Fragen

- Was sind global die wichtigsten anthropogenen Quellen für CO_2, CH_4 und N_2O?
- Wie beeinflusst der Wasserspiegel die Bildung und den Verbrauch von CO_2, CH_4 und N_2O?
- Wann können Peaks von N_2O aus dem Boden auftreten?
- Soll Landnutzung einen Beitrag zum Klimaschutz leisten oder lieber Nahrungsmittel und sonstige Güter produzieren?
- Wie könnte klimafreundliche Landnutzung aussehen?
- Wie können Treibhausgasemissionen in der Landnutzung reduziert werden?

Die Rolle der Biodiversität für biogeochemische Prozesse

Contents

- Theory
  - Definition of biodiversity
  - Aspects of biodiversity
- Biodiversity and ecosystem services
  - Productivity
    - Theory
    - Field observations and experiments
    - Models
    - Overyielding
  - Stability of ecosystems in a changing climate
  - Nutrient – biodiversity links
  - Biodiversity – soil interactions:
    - New experiments: JENA, BIOTREE

Definition

Biodiversität

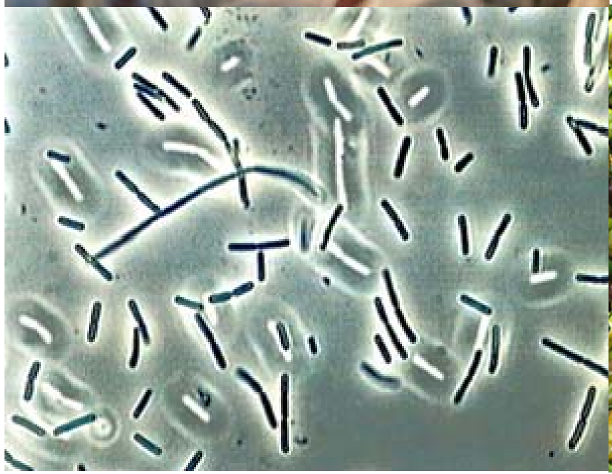
= biologische Vielfalt

= Vielfalt des Lebens in all ihren Ausprägungen

- Von der genetischen Unterschiedlichkeit...
- ...über die Artenvielfalt...
- ...bis hin zur Vielfalt der Lebensräume.

Definition in the Convention on Biological Diversity (CBD)

- Biological diversity includes all plants, animals, microorganisms, the ecosystems of which they are part, and the diversity within species, between species, and of ecosystems



Aspects of Biodiversity

- Species richness

  – Simpson‘s Diversity Index

  $D=N(N-1)/\sum n(n-1)$

  N: total number of organisms of all species present

  n: number of individuals of a particular species

  – Shannon Index

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

S: number of species

p_i: relative abundance of each species (n_i/N)

Aspects of Biodiversity

- Evenness / dominance of species

$$E = \frac{H'}{H'_{\max}}$$

$$H'_{\max} = -\sum_{i=1}^{S} \frac{1}{S} \ln \frac{1}{S} = \ln S$$

  – E is between 0 and 1, it is the higher, the more even the population

Aspects of Biodiversity

- Functional diversity

  (Petchey & Gaston 2002) – species with different ecosystem functions and properties, that indicate resource use and process intensities, e.g.

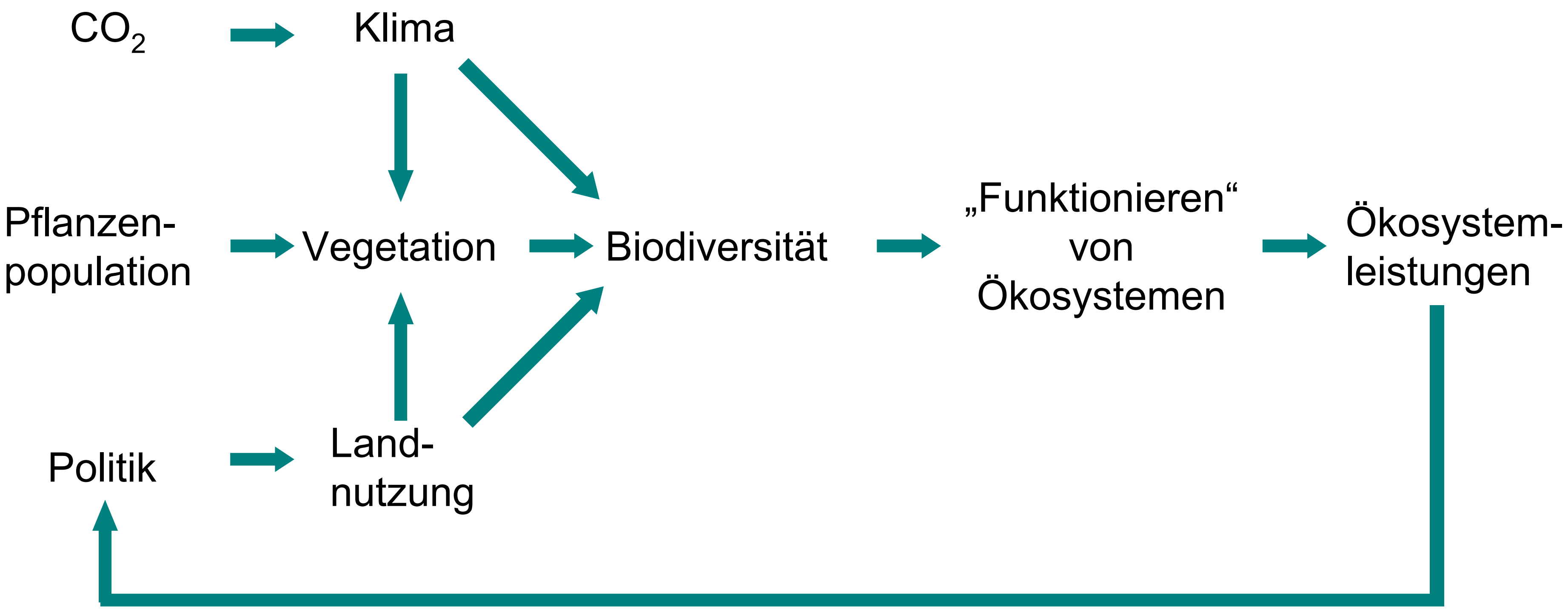
  - grasses
  - legumes
  - other herbs
  - broadleaved trees
  - coniferous trees

Functional diversity: Grasses

Functional diversity: Legumes

Functional diversity: Herbs

Biodiversity and ecosystem services – a new research direction



Typical research questions

- Does diversity per se determine ecosystem processes?
- Is functional group diversity the key parameter determining ecosystem processes?
- Is species identity important, and are there keystone species?
- Is the relationship between plant diversity and ecosystem processes dependent on the diversity of other groups of organisms?
- What are the relationships between C and N cycling and biological diversity? Does diversity drive C-N cycling or vice versa?
- Does higher biodiversity affect interannual variability of ecosystem fluxes?
- How can we model diverse ecosystems at different spatial and temporal scales?
- How can we assess these complex interactions and improve our understanding of diversity-C-N interactions?

Ecological effects of Biodiversity

- Diversity mainly influences ecosystem functions in these areas:
  - Productivity (aboveground biomass of all plants of a specific area)
  - Stability (low chance for extinction, resistance and resilience against disturbances)
  - Nutrients
  - Plant-soil interactions

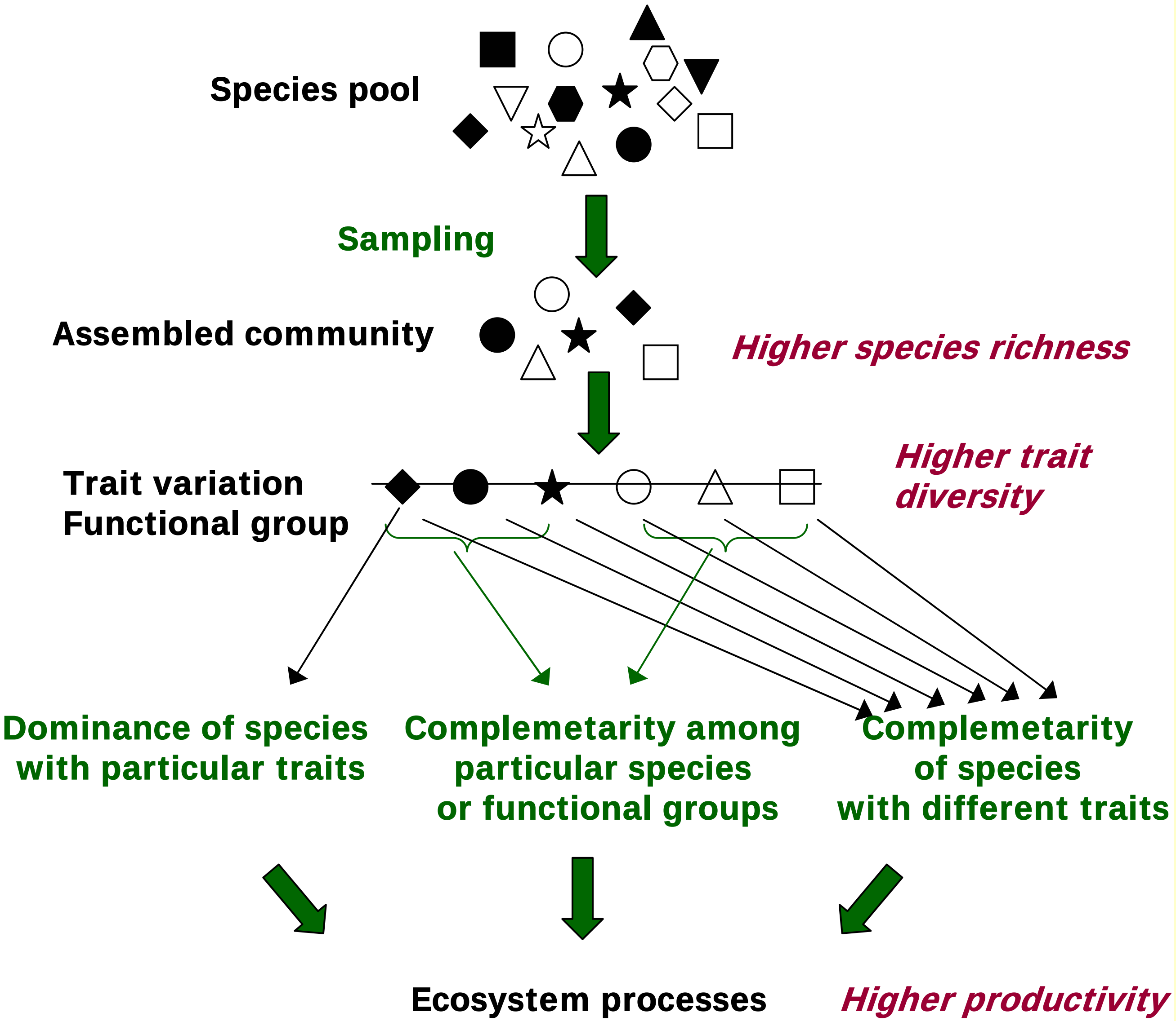
Influence of biodiversity on ecosystem productivity

- Complementarity
  - Better use of resources because of different niches

- Facilitation
  - one species provides favourable conditions for other species

- Sampling effect
  - A plot rich in species has a better chance to include:
    - species with high productivity
    - well adapted species
    - pairs of species that promote each other
    - species with a high potential for facilitation

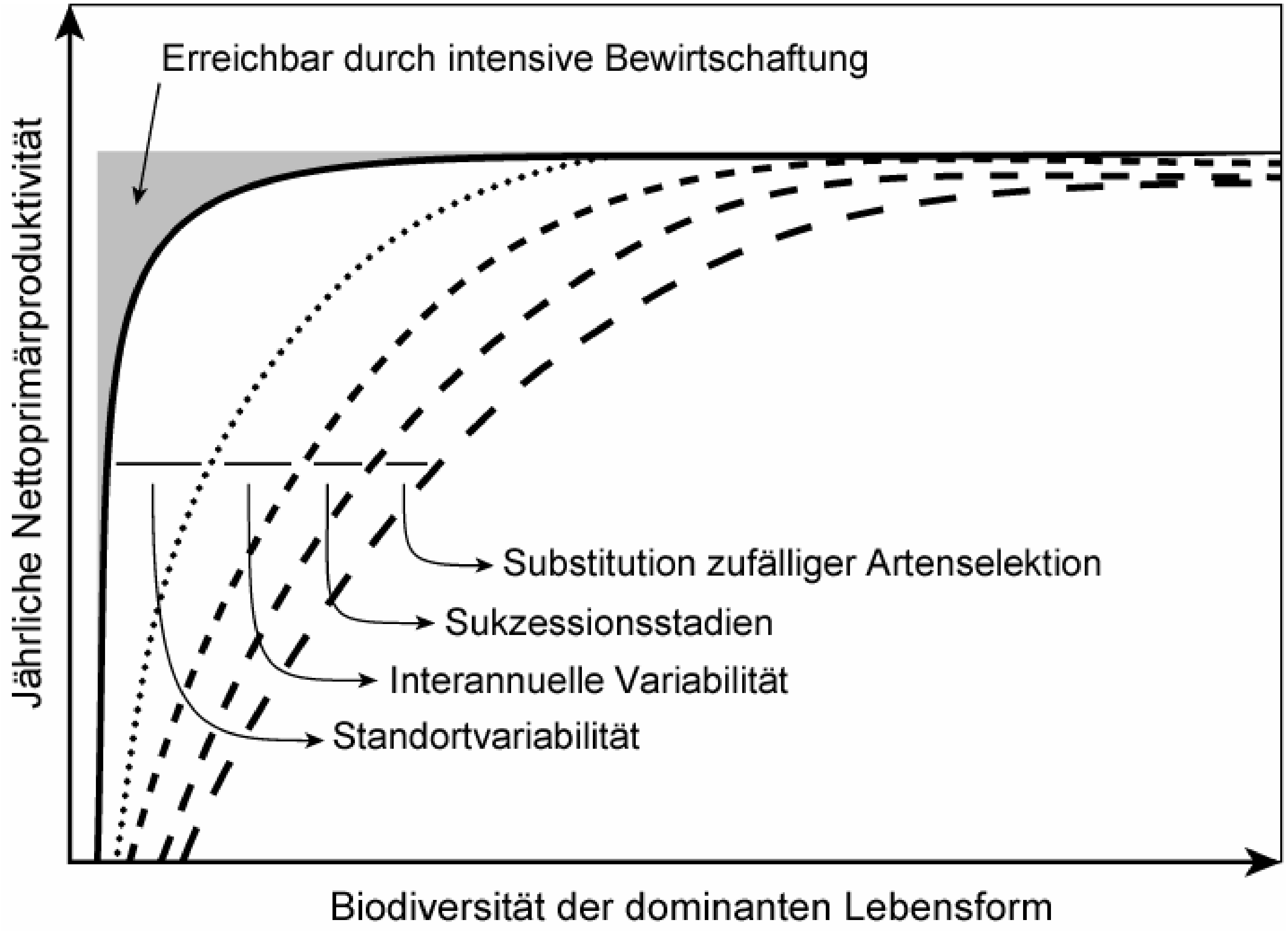
Theory: Sampling effects and complementarity



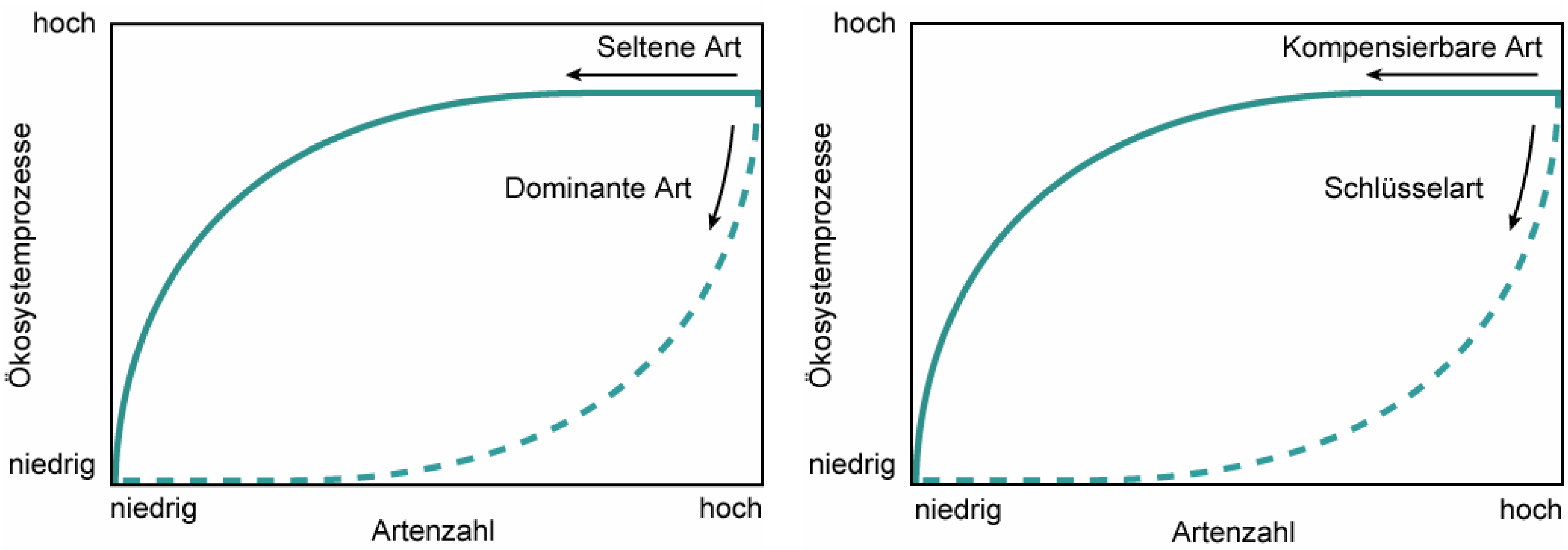
Loreau et al. 1999 Science

Hypothesized mechanisms involved in biodiversity experiments using synthetic communities. Sampling effects are involved in community assembly, such that communitues that have more species have a greater probability of containing a higher phenotypic trait diversity. Phenotypic diversity then maps onto ecosystem processes through two main mechanisms: dominance of species with particular traits, and complementarity among species with different traits. Intermediate scenarios involve complementarity among particular species or functional groups or, equivalently, dominance of particular subsets of complementary species.

Theory of biodiversity – productivity links

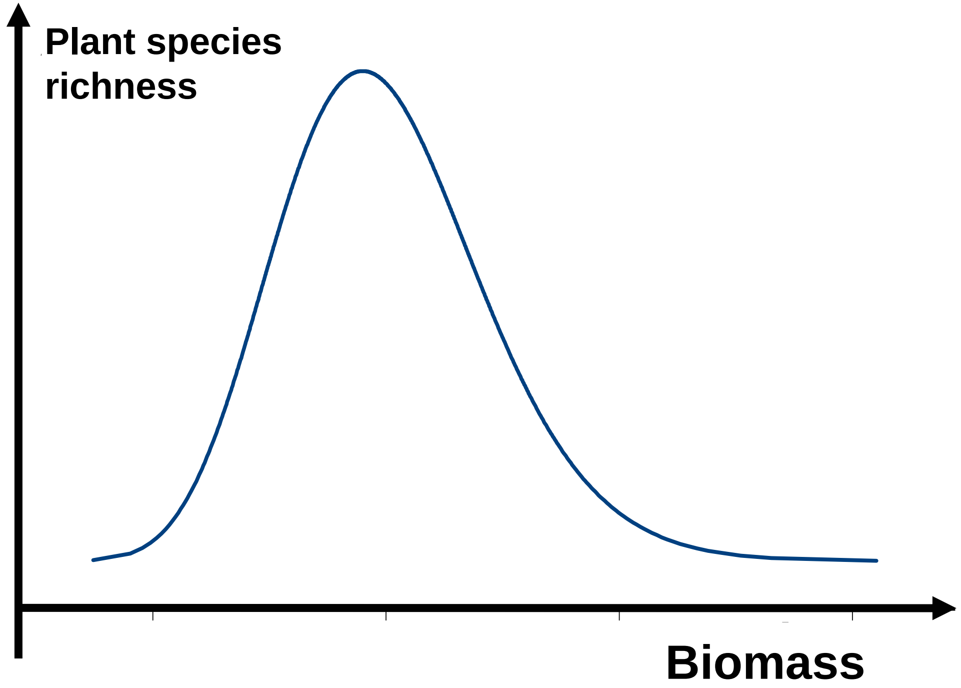


Theory: keystone species



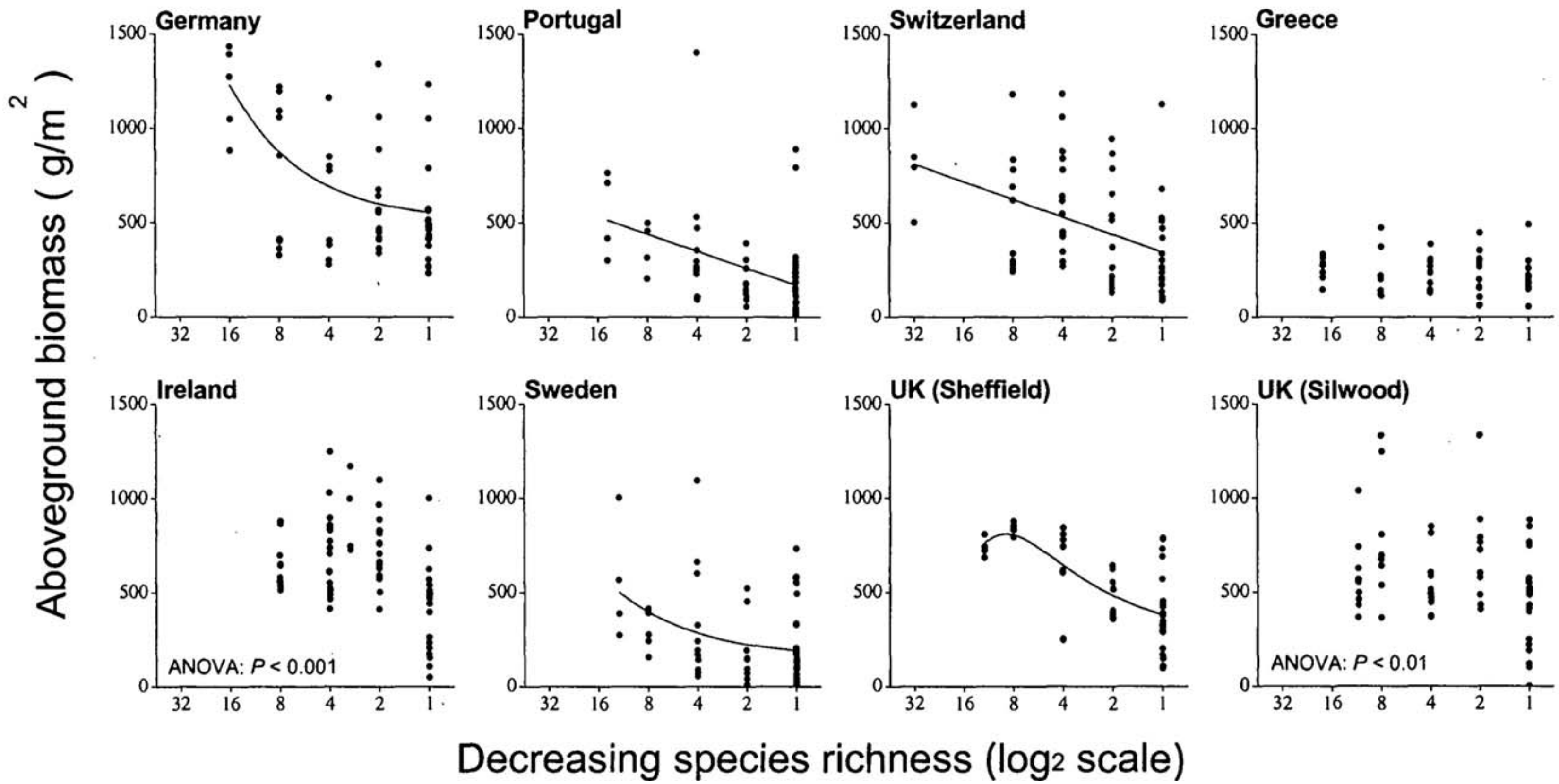
Biodiversity observations

- Spatial variation of biodiversity and productivity (given as maximum biomass of annuals) across ecosystems along environmental gradients



(Al-Mufti et al. 1977)

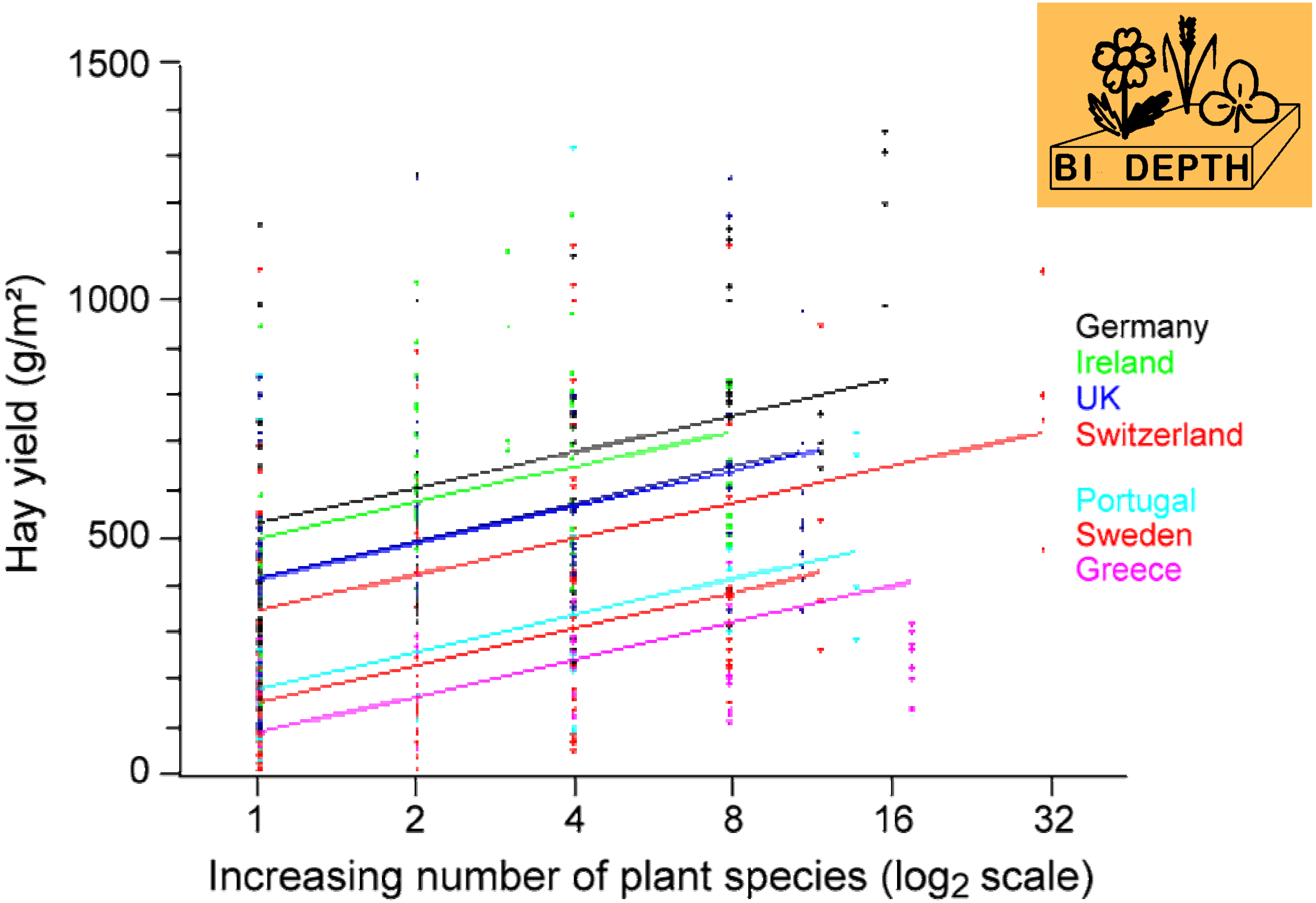
Species richness – productivity in grasslands: BIODEPTH



Biomass patterns at each site (displayed with species richness on a Log_2 scale). Best-fit models from individual sites based on adjusted R^2 are as follows: log-linear in Switzerland and Portugal; linear (untransformed species richness) in Germany and Sweden; quadratic in Sheffield; ANOVA with five species richness levels (significant treatment effects with no simple trend) in Ireland and Silwood; and no significant effect in Greece.

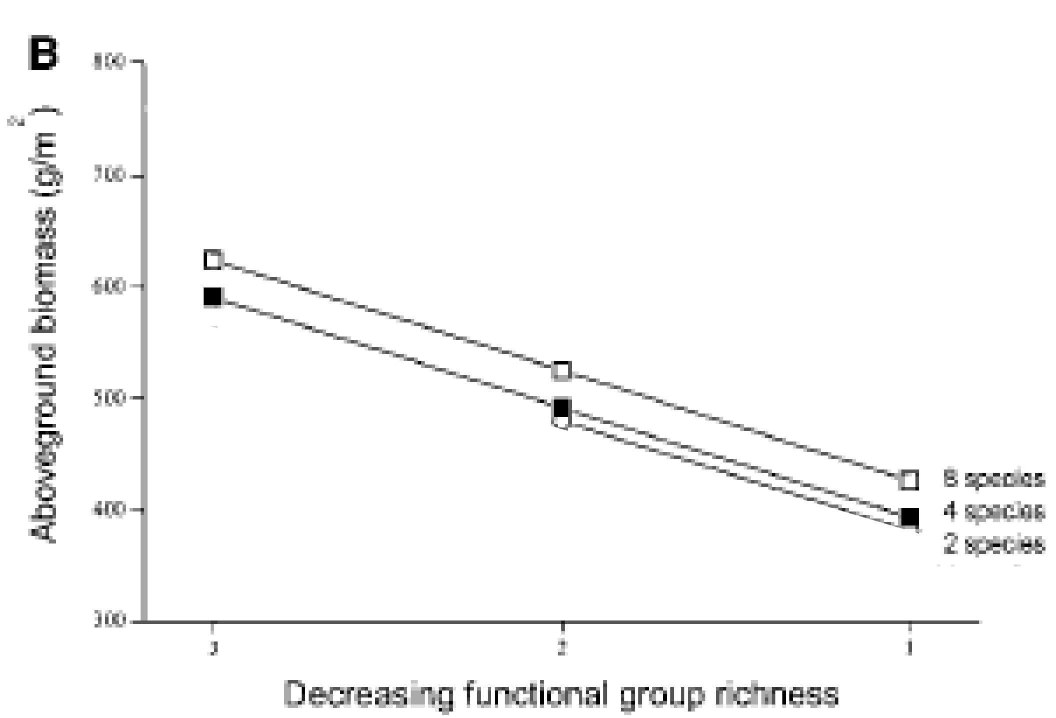
Hector et al. 1999 Science

Species richness – productivity in grasslands: BIODEPTH



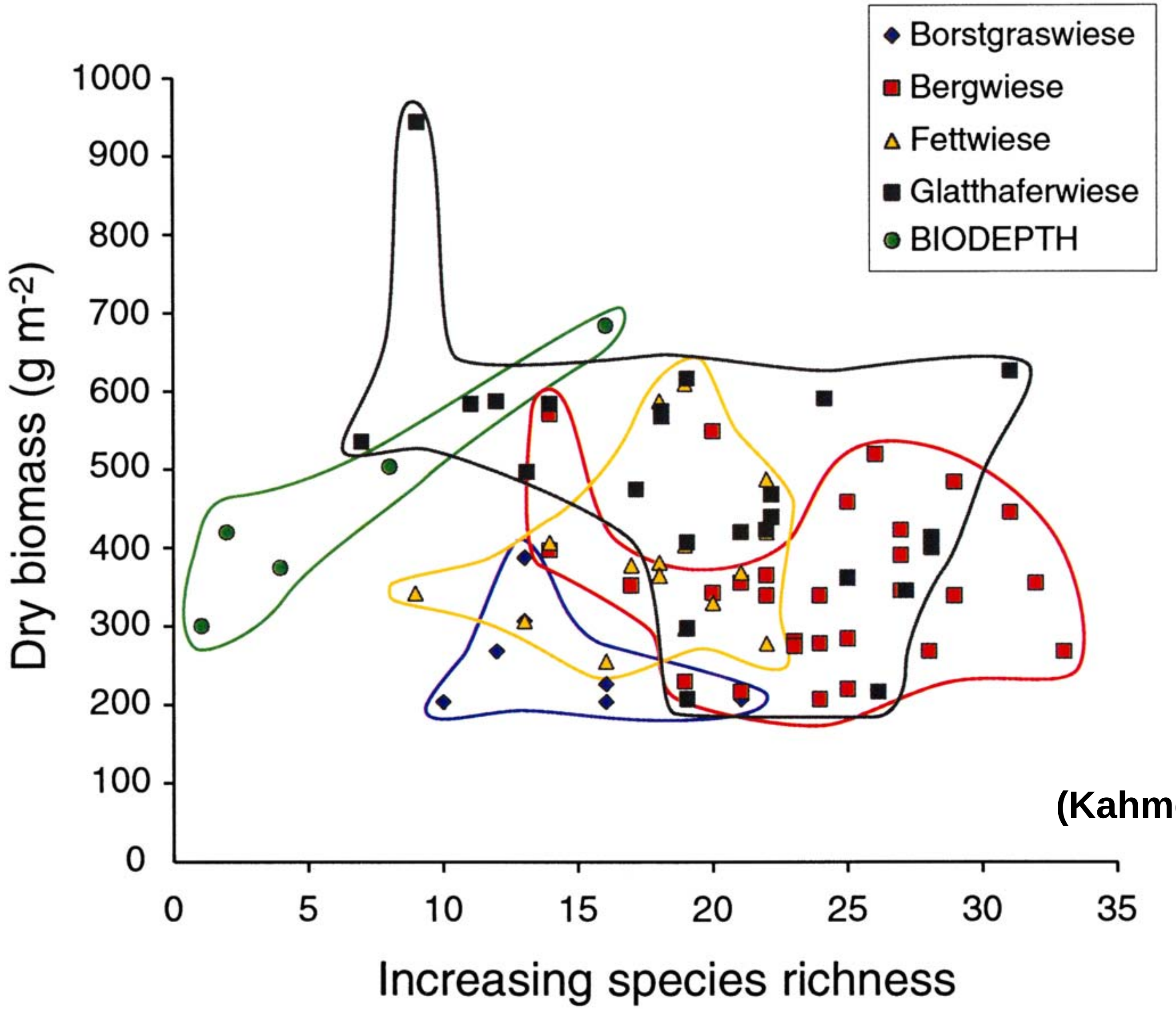
Hector et al. 1999 Science

Functional diversity - productivity



Hector et al. 1999 Science

Species richness – productivity in montane grasslands

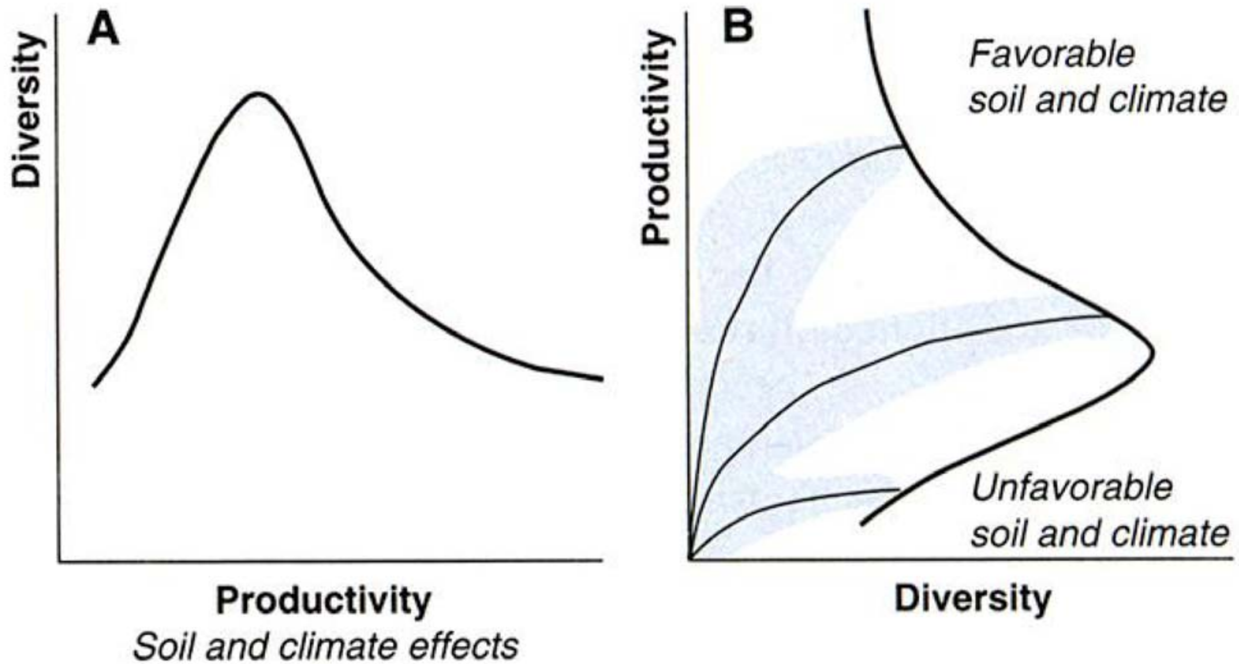


Dry biomass is maximum biomass, an indicator of productivity

Field studies: species composition is more important than species richness

(Kahmen et al., Roscher unpubl.)

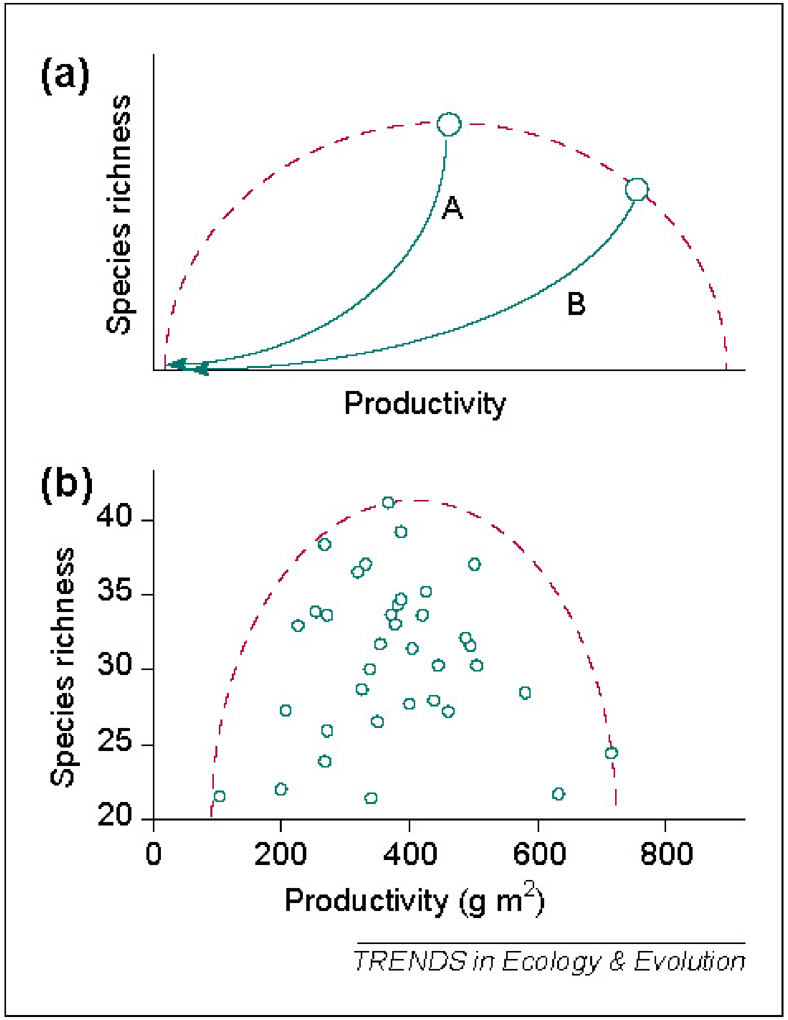
Synthesis (1)



Hypothesized relation-ships between (A) diversity-productivity patterns driven by environmental conditions across sites, and (B) the local effect of species diversity on productivity. (A) Comparative data often indicate a unimodal relationship between diversity and productivity driven by changes in environmental conditions. (B) Experimental variation in species richness under a specific set of environmental conditions produces a pattern of decreasing between-replicate variance and increasing mean response with increasing diversity, as indicated by the thin, curved regression lines through the scatter of response values (shaded areas).

Loreau et al. 2001 Science

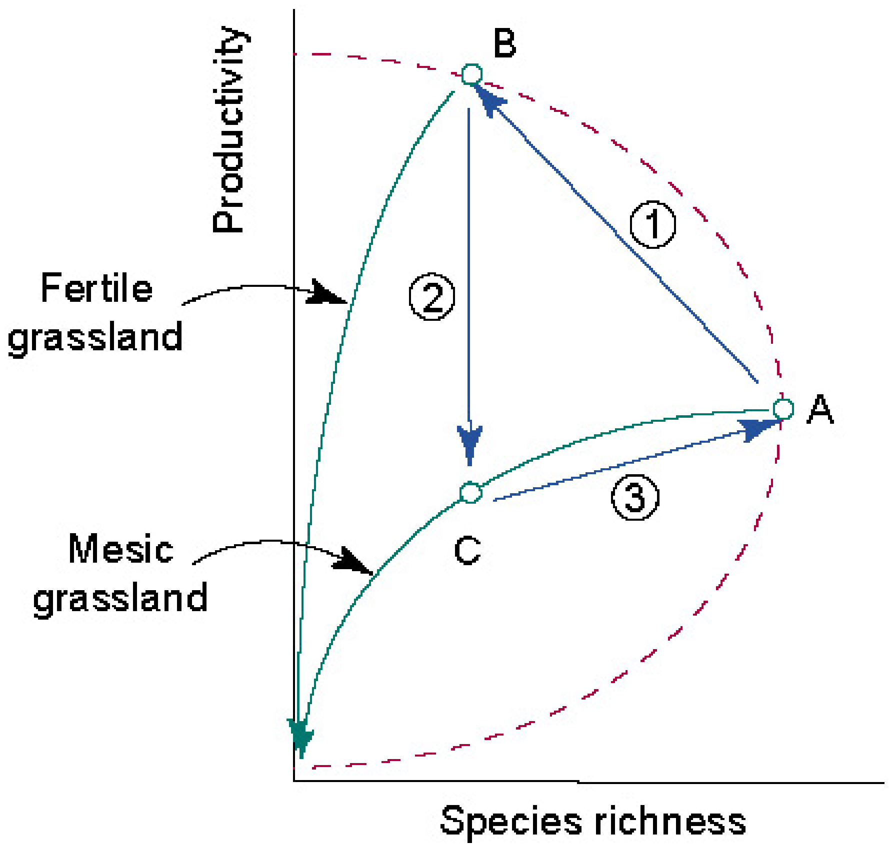
Synthesis (2)



The relationship between plant species richness and productivity in grassland ecosystems (a). The dashed line has been observed in field surveys; the solid lines (A and B) indicate trajectories that are typically obtained in experiments that simulate random species loss. (b) Example of real data from an observational study that included 36 pre-alpine wet grasslands in Switzerland. Each data point is the average of eight sample plots. The dashed curve is an upper envelope over the point cloud.

Schmid 2002
Trends Ecol Evol

Consequences for management



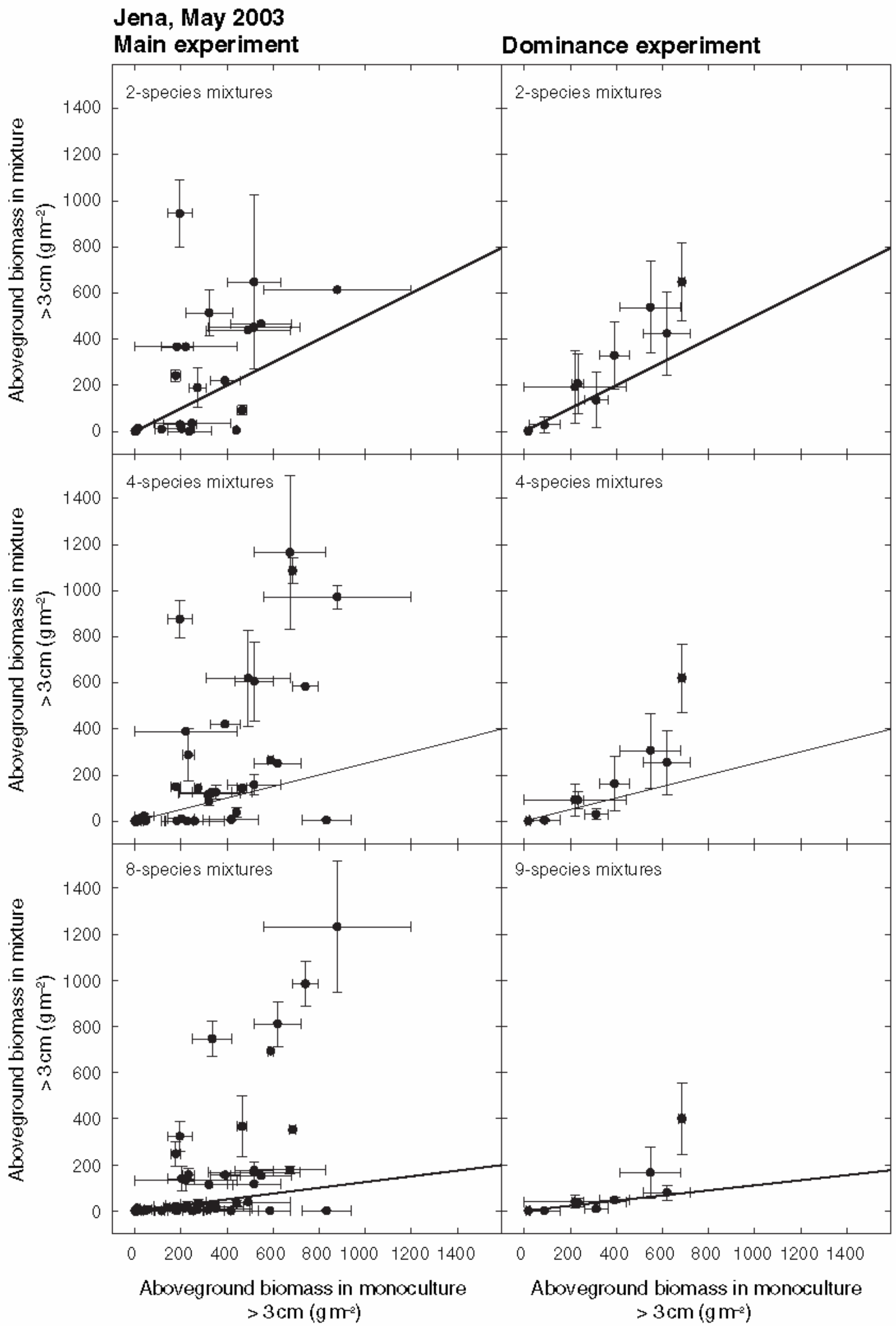
Processes that can take place during land-use changes typical in European grasslands. In a first step (1), the intensification of mesic grassland with a naturally high species richness (A) leads to species loss and an increase in productivity. Extensification (2) reduces site fertility and productivity but does not automatically bring back species that have been lost in Step 1 from the wider region. C can also be reached directly if species loss is simulated in mesic natural grassland.Management should include a third or restoration step (3): adding species lost during the intensification step increases both diversity and productivity.

Schmid 2002
Trends Ecol Evol

Causes for increased productivity in diverse communities

- Overyielding
- Sampling effect versus complementarity
- Competition

- Part of the Jena experiment
  - main experiment with species mixtures out of a pool of 60 species,
  - dominance experiment with mixtures comprising up to 9 potentially dominant species



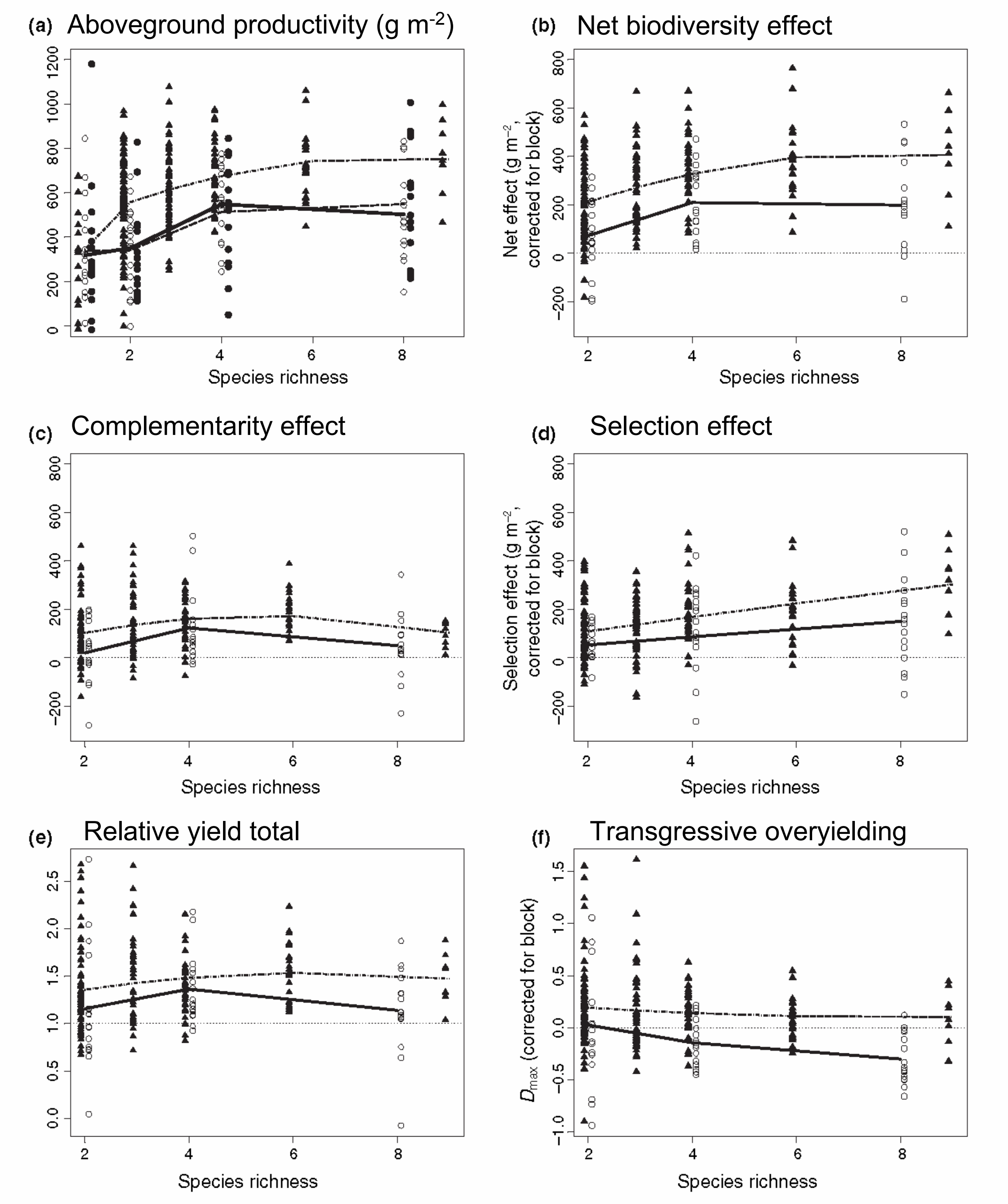
Overyielding

Species-specific biomass in monocultures and mixtures. The line represents the mixture biomass of species predicted from their yield in monoculture.

Non-transgressive overyielding: Biomass of mixture > average biomass of its component monocultures.

Transgressive overyielding: Productivity of mixture per unit area > productivity of its most productice component monoculture.

Roscher et al., 2005
Ecology Letters



Solid line: main experiment. Dash-dot-line: dominance experiment.

Biodiversity influences productivity through complementarity and selection effect.

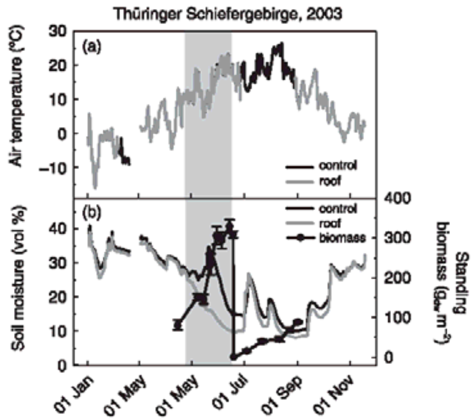
Species richness has higher influence on productivity of dominant species: higher intraspecific than inter-specific competition.

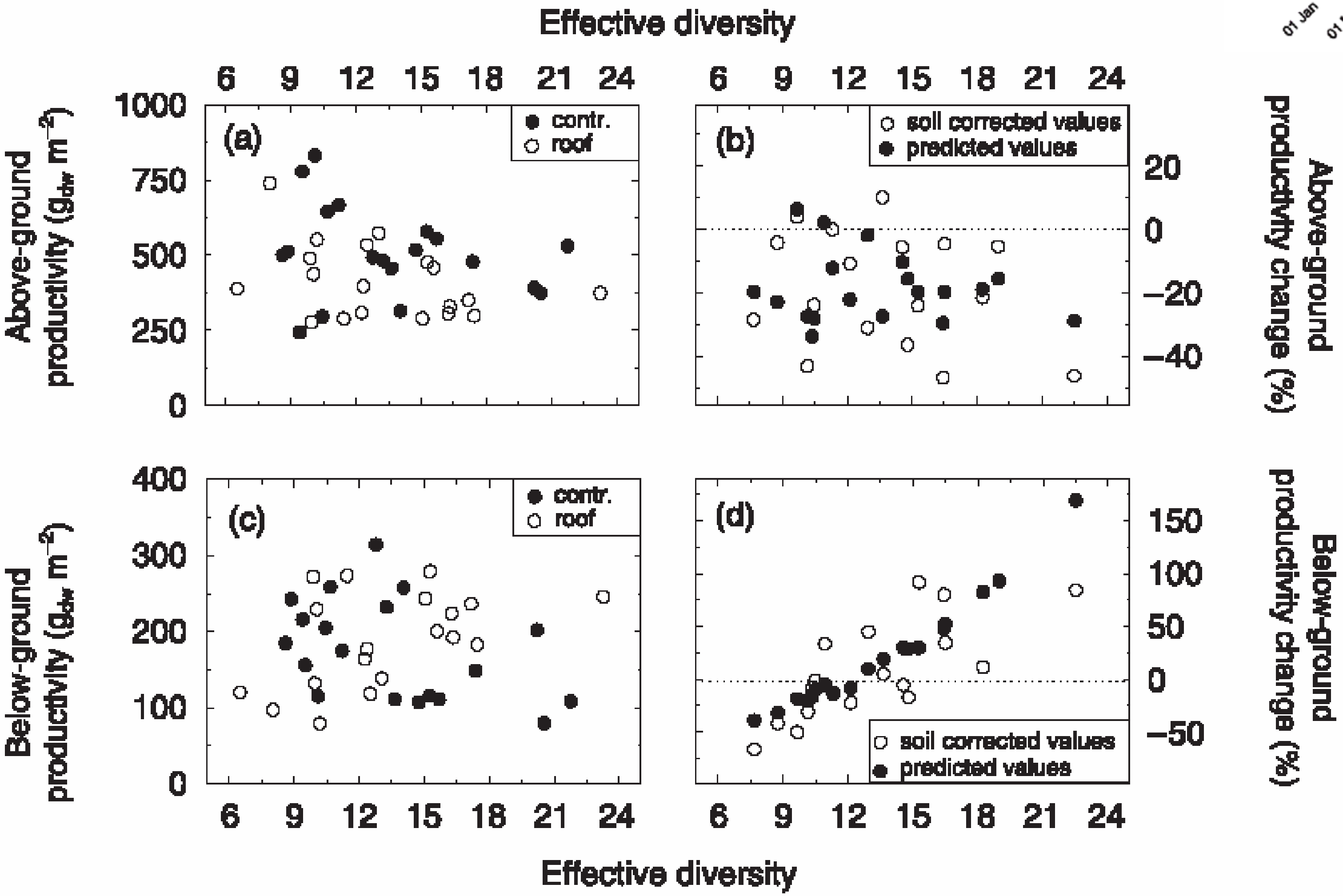
Complementarity reaches maximum above which additional species do not cause better niche exploitation any more.

Biodiversity and stability of ecosystems in a changing climate

- Experimental early summer drought experiment on mountain meadows in Thuringia
- Hypothesis: increasing biodiversity acts as insurance for ecosystem functions in case of extreme weather events because of the different reaction ranges of the individual species.

Kahmen et al., 2005
Functional Ecology

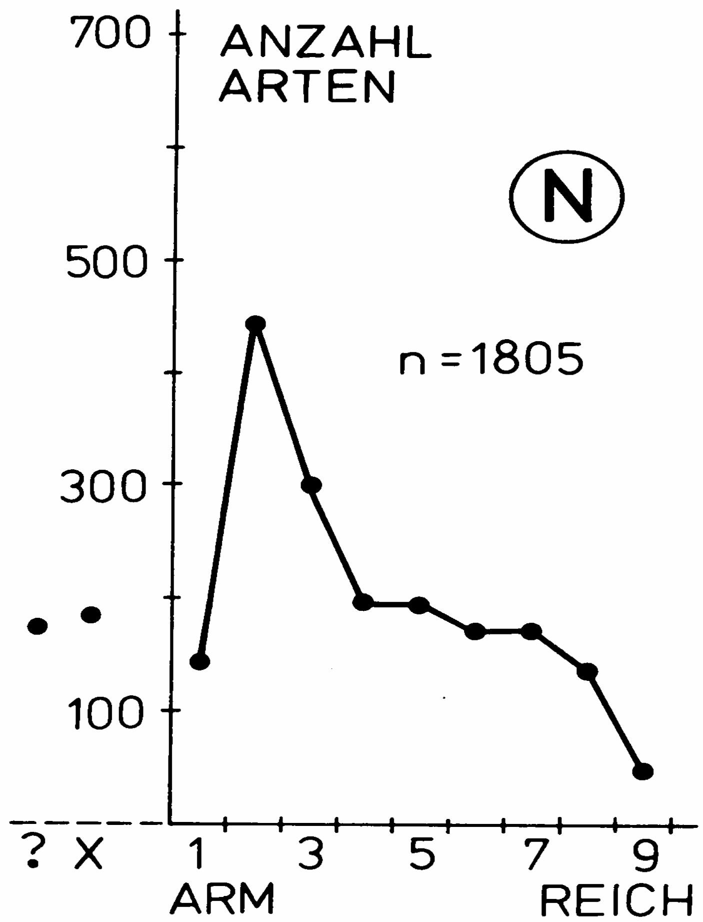




Biodiversity and stability of ecosystems in a changing climate

- Biodiversity effects the response of below-ground biomass, but not aboveground biomass, to experimentally induced early summer drought
- A higher or at least only slightly reduced below-ground biomass increases the probability for the ecosystem to withstand the drought event and to maintain its functioning.
- Likely cause: higher probability for the grasslands to include drought resistant species at higher diversity levels.

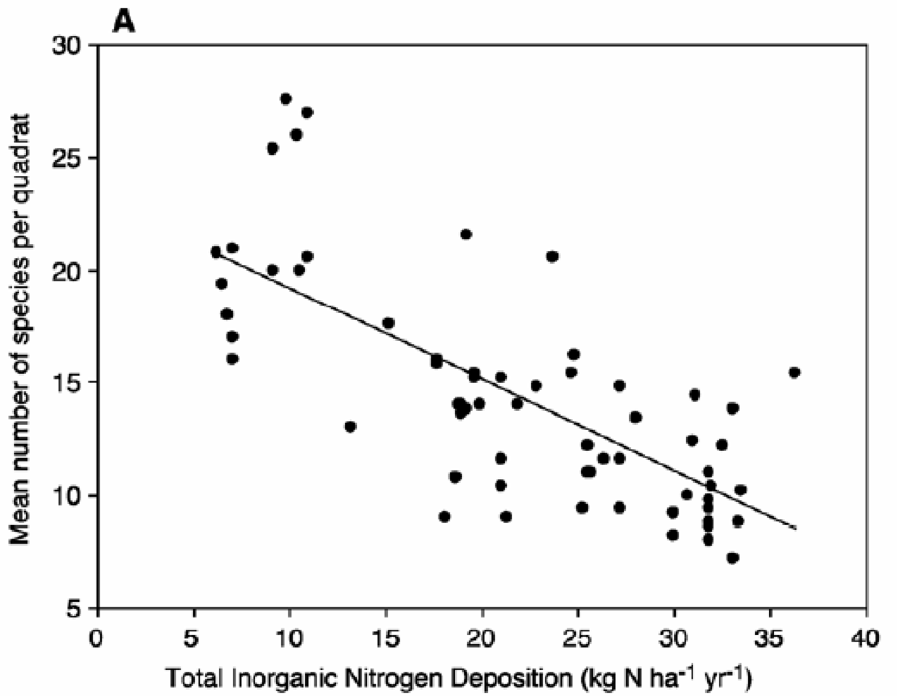
Anpassung der Arten an das Nährstoff-Angebot



Die Verteilung mitteleuropäischer Gefäßpflanzenarten im Gradienten der Stickstoffzeigerwerte

Ellenberg, (1989)

Species number related to N availability in grasslands



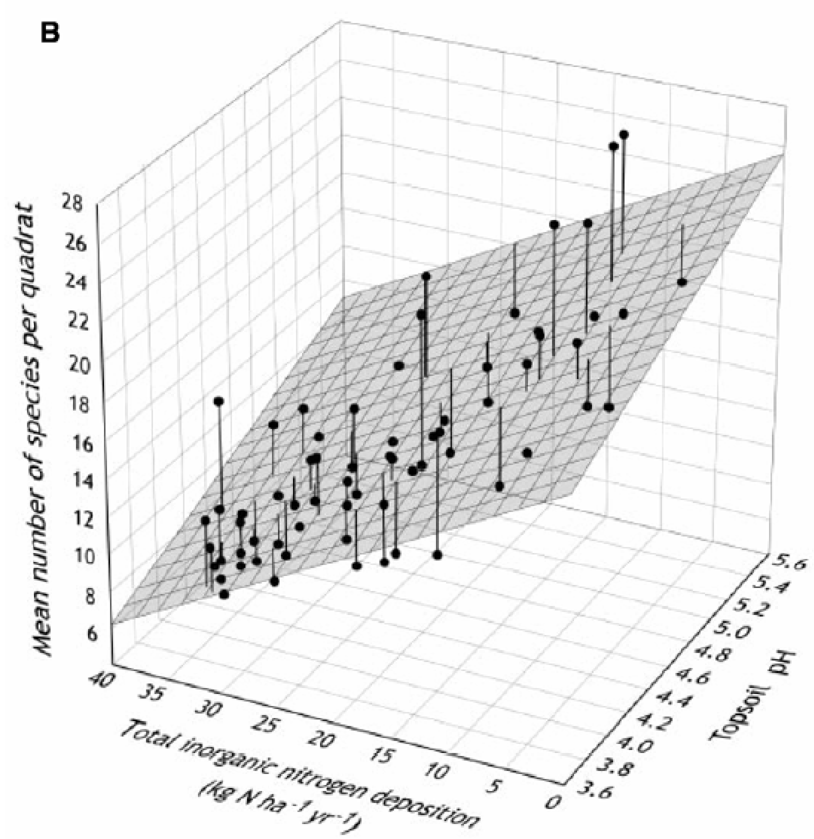


Fig. 2. (**A**) Acid grassland species richness plotted against N deposition for 68 field sites visited in the summers of 2002 and 2003. The regression line shown is Eq. 1. (**B**) Plant species richness versus N deposition and topsoil pH. The regression equation shown is: *Plant Species Richness* = 6.63 + 3.40(*Top pH*) − 0.316(*Nin*); $r^2 = 0.61$, $N = 68$, $P < 0.004$.

Stevens et al. (2004)

Biodiversity – ecosystem processes

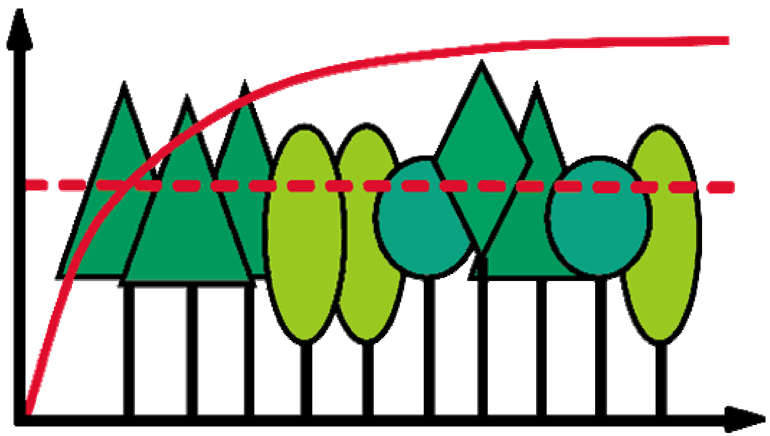
- Soil organisms, decomposition, C storage have so far been largely neglected
- New experiments:
  - JENA Experiment Saaleaue (Grassland)
  - BIOTREE (Afforestation)

JENA-Experiment: Saaleaue

Species richness
Functional diversity
Sampling versus complementarity
Soil processes
Insects, predators

http://www2.uni-jena.de/biologie/ecology/biodiv/index.html

BIOTREE



Species richness
Functional diversity
Different soil substrate
Carbon pools and turnover

http://www.biotree.bgc-jena.mpg.de/deutsch/index.html

Fragen

- Welche Zusammenhänge bestehen zwischen Biodiversität und der Stabilität von Ökosystemen?
- Was versteht man unter „overyielding“ und wie kann man es erklären?
- Welche Aspekte der Biodiversität sind zu berücksichtigen, wenn man sich mit ihrem Einfluss auf Ökosystemprozesse beschäftigt?