Long-term systemic changes in Europe's lands

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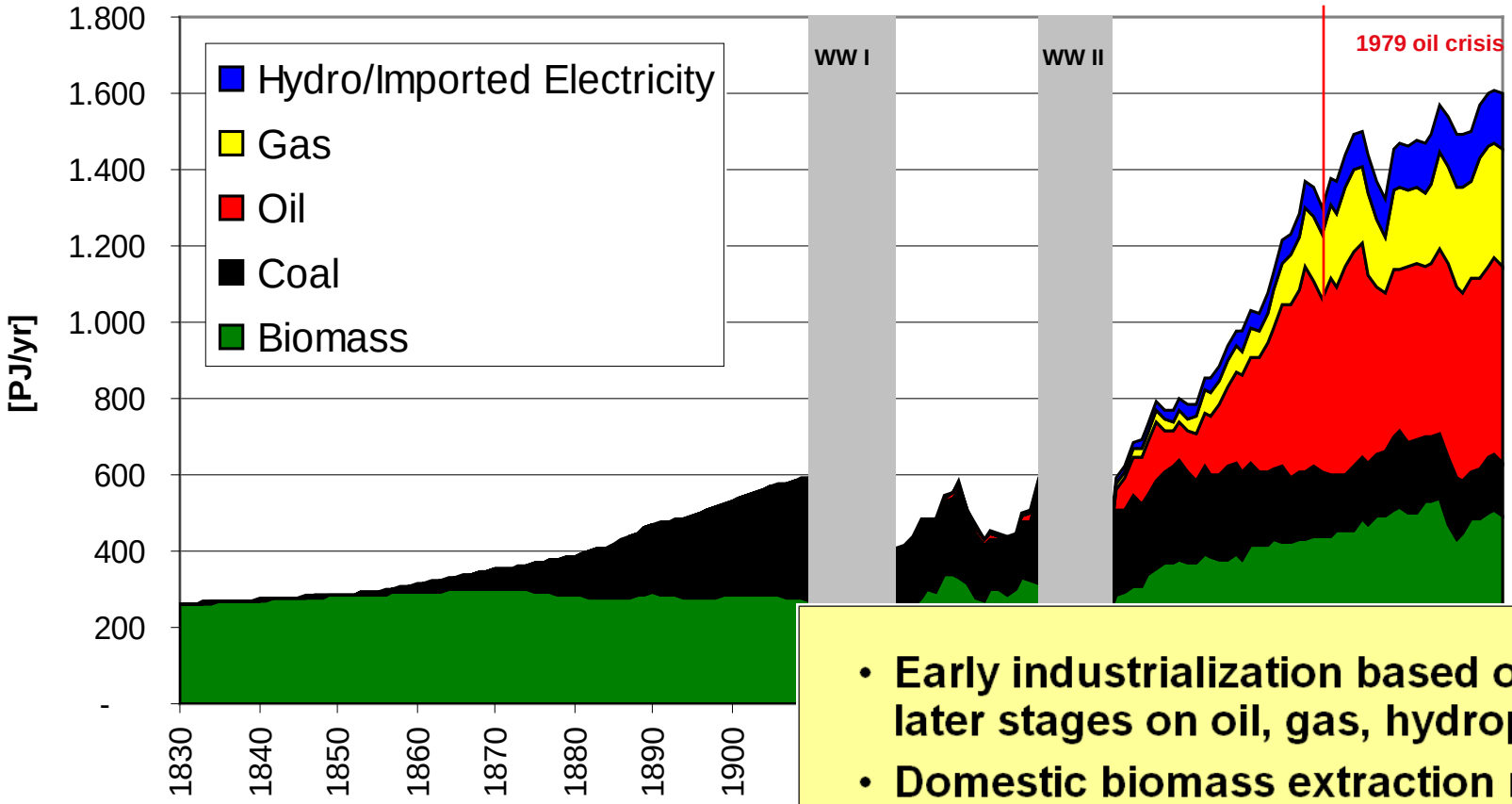
Overview

- Changing role of land for socioeconomic metabolism during agrarian-industrial transitions
  - The Austrian case 1830-1995
- Changes in land use and HANPP in nine countries analyzed in VOLANTE
  - Rising „efficiency“ of land use
- Analysis of long-term technological, institutional and economic drivers
  - How industrial agriculture has spread across Europe
- New insights on the role of land-use change for global biogeochemical cycles
  - Modelling for Austria
- Conclusions

Energy and land-use system changes during the agrarian-industrial transition

- In **agrarian society** (e.g., Austria 1830) society‘s energy supply depends almost exclusively on photosynthesis, i.e. the energy system is **area-dependent**. Agriculture has a high EROI (about 1 : 6) but low area-efficiency and labour efficiency.
- **Industrial society** runs on **area-independent energy**, above all fossil fuels. Abundant energy allows phenomenal increases in yields (i.e. area-efficiency) by factors 5-10 and of labour efficiency (factor >30). No transport/import restrictions
- As a result, biomass harvest can be increased while farmland area (and therefore HANPP) declines. Forests grow in terms of area and stocking density.

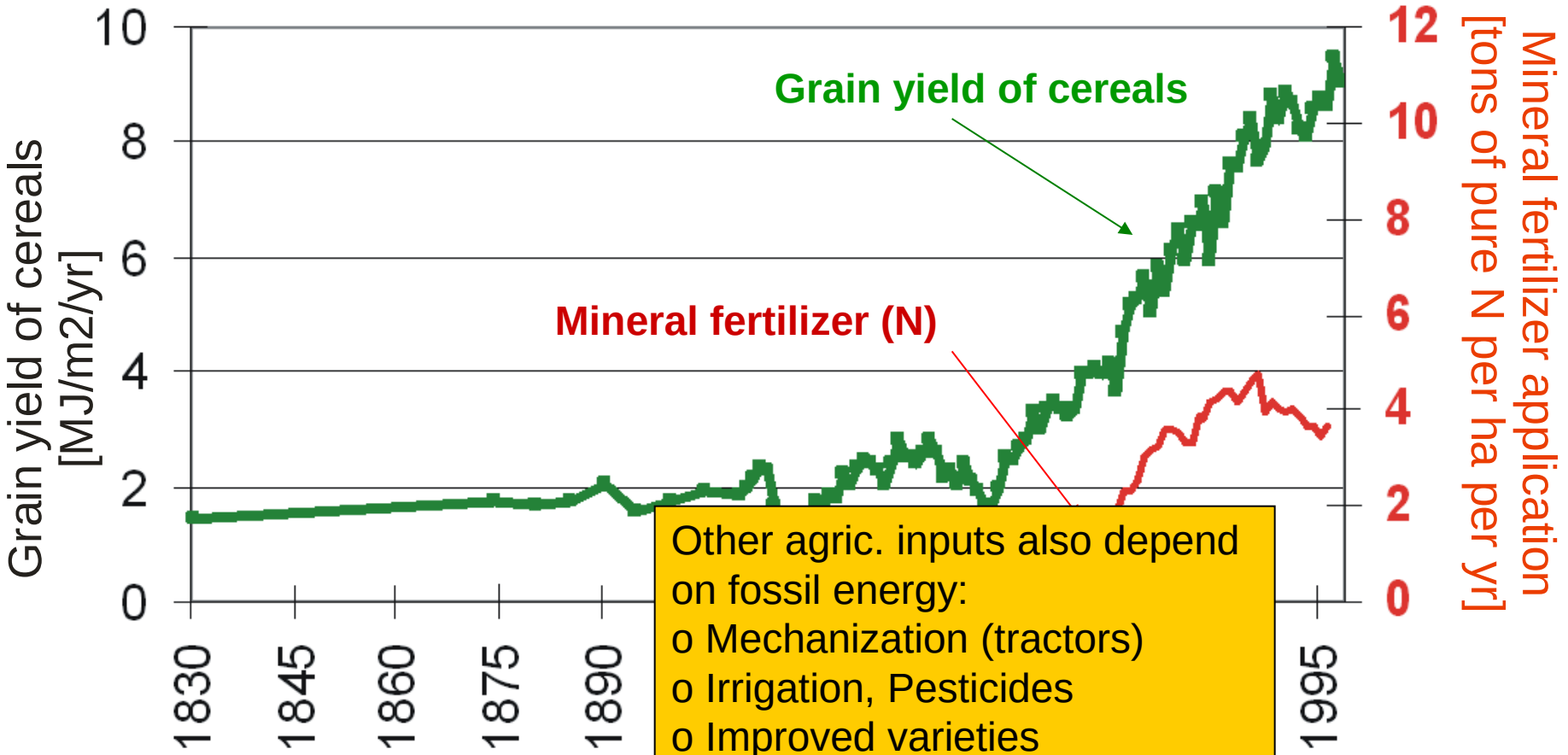
Austria's energy transition 1830-2000



- **Early industrialization based on coal, later stages on oil, gas, hydropower**
- **Domestic biomass extraction rises by 70%**

Krausmann, Haberl, 2002
Ecol. Econ. **41**, 177-201

Agricultural intensification Austria 1830-2000



Other agric. inputs also depend on fossil energy:
- o Mechanization (tractors)
- o Irrigation, Pesticides
- o Improved varieties

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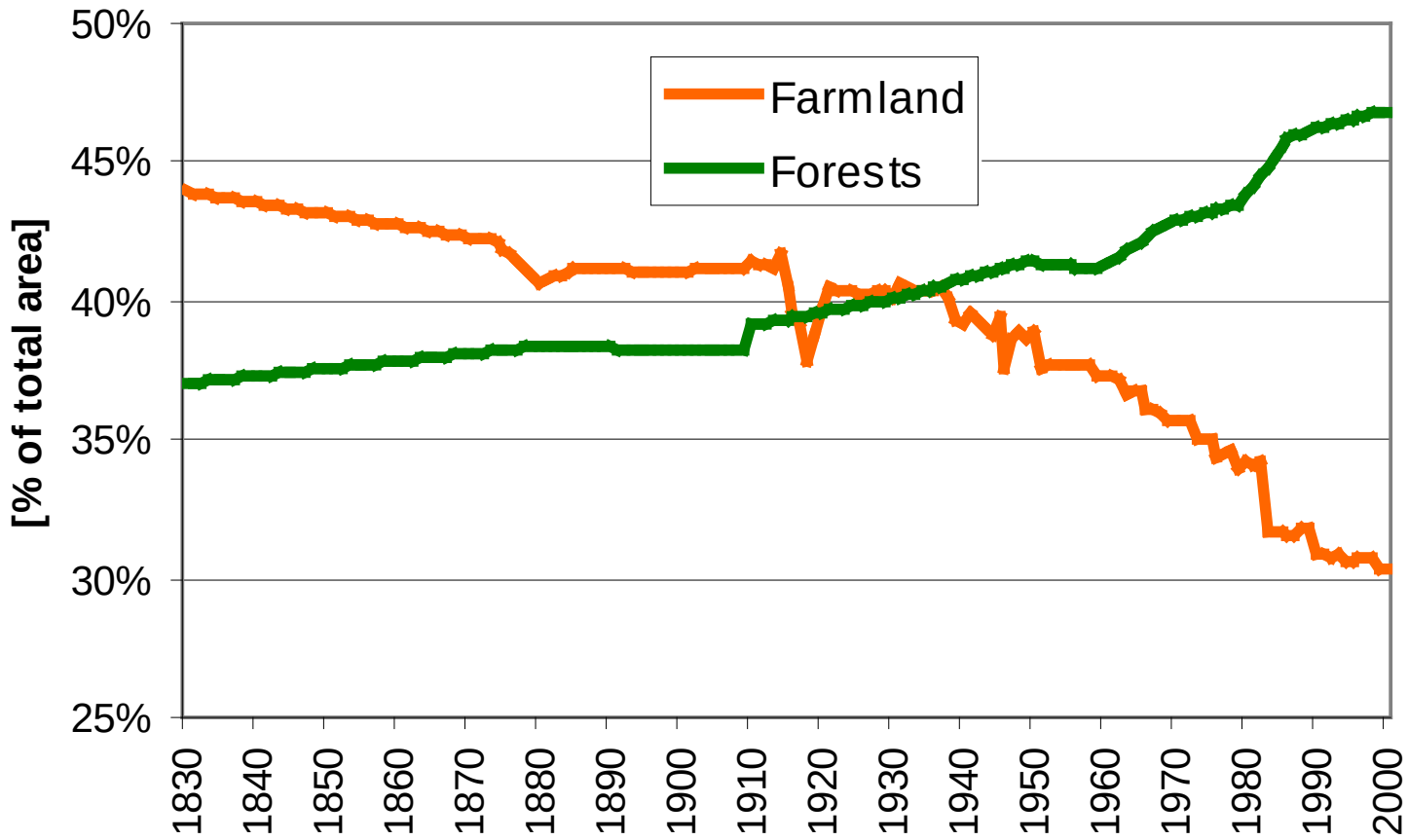
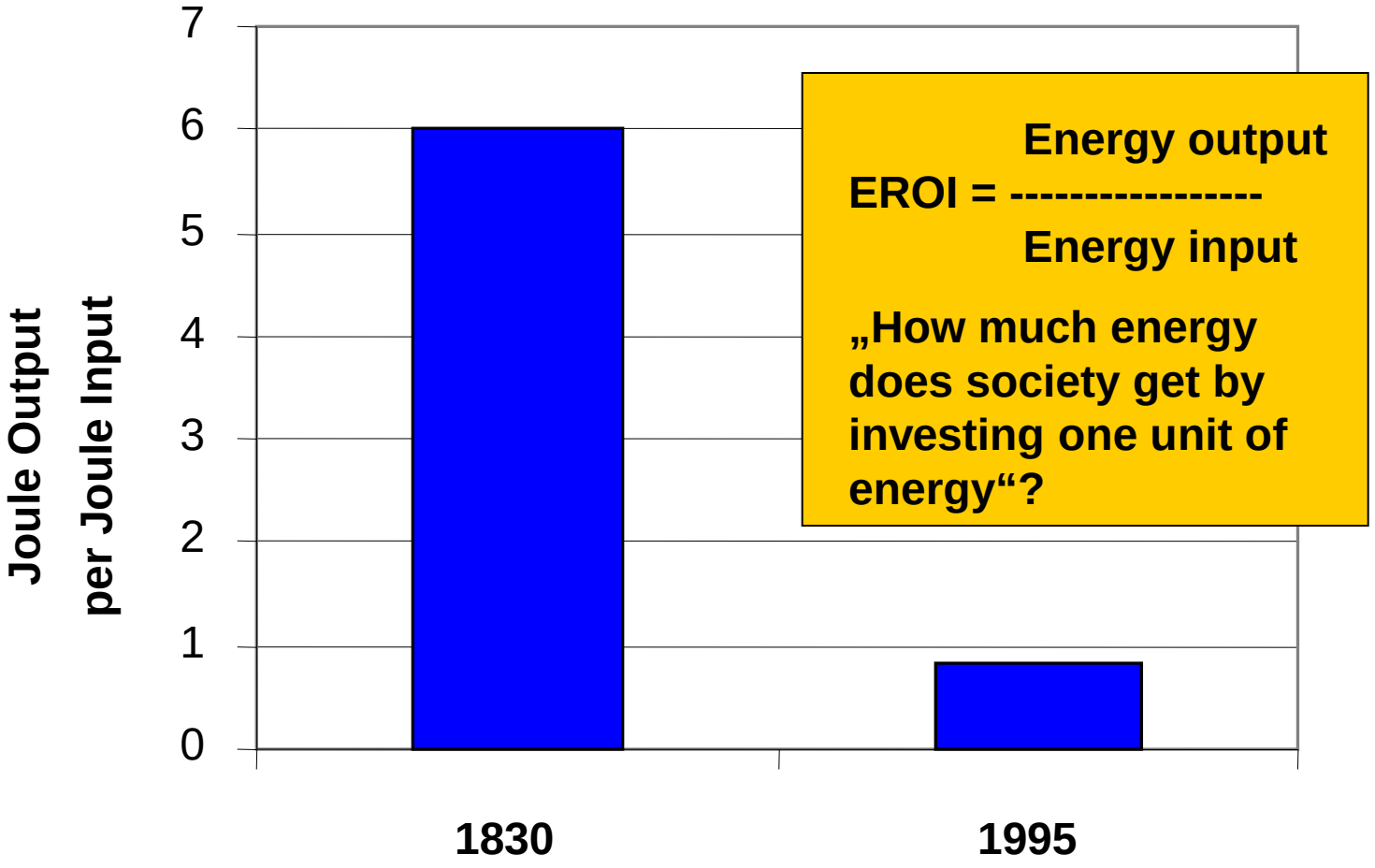
The land-use transition („forest transition“) in Austria 1830-2000

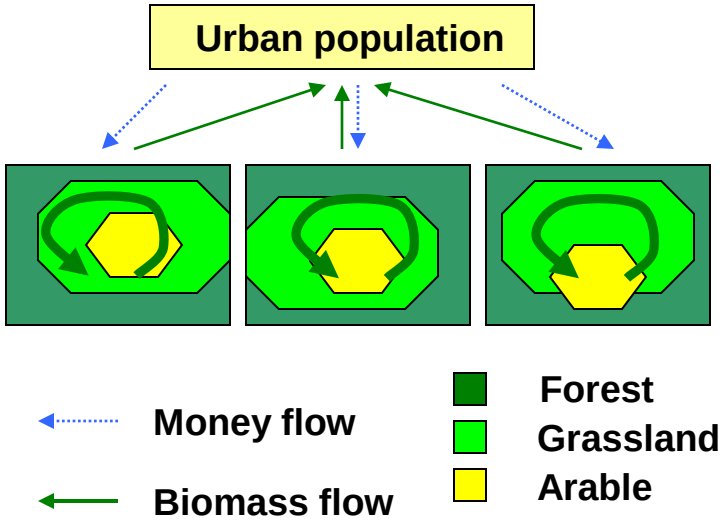


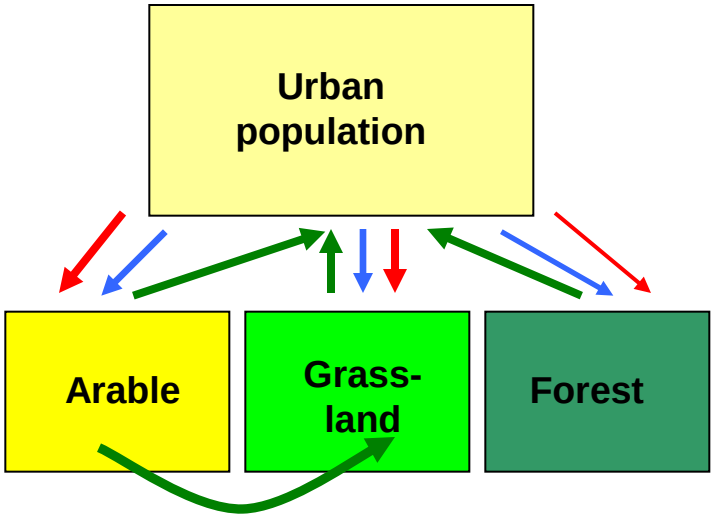
Krausmann, 2001.
Land Use Pol. **18**, 17-26

Energy return on investment (EROI)
Austrian agricultural sector 1830 and 1995



Pre-industrial versus modern agriculture





- Self-sufficient, integrated local systems ⇨ homogenous throughput systems
- Low input-low output ⇨ high input-high output
- Energy-efficient ⇨area- and labor efficient
- Surging transport intensity.
- Globalization of environmental pressures.

Biomass flow

Money flow

Flow of fossil fuels

Agrarian-industrial transitions and sustainability

Sustainability challenges change fundamentally during agrarian-industrial transitions:

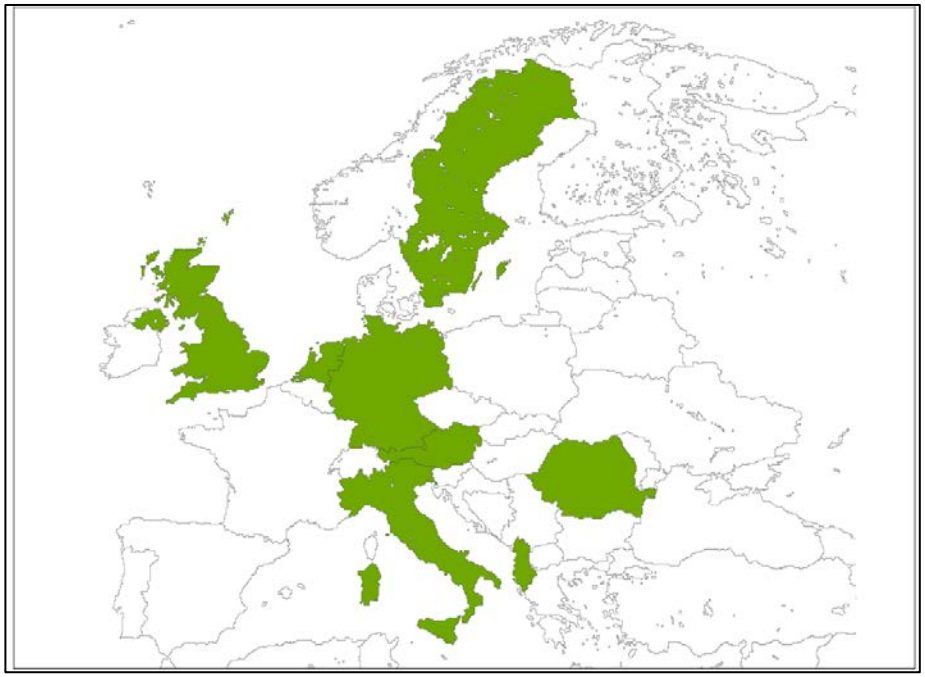
- **Agrarian society:** Maintaining a viable balance between population, (agrarian) technology, organization of labour processes and the productivity of agro-ecosystems. Failure leads to local collapse.
- **Industrial society:** Limitations of agrarian society are overcome by area-independent energy and transport/trade. Local sustainability problems are solved at the expense of global ones → globalization of the sustainability challenge (e.g., climate change). Failure might lead to global collapse.

> Two thirds of the world population are in the midst of this transition right now.
> A globalization of our industrial metabolism is not sustainable (peak oil, climate change, biodiversity loss, etc.).

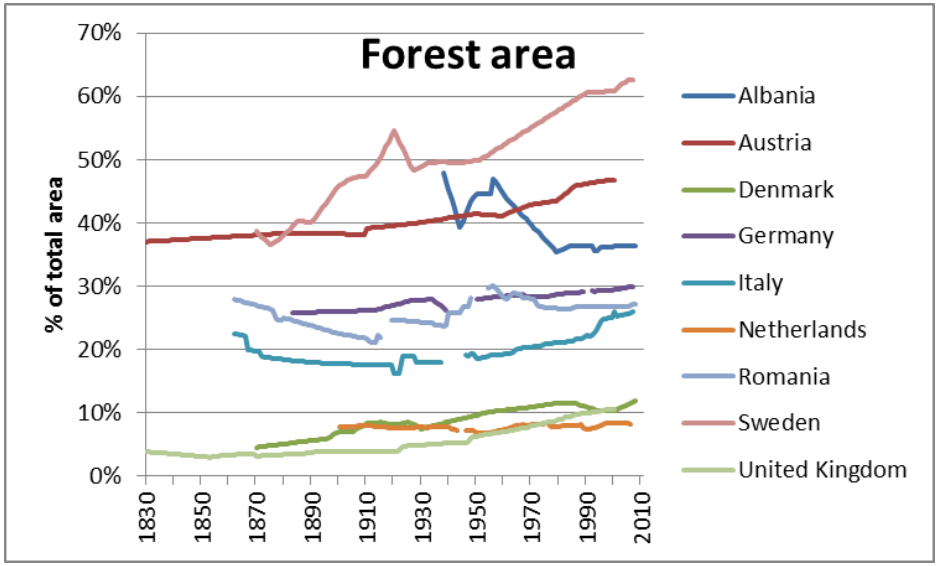
VOLANTE WP4 Database

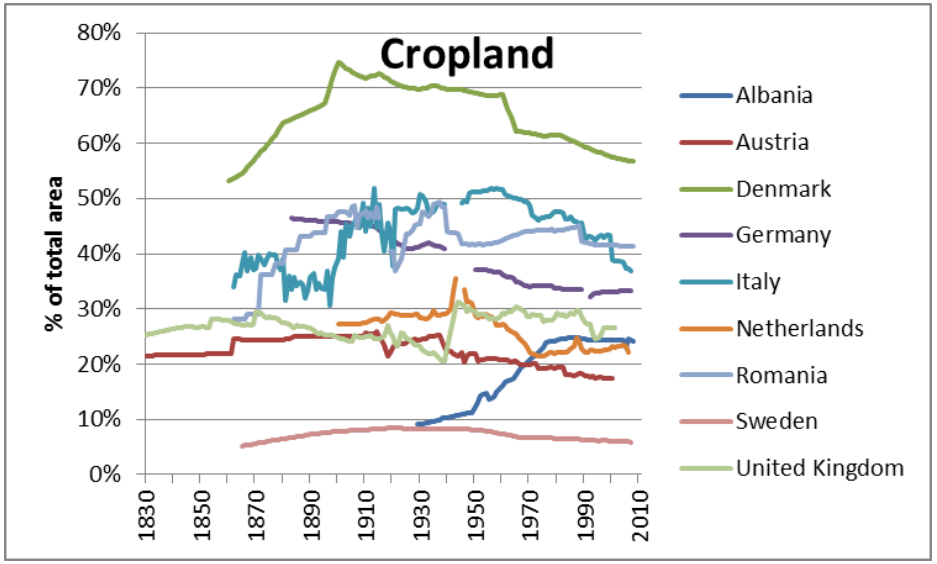
Long term changes of land use and biomass flows in 9 European countries

country	*Start of time series*	*Start of robust data*
Albania	1911	1938
Austria	1830	1830
Denmark	1860	1900
Germany	1880	1938
Italy	1883	1920
Netherlands	1900	1900
Romania	1860	1862
Sweden	1853	1921
UK	1830	1830

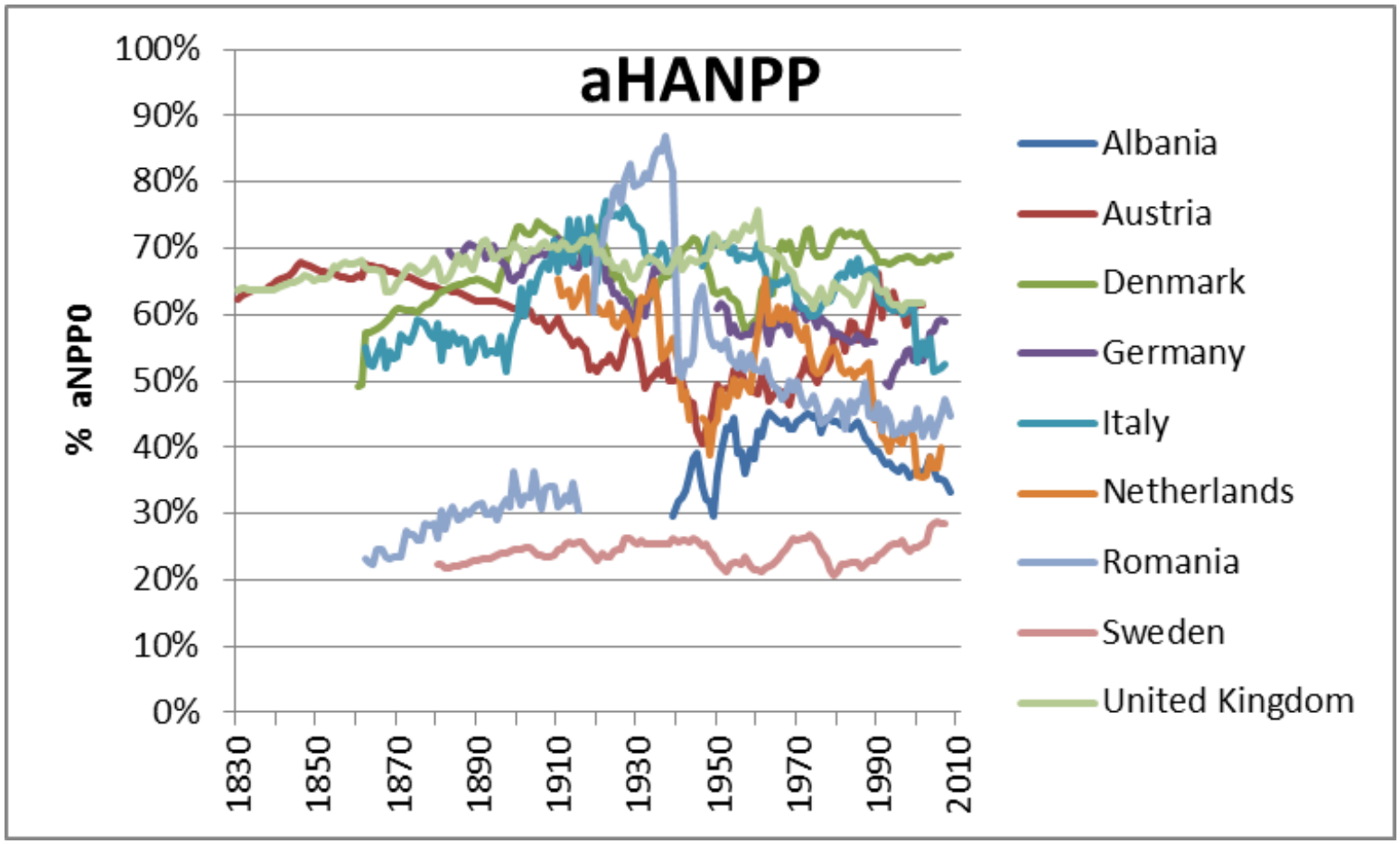


Long-term land use change in Europe

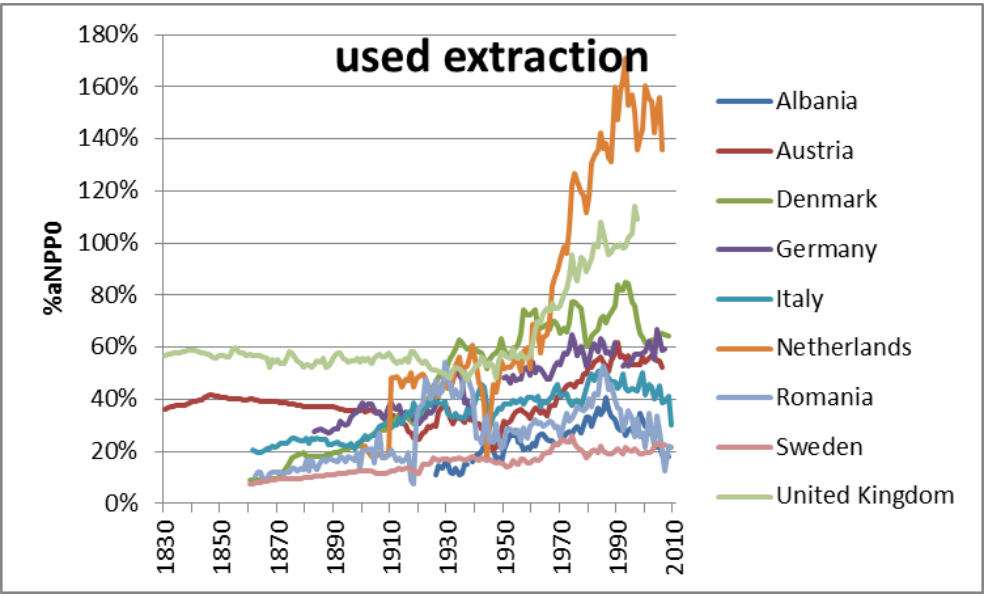




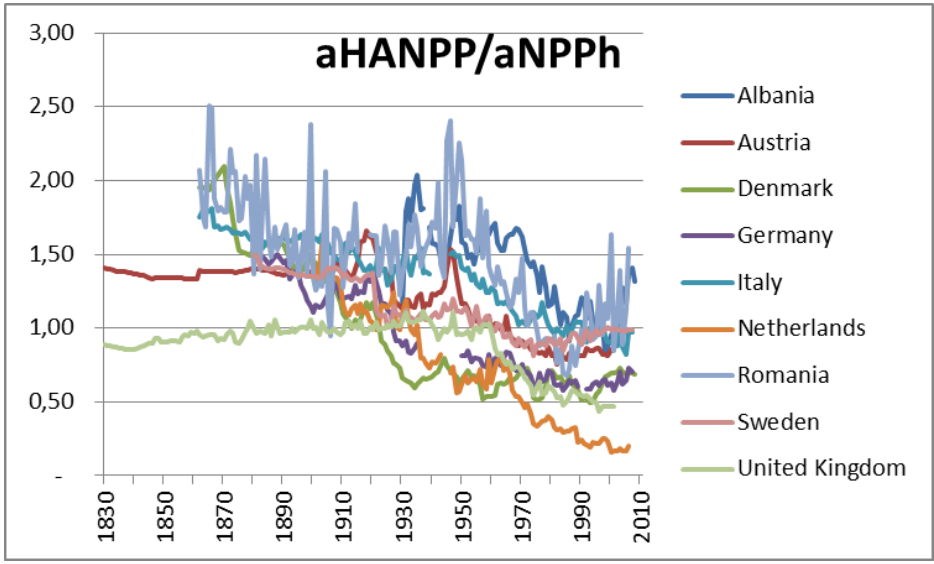
Aboveground HANPP trajectories nine countries



HANPP efficiency increased



HANPP intensity: HANPP per $HANPP_h$



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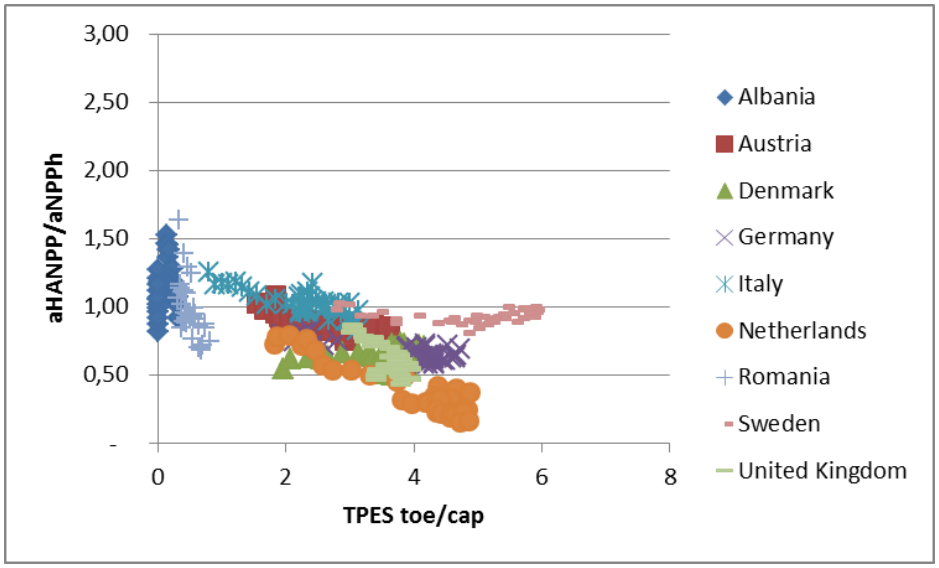
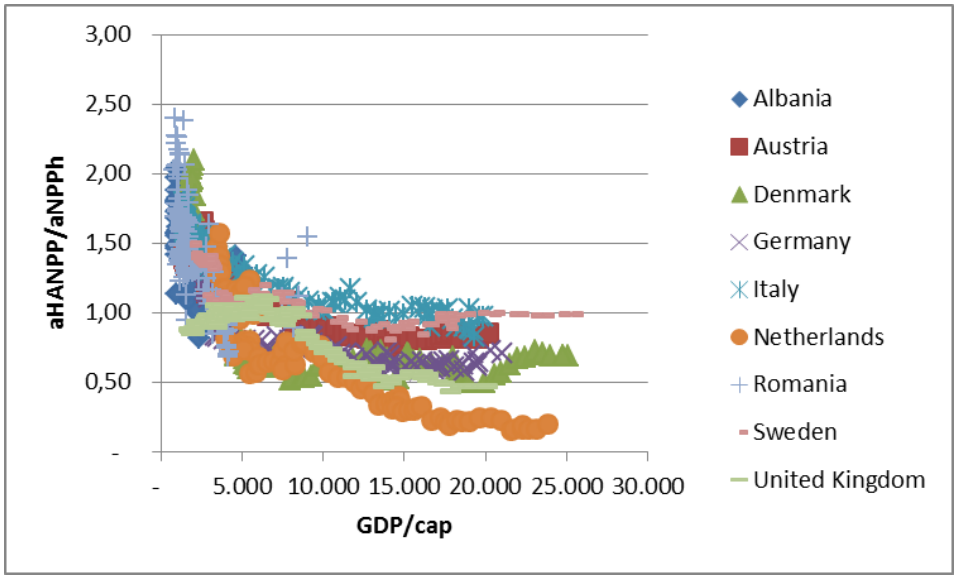
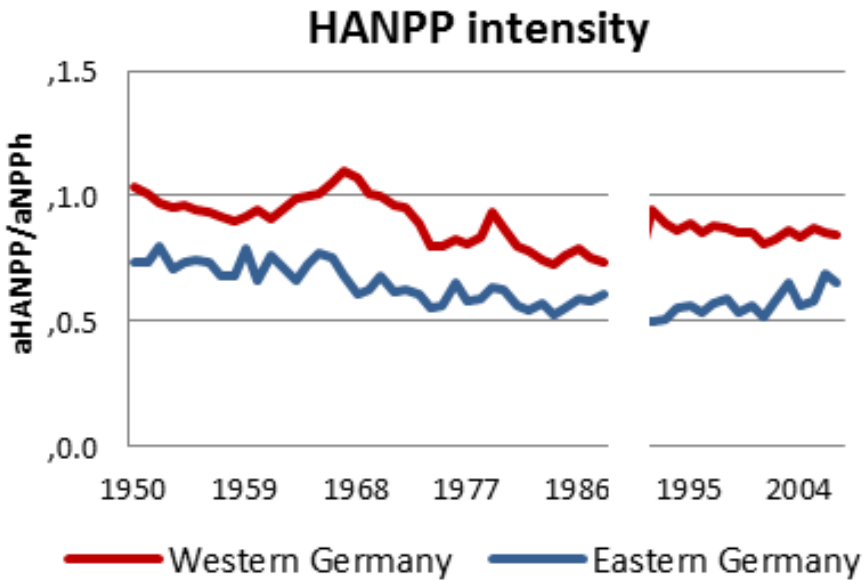
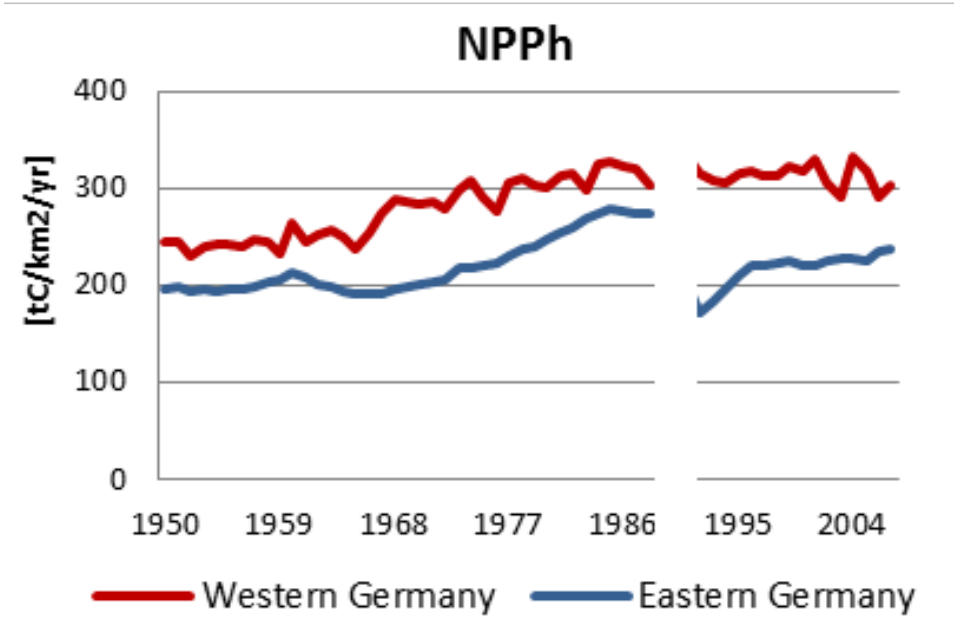
HANPP intensity vs. energy and GDP



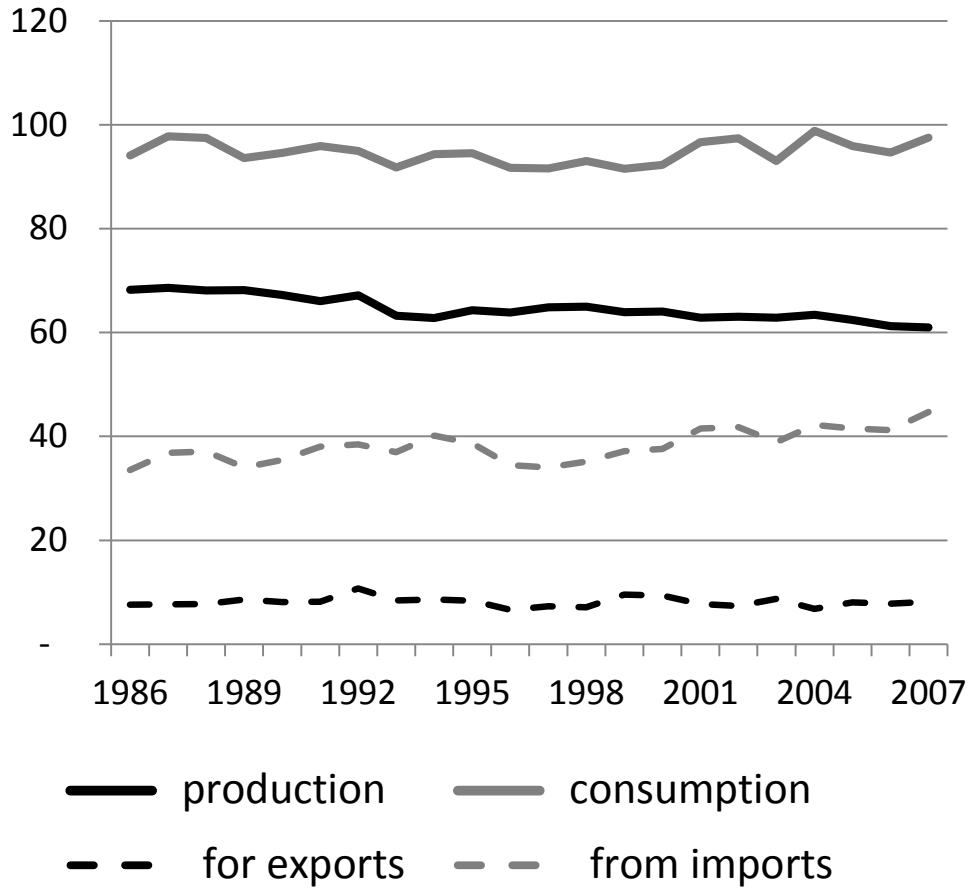


Regional trajectories Germany: East vs. west?



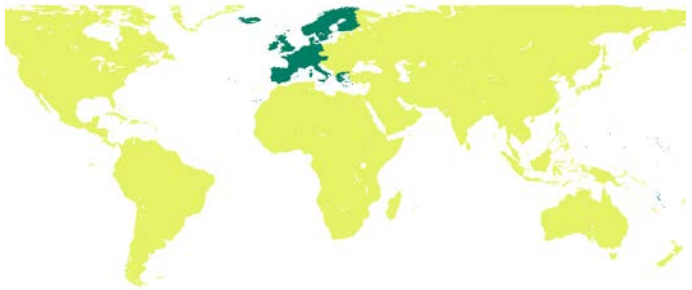


Results: regional trends European Union 15+

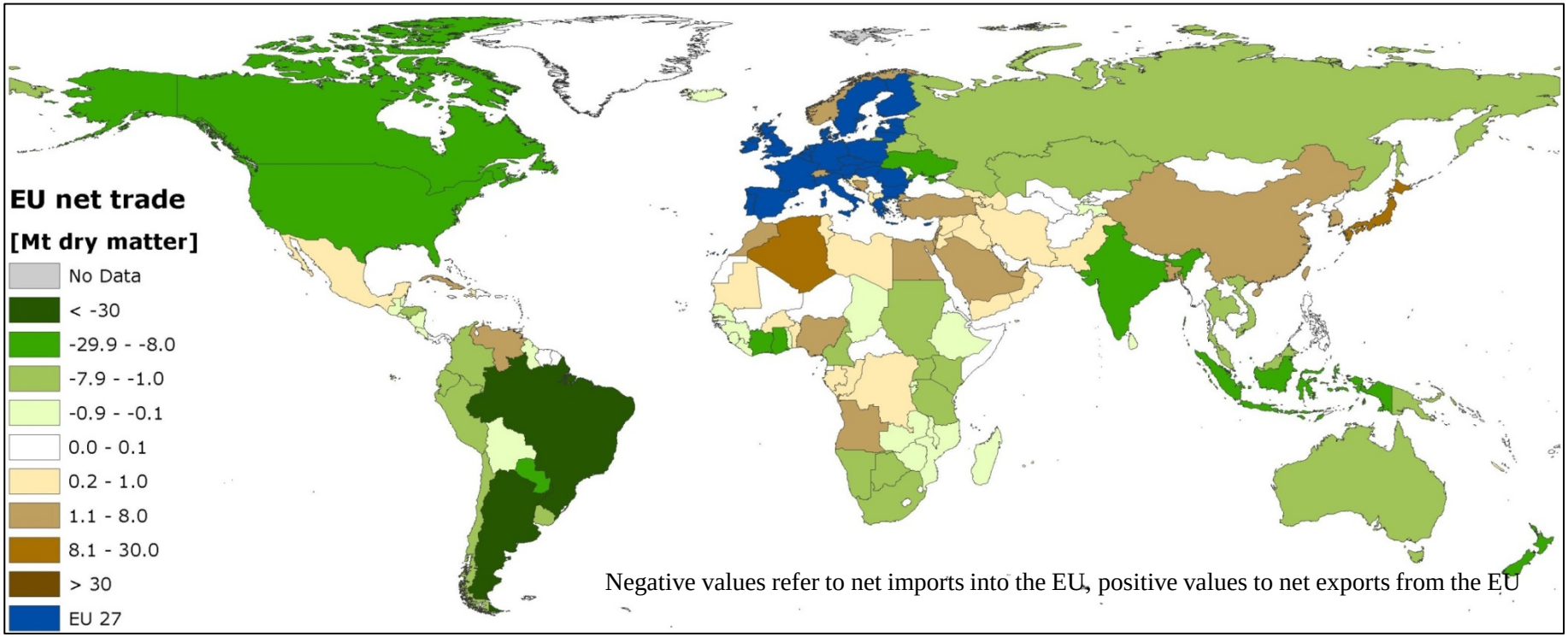


Values in million hectares cropland area harvested

- Cropland in the EU declined
- Cropland for consumption stable, at much higher levels



EU27 net trade in terms of eHANPP in 2007



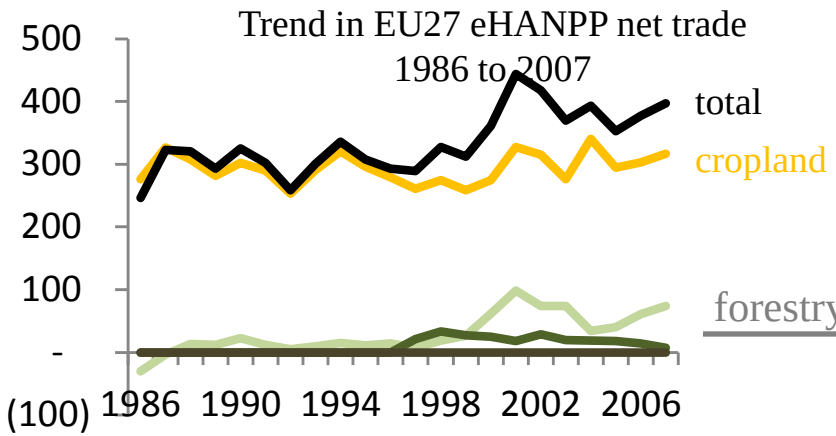
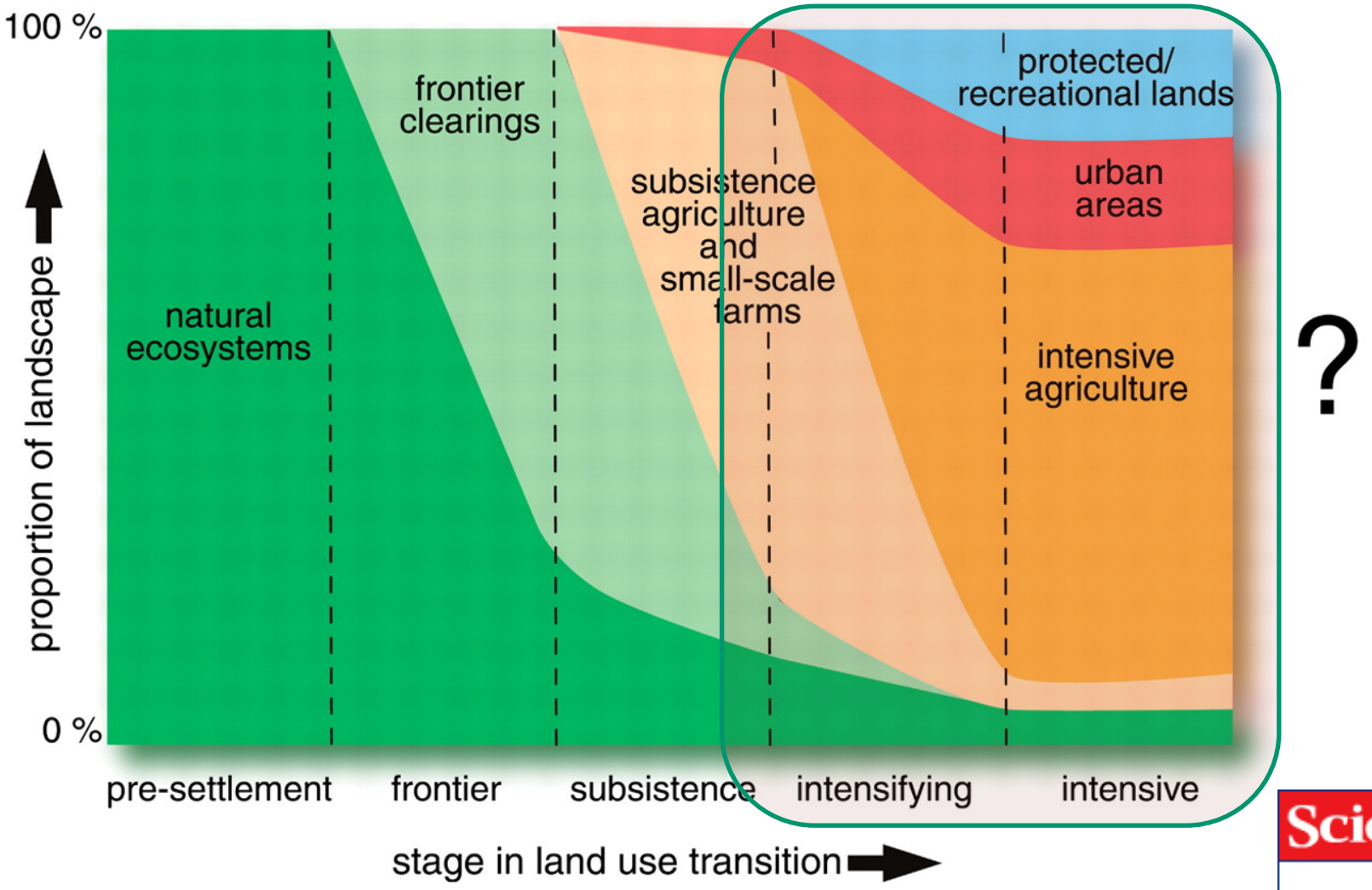


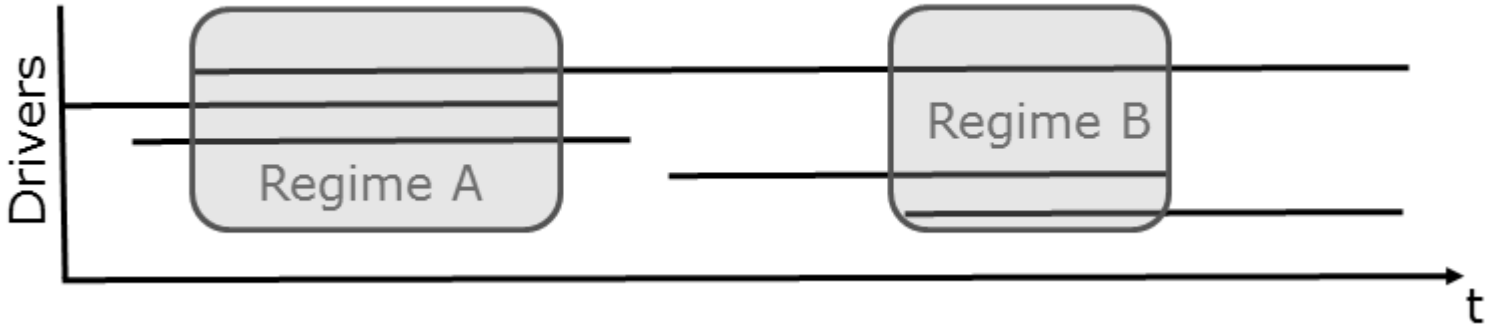
Fig. 1. Land-use transitions.



Science
AAAS

Research questions

What has been identified as major technological, institutional and economical drivers (mega-drivers) of land use changes in Europe?



Do we see temperal co-occurence of particlar drivers resulting in land use transitions?

If so, how can a specific combination of co-ocurring drivers be conceptualized?

Are there specific events causing fundamental changes in management regimes?

Narratives of drivers of land use change 1800-2010

Extent

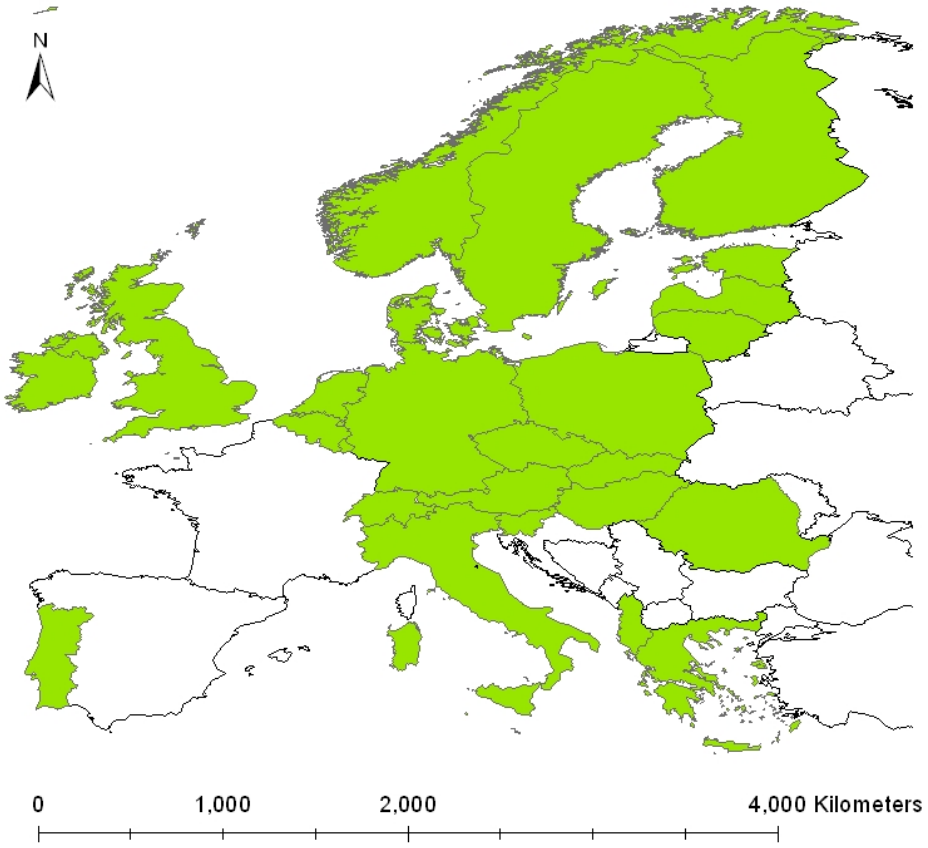
Spatial: EU24+NO+CH

Temporal: 1800->

Resolution

Spatial: Nation states

Temporal: Varies



Green: Included

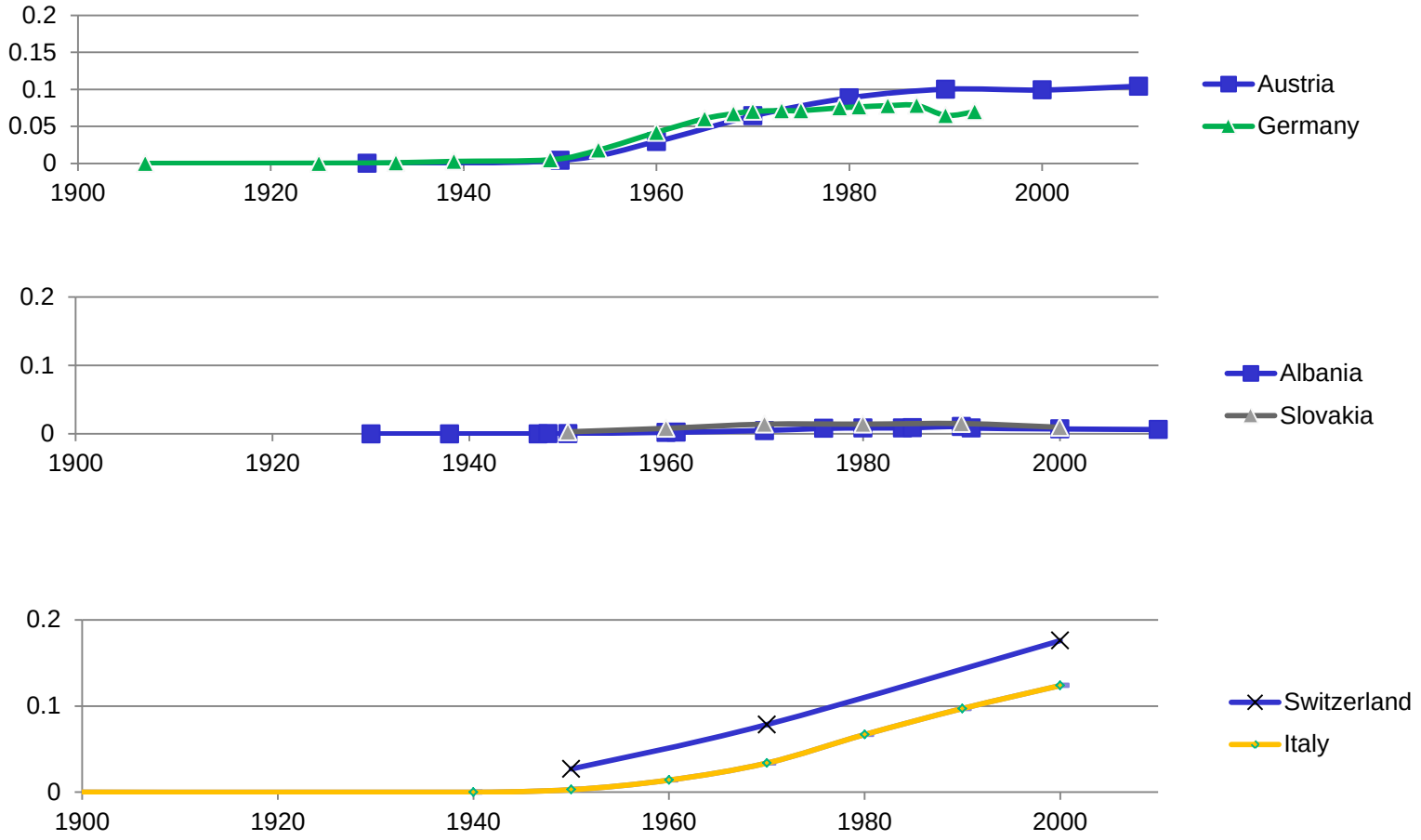
N=26

Drivers of land use change 1800-2010

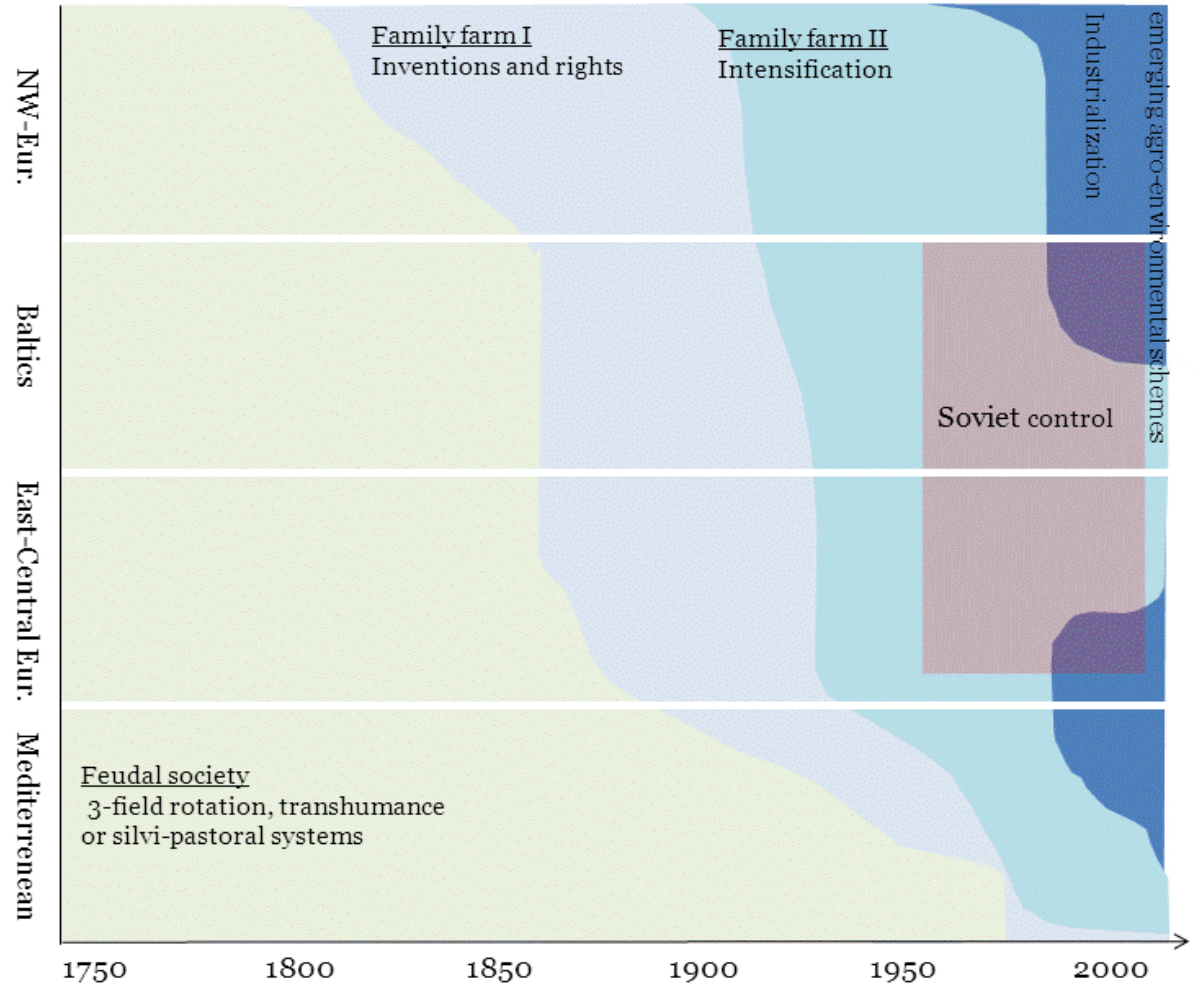
Class	Type	Driver/proxy
Technological	Motorization	**Tractors** **Railroads**
	Technology	**Drainage/irrigation** **Imported/synthetic fertilizer** **Modern Crops**
Institutional	Geo-political	**Military operations**
	Legislation/national schemes	Forest protection Land conservation **Land reclamation**
	Bottom-up	*Voluntary cooperatives*
	Land reforms	**Abolition of serfdom or corvee** **Rights to buy/own land** **Communism (kolkhoz/Sovkhoz)** **Other land reforms**
Economic	Legislation	Protectionism Subsidies/fixed prices EU Common Agricultural Policy
		Demand for timber
		Access to markets/urbanization

Drivers of land use change 1800-2010

Tractors/ha agricultural land



Regimes


Family farm I
Inventions and rights
Family farm II
Intensification
Industrialization
emerging agro-environmental schemes
Soviet control
Feudal society
3-field rotation, transhumance
or silvi-pastoral systems
NW-Eur.
Baltics
East-Central Eur.
Mediterrenean
1750
1800
1850
1900
1950
2000

Answers to research questions

What has been identified as major technological, institutional and economical drivers (mega-drivers) of land use changes in Europe?

- *Mechanization, fossil fuels, land reforms, large-scale subsidy schemes, national reclamation policies, command&control*

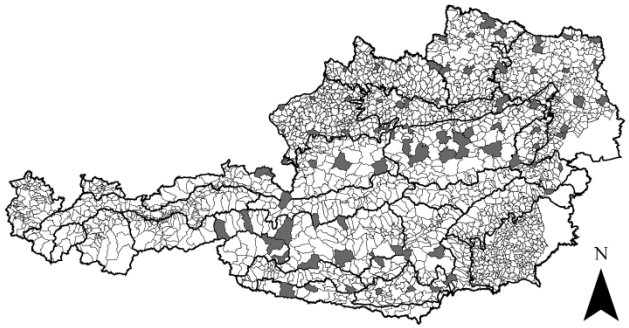
How has management regimes varied spatio-temporally in the past 150 years?

- *Diffusion from England/NW-Europe->Baltics->Central Europe->Mediterrenean*
- *Shift towards family farm I/II after Soviet breakdown*

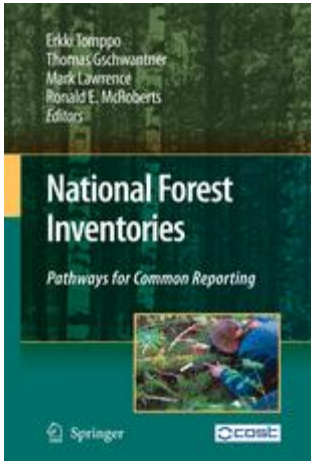
Are there specific events causing fundamental changes in management regimes?

- *EU and national production support policies post-WW2, Soviet agrarian policy (1965->), Soviet break-down, strong policy instruments aimed at set-aside*

Carbon stocks in Austria‘s vegetation, 1830-2000

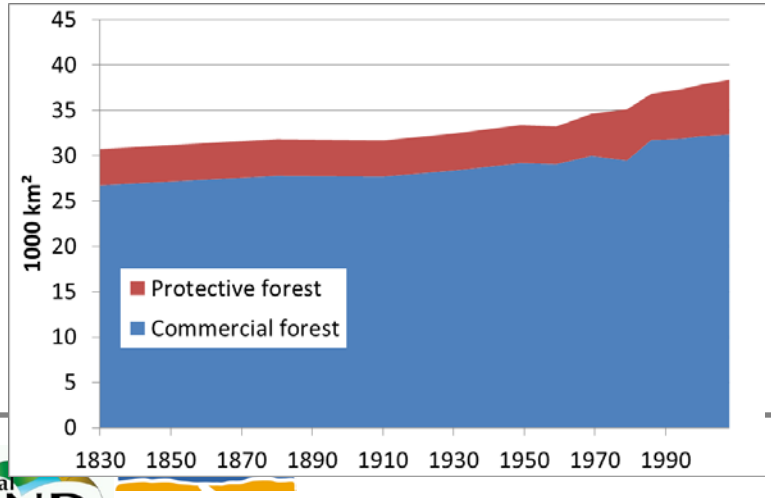


Franziscaen Cadastre

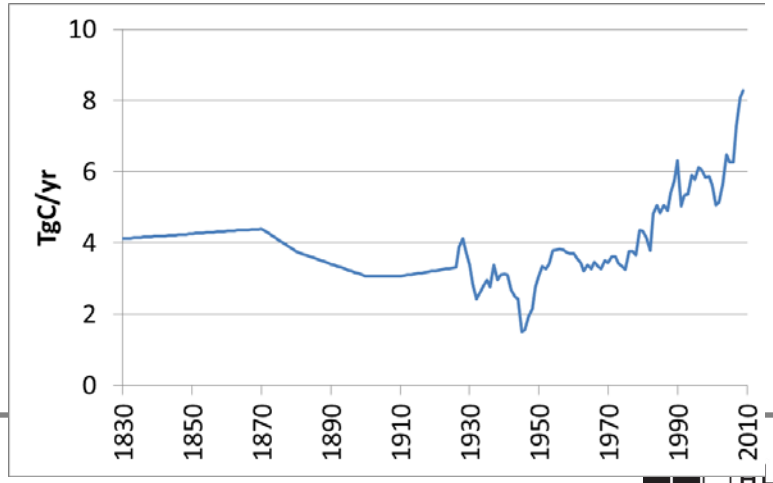


Forest inventories 1950 - 2006

Forest area

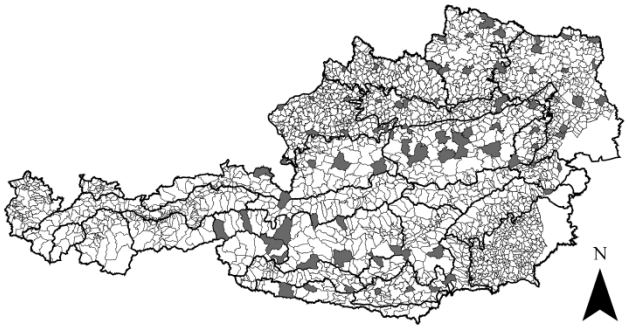


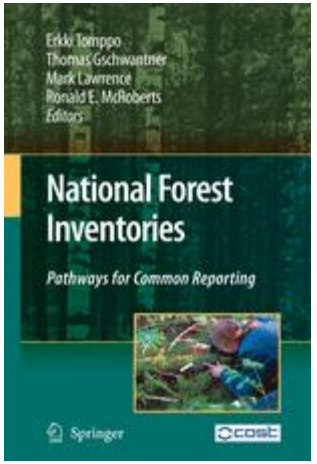
Forest harvest



Source: Gingrich et al. REC 2007

Carbon stocks in Austria‘s vegetation, 1830-2000





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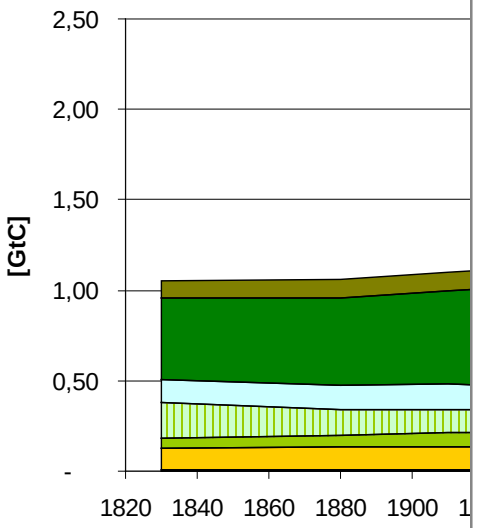
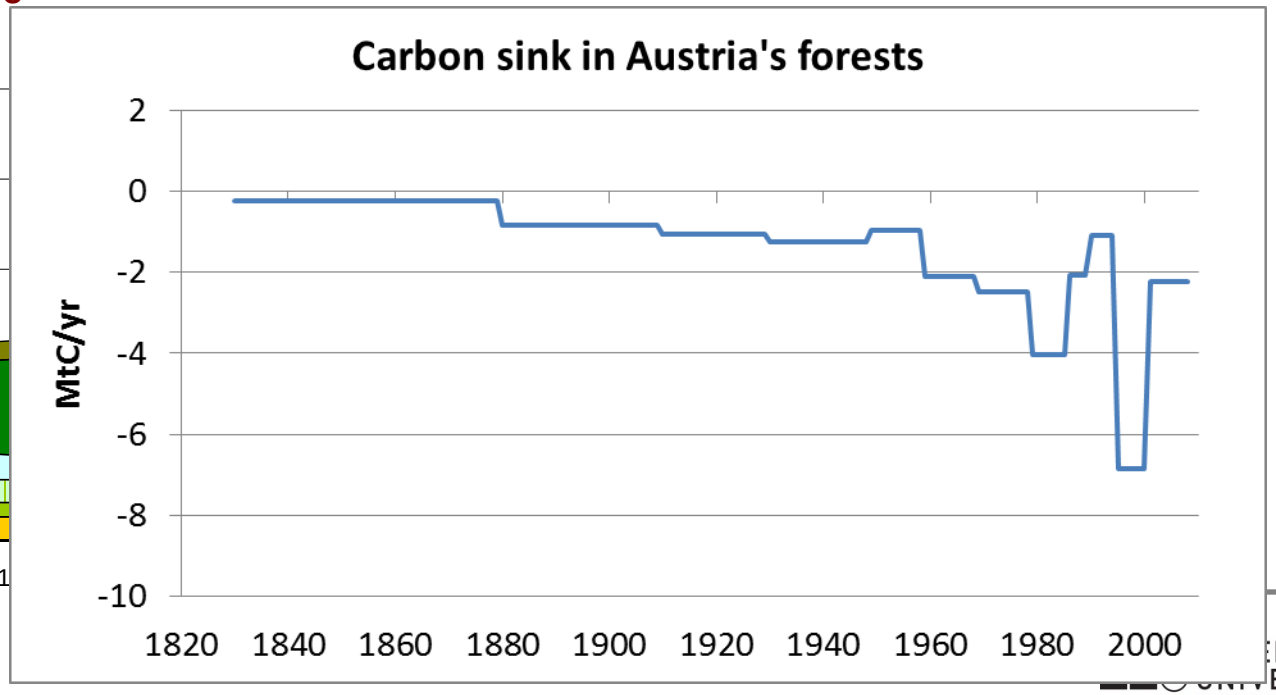
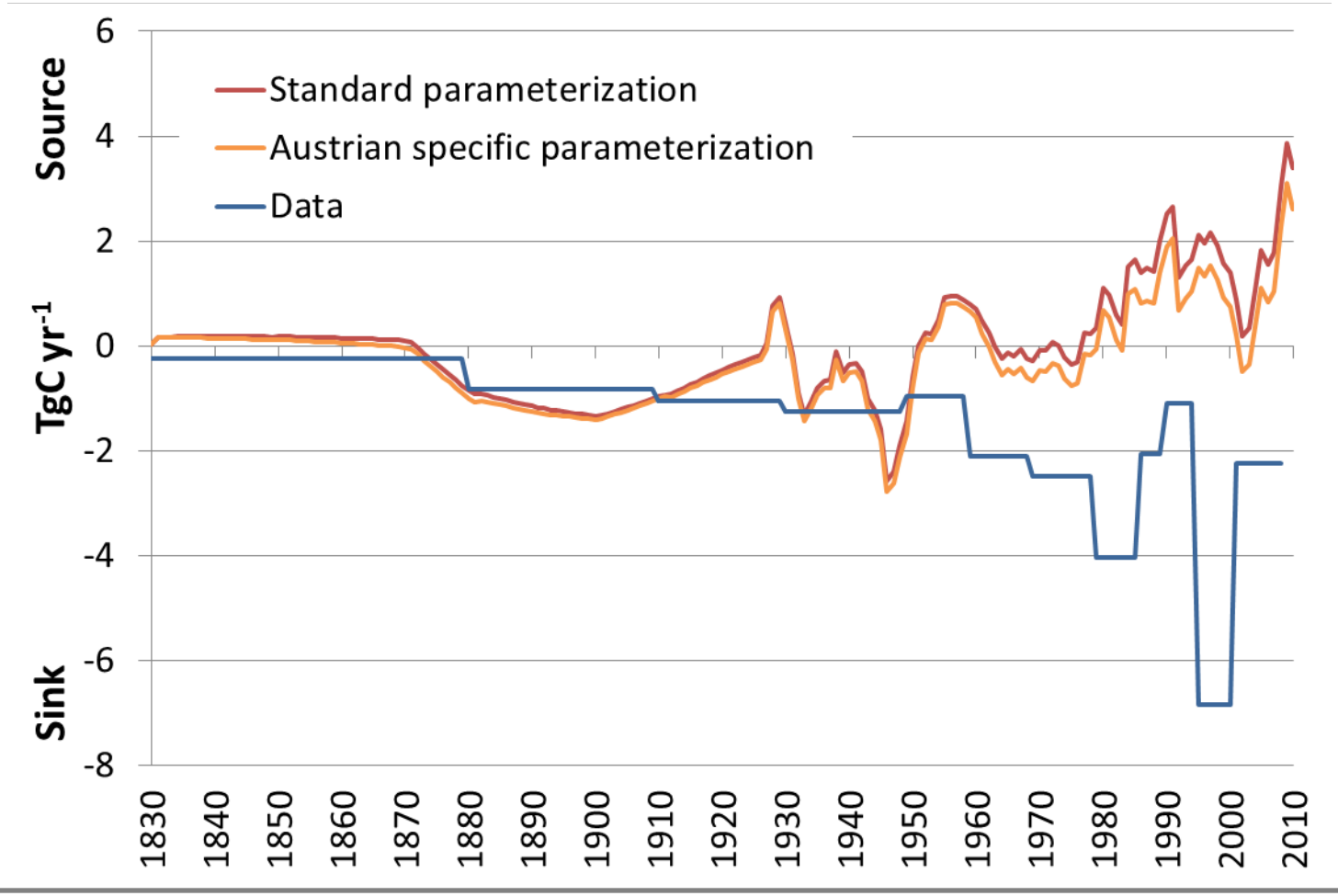


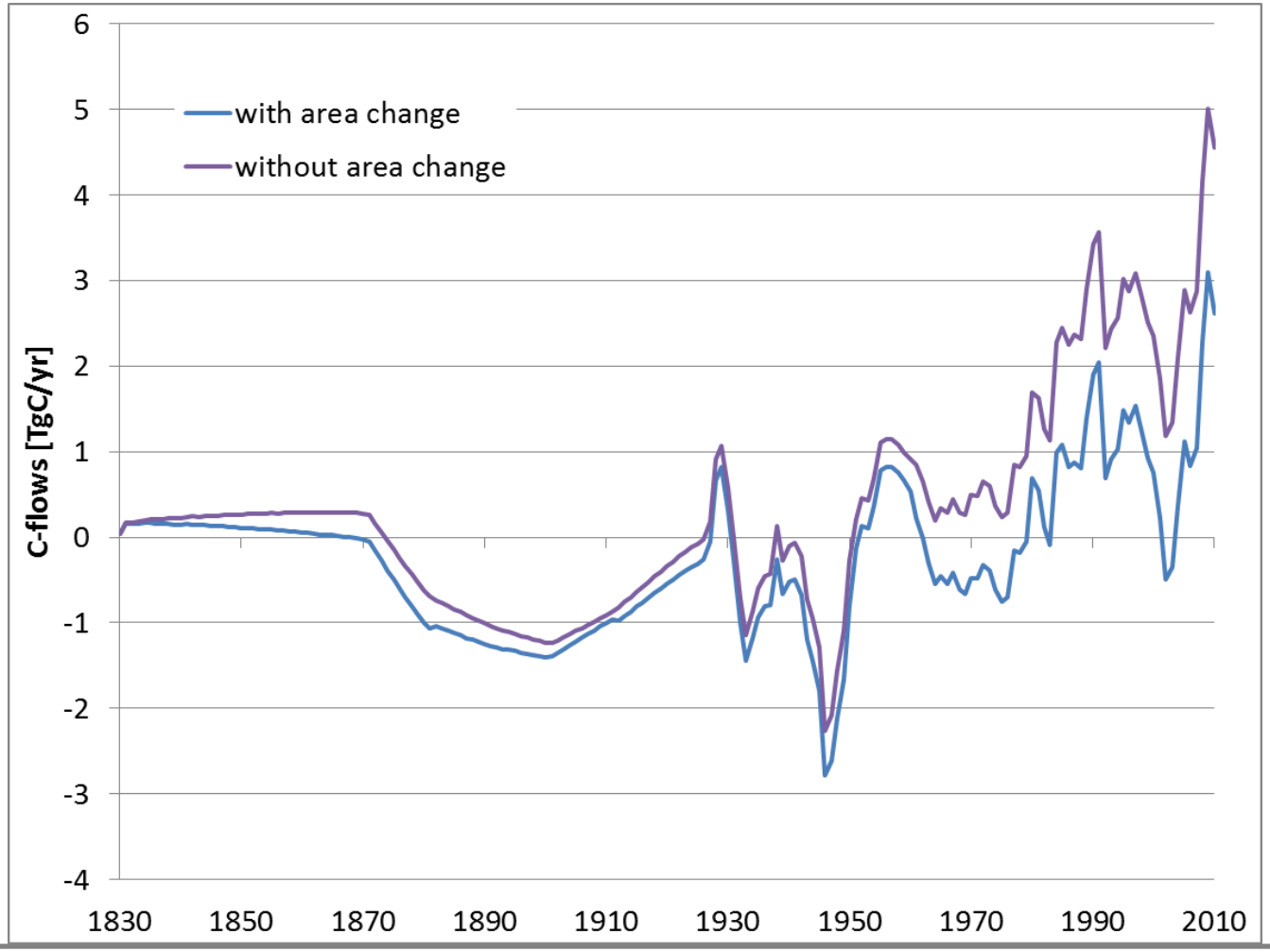


Source: Gingrich et al. REC 2007

Application of the bookkeeping model to the Austrian land-use/wood harvest database

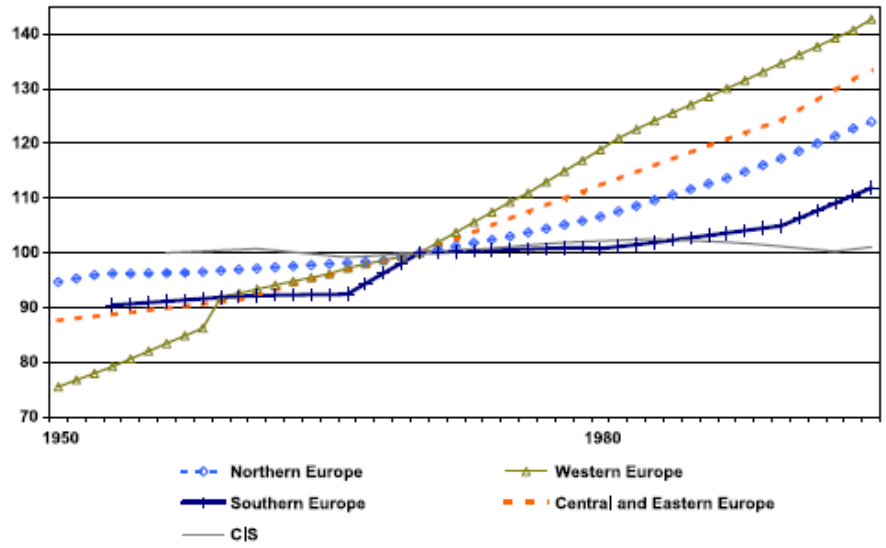


Area increase– cannot explain the result

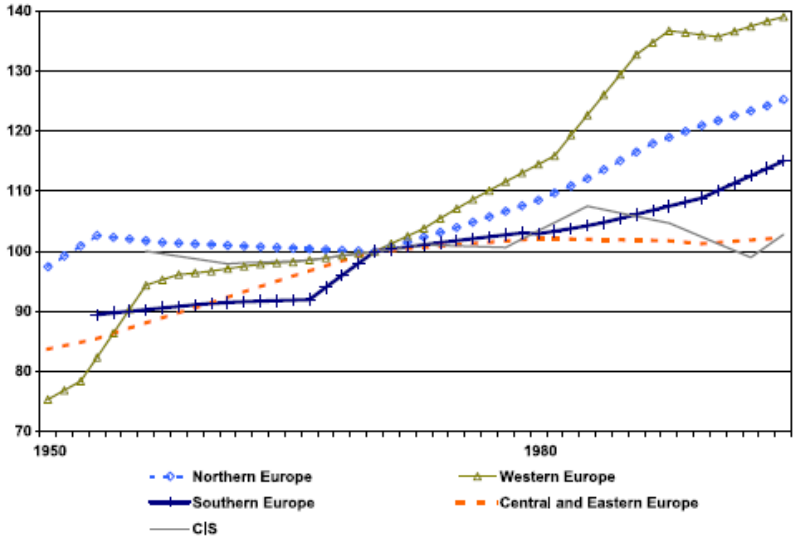


But what is it then?

S. Gold et al. / Forest Policy and Economics 8 (2006) 183–192



Graph 2. Development of growing stock (per ha) in Europe by regions (1970=100%).



Graph 3. Development of net annual increment (per ha) in Europe by regions (1970=100%).

Drastic increases of growing stock per ha, in particular after 1950 – due to increases in increment per ha

This phenomenon is not implemented in the bookkeeping model, all forests show the same Growth pattern across time.

Drivers for this change:

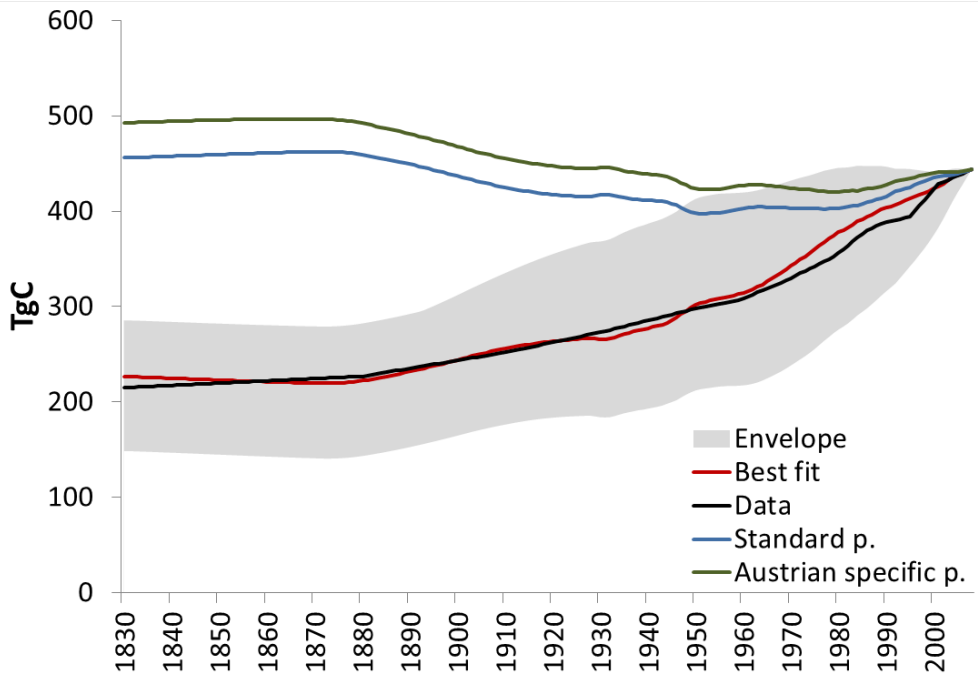
a) cessation of forest uses like forest grazing, litter raking, lopping
b) maybe also changes in tree demography due to reduced harvest levels in the late 19th century

Modulation of C-stock increase

- Modulation 1: Carbon stock is 20%, 30%, 40%, 50%, 60%, 70%, 80% in 1830 of value in 2010
- Modulation 2: Increase of C-Stock starts 1800, 1810, 1820, … , 1950, 1960 (NB. 50 years of „recovery time“ means that this is effective only 50 years later)

- Results in 119 „scenarios“

Top 20 scenarios

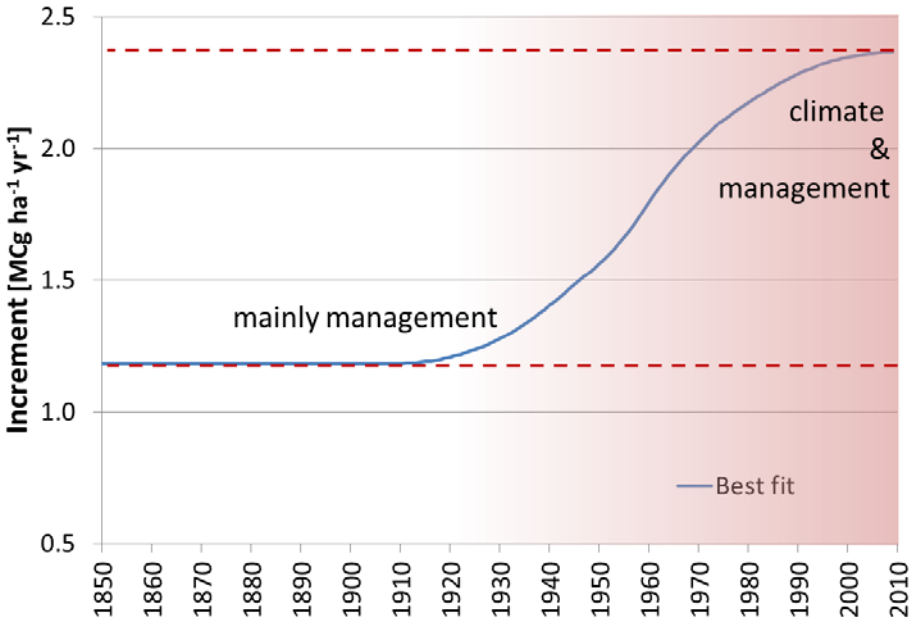


Least square fit (standardized to 1910 – 50%)

Start year of carbon density increase

Initial Standing biomass [% of 2000]	1880	1890	1900	1910	1920	1930	1940	1950	1960
20%	848.3	774.9	711.8	677.8	583.9	478.3	383.1	282.8	149.8
30%	221.8	189.7	162.1	140.3	108.3	79.4	57.7	39.5	22.0
40%	54.0	40.7	29.7	21.1	12.6	7.9	7.4	9.5	17.2
50%	9.6	5.3	2.3	1.0	1.9	5.5	11.4	18.6	31.1
60%	7.3	7.2	7.9	9.9	14.1	20.0	27.0	34.5	45.8
70%	20.7	22.2	24.2	27.2	31.8	37.4	43.5	49.5	58.1
80%	39.6	41.3	43.3	45.9	49.6	53.7	58.0	62.0	67.6

But what does this mean?



1. Carbon stock at harvest time most likely started to increase in 1950
2. Increment started to increase already in 1910 (50 years of recovery time
3. This increase can hardly be influenced by changes in environmental conditions (started to be effective around 1950)
4. Questions attribution of the carbon sink in returning forests to GEC
5. Quantification of the „residual sink“ in standard assessments may be wrong

Conclusions

- Long-term changes in land systems intimately related with changes in socioeconomic metabolism, above all changes in energy systems
- Increases in area efficiency and biomass-use efficiency can be seen across Europe, but these are causally linked to the transition from agrarian to industrial energy system (fossil fuels)
- Institutional changes are related – and modulate – these socioecological ‚megatrends‘
- Role of land use, also ‚subtle changes‘ needs to be reconsidered when attributing observed changes to socioeconomic and biophysical drivers

Thanks for your attention