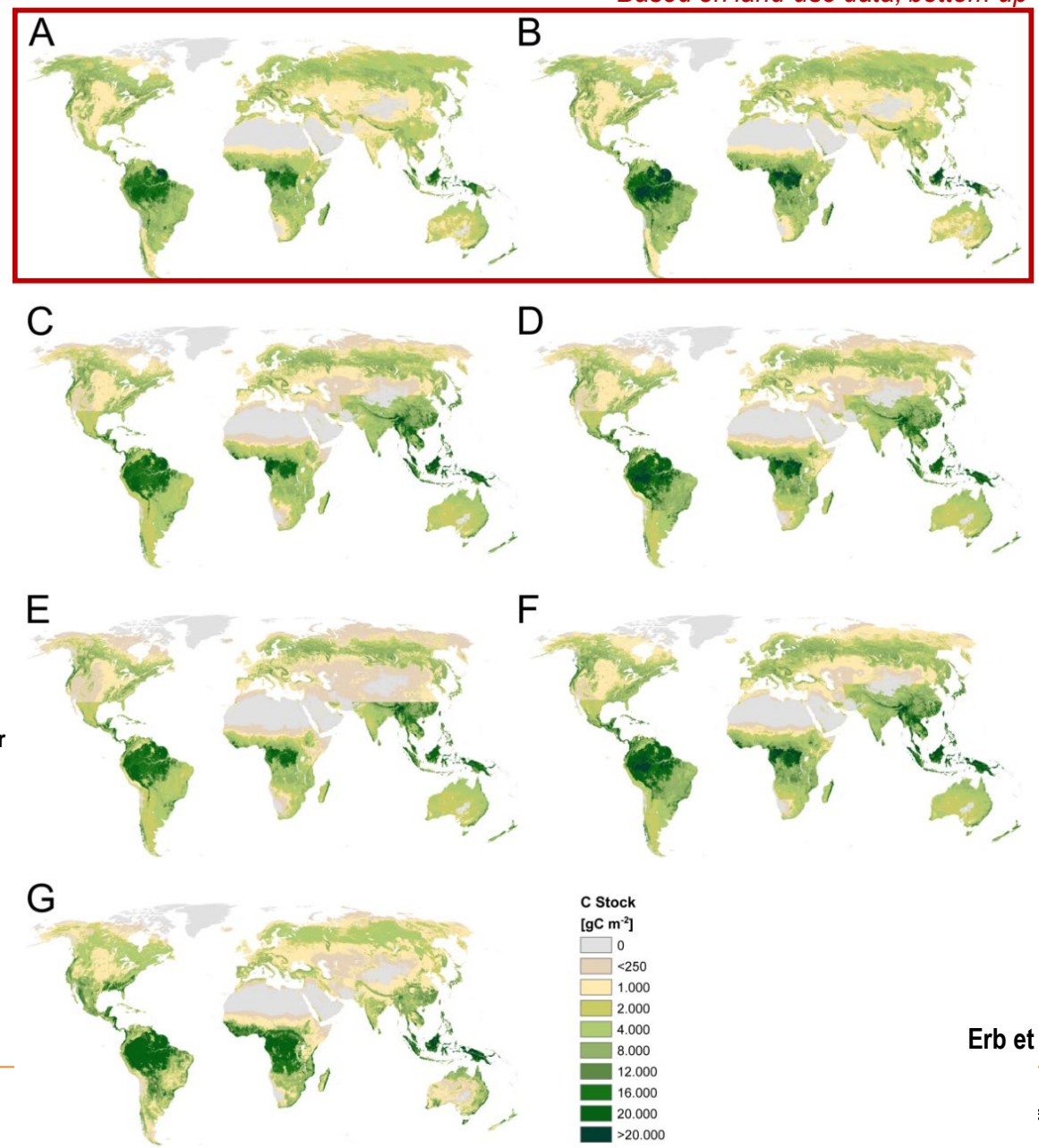
C Saatchi+Thurner-based

D Baccini+Thurner-based

E Cell-based minima

F Cell-based maxima

G Ruesch & Gibbs
Ruesch. A. & Gibbs. H. K. New IPCC Tier-1 global biomass carbon map for the year 2000. (2008)



Erb et al. 2018, doi:10.1038/nature25138

Six maps of potential biomass stocks

Based on land-use data, bottom-up

A IPCC-based. FRA-adjusted

B IPCC-based. PAN-adjusted

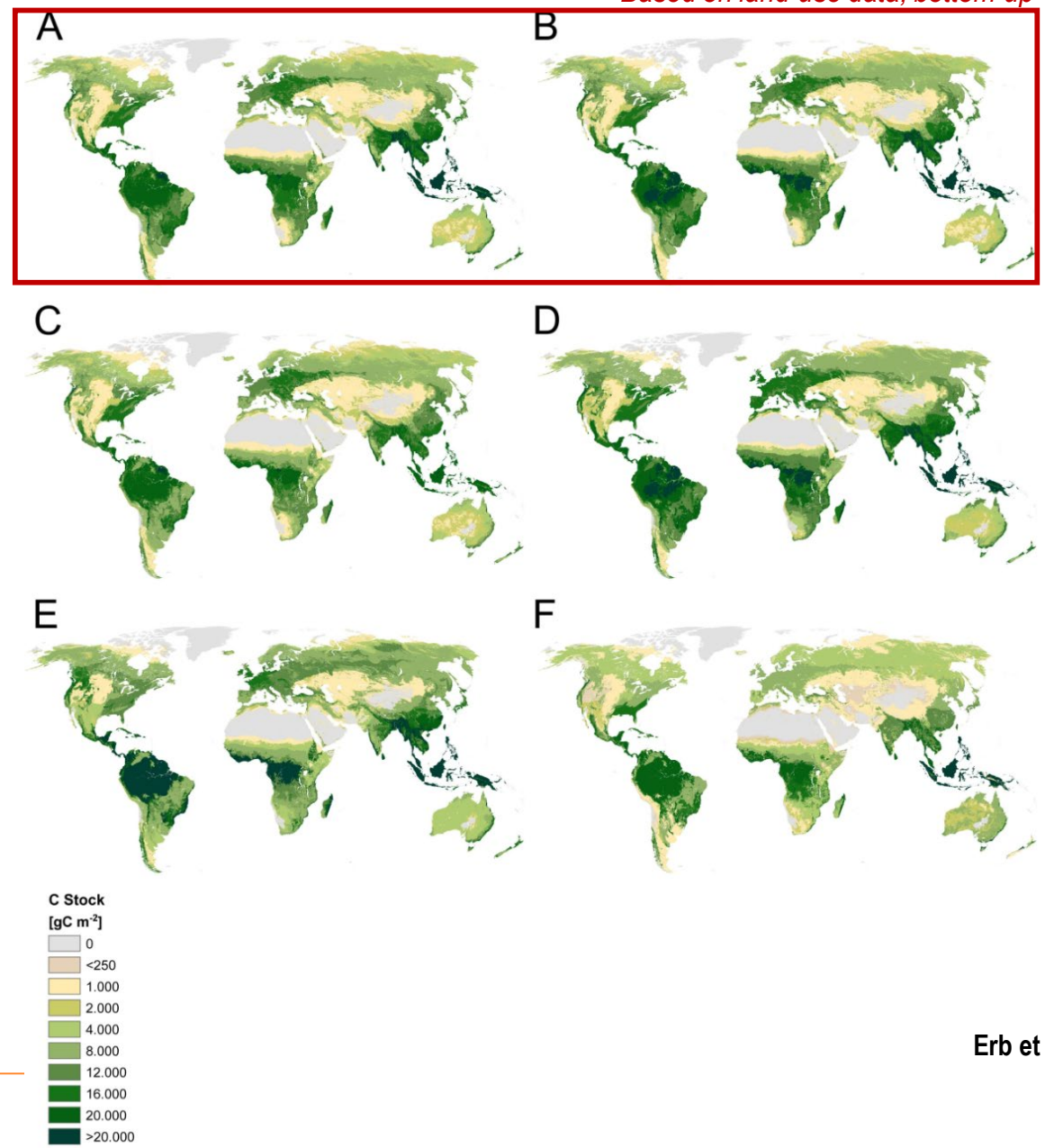
C Biomass stock density, cell-based minimum of „classical ecological“ values

D Biomass stock density cell-based maximum of „classical ecological“ values

E Remote sensing based

F West et al.

West. P. C. et al. Trading carbon for food: Global comparison of carbon stocks vs. crop yields on agricultural land. PNAS 107. 19645–19648 (2010)



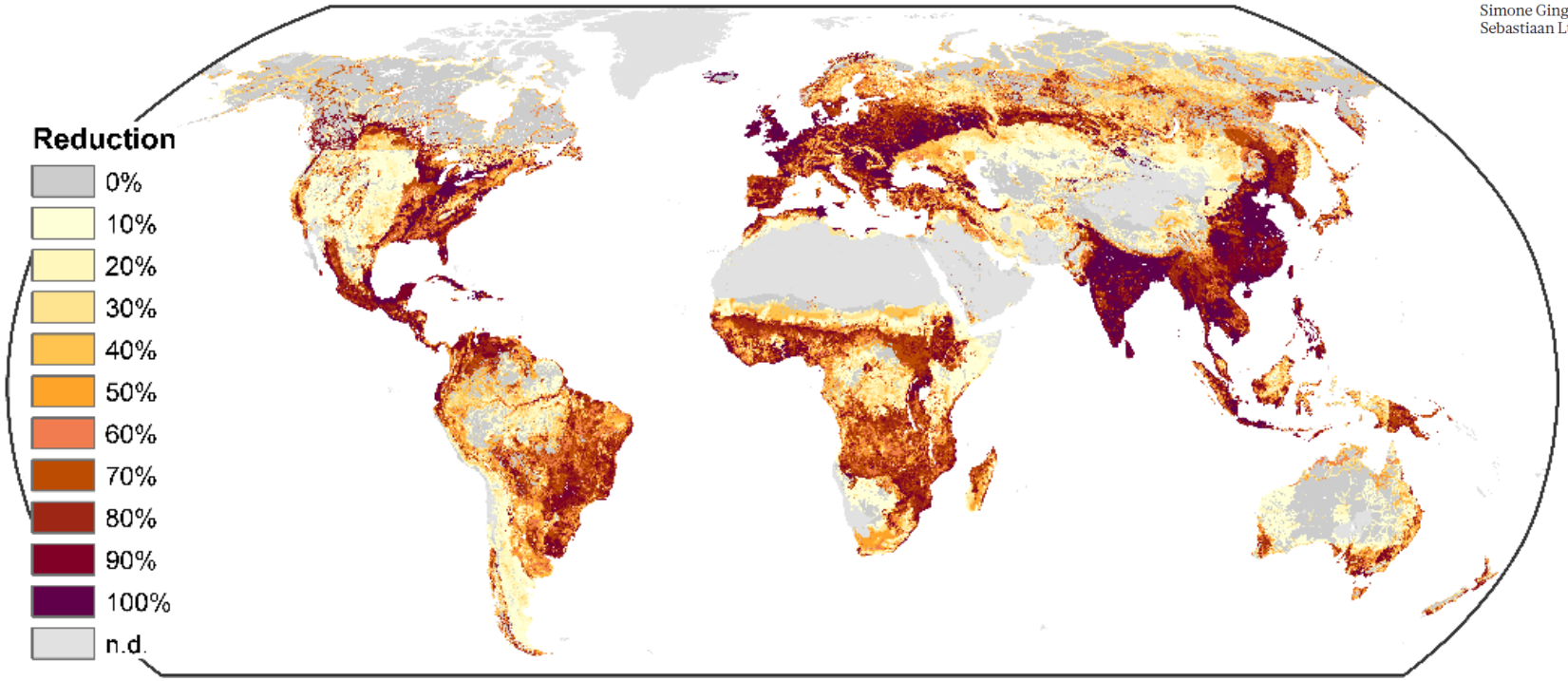
Erb et al. 2018, doi:10.1038/nature25138

Reduction of global biomass stocks

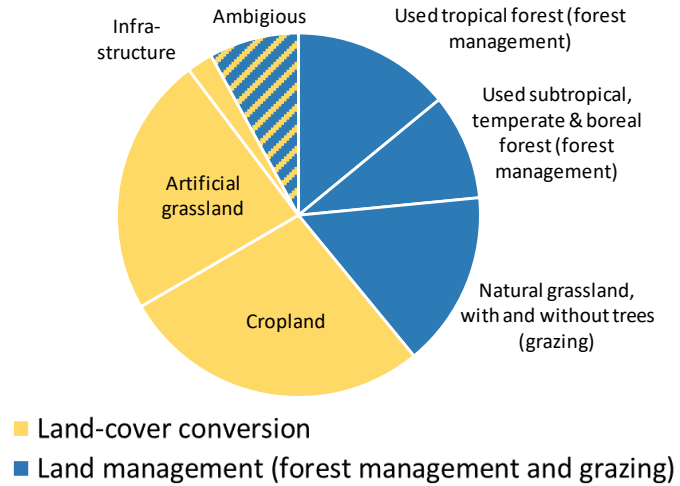
LETTER
doi:10.1038/nature25138

Unexpectedly large impact of forest management and grazing on global vegetation biomass

Karl-Heinz Erb[1], Thomas Kastner[1,2*], Christoph Plutzar[1,3*], Anna Liza S. Bais[1], Nuno Carvalhais[4,5], Tamara Fetzel[1], Simone Gingrich[1], Helmut Haberl[1], Christian Lauk[1], Maria Niedertscheider[1], Julia Pongratz[6], Martin Thurner[7,8] & Sebastiaan Luyssaert[9]



Mean of all 42 permutations



→ **Halving of biomass stocks**

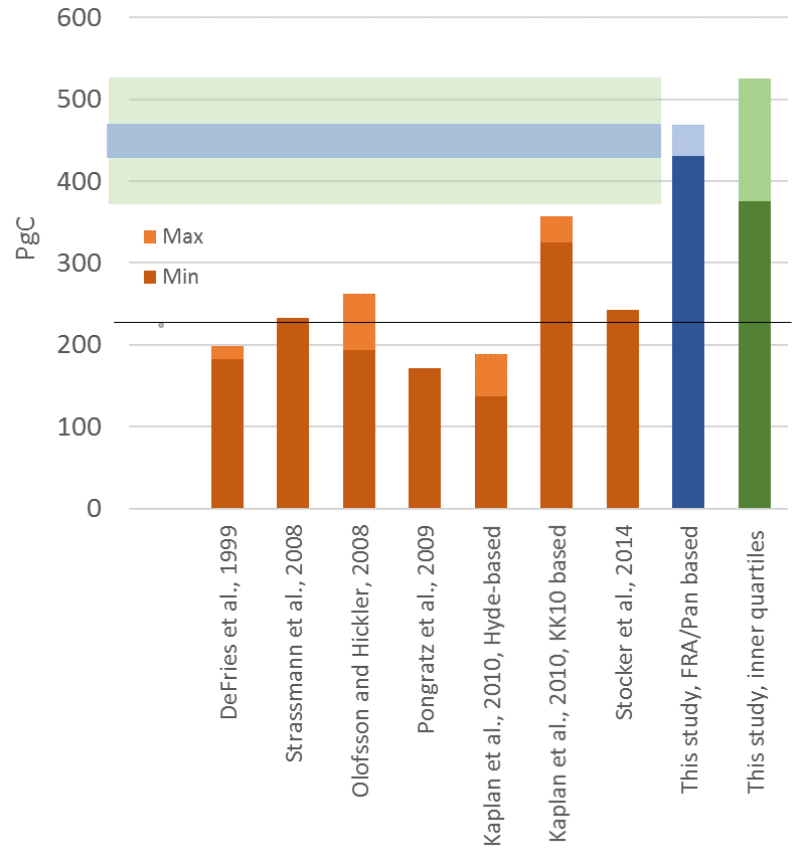
→ **Effects of land management (land cover modifications) as important as effects of land cover conversions**

* actual: mean (n=7)	450 PgC (380-536)
* potential: mean(n=6)	916 PgC (771-1107)
→ reduction, median (n=42)	447 (inner quartiles: 375-525)

Erb et al. 2018, doi:10.1038/nature25138

Are 450 PgC a lot?

- Current C-emissions from Fossil Energy & Cement ~ 9 PgC
- Global Net Carbon Emissions from Land Use ~ 1 PgC;
- "Land Sink" - C-absorption processes of terrestrial ecosystems, caused by climate changes: ~ -3 PgC
- A recovery of potential would absorb an equivalent of 50 years of emissions (as of today). (but that would not make much sense ...)
  - More realistic potentials: Agricultural land at 30% of potential: 7 years, all forests at 90% of potential: 7-12 years, tropical forests at 90%: 5-10 years
- 450 PgC are significantly higher than those found in modeling studies - there, the effect of "management" is mostly ignored.
- Or are the 900 PgC potential biomass stocks overestimated?



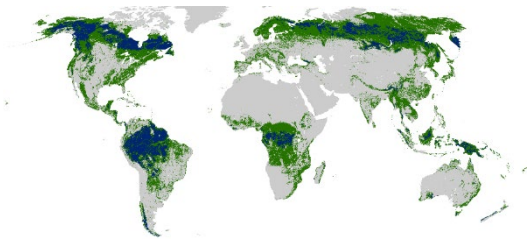
Erb et al. 2018, doi:10.1038/nature25138

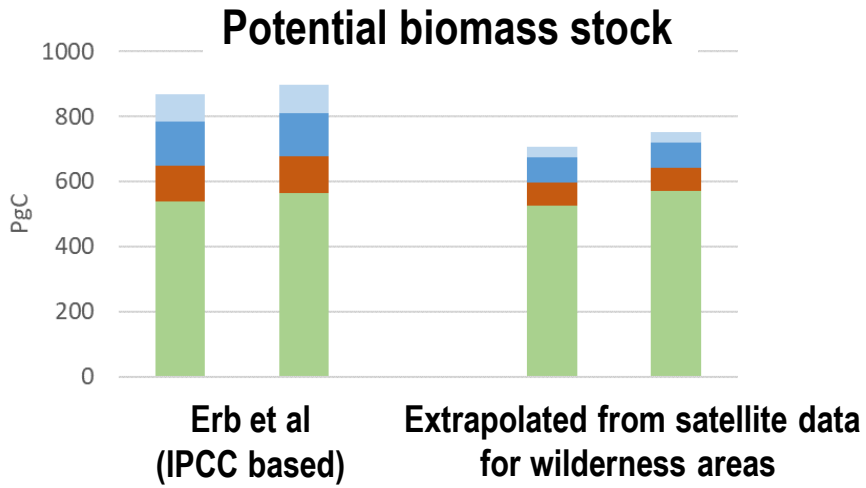
Are the ~900 PgC an overestimate?

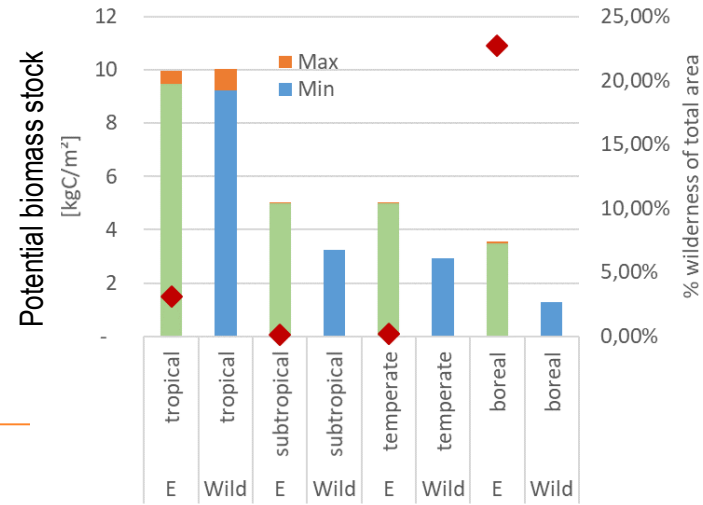
[oder: are IPCC data too high?]

- "Bias" of ecological images, focus on undisturbed habitats (→ overestimation)
- But: in many regions there is no longer any "untouched" nature (→ underestimation)
- Countercheck: Calculation of potential biomass stocks from satellite data in wilderness areas (Potapov et al., 2017, Venter et al., 2016)
- For temperate and subtropical zone, to small sample size. But: national SCpot estimate for AUT: 13 kgC / m2; local, Switzerland: 19kgC / m2 (Global, average: 5kgC / m2)
- Boreal: known problems of satellite data
- → a substantial overestimation can be ruled out.

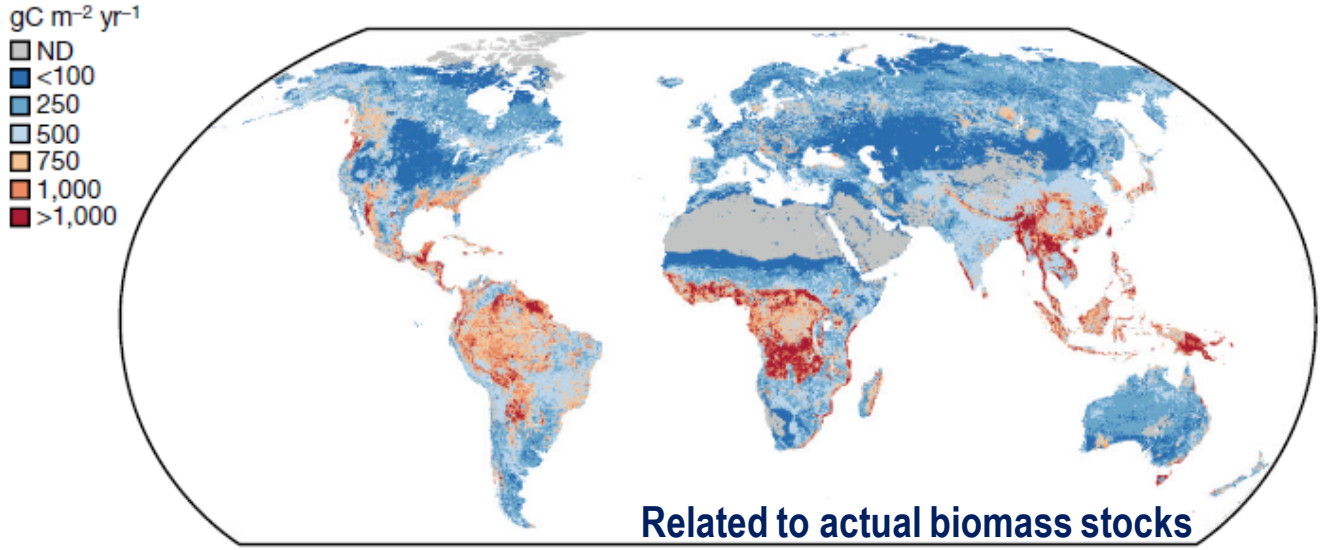
Intact forests







Uncertainties, and their meaning

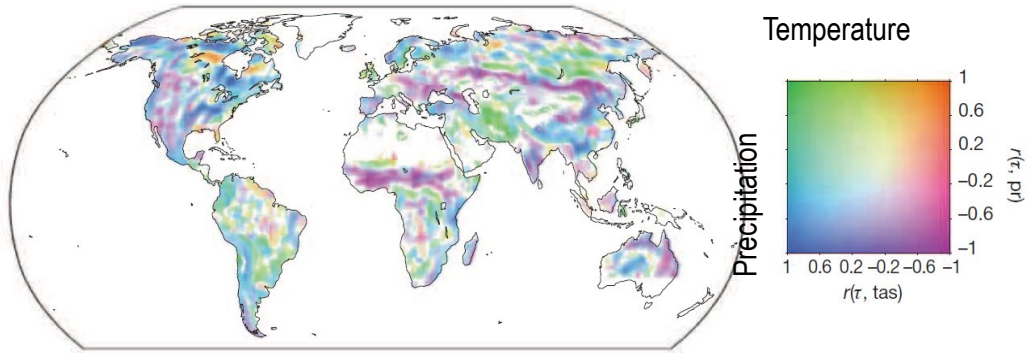


- (Regional) uncertainties of the current biomass stocks are very high, especially in regions on the edge of the tropical core areas
- If one translates the uncertainties in "detection limits" (the signal must be greater than the uncertainty), then the map shown here results. eg. In many areas in the tropics, the detection limit is> 750gC / m² / yr, which is within the range of annual crop production (NPP)
- A problem for climate change migitation strategies

Stocks & Flows: Turnover

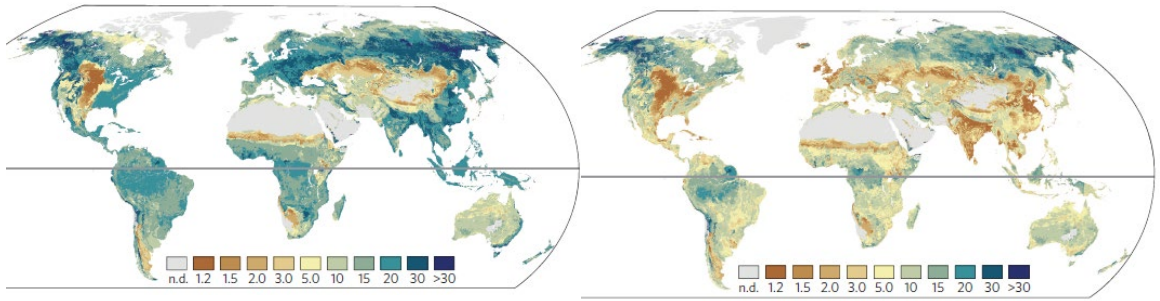
- Turnover rate: Key paramter of ecosystems. The ratio of stocks and flows :
  τ_b = SC / NPP
- Unit [yr^{-1}] (turnover) or [yr] (mean residence time)
- Turnover determines the size of the carbon pool
- **The impacts of land use on turnover rates are underresearched, if not ignored**

Determinants of ecosystem carbon turnover time



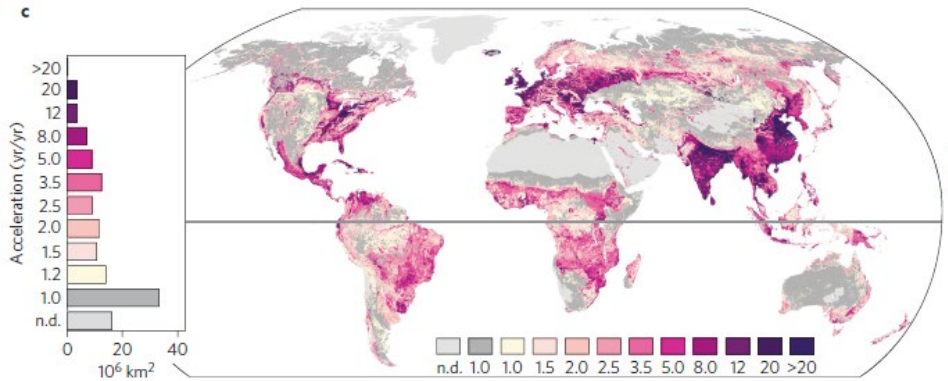
Carvalhais et al., 2014 doi:10.1038/nature13731

A fundamental restructuring of ecological processes



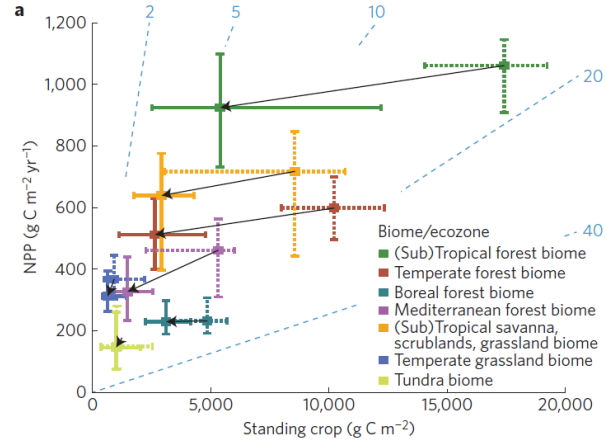
Potential vegetation: 13.7 yrs

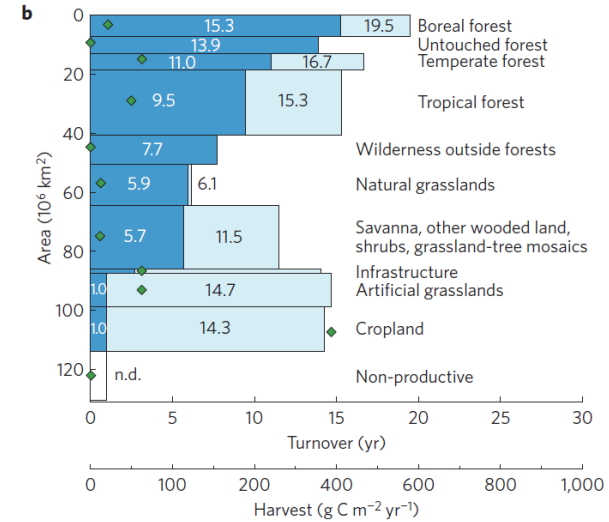
Actual vegetation: 7.1 yrs

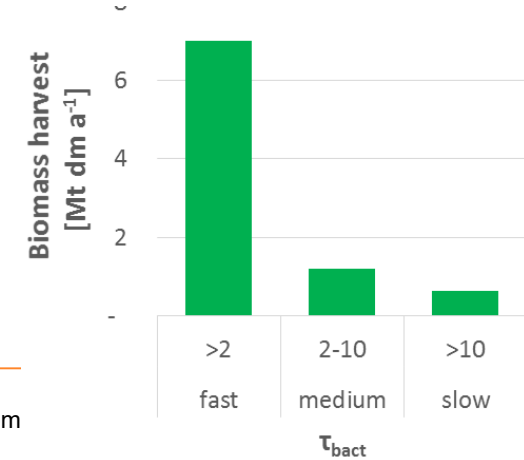


Global Acceleration factor: 1.9

- All biomes show similar patterns.
- The effect of land use on stocks is much stronger than on NPP (NPP ↓, SC ↓↓)
- High harvest pressure correlates with high acceleration.
- Biomass demand is likely to increase - already today most harvest products come from "fast" ecosystems







Erb et al. 2016 doi:10.1038/ngeo2782

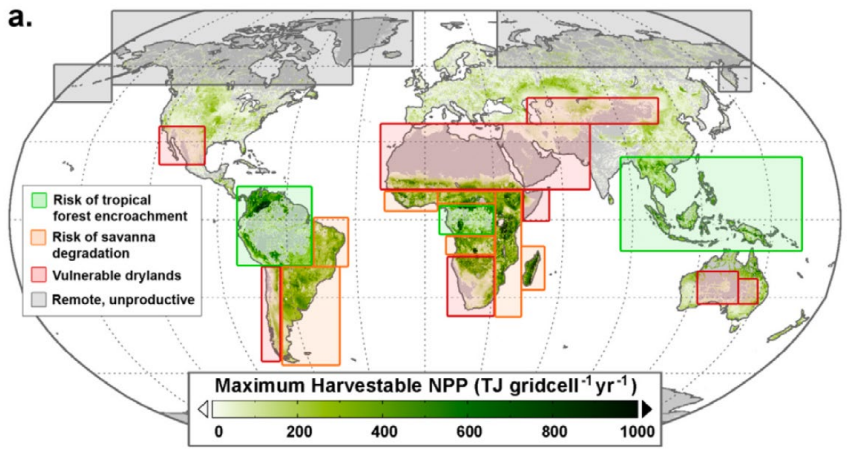
Landnutzung-Biom

A look ahead...

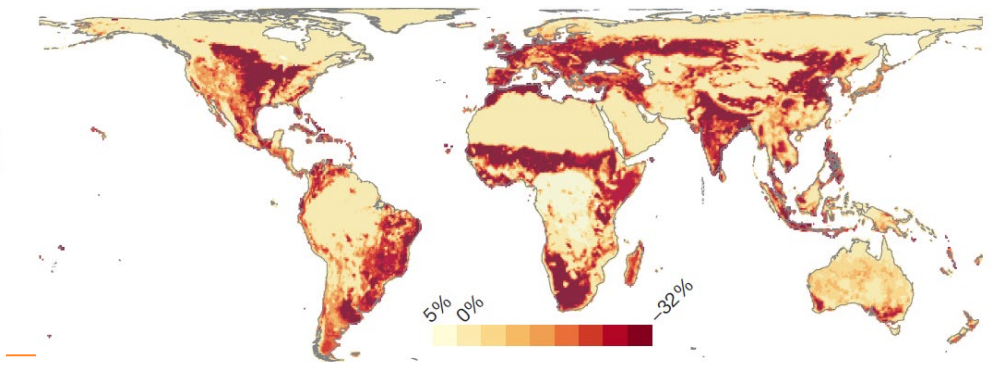
How much bioenergy is possible?

- Current global technical energy ~ 450EJ / yr
- Of which bioenergy ~ 50 EJ / yr (mainly firewood)
- For comparison: total biomass harvest: ~ 250 EJ / yr
- Today's land use is accompanied by serious environmental problems: GHG emissions, degradation, biodiversity loss, etc.
- What are the global effects of a bioeconomy aimed at the (~ simple ~) substitution of fossil energy by biomass?

→ Demand-side strategies bring many advantages over efficiency strategies: large options room, no rebound effect



Haberl et al., 2012



Newbold et al., 2015

nature COMMUNICATIONS

ARTICLE

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Exploring the biophysical option space for feeding the world without deforestation

Karl-Heinz Erb[1], Christian Lauk[1], Thomas Kastner[1], Andreas Mayer[1], Michaela C. Theurl[1,2] & Helmut Haberl[1]

Erb et al., 2016

Conclusions

- The impact of land use on biomass flows and stocks is massive: 25% HANPP, -50% biomass stock (Austria -64%.)
- Increasing yields was and is possible, HANPP can be detached from population growth. But: today mainly based on inputs that pollute local ecosystems and / or the climate **- central trade-off**
- Biomass production and consumption are increasingly separated spatially- challenge for science and (sustainability) policy (complex cause-and-effect chains, leakage)
- Management effects (forest use, grazing and other uses of natural grasslands) are as significant as deforestation. These effects are currently underappreciated.
  - Protecting global forest areas is essential, but not sufficient in the sense of mitigating climate change. From the protection of areas to the protection of functions (e.g. biomass stocks).
- Uncertainties are greatest in those areas that are being discussed as “big hopes" for bioenergy.
- Central challenge: How can harvest be increased without massively accelerating the turnover? **Central trade-off**
- Demand-side strategies will become decisive and have a high potential to harness synergies

The End

Thank you very much

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