Landsystems and their use
– Challenges of Tomorrow -

Uwe Schneider & Reinhard F. Hüttl &

GFZ German Research Centre for Geosciences, Potsdam

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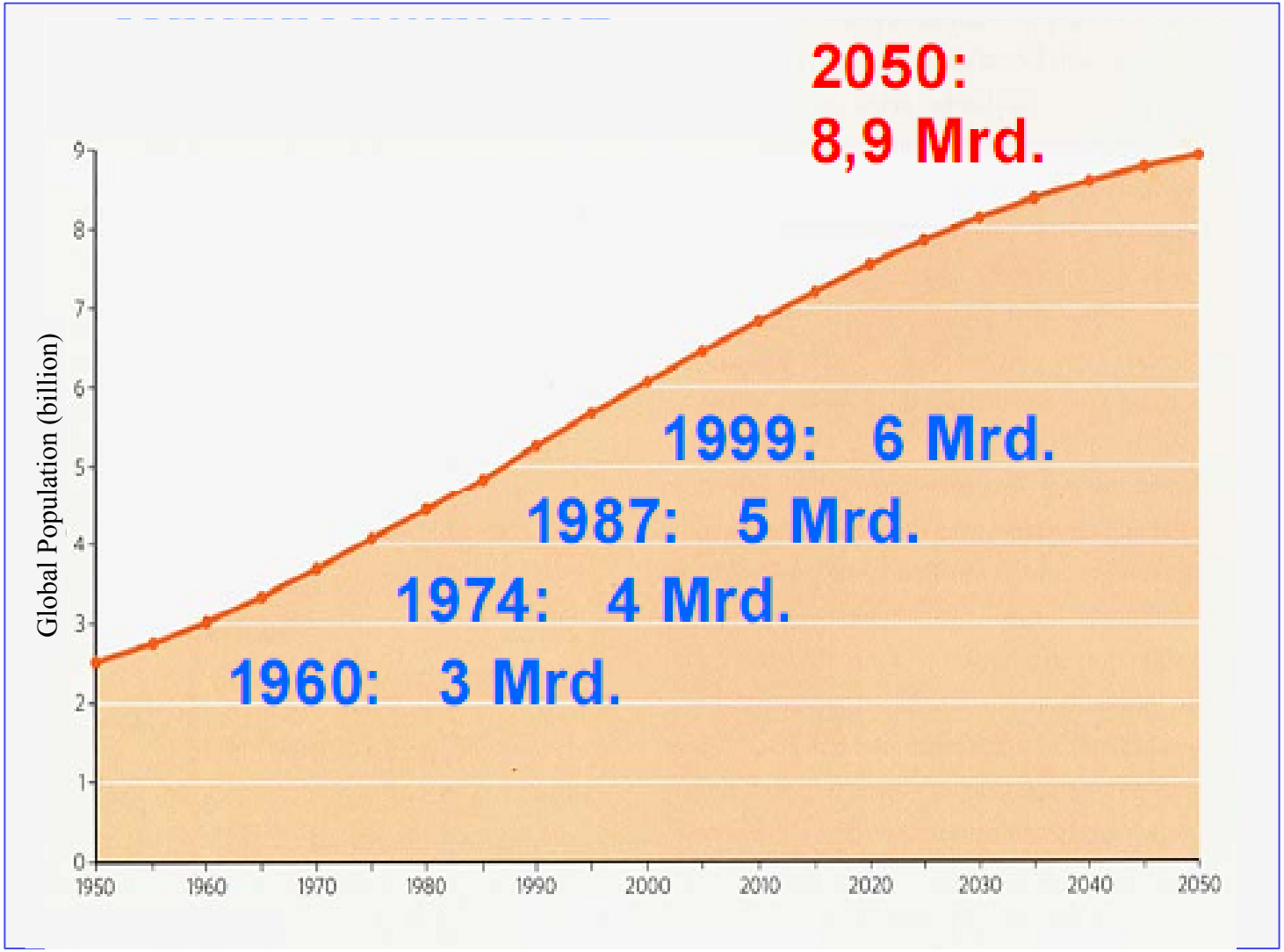
Increase of the Global Population between 1950 and 2050



Source: UN

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Boden in den Medien

Kampf ums Ackerland: Länder wie Kuwait und China pachten weltweit Flächen, um die eigene Bevölkerung zu ernähren

Im Märzen der Forsch… er

ZEIT ONLINE | WIRTSCHAFT

AGRARWIRTSCHAFT

Land für die große Spekulati…

Mehr Menschen, mehr Hunger – und nur eine Erde: Investoren… Europa bis Afrika Ackerland auf, um sich Ernten und Rendite…

von Anna Marohn | 11. Februar 2010 - 07:00 Uhr

Bernhard Termühlen will partout kein Bauer sein – obwol… wie einer zu wirken. Sein gebräunter Teint sieht weniger … dem Feld aus als nach Sonnenbank, und in Gummistiefe… Exvorstand des Finanzvertriebs MLP auch …

Wertvoller Boden

Die Haut der Erde

Von Christiane Grefe

Raubbau und Klimawandel … Revolution" muss her

…wolde Berhan Gebre Egziabhe… Denken, sagt der äthi… geprägt, …

Unsere Böden: Begehrt, bedroht, beschützt

Mangel an Böden

Verbaut, verwüstet, verloren

Von Martin Kotynek

Raubbau, Erosion und Beton verwandeln immer mehr Erdboden in Ödland. Damit steht die Ernährung der Welt auf dem Spiel. Teil 1 einer neuen Serie zu den versiegenden Ressourcen der Erde.

…ge seiner … zu trocken, zu … oder dauernd gefroren. … wird – neben Wasser – zu ei… nem der knappsten Güter des 21. Jahr… hunderts, prophezeit der Agrarjournalist

Versteppung in China

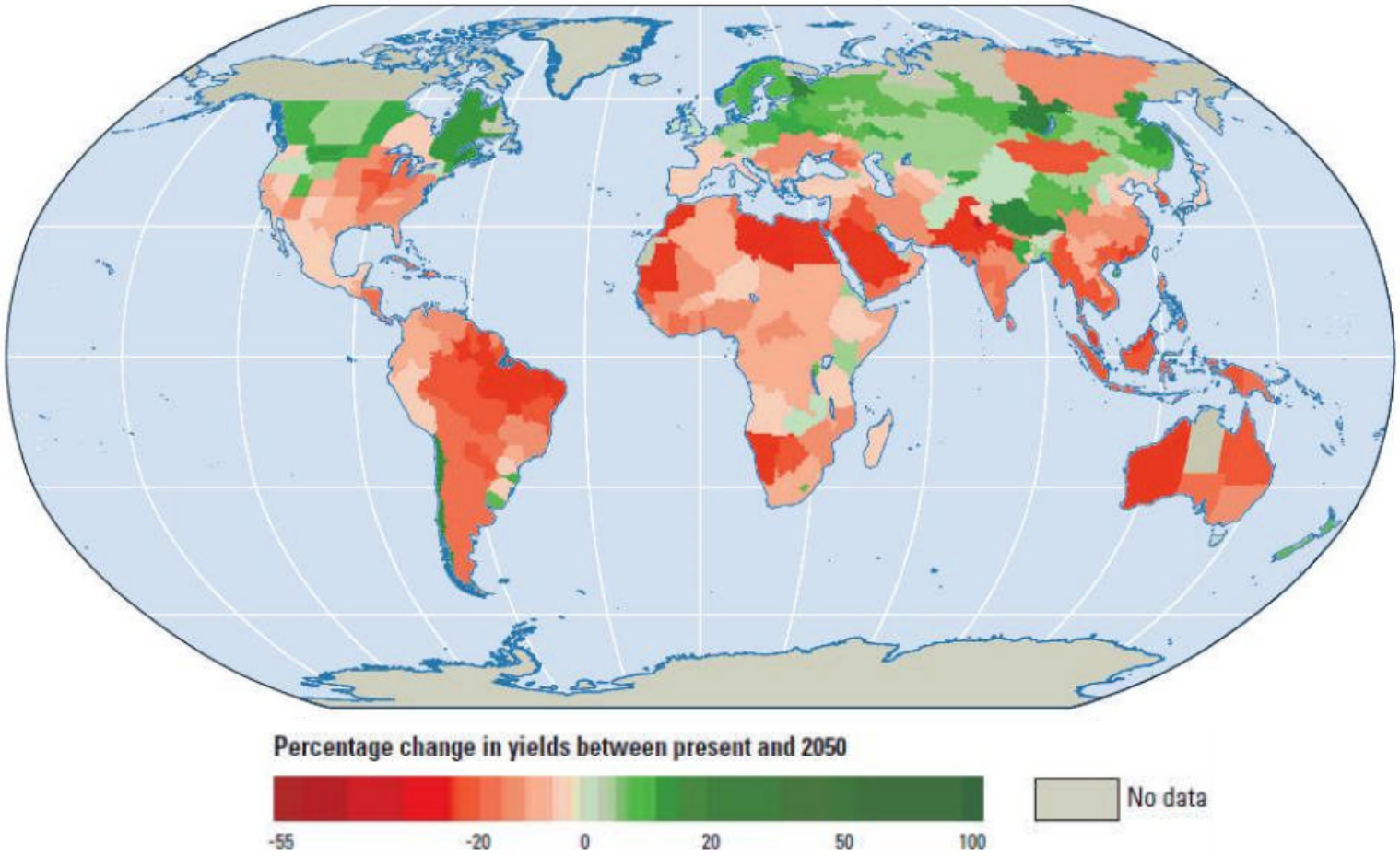
Eine Schüssel Wasser pro Tag

Protokoll: Henrik Bork

Millionen Chinesen sind schon geflüchtet, doch der Bauer Xu Ka… kämpft weiter gegen die Wüste.

Klimawandel – Biomasseproduktion

- Veränderungen der landwirtschaftlichen Erträge bis 2050



Quelle: Müller et al., 2009; World Bank, 2008

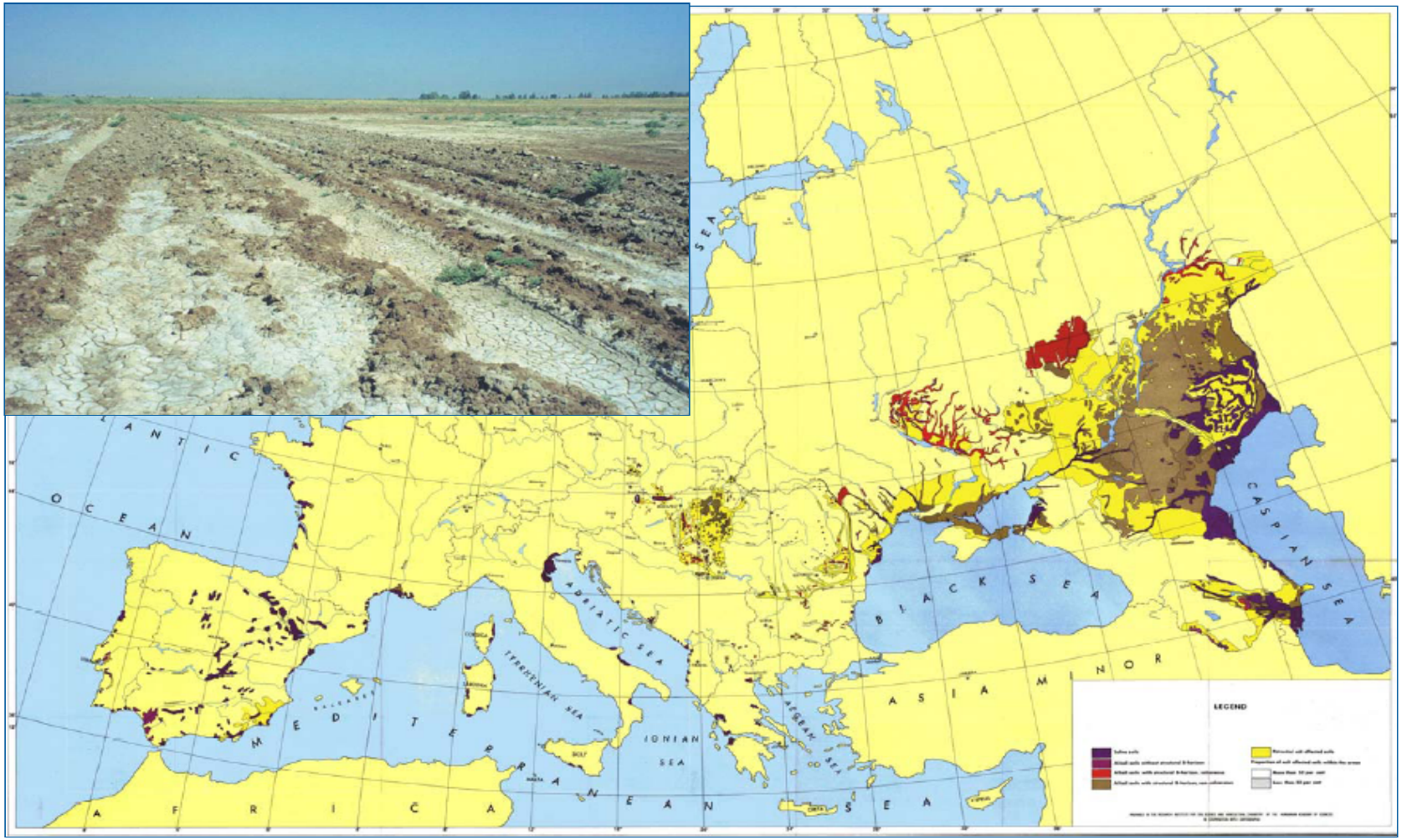
Note: The figure shows the projected percentage change in yields of 11 major crops (wheat, rice, maize, millet, field pea, sugar beet, sweet potato, soybean, groundnut, sunflower, and rapeseed) from 2046 to 2055, compared with 1996–2005. The values are the mean of three emission scenarios across five global climate models, assuming no CO_2 fertilization (a possible boost—of uncertain magnitude—to plant growth and water-use efficiency from higher ambient CO_2 concentrations). Large negative yield impacts are projected in many areas that are highly dependent on agriculture.

Degradation – Erosion

Although there is consensus that soil erosion is often a severe problem, there are few systematic measurements of its extent and severity. Indicators include barren ground, removal of topsoil as sheet erosion over a wide area or concentrated as rills and gullies, or through landslides.

(UNEP Report GEO4)

Degradation – Bodenversalzung in Europa



Quelle: European Commission, 2006

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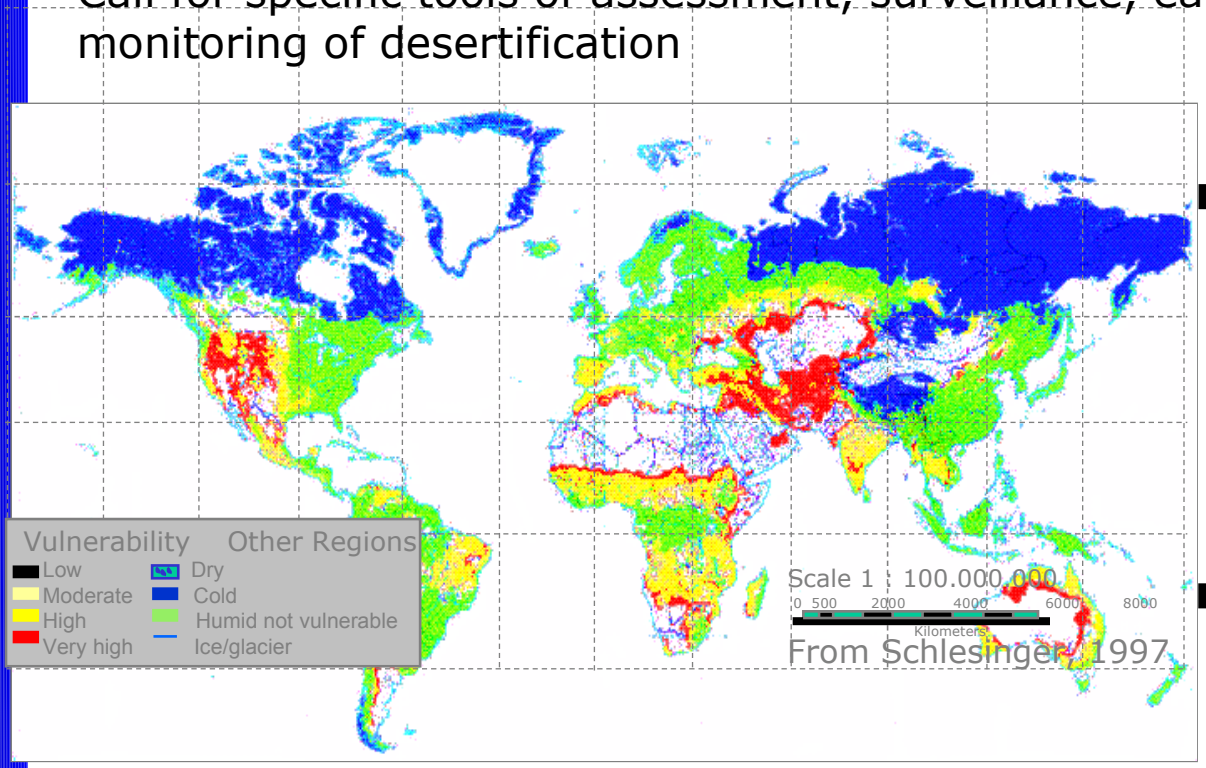
Desertification and land degradation activities

UNCCD United Nations Convention to Combat Desertification

- UNCCD ratified by almost 200 nations
- Call for specific tools of assessment, surveillance, early warning and monitoring of desertification



Global desertification vulnerability

→ Accurate assessment of surface properties & monitoring of surface changes (bio- and geophysical variables)

→ Modelling of erosion and land degradation processes

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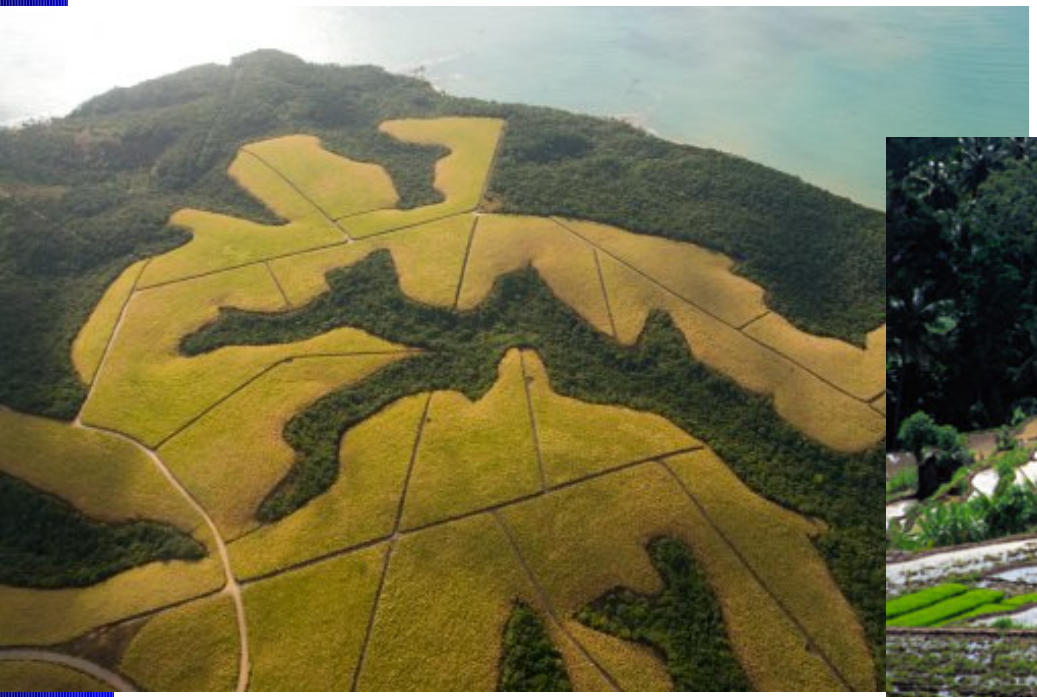
Einfluss von Landnutzung auf die Freisetzung von Treibhausgasen aus Böden

Zuckerrohrplantagen



Reisanbau

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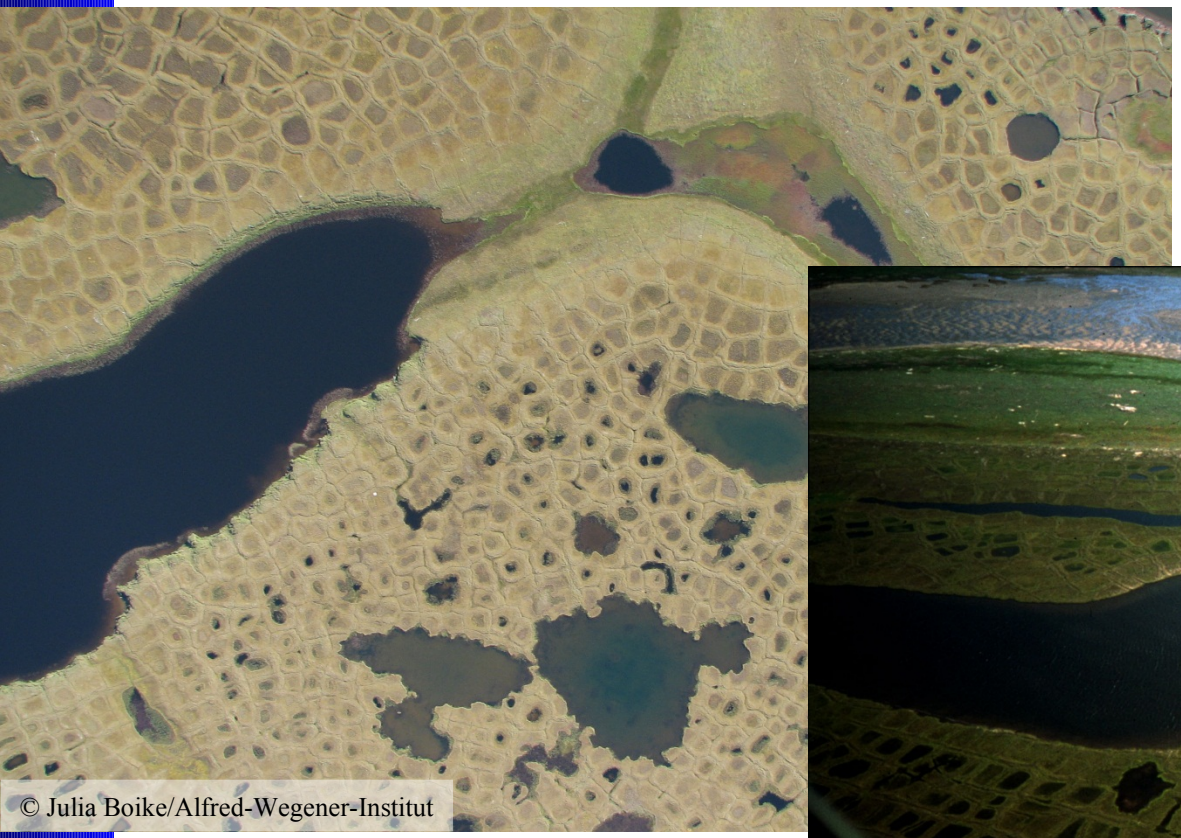
Einfluss von Landnutzung auf die Freisetzung von Treibhausgasen aus Böden

Rapsanbau

Maisanbau

Einfluss von Landnutzung auf die Freisetzung von Treibhausgasen aus Böden



Permafrostböden

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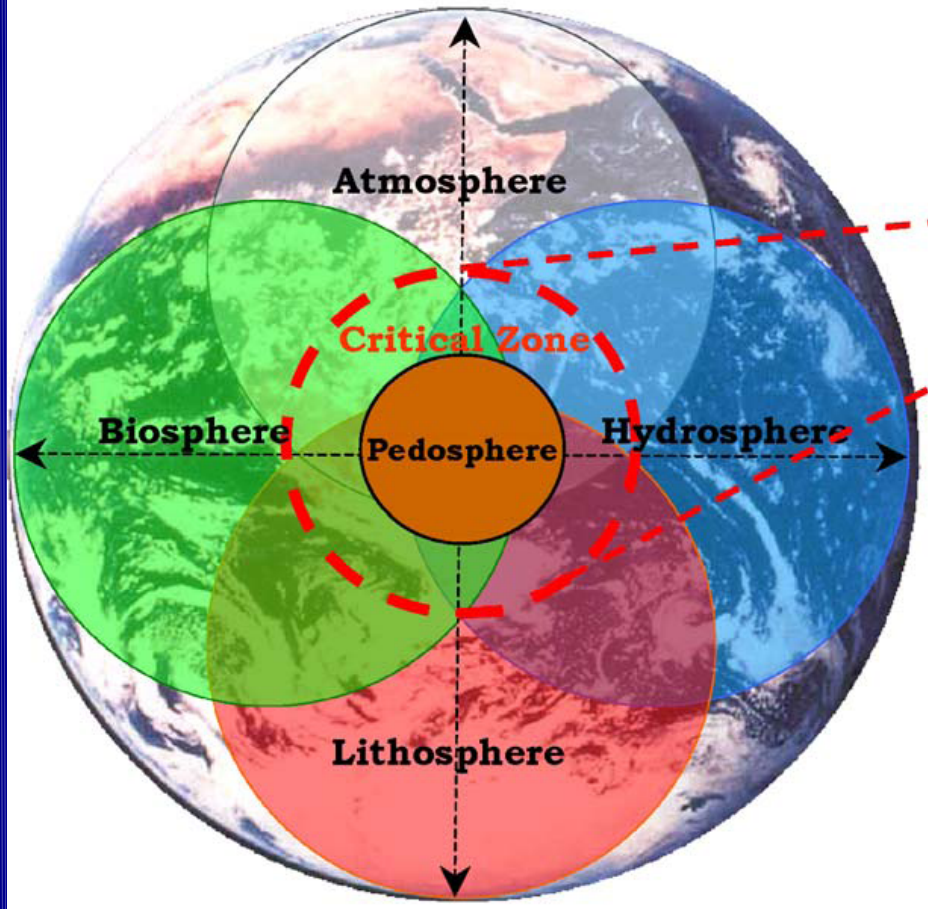
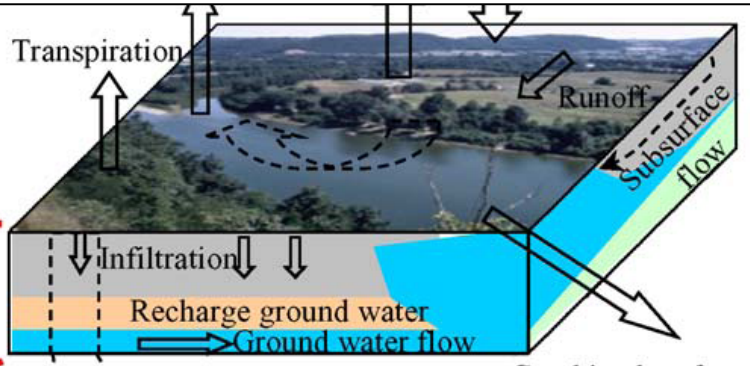
Motivation

The soil carbon content plays a key role for the preservation and improvement of soil fertility as well as for the perpetuation of biodiversity and ecosystem stability.

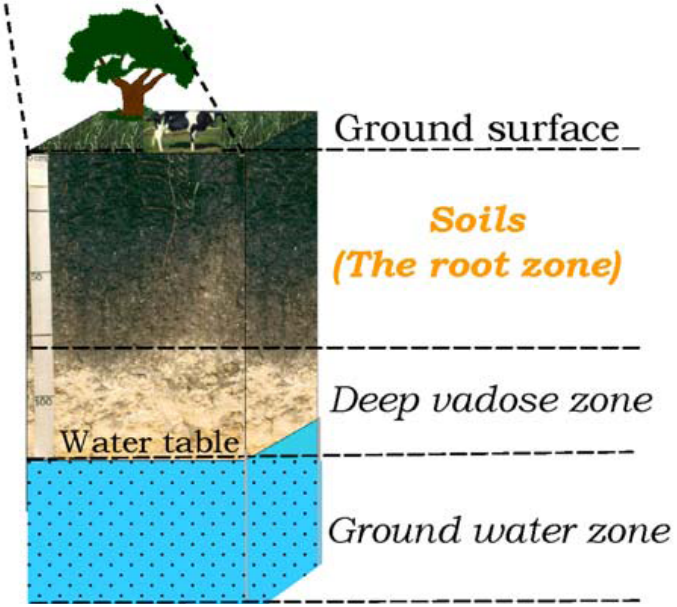
Therefore, major efforts are required to maintain or enhance the fixation and stabilisation of carbon in the soil-plant-system.

Forschungsansatz: Critical Zone-Konzept



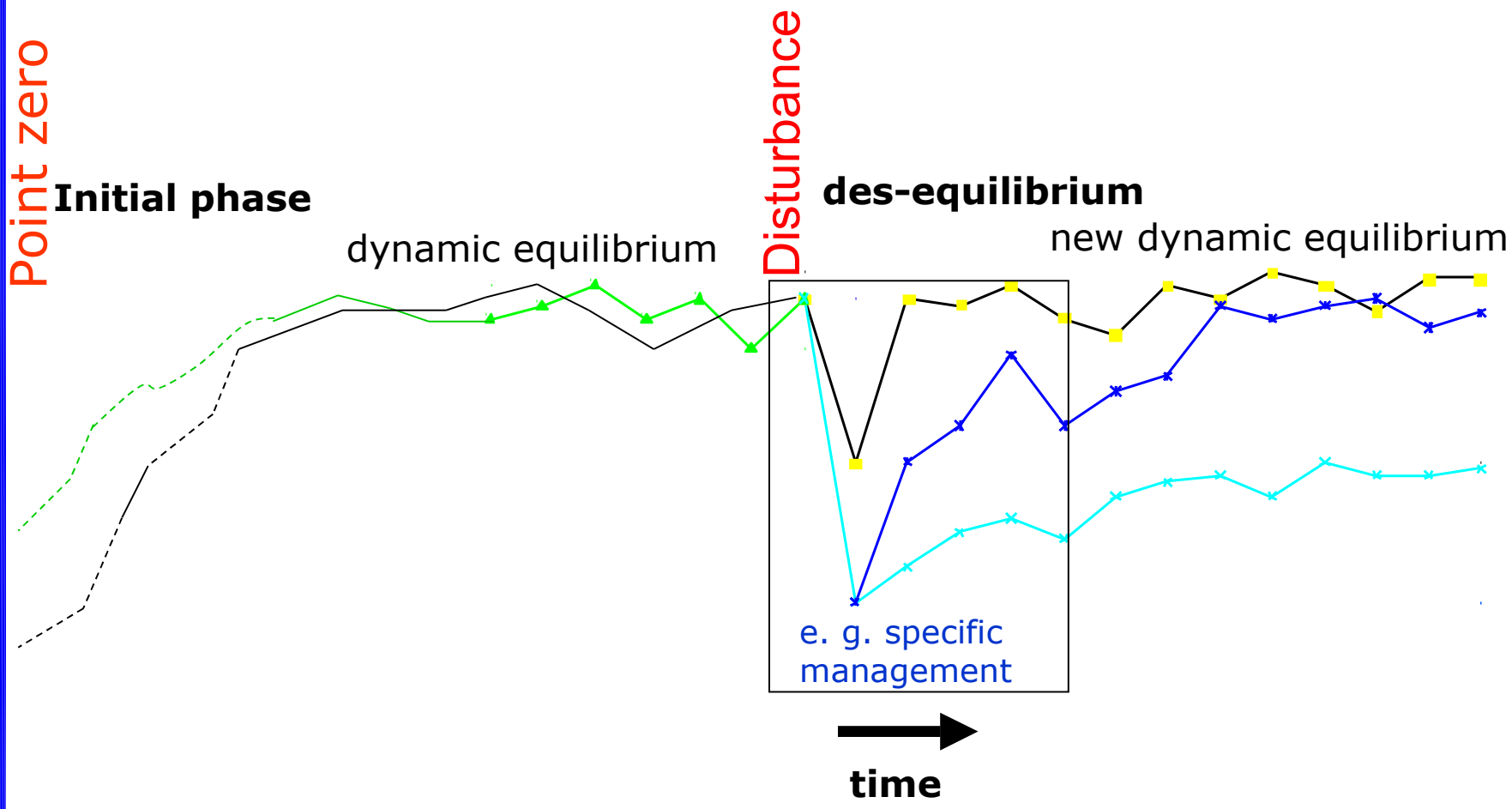


Combined surface and ground water flow to the ocean



Wilding & Lin 2006

Ecosystem Development



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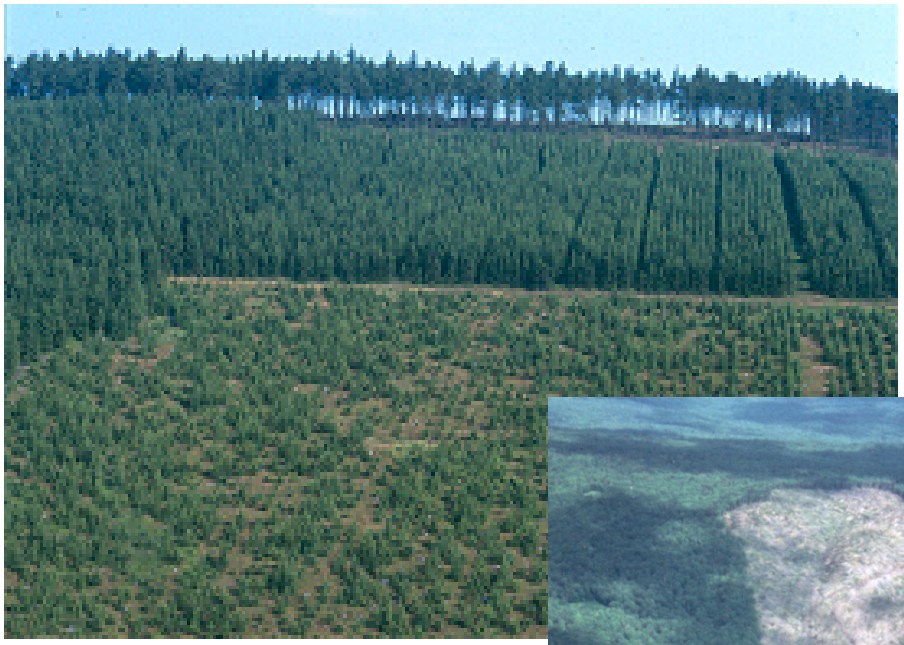
Forests and Forest management



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Forest Ecosystem disturbance

High-intensity surface and crown fire occurring in a forest with artificial structure and composition.

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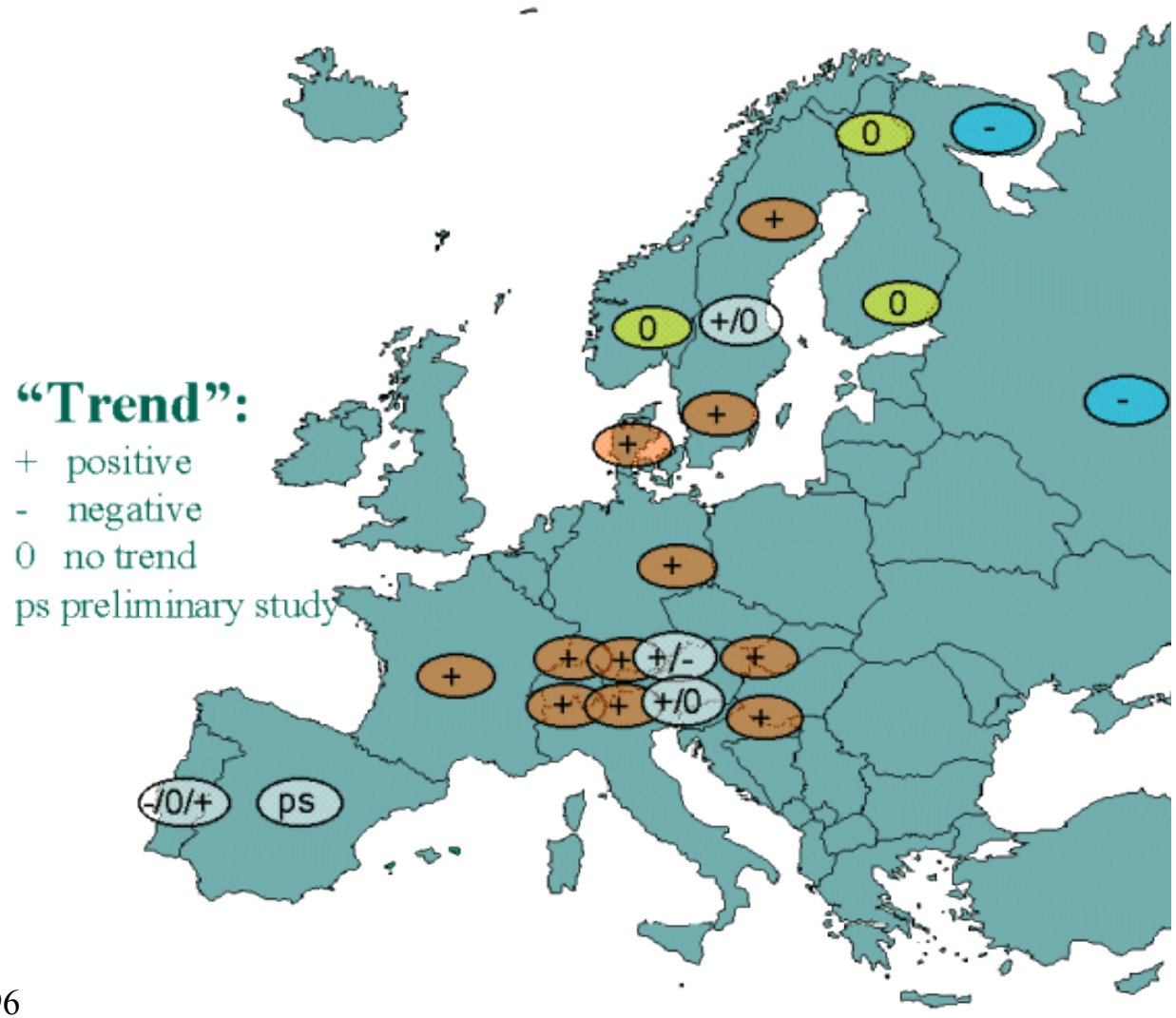
Growth trends in Europe



Spiecker et al. 1996

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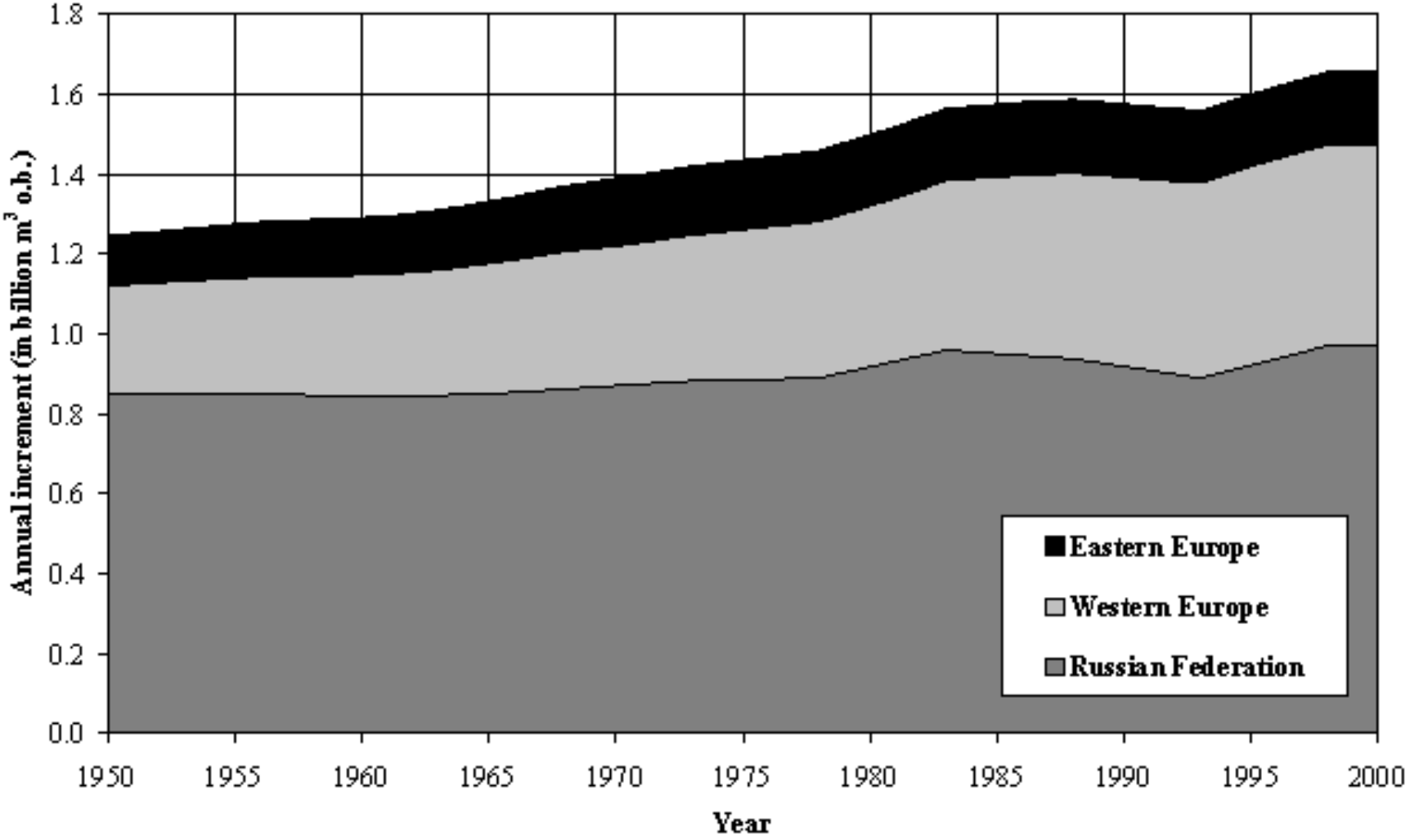
Trends in annual increment in selected European countries from 1950 to 2000



Source: www.fao.org/docrep/008/

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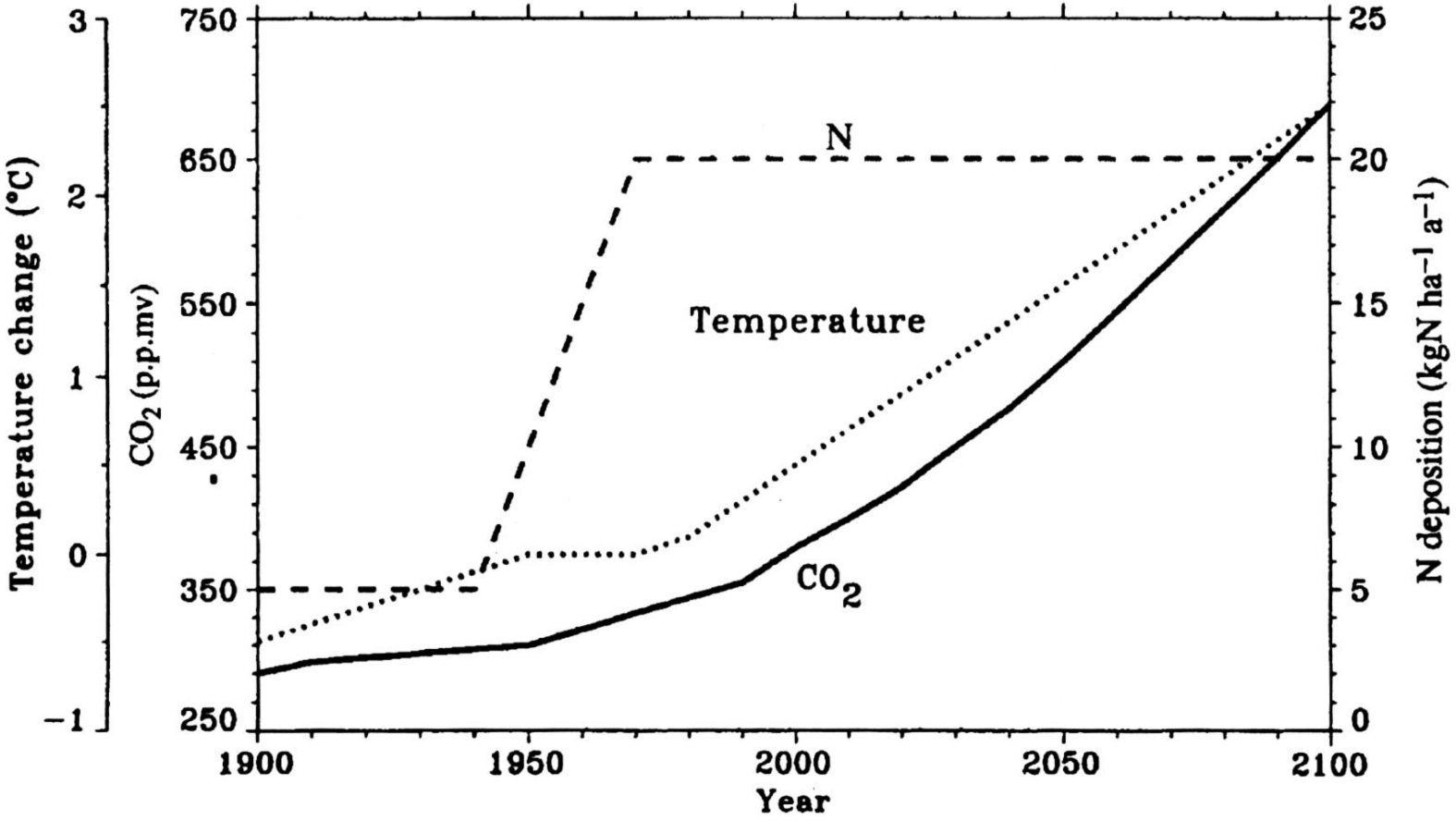
RECOGNITION

EU Project No. FAIR 6 CT98-4124

Relationship between recent changes of growth and nutrition in Norway spruce, Scot pine and European beech forests



To what extent does the global climate change, N eutrophication and elevated atmogenic CO_2 account for the growth of European forests?

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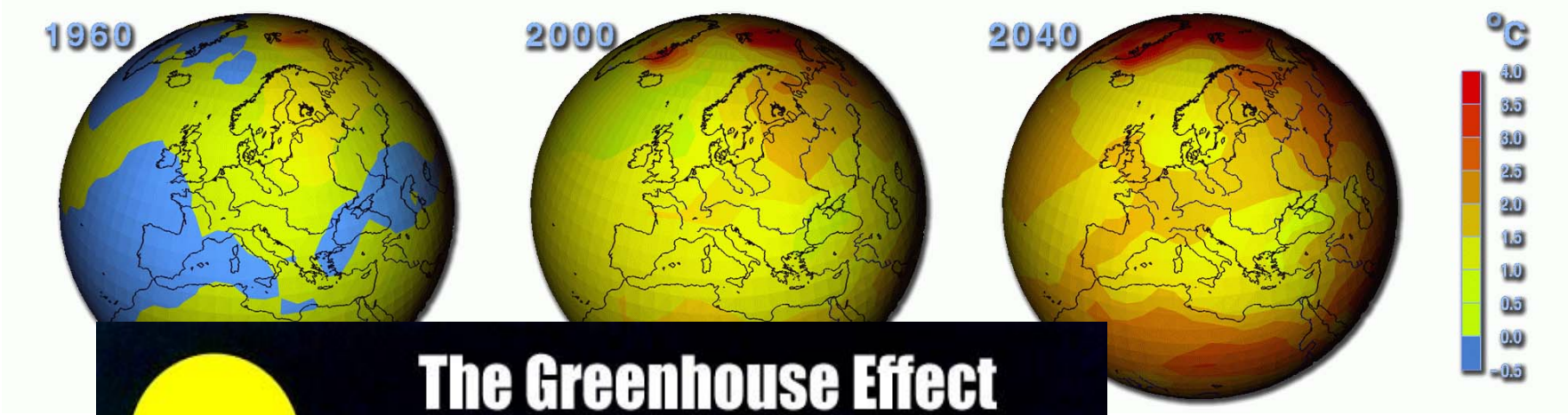
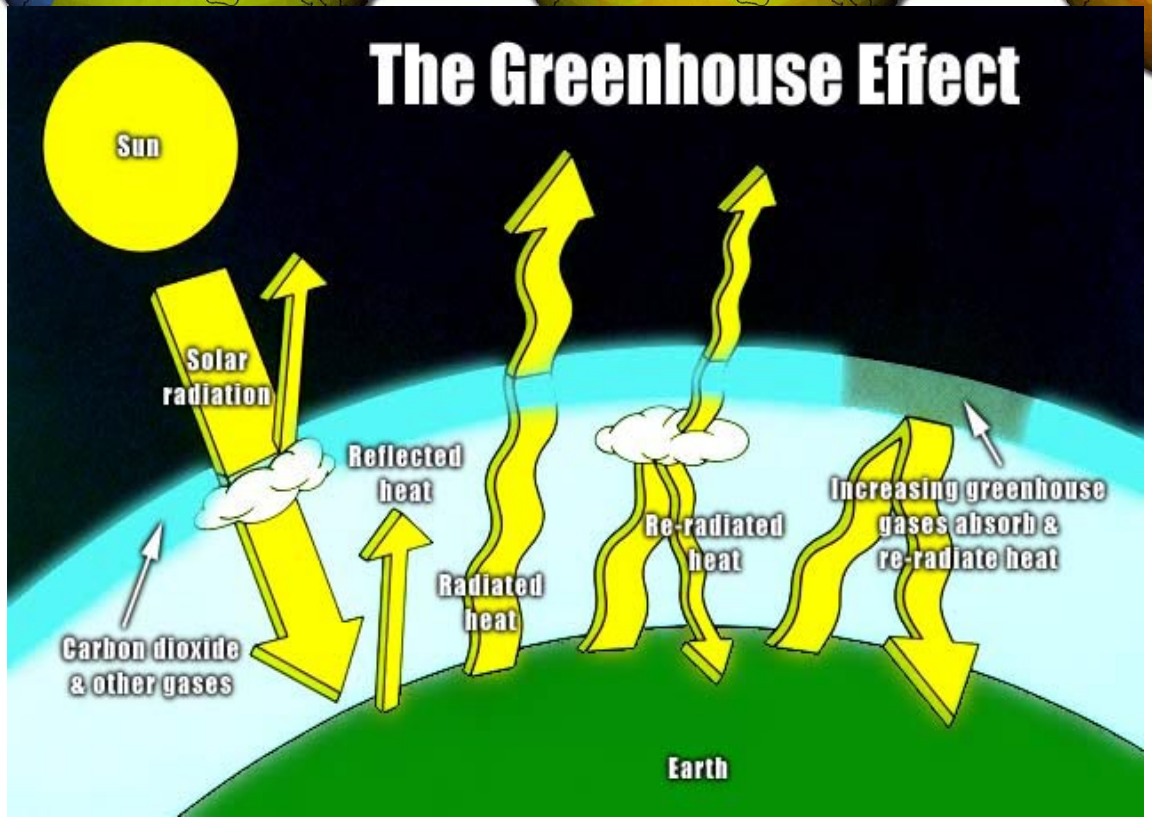
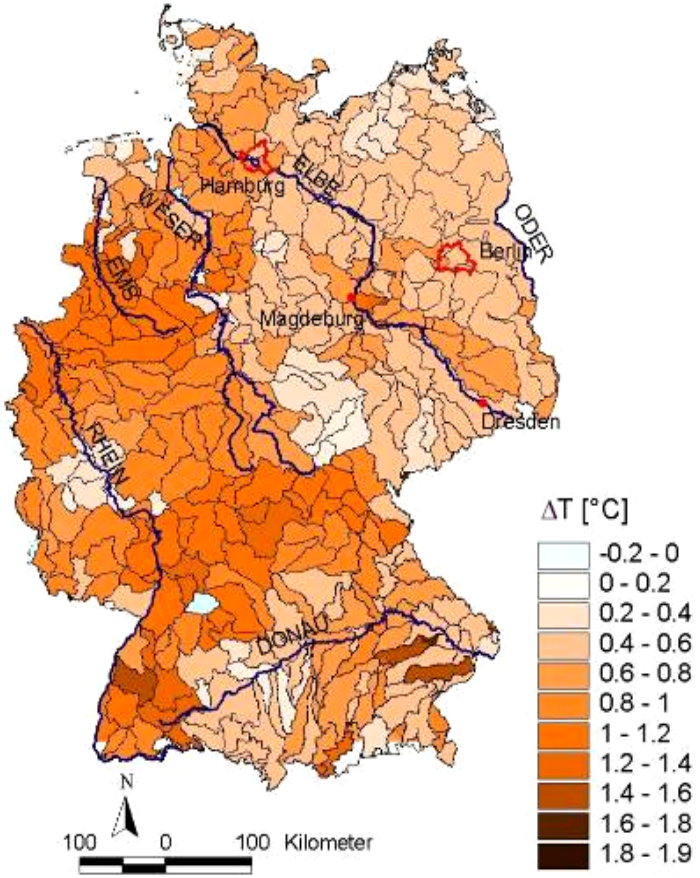
Global Warming



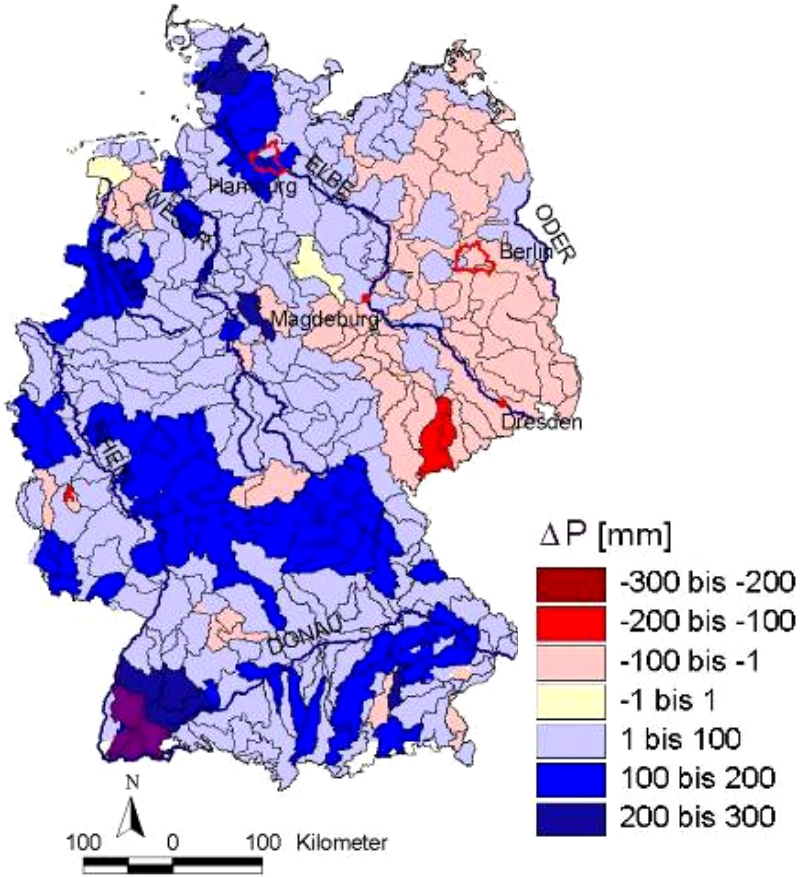


Disturbance: Climate Change Effects

Temperature scenario



Precipitation scenario

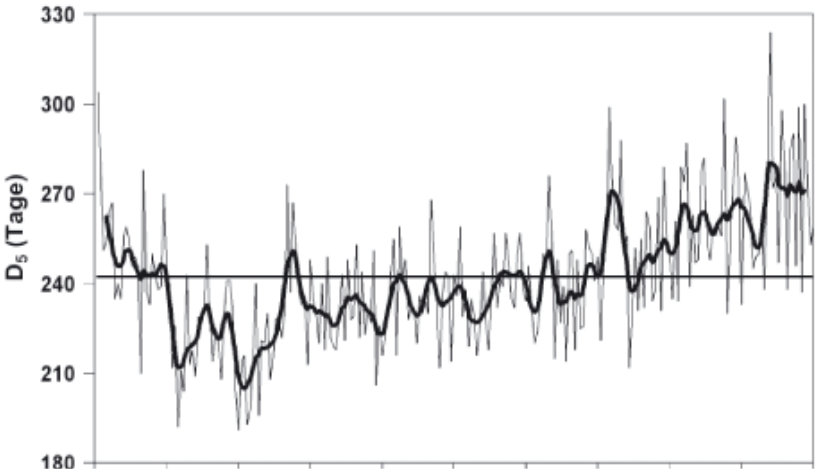


DWD, Gerstengarbe et al., 2003

Trend towards more Droughts during the Vegetation Period in Northeastern Germany

Change of the Environmental Conditions

Duration of the vegetation period

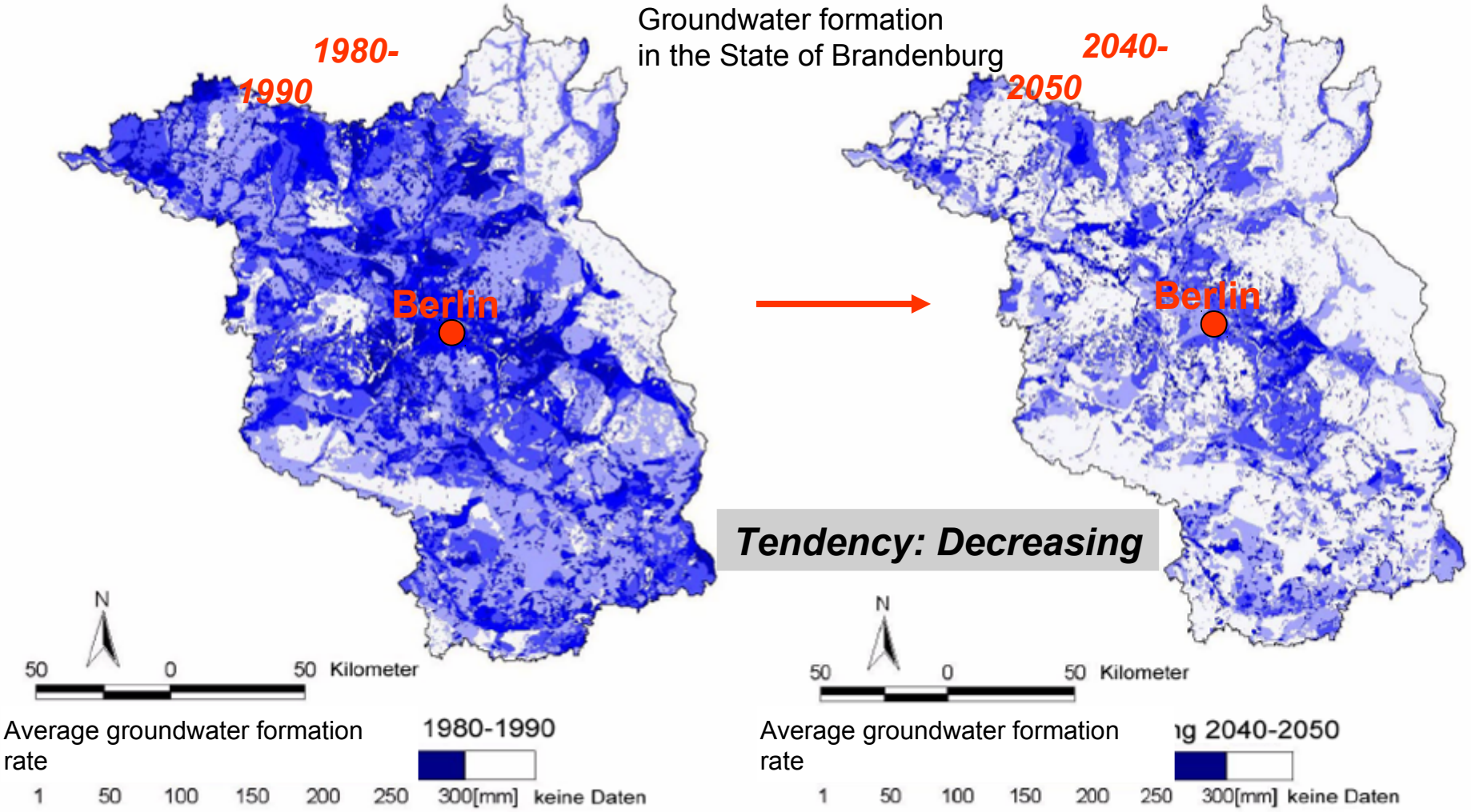


(Cubasch 2008)

Temperature increase

Extends the duration of the vegetation period and the rate of annual evapotranspiration

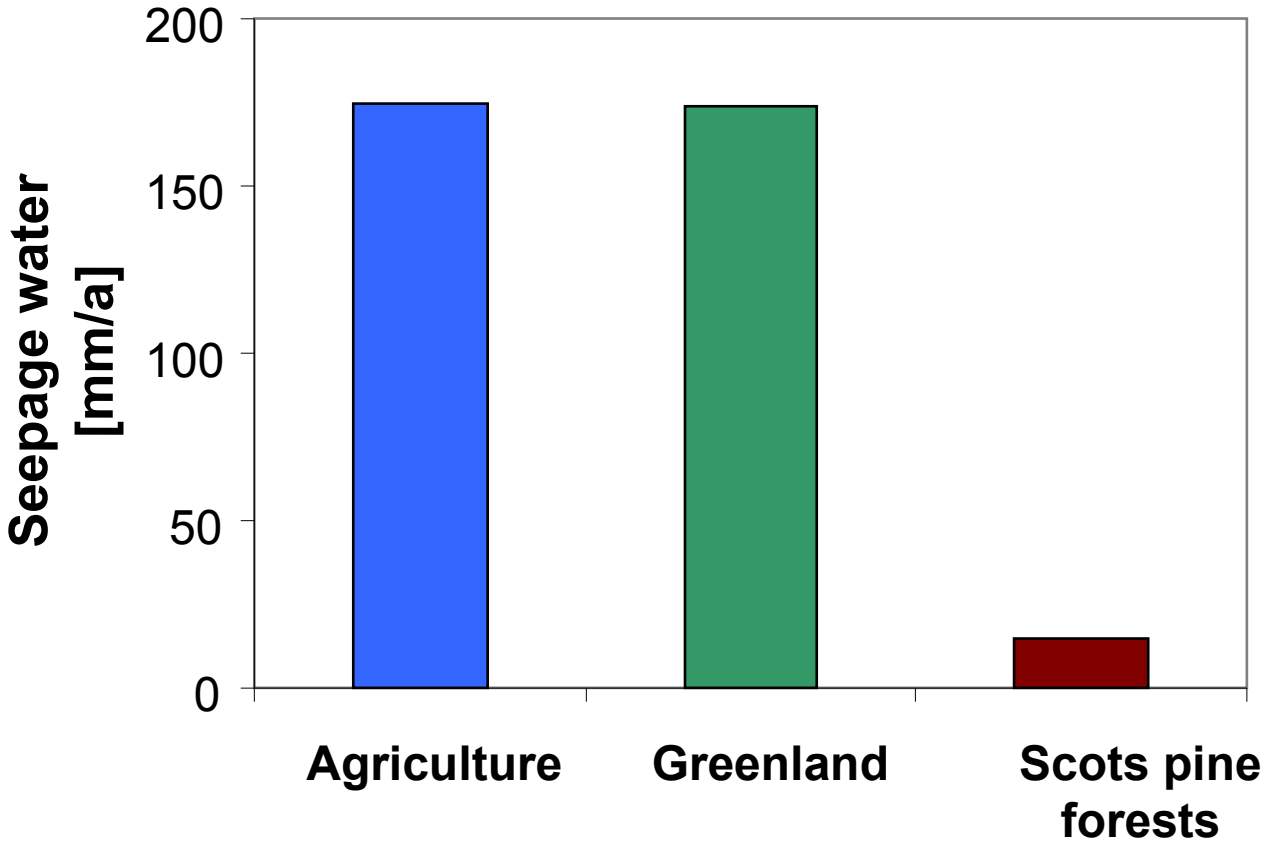
Consequences for regional development: Water availability will become a risk factor



(Source: Gerstengrabe et al. 2006)

Rate of Groundwater Formation

Site Müncheberg, 1995-2005 (Schindler et al. 2008)



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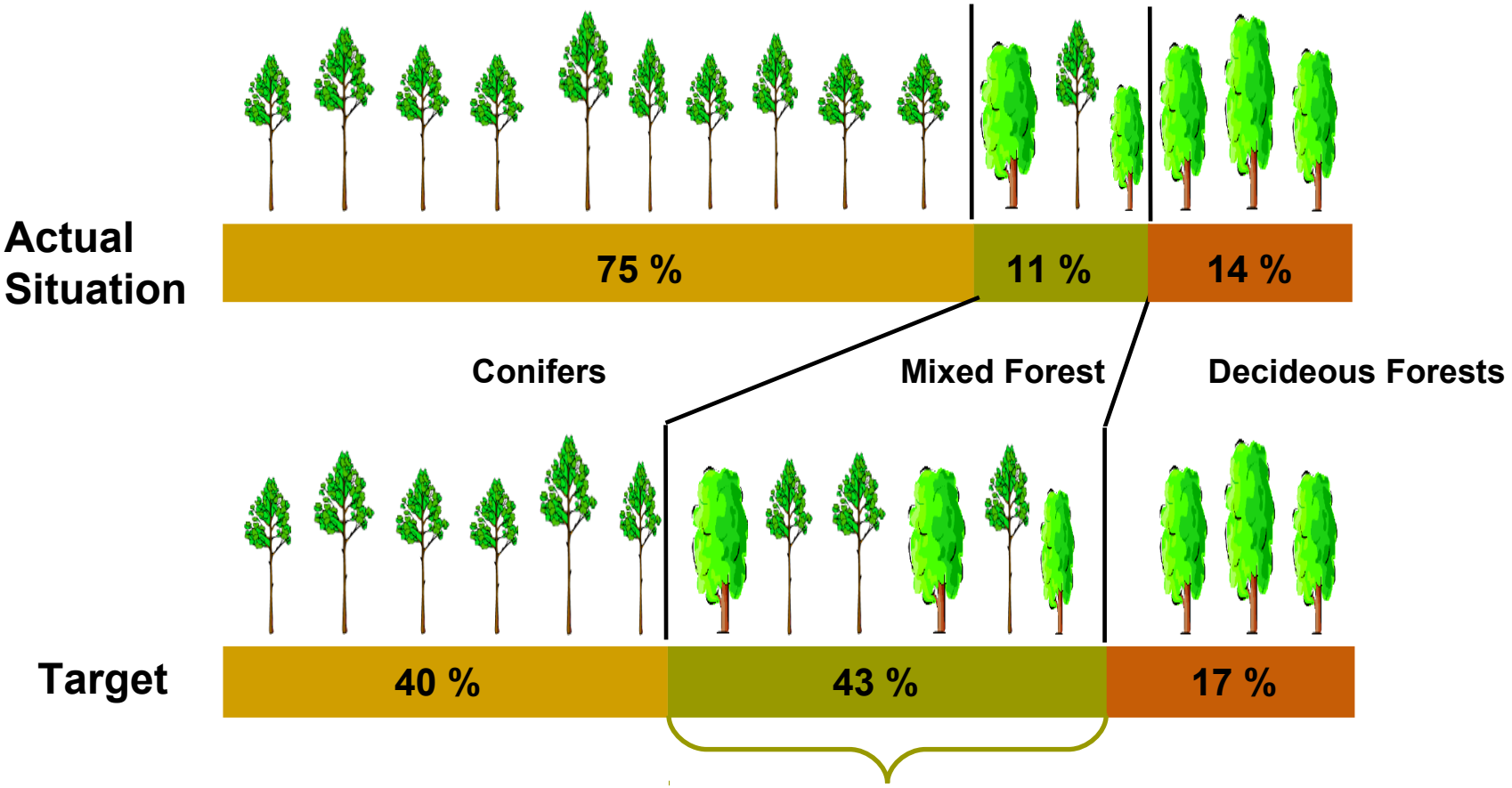
In Germany forest management aims at significantly increasing the share of semi-natural decideous mixed forests (here: State of Brandenburg).

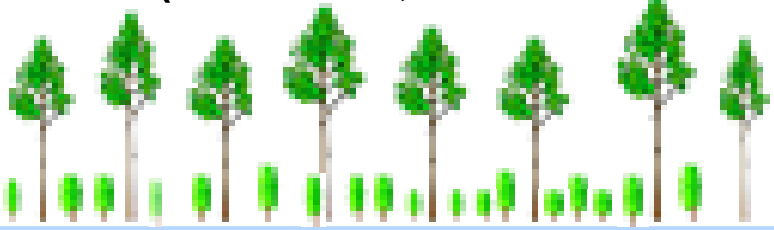


What can we learn from chronosequence studies on forest transformation ?

Forest Transformation: From Scots Pine to Beech

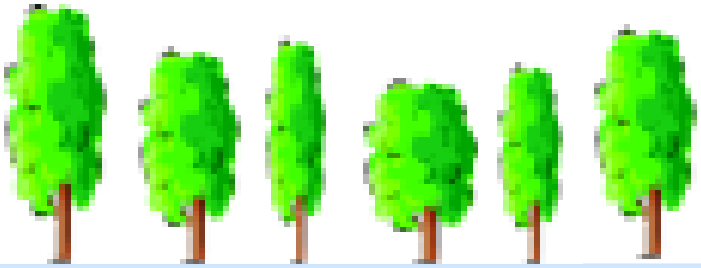
Monoculture Scots Pine (p 84)

Young transformation state (p/b34)
(S. Pine 76, Beech 34)



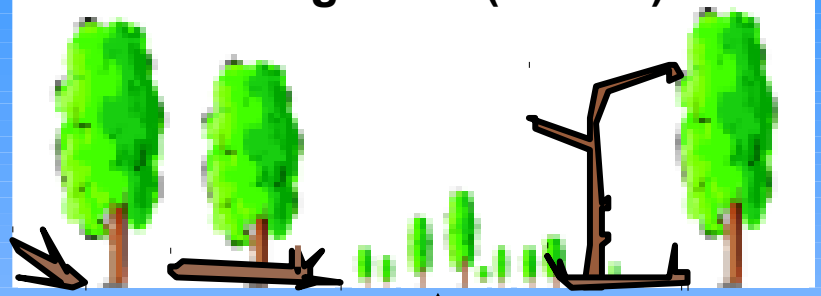
Advanced transformation state (p/b 57)
(S. Pine 114, Beech 57)

Beech (b 91)



Beech (b 140)

Beech - Old growth (b >180)



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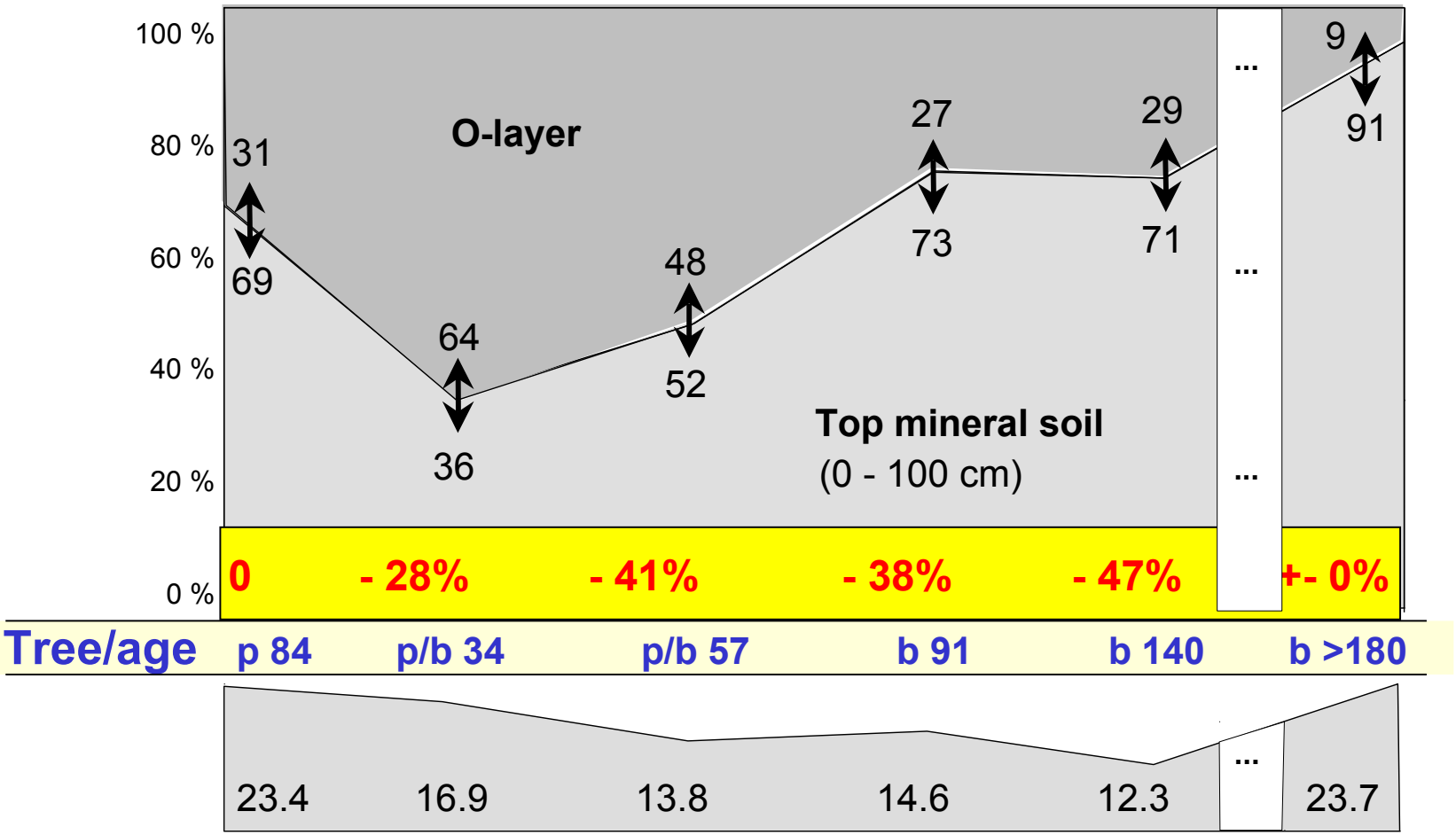
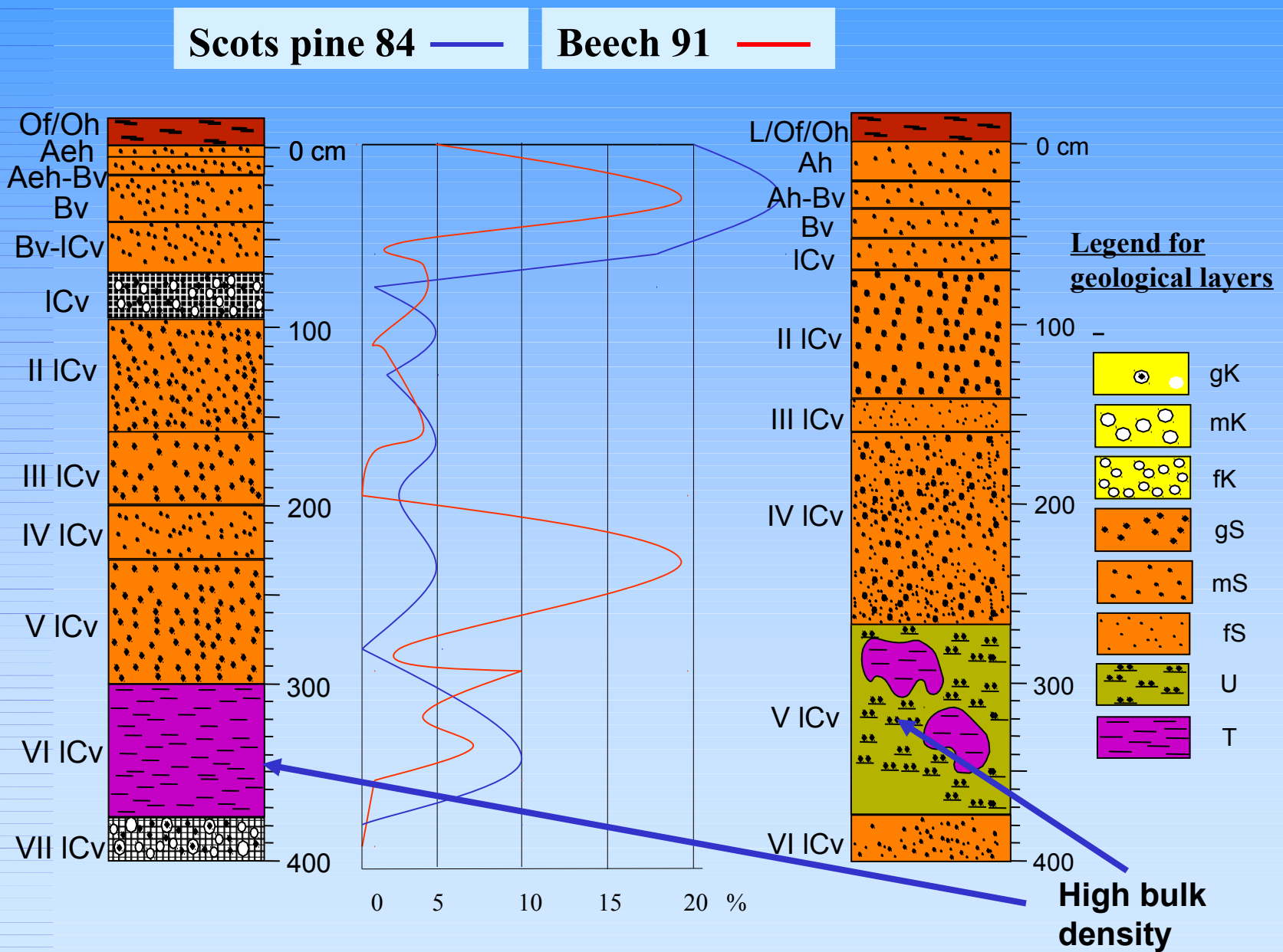
Total C_{org} stock [kg m^{-2}] and its allocation between organic surface layer and mineral soil (100 cm depth) along a forest transformation chronosequence from monocultural Scots pine, mixed pine-beech to a natural beech stand



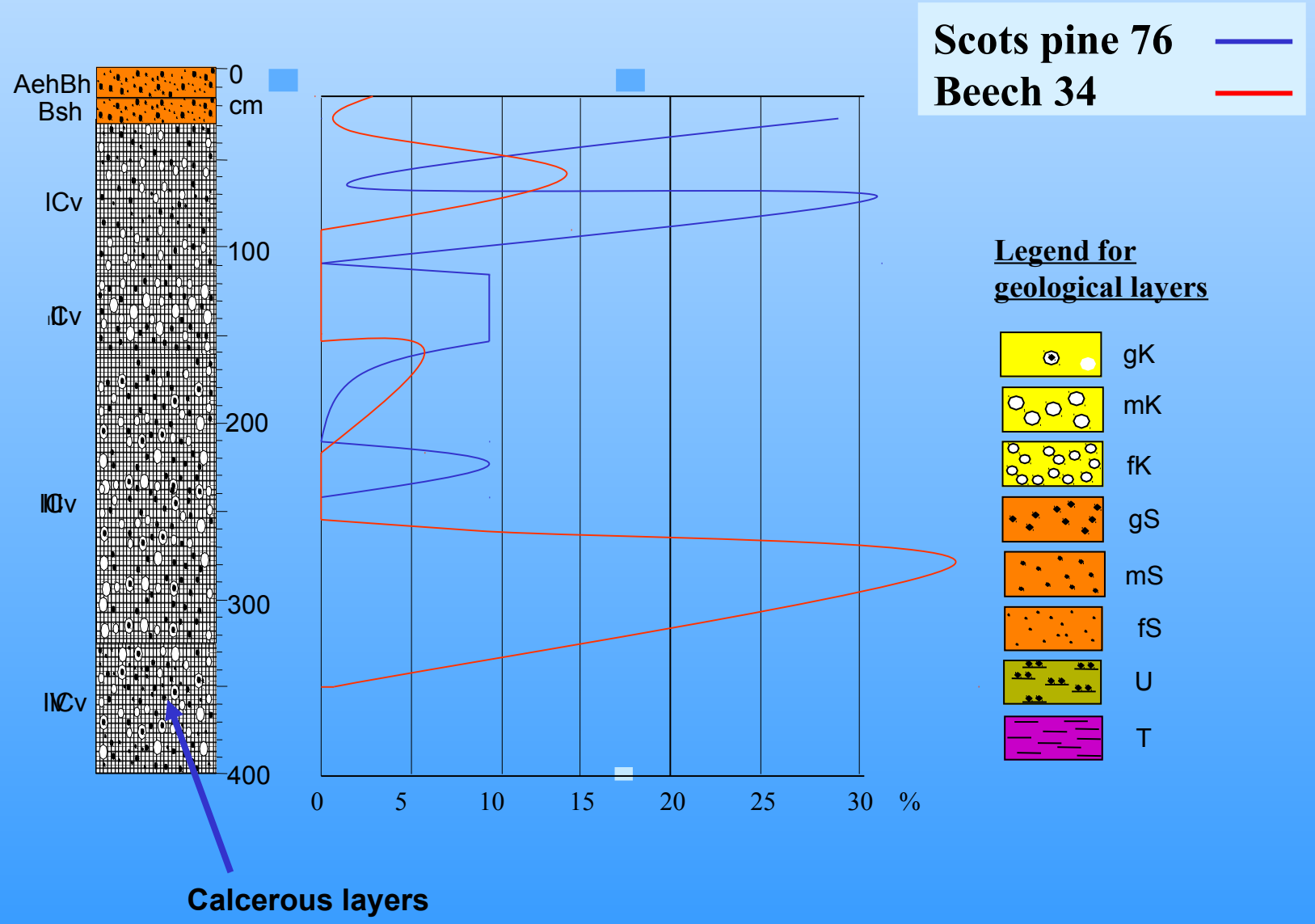
p = Pinus sylvestris
b = Fagus sylvatica

Bens et al., 2007

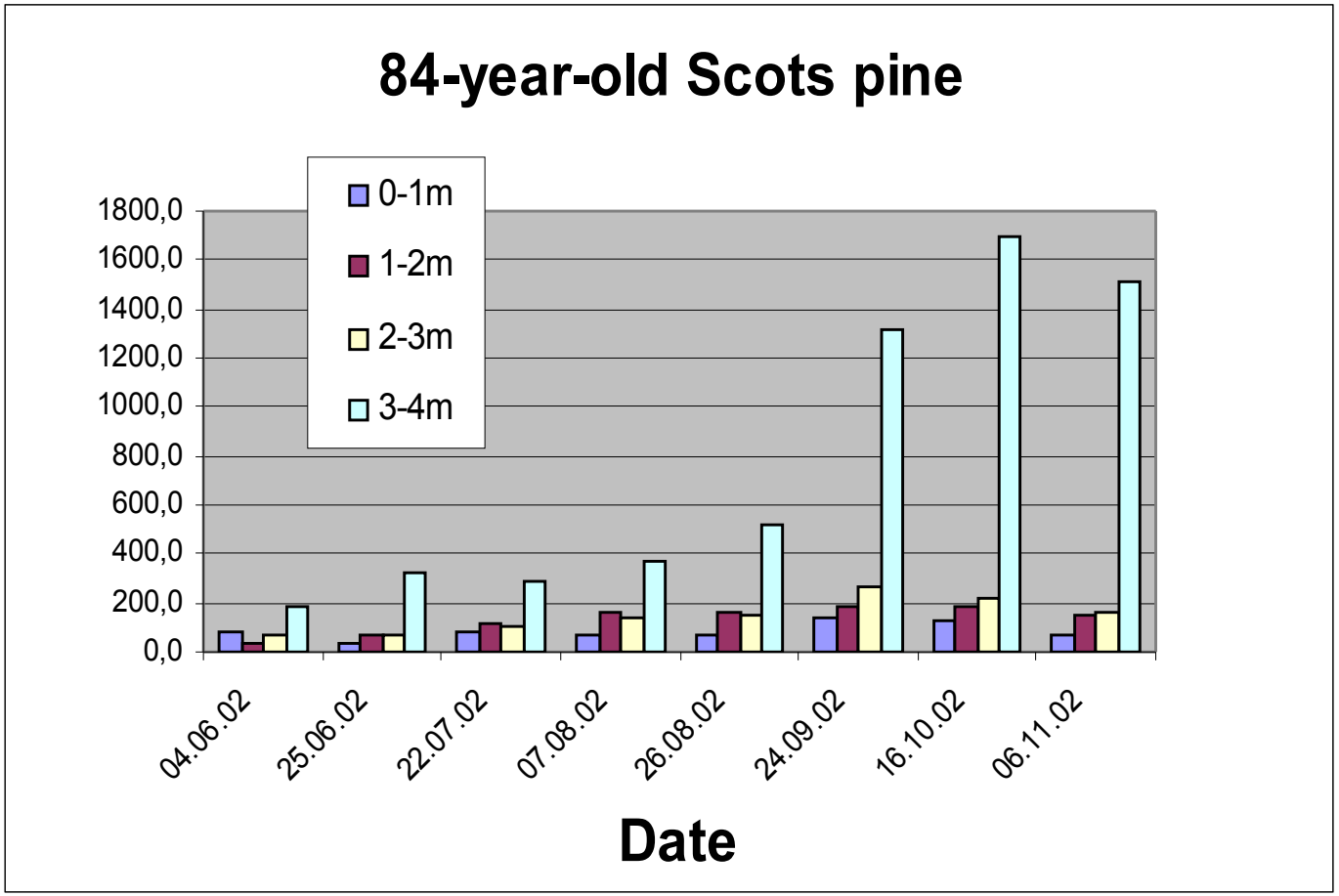
Vertical distribution of root tips for monoculture Scots pine (age 84 yrs.) and Beech (age 91 yrs.)



Vertical distribution of root tips for mixed Scots pine and Beech stands



Seasonal dynamic of fine root tip formation



Reference point: Number of root tips March 2002

1 m	47
2 m	101
3 m	82
4 m	7

Schneider et al., 2005

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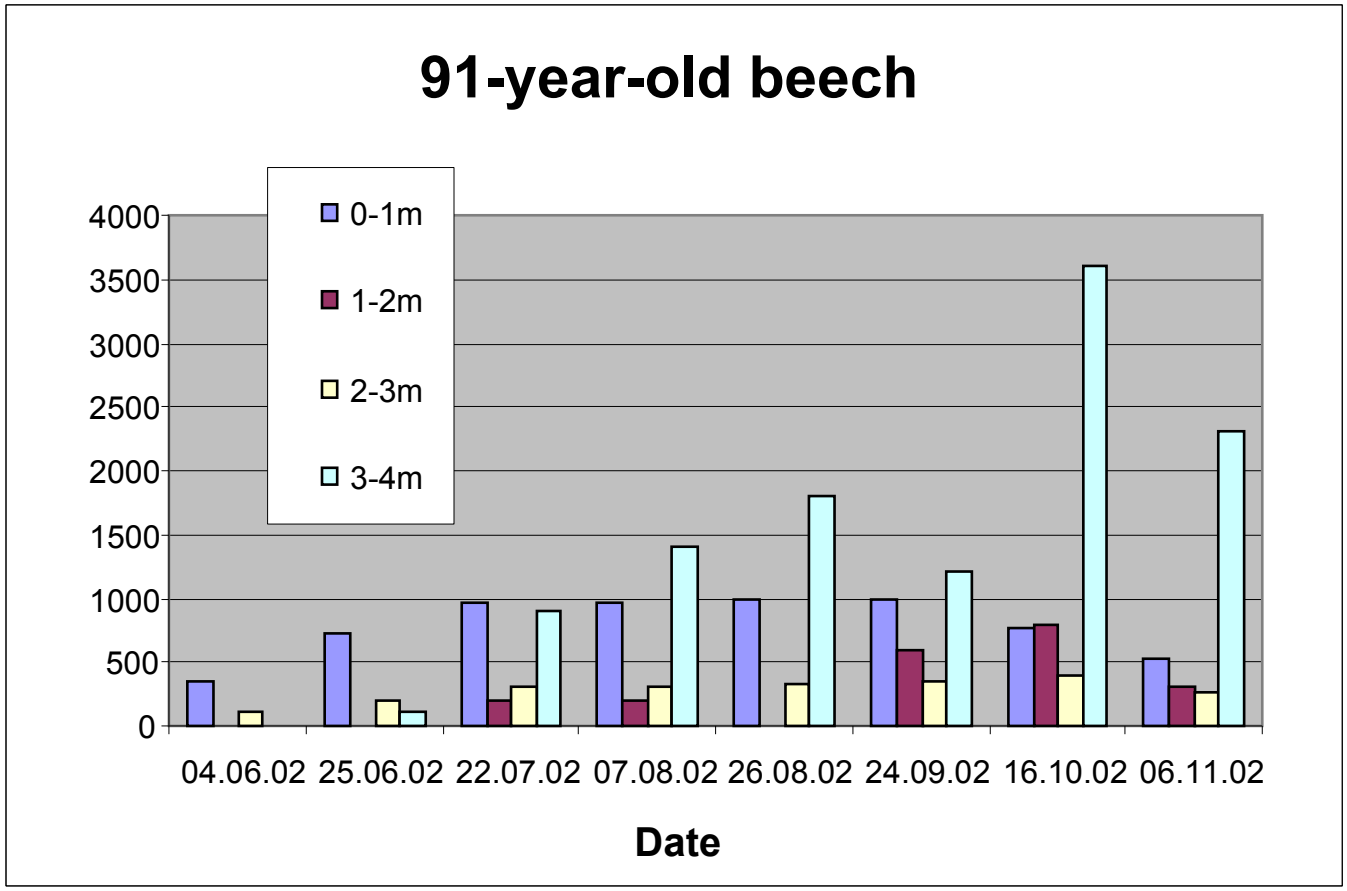
Seasonal dynamic of fine root tip formation



Schneider et al., 2005

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Nutritional status of pine and beech in monocultural pine and mixed stands with beech

	N [%]		P [*mg/g*]		K [*mg/g*]		Ca [*mg/g*]		Mg [*mg/g*]	
Stand	**Beech**	**Pine**	**Beech**	**Pine**	**Beech**	**Pine**	**Beech**	**Pine**	**Beech**	**Pine**
Pine/age 84	-	1,92	-	1,86	-	6,46	-	3,03	-	0,95
Pine/age 74 Beech/age 34	2,32	1,63	1,57	1,63	5,04	4,96	8,71	2,95	1,36	1,05
Pine/age 114 Beech/age 57	2,70	1,67	1,20	1,58	7,19	6,49	13,05	2,30	1,84	1,01
Beech/age 91	1,92	1,75	0,86	1,85[2]	4,22	7,71	8,93	3,52[2]	1,49	0,90[2]

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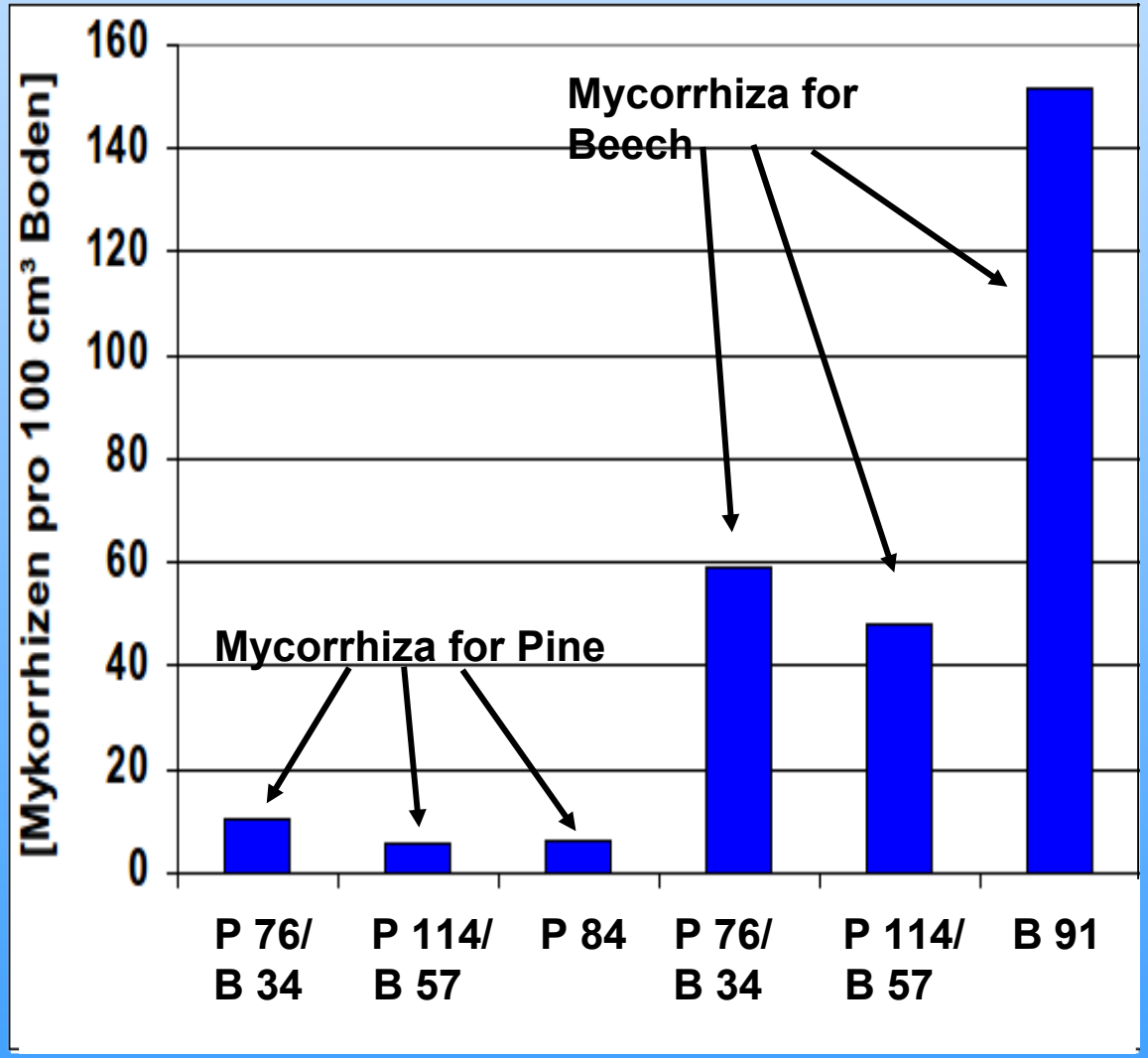
Mycorrhiza Frequency (April 2002)



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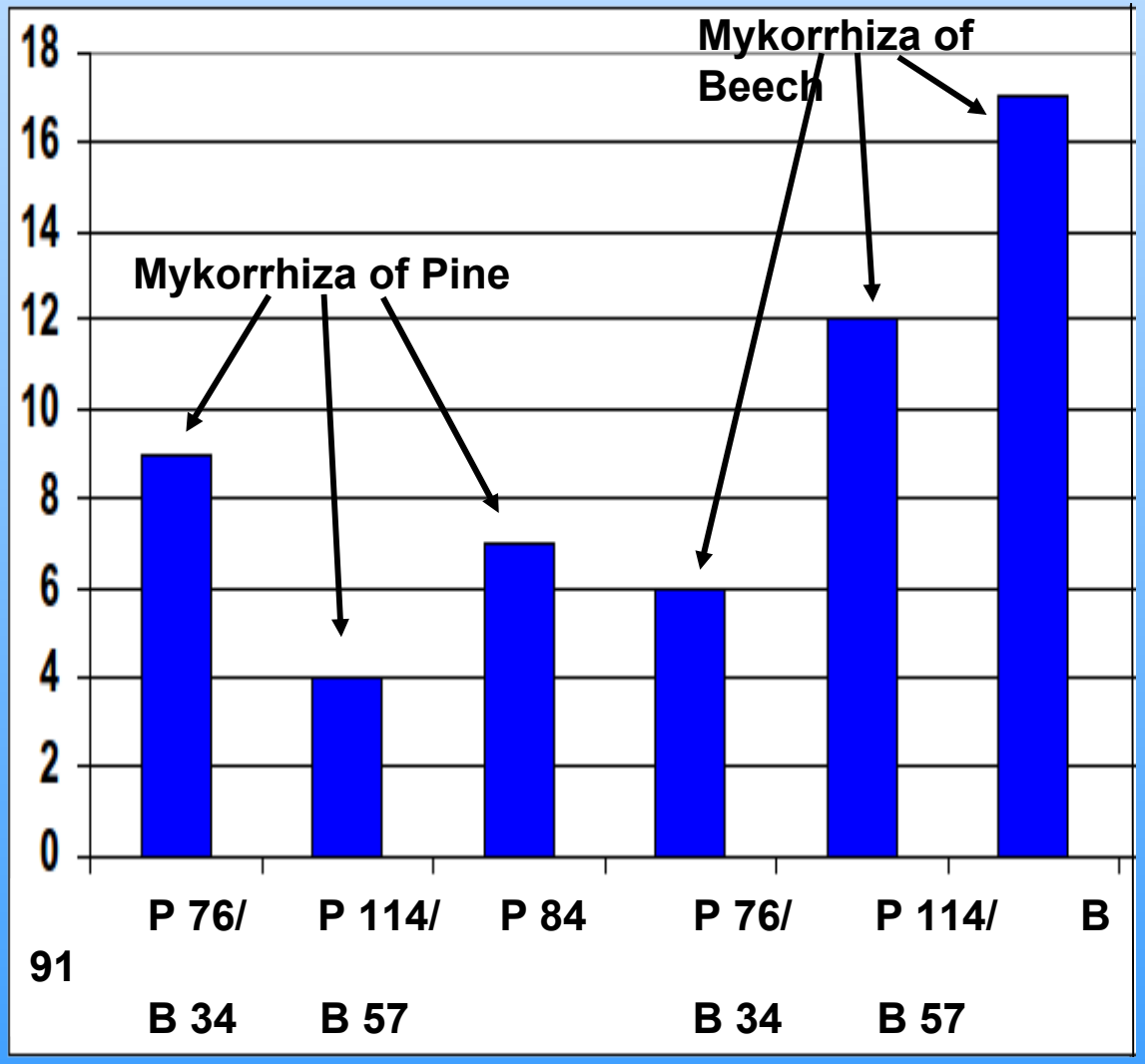
Number of Mycorrhiza types (April 2002)



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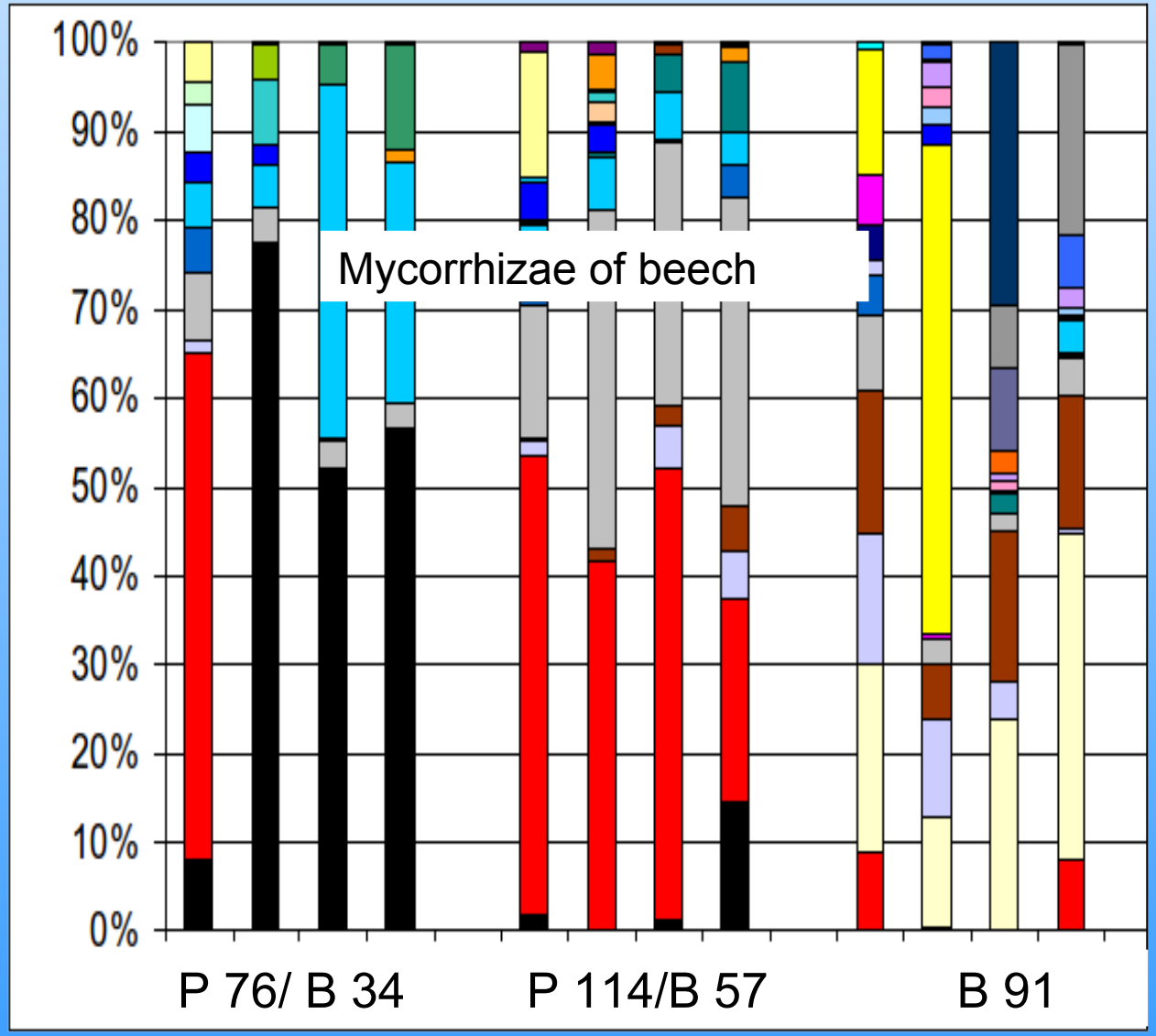
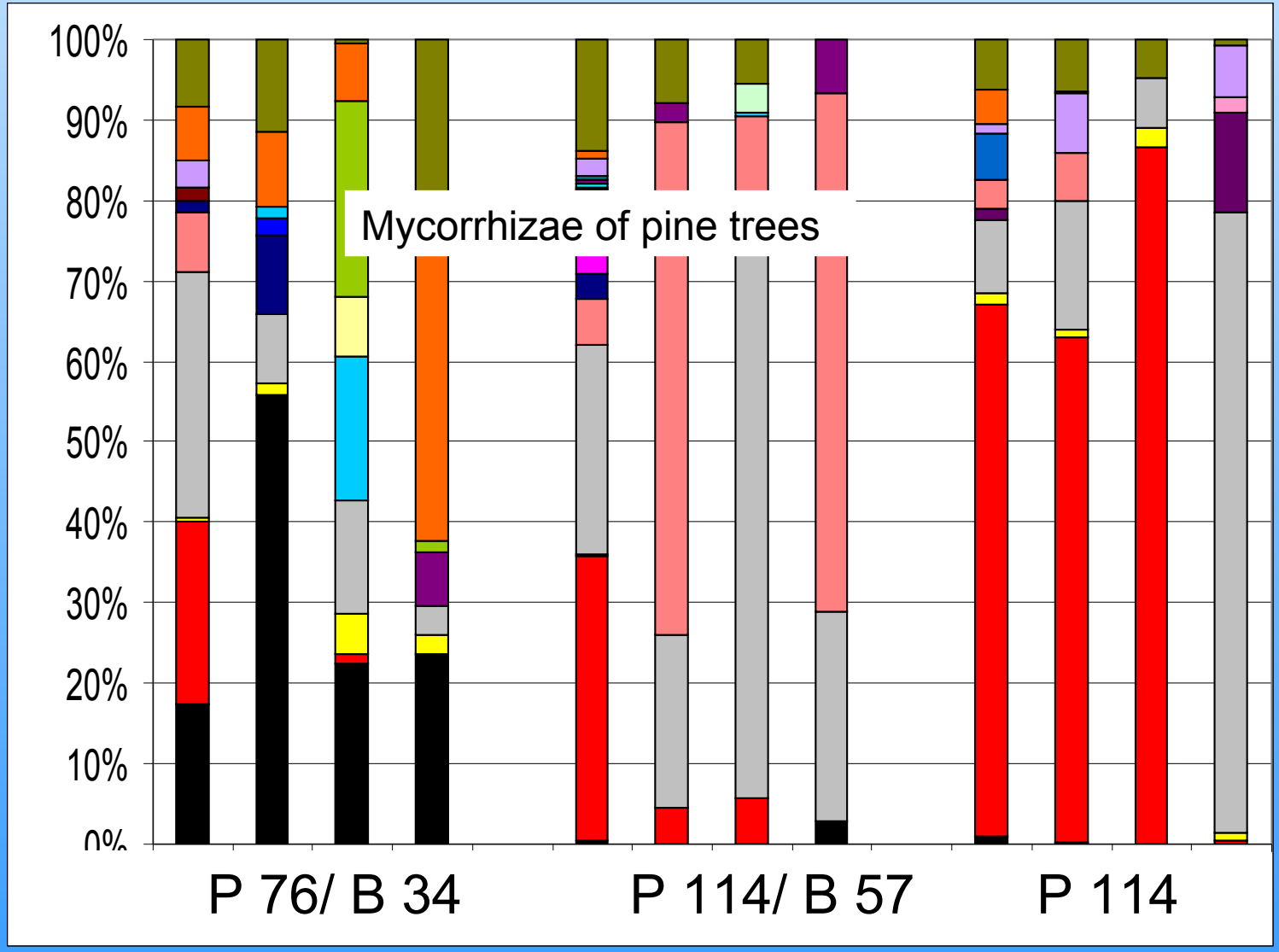
Dominance structure of mycorrhizal communities



Dominance structure of mycorrhizal communities



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Alternative Landuse Systems

Biogeographic conditions in Northeastern Germany

Precipitation		**Average**	**Minimum**	**Maximum**
annual	(mm a^{-1})	560	335	865
Summer period	(mm a^{-1})	329	127	607
Winter period	(mm a^{-1})	232	125	366
Temperature - annual	°C	9,1	7,8°C	10,9°C

Station Cottbus 1960-2001; Quelle DWD

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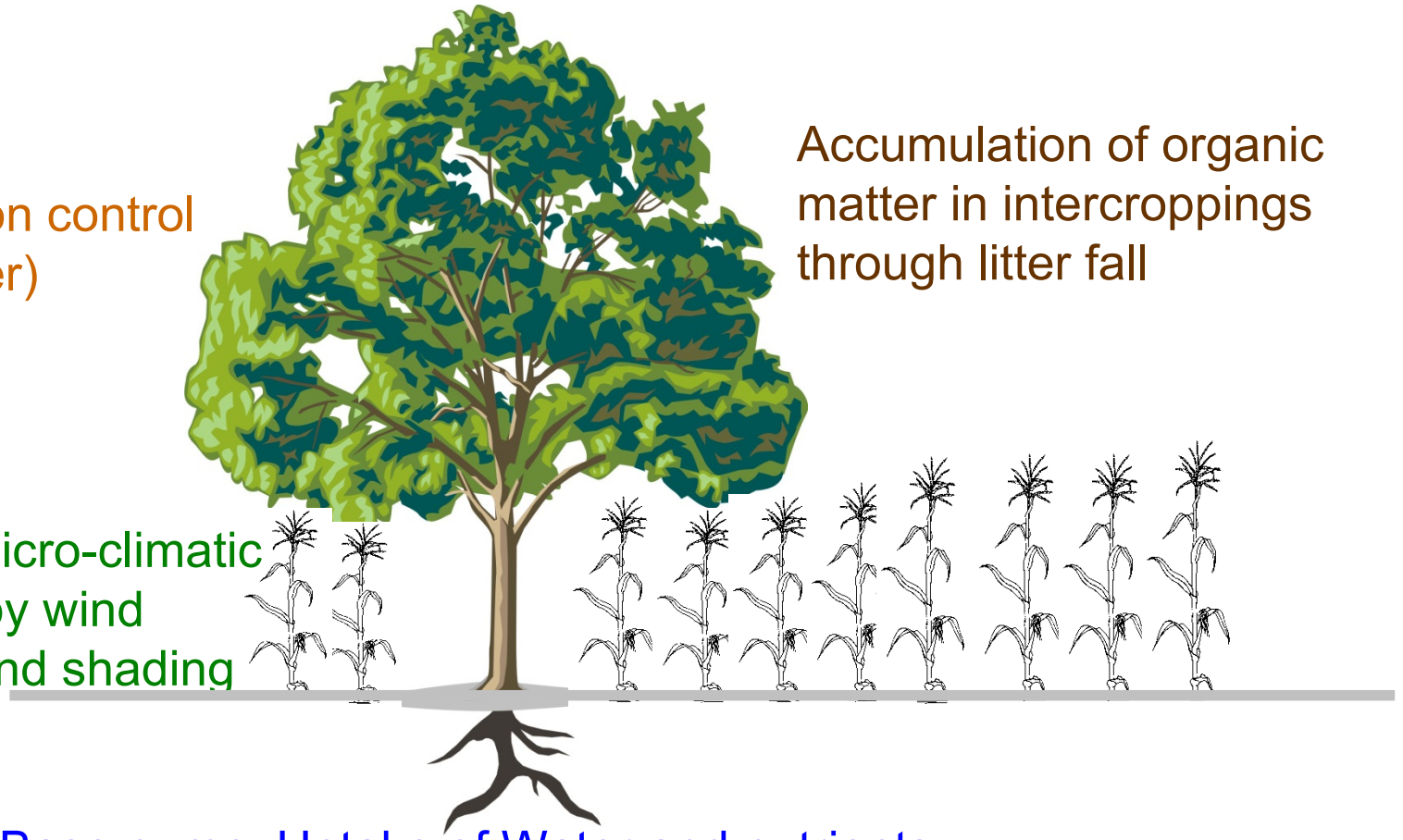
Agroforestry: Ecosystem Service Surplus



High erosion control (wind, water)

Accumulation of organic matter in intercroppings through litter fall

Improved micro-climatic conditions by wind deflection and shading

Base pump: Uptake of Water and nutrients from the deep soil

(cf. Young 1998; modified)

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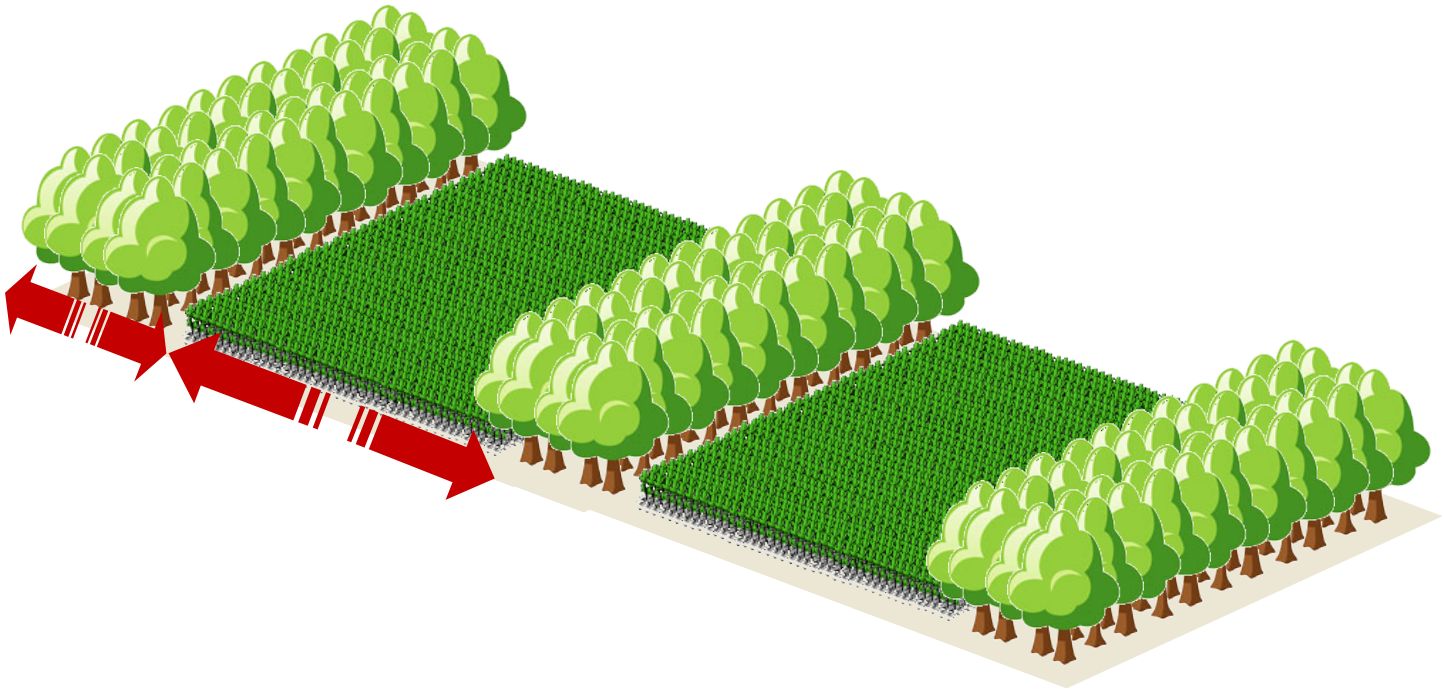
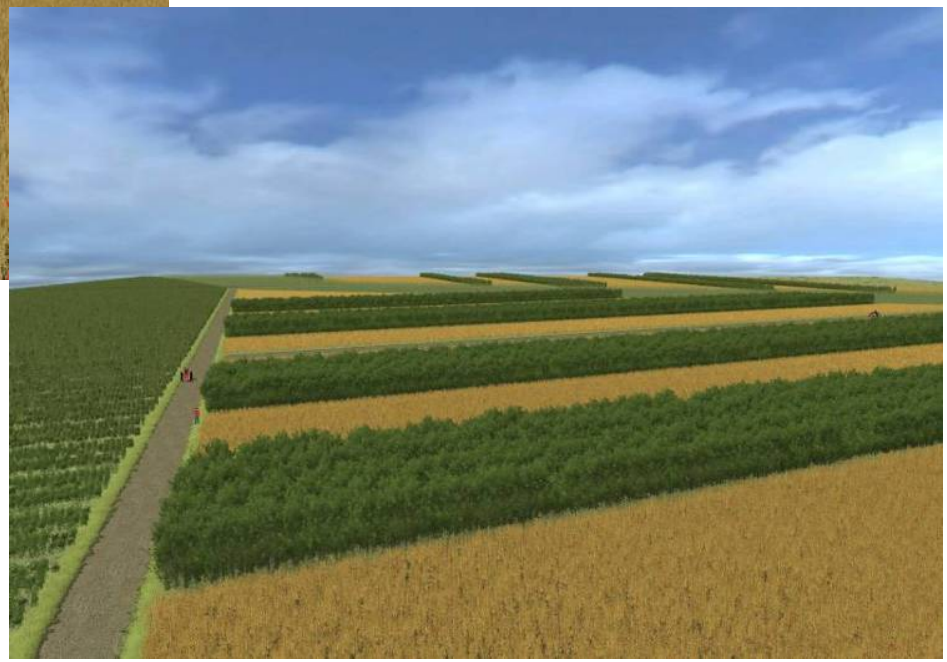
Alley-Cropping



Alley-Cropping is a form of Agroforestry combining hedges or tree rows with intercroppings thus integrating biomass and crop production

Agroforestry Systems serve as elements for designing landscapes



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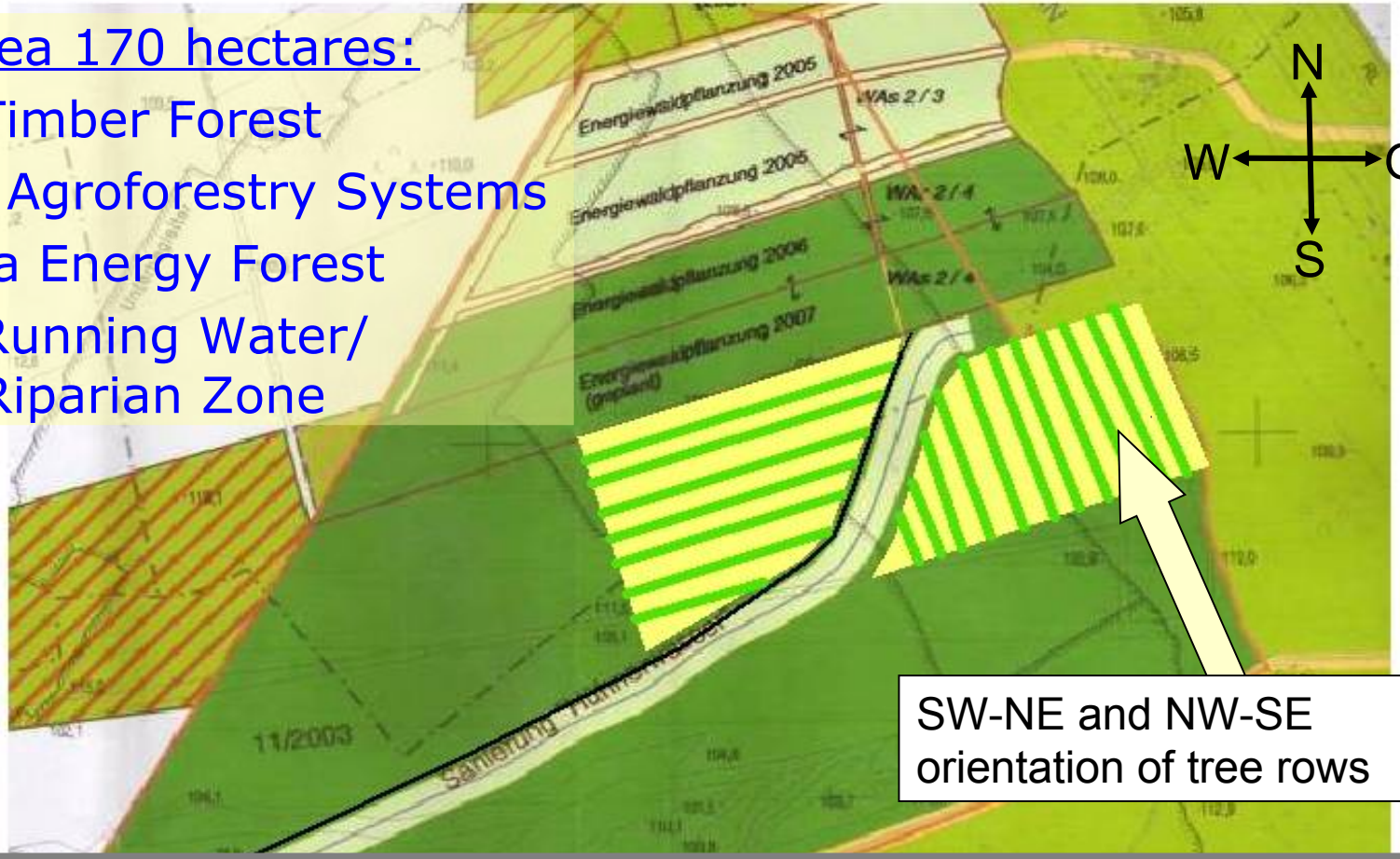
Landscape Laboratory in the Welzow Lignite Mining District

Total area 170 hectares:

- 7 ha Timber Forest
- 27 ha Agroforestry Systems
- 142 ha Energy Forest
- 4 ha Running Water/ Riparian Zone



Largest experimental areas for *in situ* research on short rotation coppice and agrofrostry

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Ecosystem Services: Aesthetic Aspects

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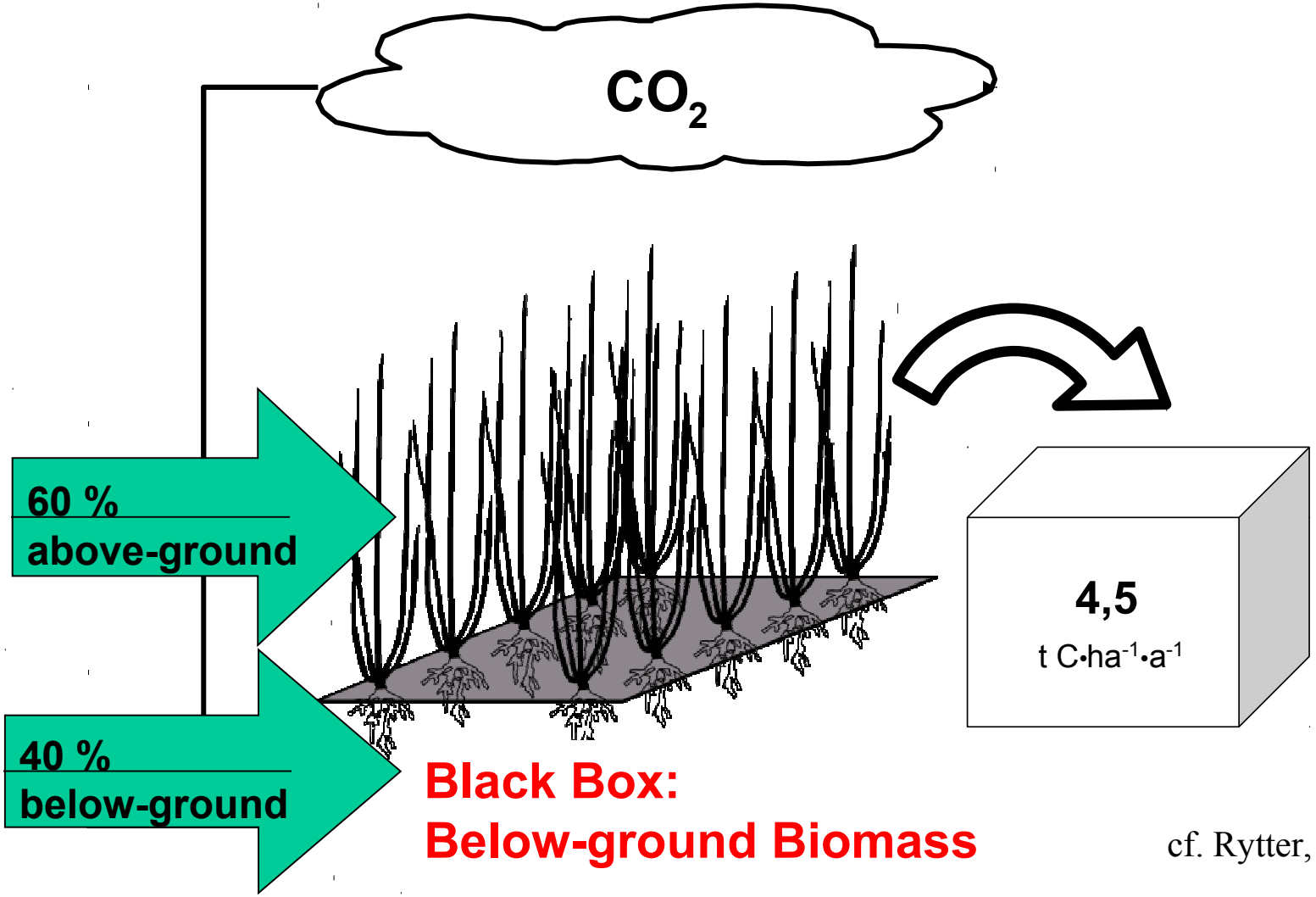
C-Sequestration in short rotation coppice systems



cf. Rytter, 2001

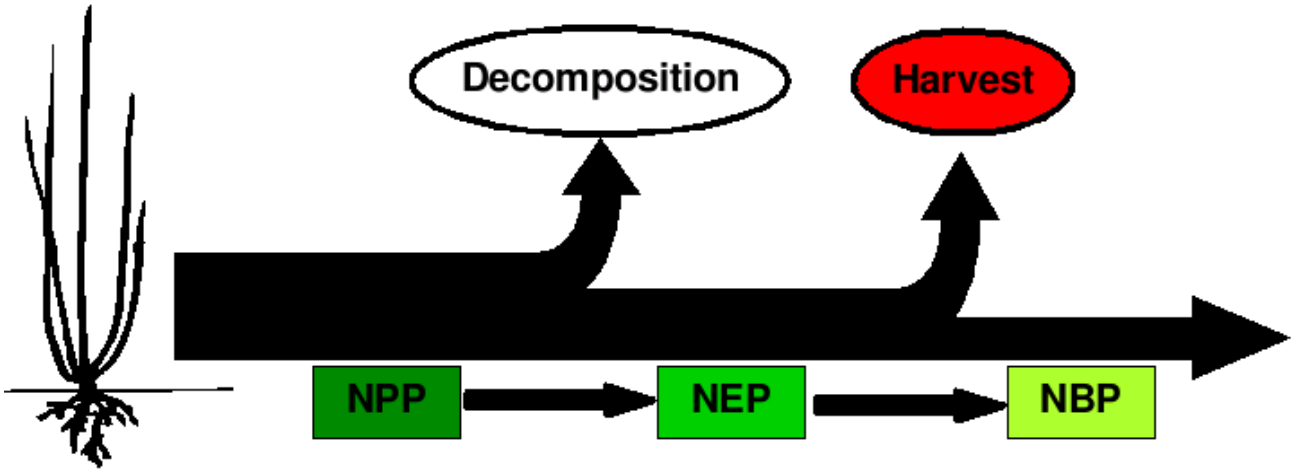
Modeling of the C-Sequestration in short rotation coppice systems

Methodological approach:

- Data driven Parametrisation
- Comparison of tree species and rotation periods
- Extrapolation of results to the stand level

Modell-Output:
C-Fluxes p. a.
C-Storage Biomass p. a.
C-Storage Soil p. a.

NPP	= Net Primary Production
NEP	= Net Ecosystem Production
NBP	= Netto Biome Production
Decomposition	= Decomposition Losses
Harvest	= Removal by Harvest



Mollicone et al. 2002, modifiziert

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Accumulation of Soil Carbon (%) in Quarternary sands 8 years after establishment of an Alley-Cropping-System

Soil Depth (cm)	1997	2005 Tree rows	2005 Interface Tree rows – Intercroppings	2005 Intercroppings
0-10	**0,45** (0,26) *	1,55 (0,64)*	1,13 (0,25)	1,04 (0,24)
10-30		0,85 (0,28)	1,03 (0,34)	0,99 (0,28)

Triplication of the Soil Carbon contents after 8 years !

* Standard deviation

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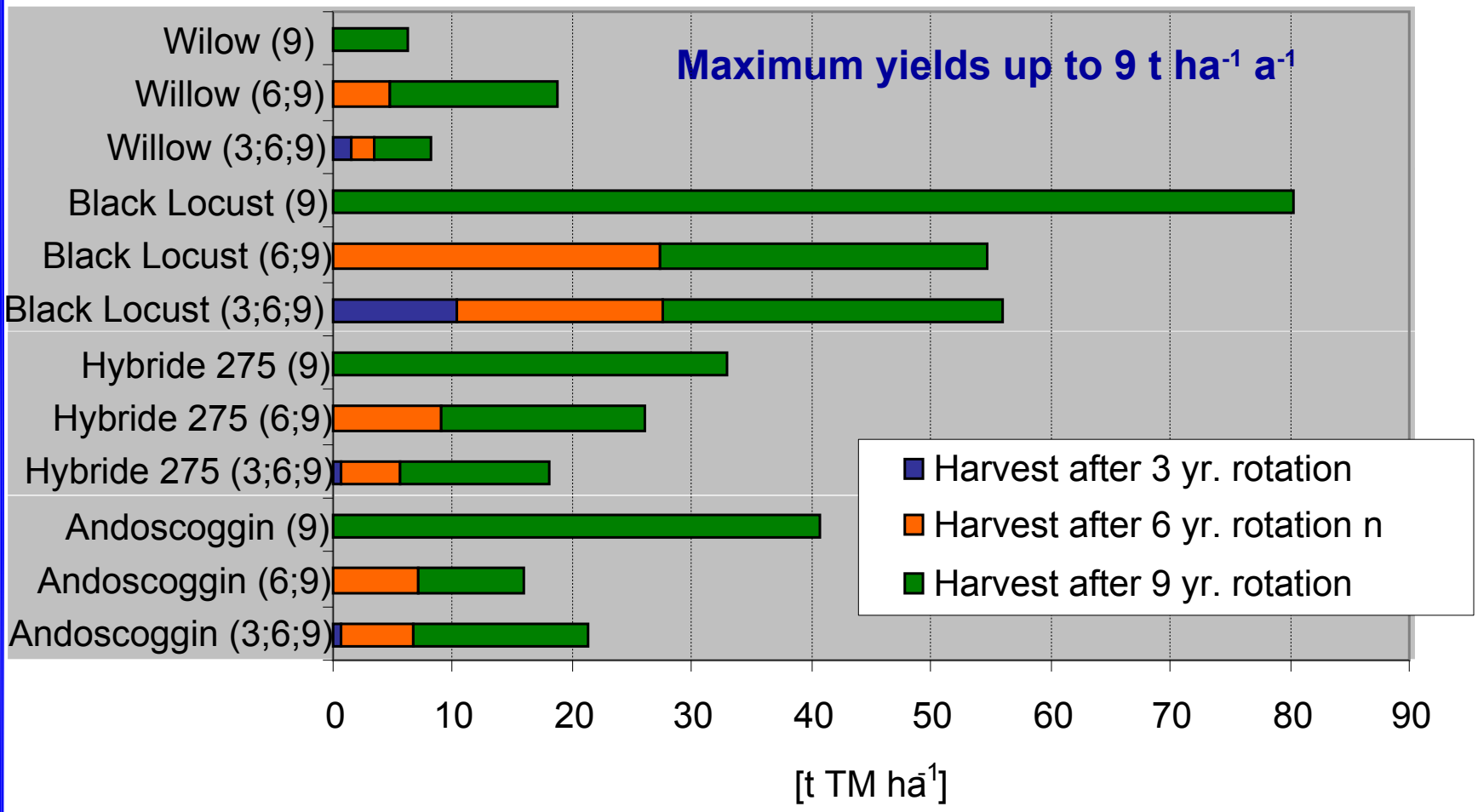
Productivity of different tree species growing on sandy soils derived from quarternary sediments in the Lusatian lignite mining district

Rotation periods: 3, 6+3, 9 years



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Preliminary Results from Modeling of Carbon Pools for short rotation tree systems

- The carbon balance of stands mainly depends on above-ground increments and below-ground decomposition rates
- A prolongation of rotation periods has a positive effect on the carbon pool of the system
- More data/research is needed to show differences between tree species
- All scenarios under study show an additional soil carbon accumulation

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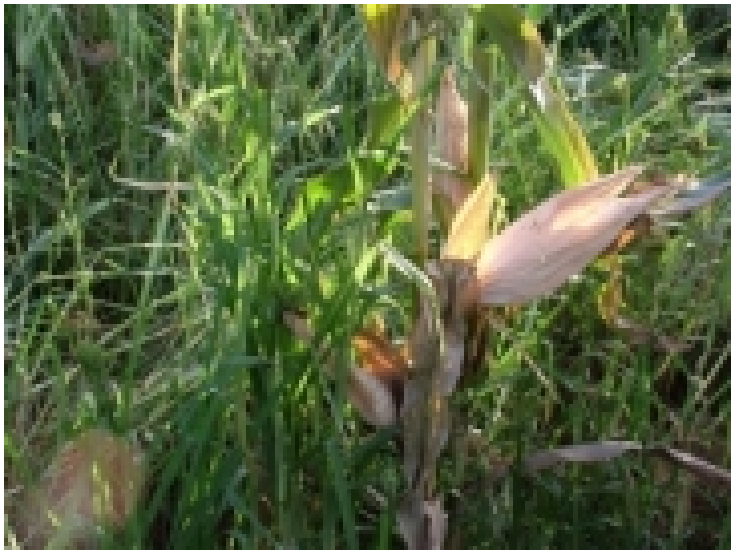
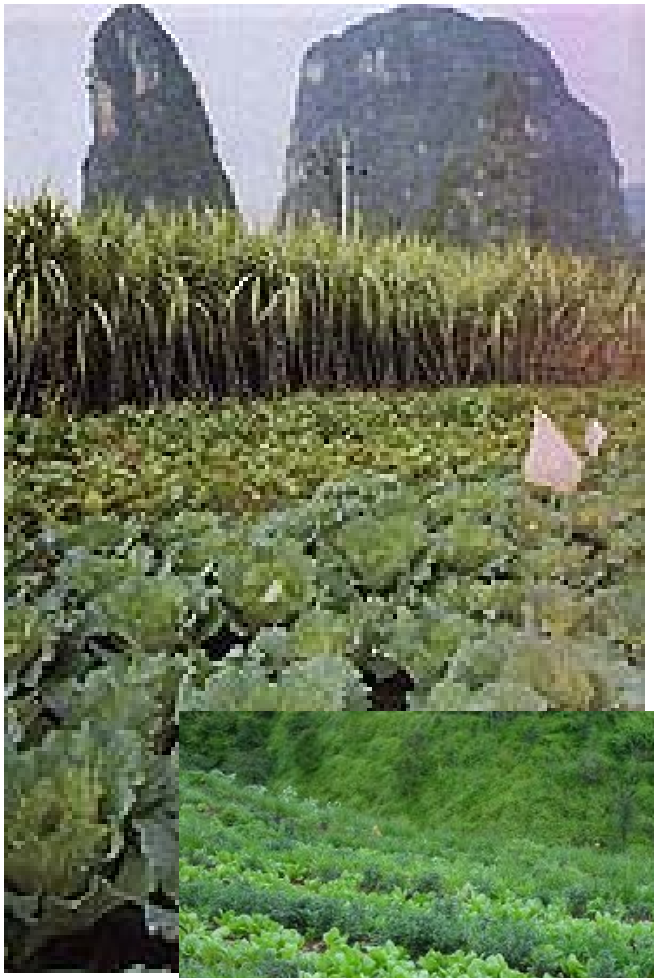
Mixed Cropping





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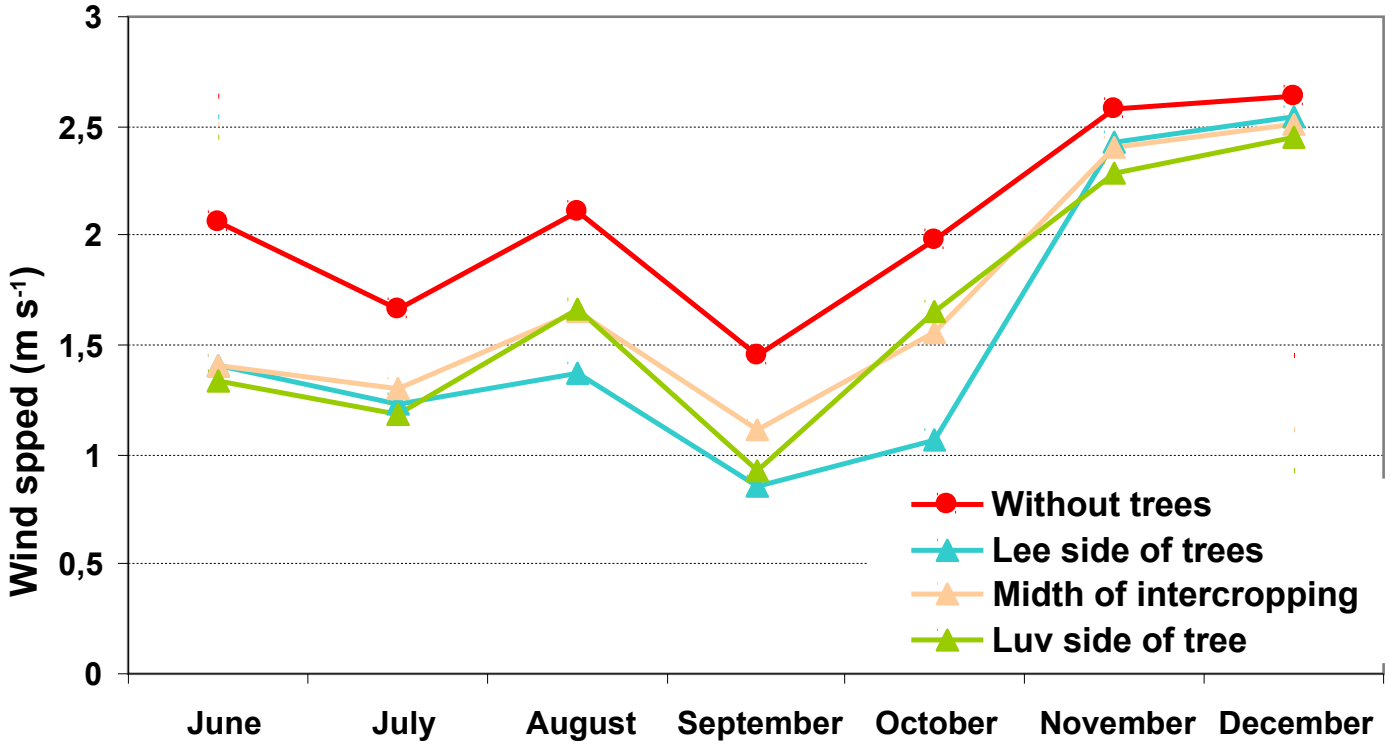
Microclimate

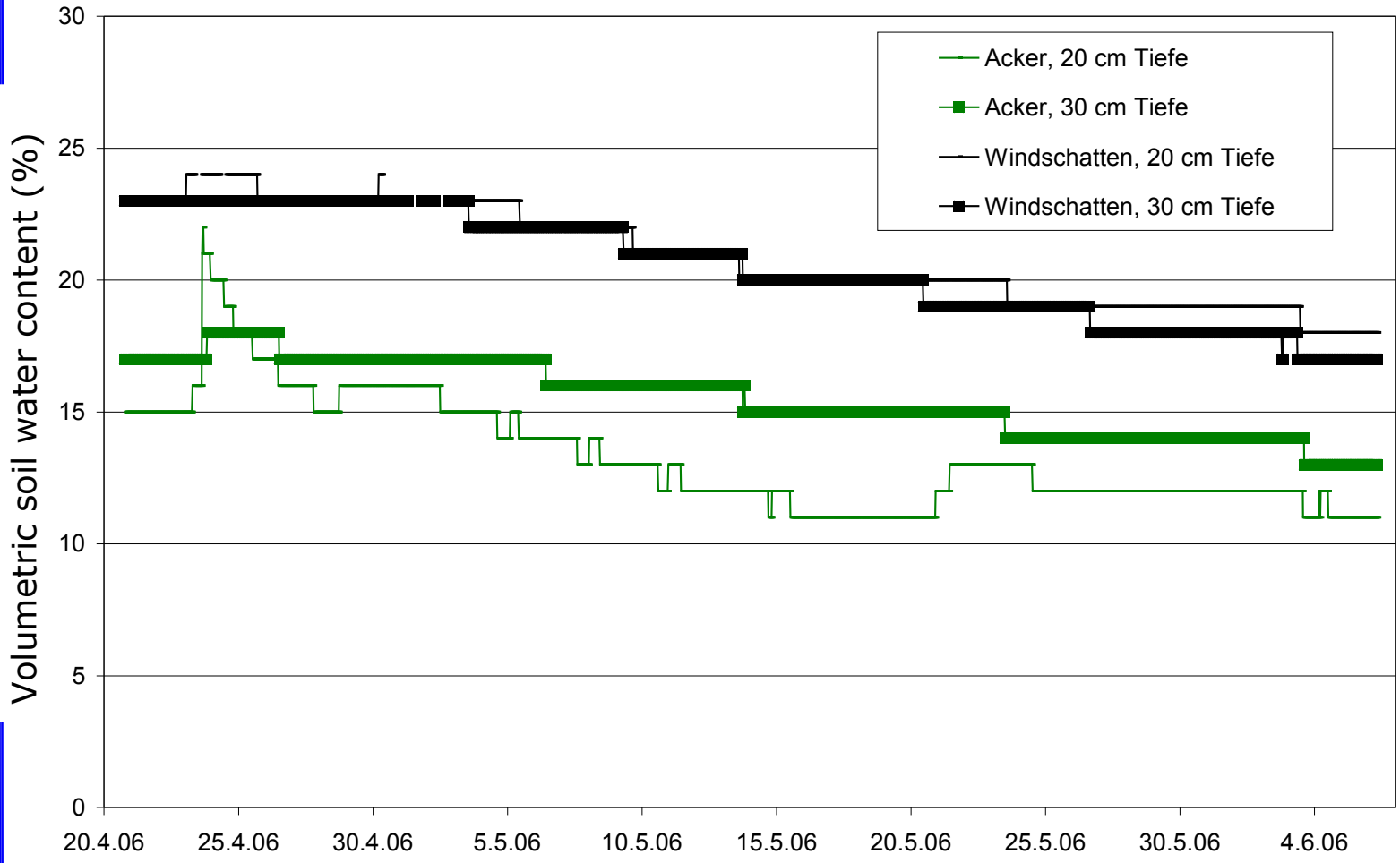
Alley-Cropping Field Trial in the Post-mining Landscape of the Welzow Mining District

Monthly mean values of wind speed comparing traditional agricultural management with an alley-cropping system (June 2008 bis December 2008)



Alley-Cropping Field Trial in the Post-mining Landscape of the Welzow Mining District

Change of soil water content on the lee side of tree rows of Black locust and on adjacent agricultural systems without tree shelter



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Other Ecosystem Services

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Ecosystem Services: …not only for Aesthetic aspects

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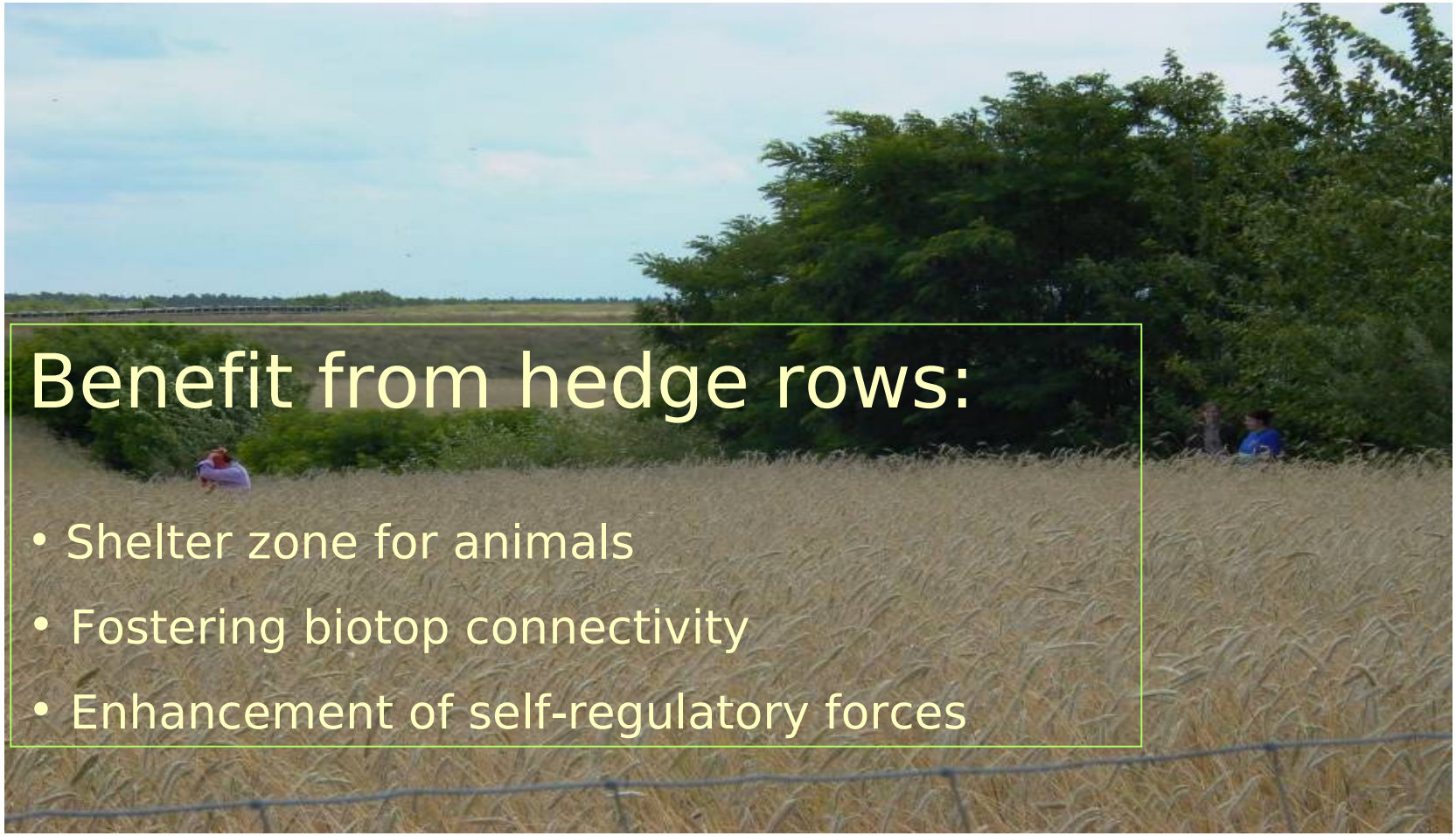
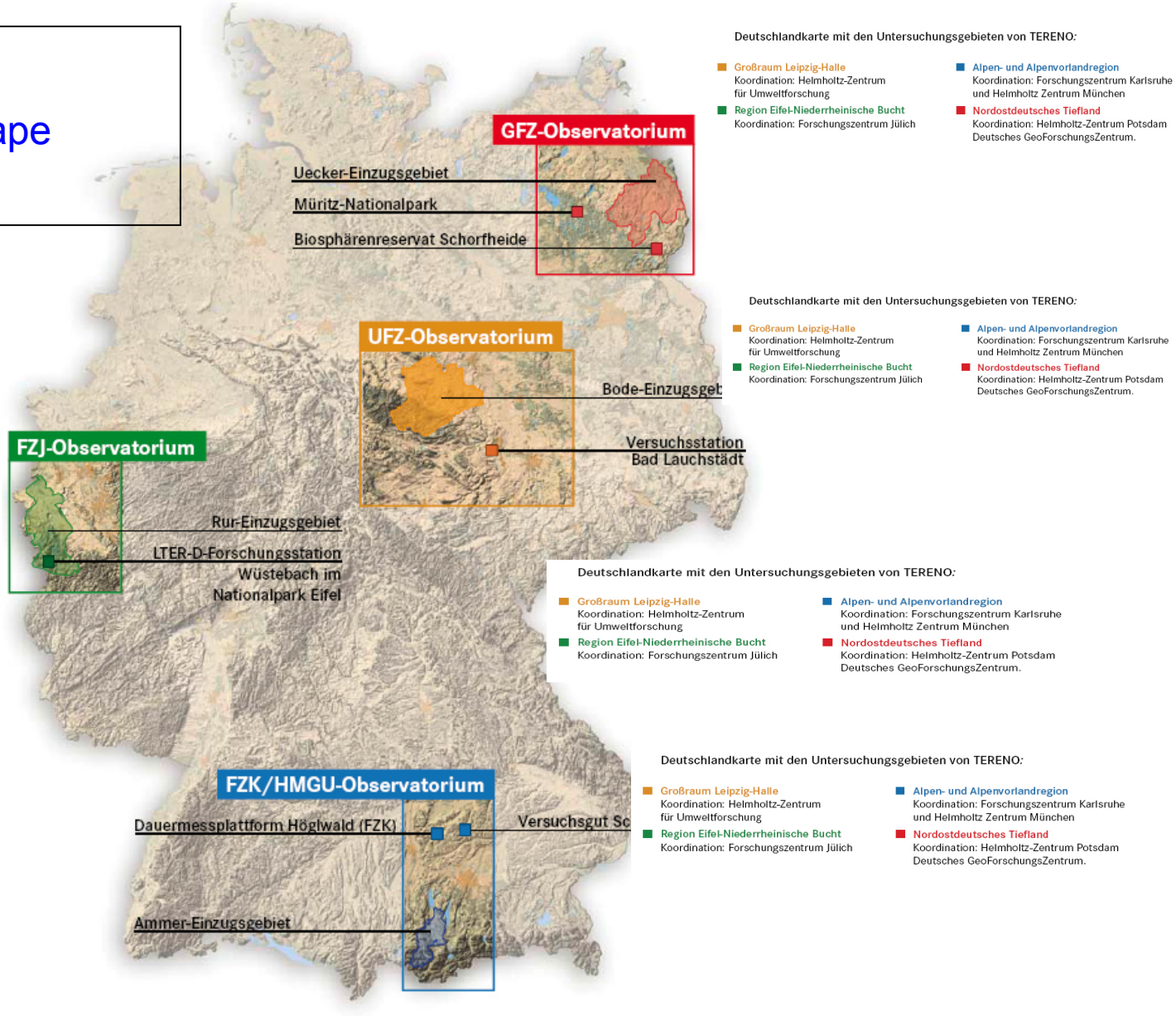
Ecosystem Services: Enhancement of Biodiversity

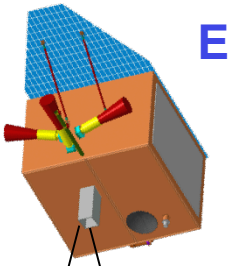


Montoring at the landscape level

TERENO –
Helmholtz Landscape
Observatories

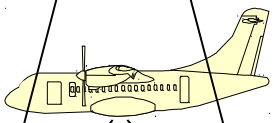


EnMAP – Hyperspectral Sensors



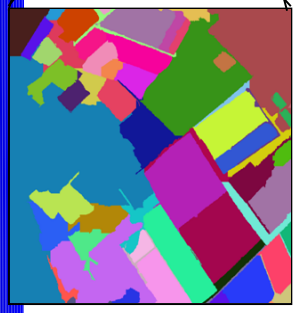
EnMAP

Flughöhe: 644 km
Bodenauflösung: 30 x 30 m
Streifenbreite: 30 km



ARES

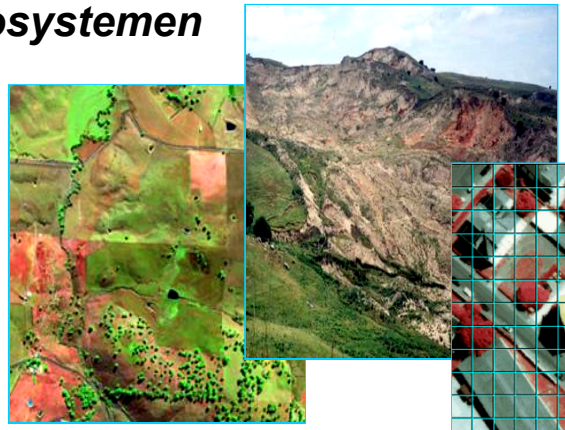
Flughöhe: 1-5 km
Bodenauflösung:
2 x 2 m bis 10 x 10 m



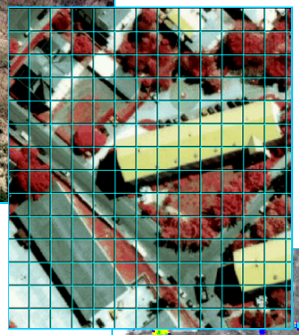
Parameter Extraktion und Modellierung

Kooperations-Netzwerk GFZ – DLR

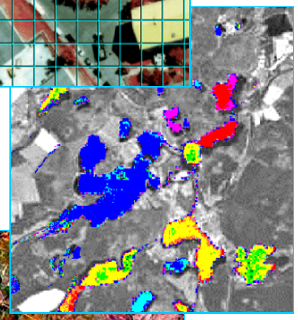
Management von Landwirtschaft und Wald-Ökosystemen



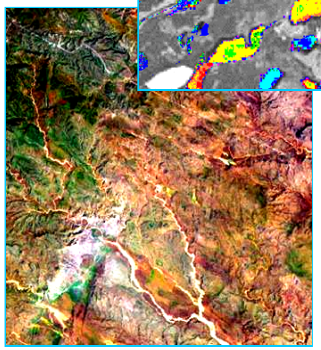
Risiko-abschätzung



Stadtent-wicklung



Binnen-gewässer



Desertifikation

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Challenges to Secure/Improve the Organic Matter Contents of Soils

- Monitoring of carbon pool and flux changes related to management systems
- Research into the benefits of alternative landuse systems (e.g. agroforestry, multi-crop cultivation) as well as into forest transformation practices
- Development of stable organic matter compounds as soil amendments
- Lowering the CO_2-footprint of management systems