Soil biota:

Global change and the function of forest soils as a habitat for soil organisms

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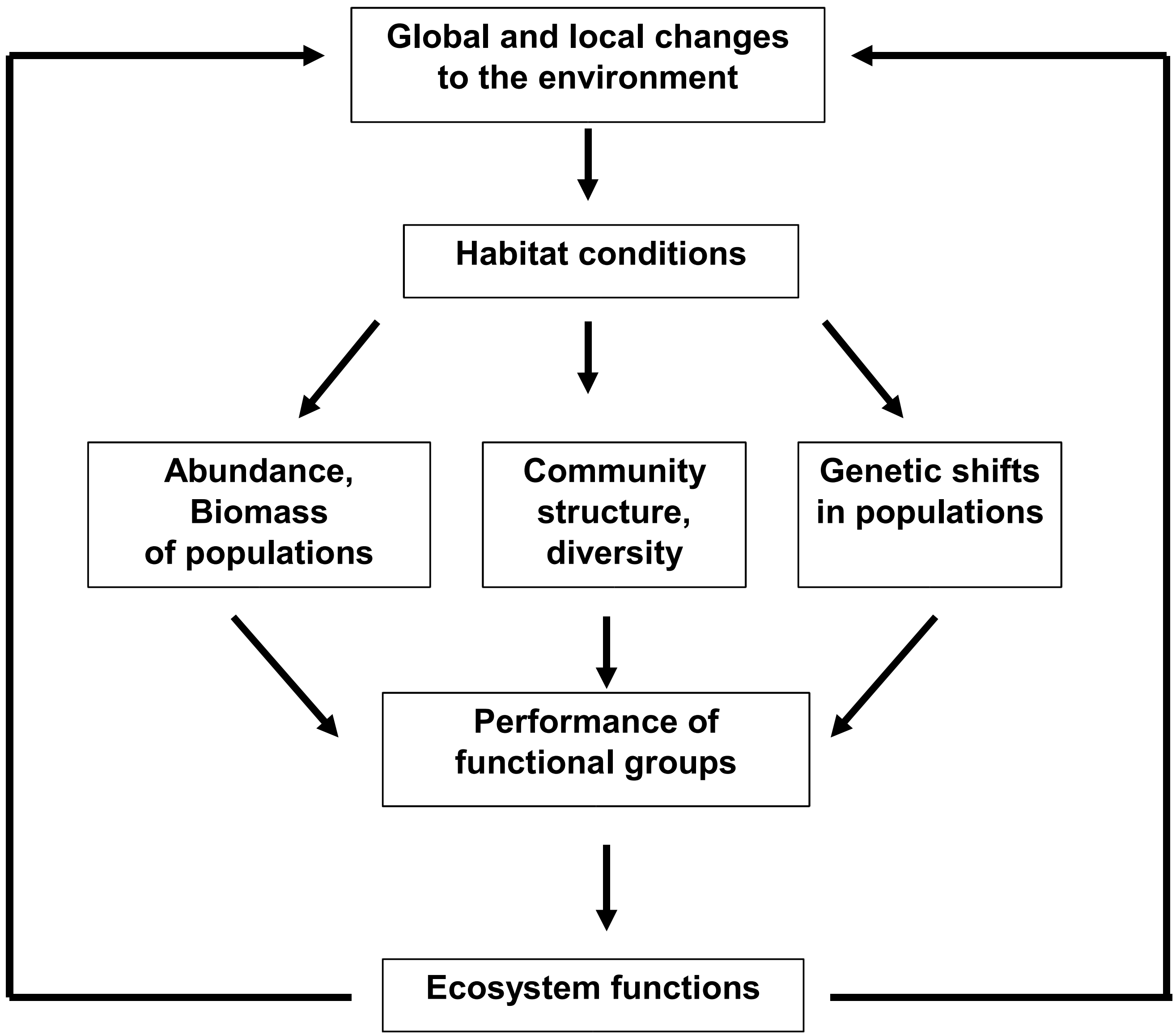
Forests soils under global and local changes *from research to practice*

International symposium, 15 to 18 September 2004, Bordeaux-France

Habitat conditions rule soil biota performance



Ecosystem functions provided by soil biota

- **Decomposition and Mineralization**
  - **saprofagious invertebrates**
  - **bacteria and fungi**

- **Formation of Soil Structure (Bioturbation)**
  - **earthworms**

- **Regulation (Predation)**
  - **nematodes, colembola, mites….**

Ecosystem functions provided by soil biota

Functions	Organisms involved
➢ Maintenance of soil structure	Bioturbating invertebrates and plant roots, mycorrhizae and some other microorganisms
➢ Regulation of soil hydrological processes	Most bioturbating invertebrates and plant roots
➢ Gas exchanges and carbon sequestration	Mostly microorganisms and plant roots, some C protected in large compact biogenic invertebrate aggregates
➢ Soil detoxification	Mostly microorganisms
➢ Nutrient cycling	Mostly microorganisms and plant roots, some soil and litter feeding invertebrates
➢ Decomposition of organic matter	Various saprophytic and litter feeding invertebrates (detritivores), fungi, bacteria, actinomycetes and other microorganisms
➢ Suppression of pests, parasites and diseases	Plants, mycorrhizae and other fungi, nematodes, bacteria and various other microorganisms, collembola, earthworms, various predators
➢ Sources of food and medicines	Plant roots, various insects (crickets, beetle larvae, ants, termites), earthworms, vertebrates, microorganisms and their by-products
➢ Symbiotic and asymbiotic relationships with plants and their roots	Rhizobia, mycorrhizae, actinomycetes, diazotrophic bacteria and various other rhizosphere microorganisms, ants
➢ Plant growth control (positive and negative)	Direct effects: plant r oots, rhizobia, mycorrhizae, actinomycetes, pathogens, phytoparasitic nematodes, rhizophagous insects, plant growth promoting rhizosphere microorganisms, biocontrol agents Indirect effects: most soil biota

detailed list from Swift 2001

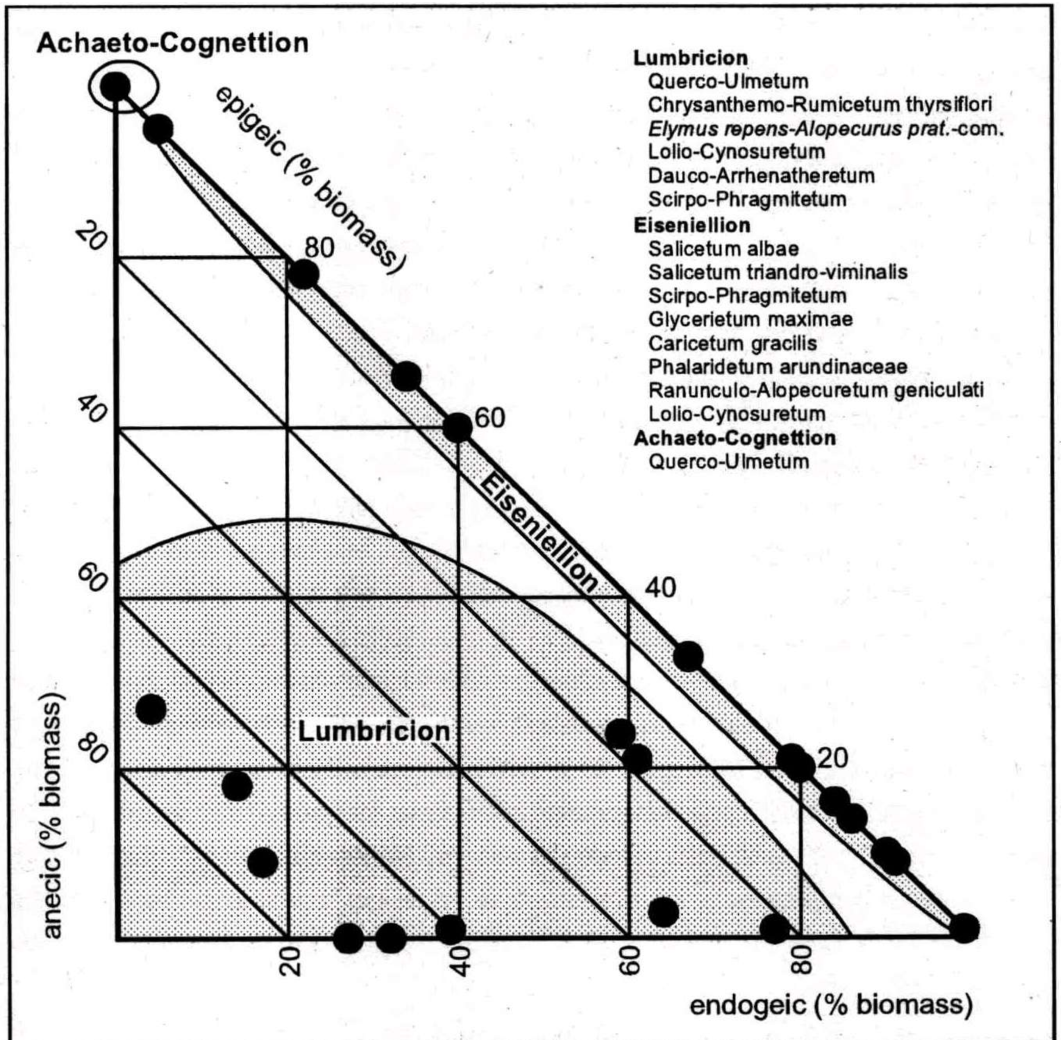
Soil biota: Groupings, Outcuts

- **Taxonomic groupings**
  - Animals, Microbs …
  - Species, families …
- **Ecological groupings**
  - life forms (earthworms)
  - feeding types (nematoda)
- **Size groupings**
  - meio-, meso-, and macrofauna
  - litterbag mesh sizes
- **Biogeografic grouping**
  - exotic vs. native
- **Anthropogenic grouping**
  - pests vs. beneficial organisms
- **Special groupings**
  - specific functions like AM fungi etc.

Classifications of Communities (Graefe)

Order	Alliance	Association
1. **Lumbricetalia** Sites moderately acid to rich in lime	1.1 **Lumbricion** Undisturbed aerated soils	1.11 **Stercuto-Lumbricetum** Forest with mull humus forms
		1.12 **Fridericio-Lumbricetum** Grassland and arable land on loamy soils
	1.2 **Enchytraeion** Disturbed and eutrophicated soils	1.21 **Fridericio-Enchytraeetum** Arable land on sandy soils
		1.22 **Buchholzio-Enchytraeetum** Eutrophicated, compacted soils under urban influence
		1.23 **Eisenietum** Compost sites
	1.3 **Eiseniellion** Water-saturated, badly aerated soils	1.31 **Octolasietum tyrtaei** Fen, alder swamp, high base saturation
		1.32 **Eisenielletum** Semiaquatic sites, floodplain
2. **Cognettietalia** Sites with acid humus layer or peat	2.1 **Achaeto-Cognettion** Dry and moist soils with low base saturation	2.11 **Achaeto-Cognettietum** Forest and heathland with moder or mor humus forms
	2.2 **Cognettion sphagnetorum** Wet organic soils with low base saturation	2.21 **Cognettietum sphagnetorum** Fen, ombrotrophic bog, low base saturation
3. **Henleetalia** Sites moderately acid to rich in lime with humus layer	3.1 **Mesenchytraeo-Henleion** Decomposition inhibited by low temperature	3.11 **Mesenchytraeo-Henleetum** Permafrost soils in arctic tundra
	3.2 **Fridericio-Henleion** Bioturbation inhibited by lack of soil dwelling earthworms	3.21 **Fridericio-Henleetum** Early succession stage in reclaimed polders and marshlands
4. **Communities influenced by salt** (not yet differentiated)		

Classifications of Communities (Graefe)



Soil biota: Groupings, Outcuts

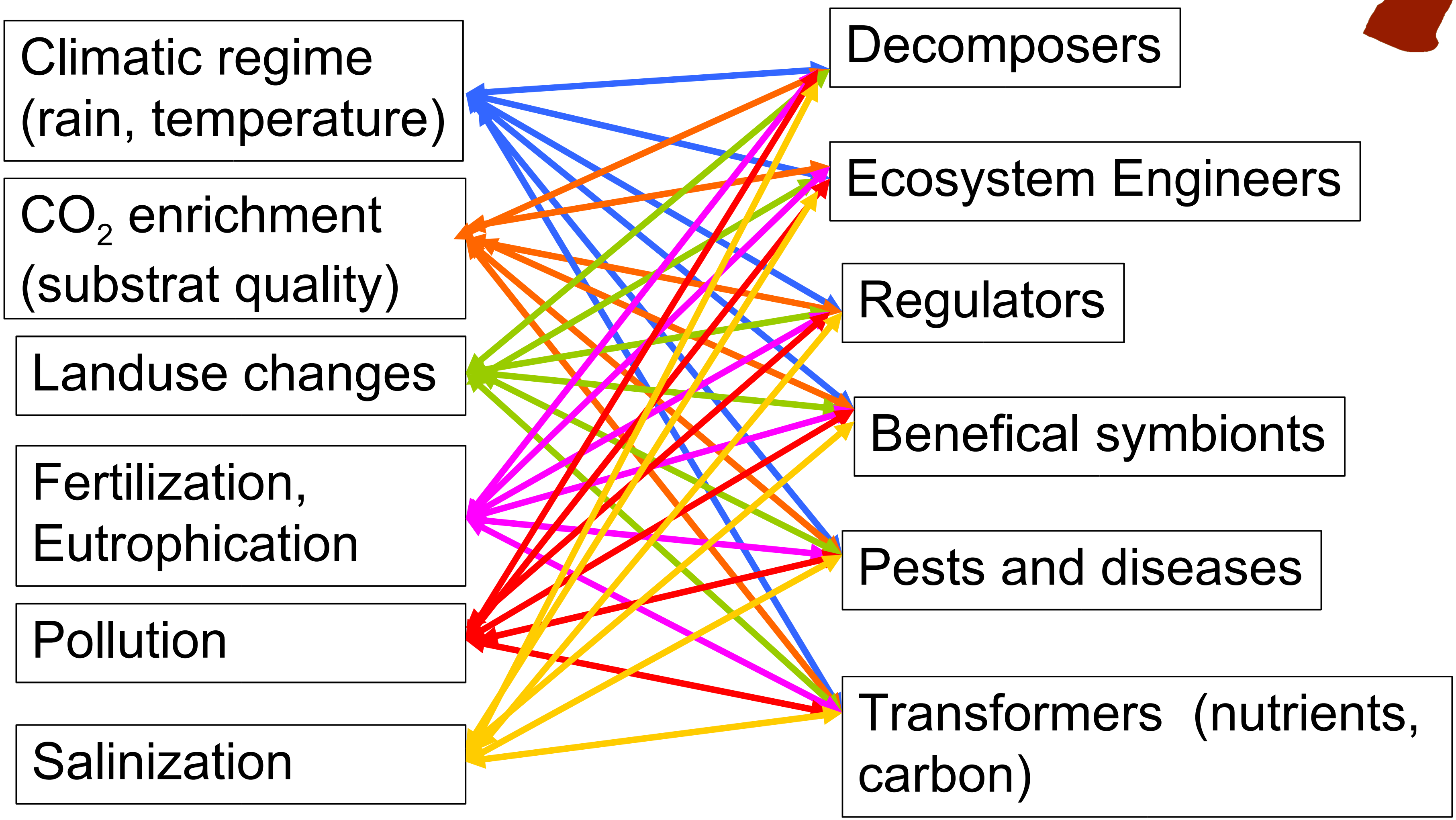
- **<u>Taxonomic groupings</u>**
  - **Animals, Microbs …**
  - **Species, families …**
- **<u>Ecological groupings</u>**
  - **life forms (earthworms)**
  - **feeding types (nematoda)**
- **<u>S</u>**

  s
- **<u>B</u>**

What is our language?

- **<u>A</u>**
  - **pests vs. beneficial organisms**
- **<u>Special groupings</u>**
  - **specific functions like AM fungi etc.**

Environmental changes vs key functional groups



Environmental changes vs key functional groups

Climatic regime
(rain, temperature)

CO_2 e
(subst

Landu

Fertili
Eutro

Pollution

Salinization

Decomposers

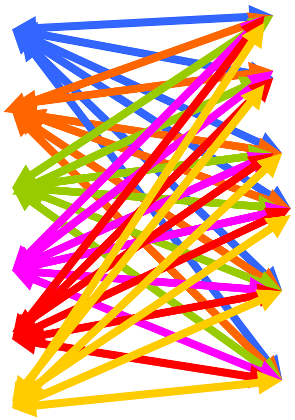
Transformers (nutrients, carbon)

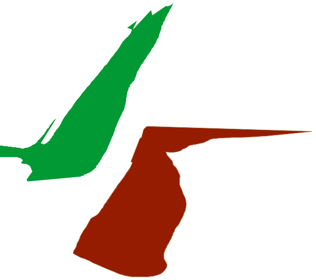
Therefore, just looking for the processes in functions,

measuring nutrient pools and transformatinons?

No, it is a multidisciplinary task!

biodiversiy vs stability and risk





diversity

specialists

specific generalists

generalists

risk

Scientific tools and design of experiments

Microcosm studies in the lab

Microcosm studies in the field

Field investigation of gradients covering trends of global change

Long term field investigations and monitoring

Increasing precion of data
Decreasing reliability to field conditions

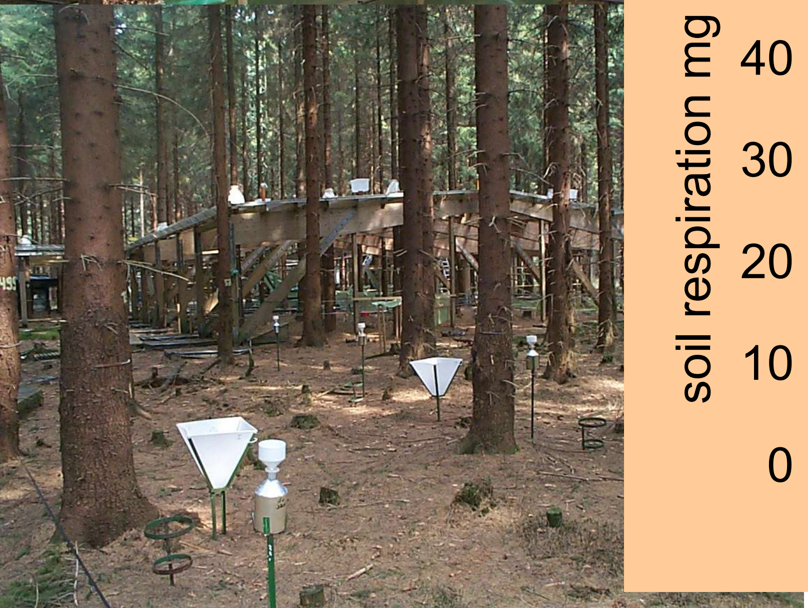
Complex field investigations $\longrightarrow$ Controlled lab experiments

Complex field investigations $\longleftarrow$ Controlled lab experiments

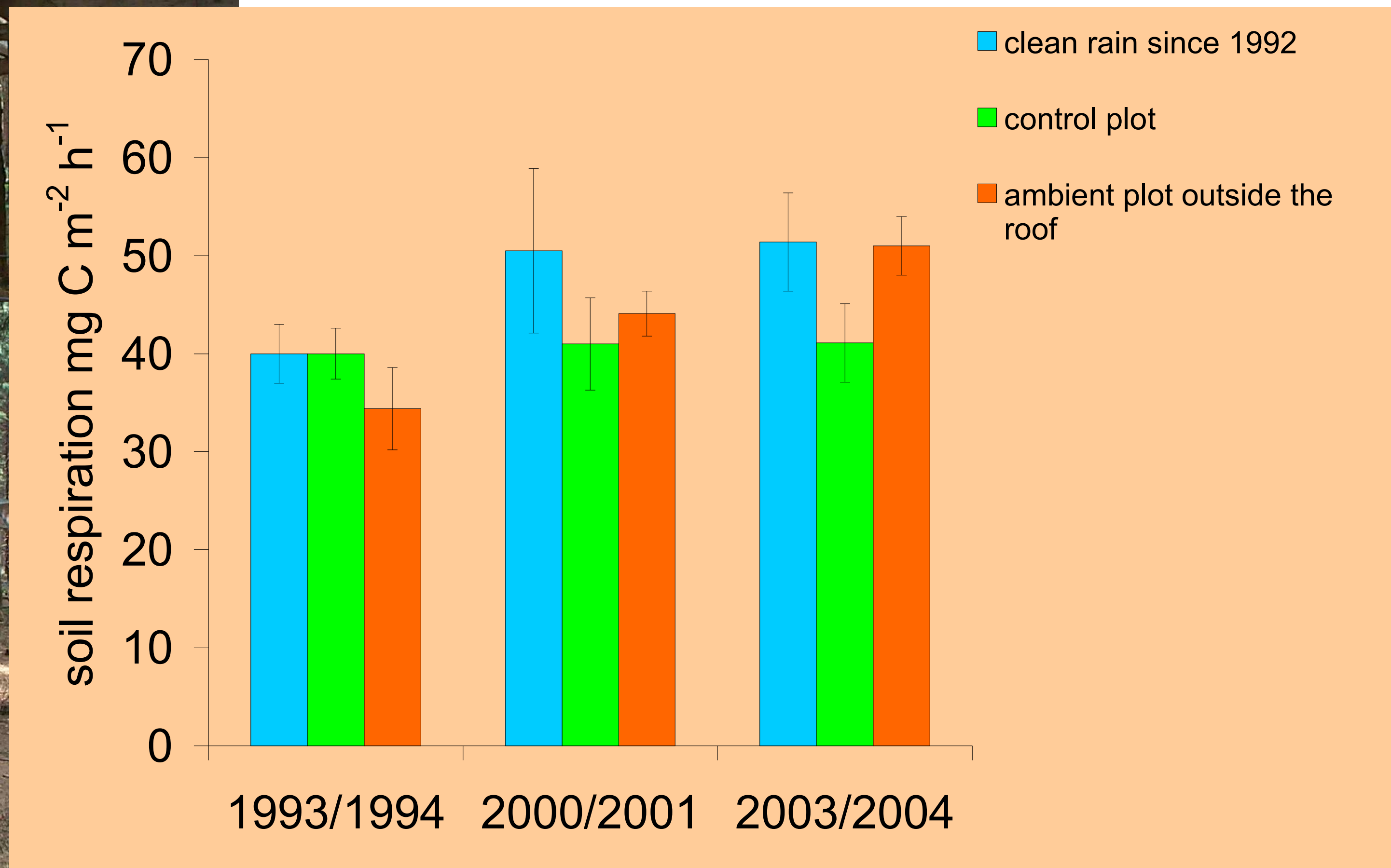
Increasing variance and pertubation of data

Some snapshots from current science (1)

Long term monitoring of forest sites



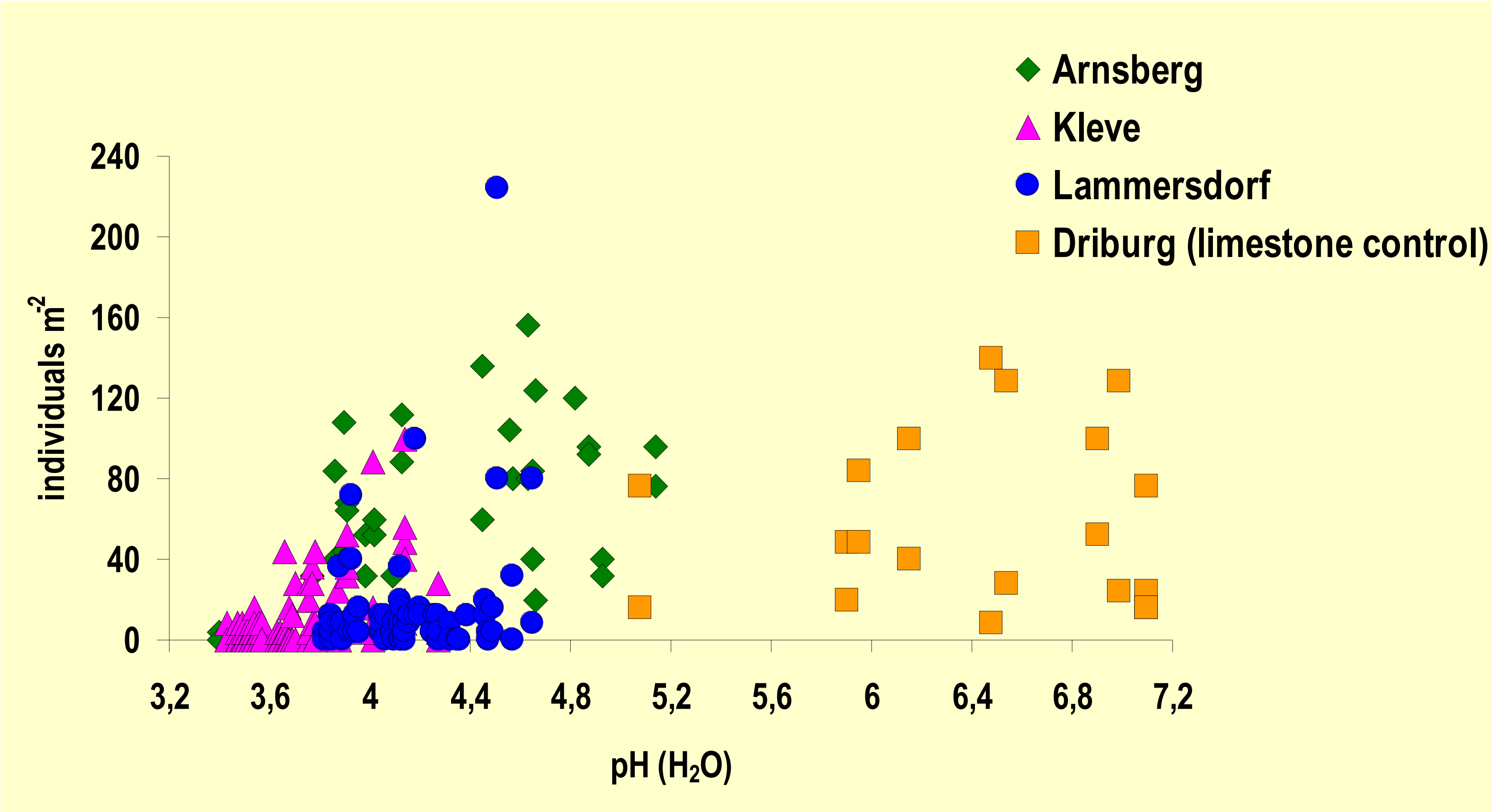
The roof project at Solling, Germany



Some snapshots from current science (2)

Forest management practices and soil biota

Earthworms in forest floors after degradation from acid rain and later liming as an restoration practice



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Some snapshots from current science (2)

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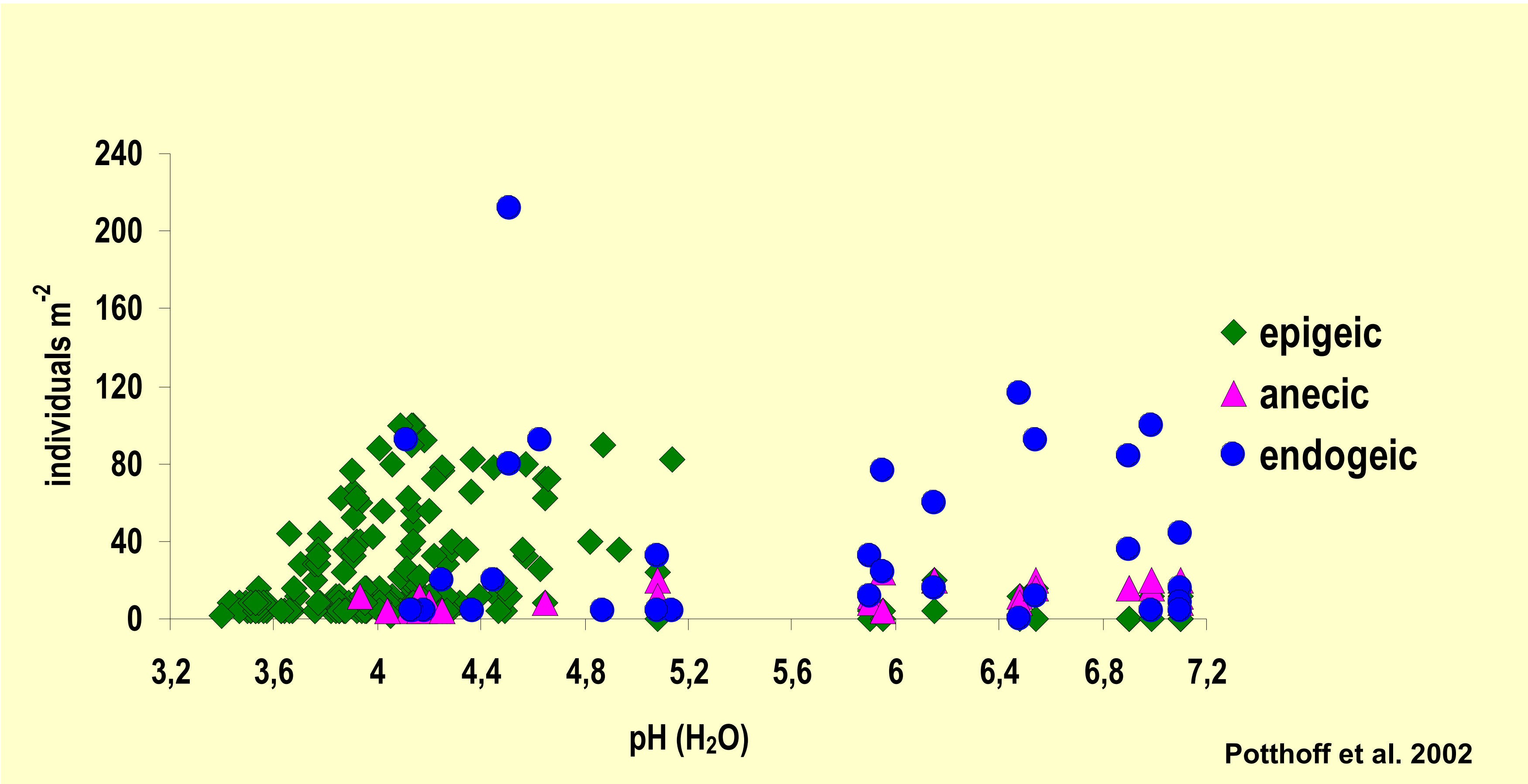
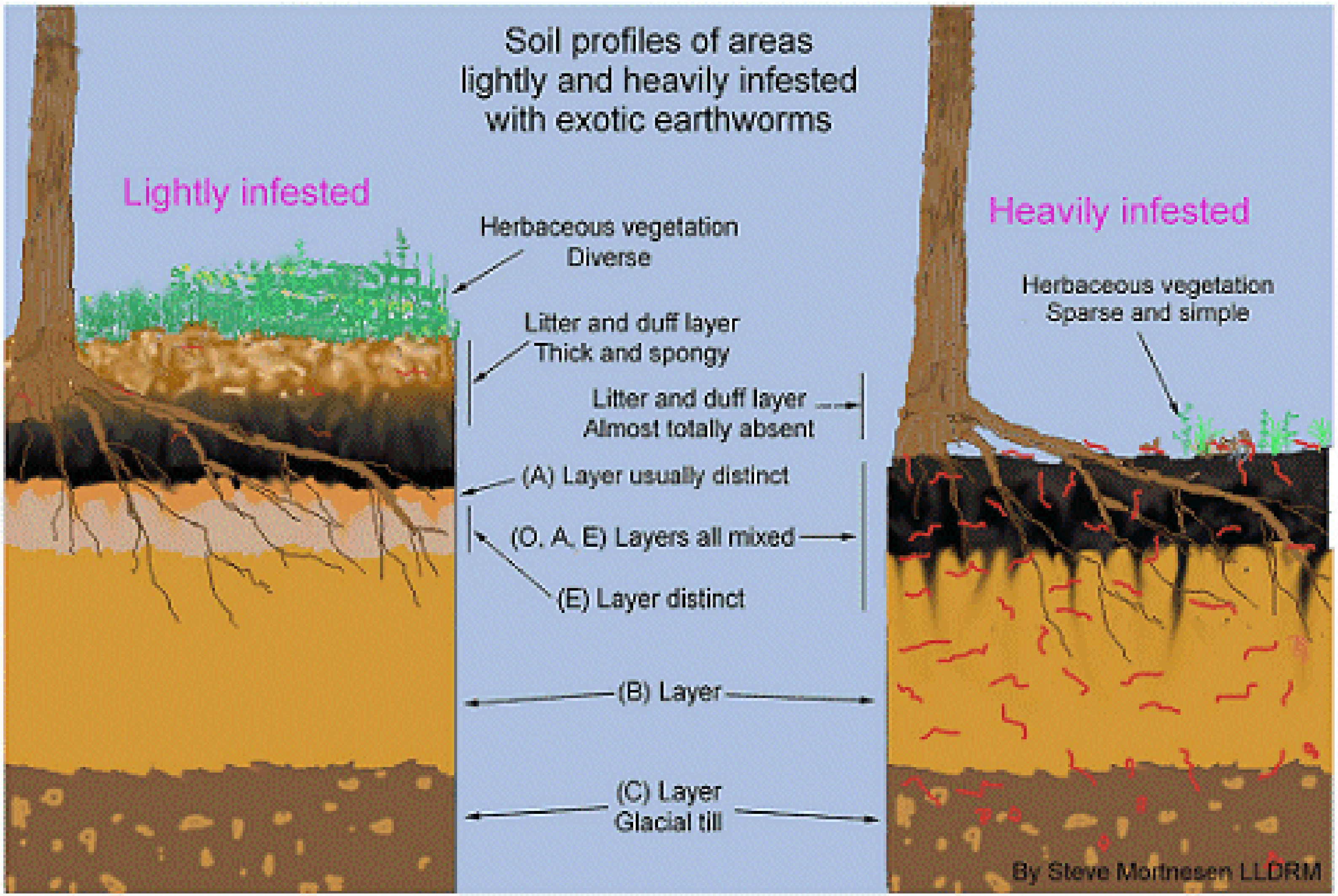


Kleve														
Monschau														
Arnsberg														
Bad Driburg														
Buffer regions	Al				Exchanger				Silicate			Carbonate		
pH (H_2O, 0-5 cm)	3.4-3.6	3.6-3.8	3.8-4.0	4.0-4.2	4.2-4.4	4.4-4.6	4.6-4.8	4.8-5.0	5.0-5.2	5.8-6.0	6.0-6.2	6.4-6.6	6.8-7.0	7.0-7.2
Lumbricus rubellus	+	+	+	+	+	+	+	+	+	+	+			
Dendrodrilus rubidus	+	+	+	+	+	+	+	+	+					
Dendrobaena octaedra	+	+	+	+	+	+	+	+						
Lumbricus castaneus		+	+	+	+	+	+	+	+	+	+	+	+	+
Dendrobaena pygmaea					+									
Lumbricus terrestris				+	+		+		+	+	+	+	+	+
Aporrectodea longa				+										
Aporrectodea caliginosa									+	+	+	+	+	+
Aporrectodea rosea				+		+		+		+		+	+	+
Octolasion lacteum						+	+	+	+	+	+	+	+	+
Octolasion cyaneum									+	+	+	+		
Eiseniella tetraedra						+								

Potthoff et al. 2002

Some snapshots from current science (3)

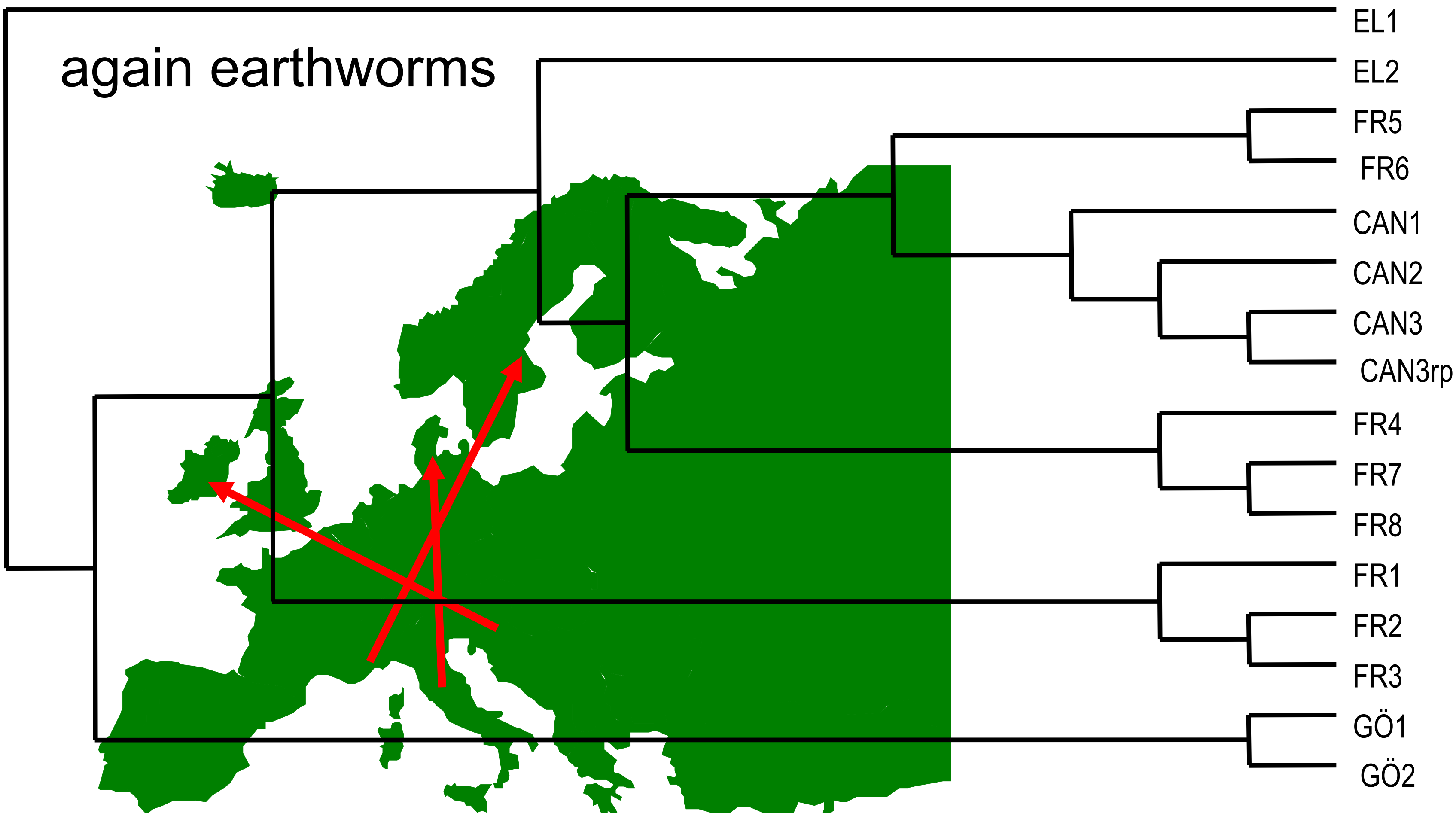
Invasion of non-native species (Earthworms in Minnesota)



Some snapshots from current science (4)

Genetic shifts due to changes in habitat quality

again earthworms



Gailing & Potthoff 2003 unpubl.

Some snapshots from current science (5)

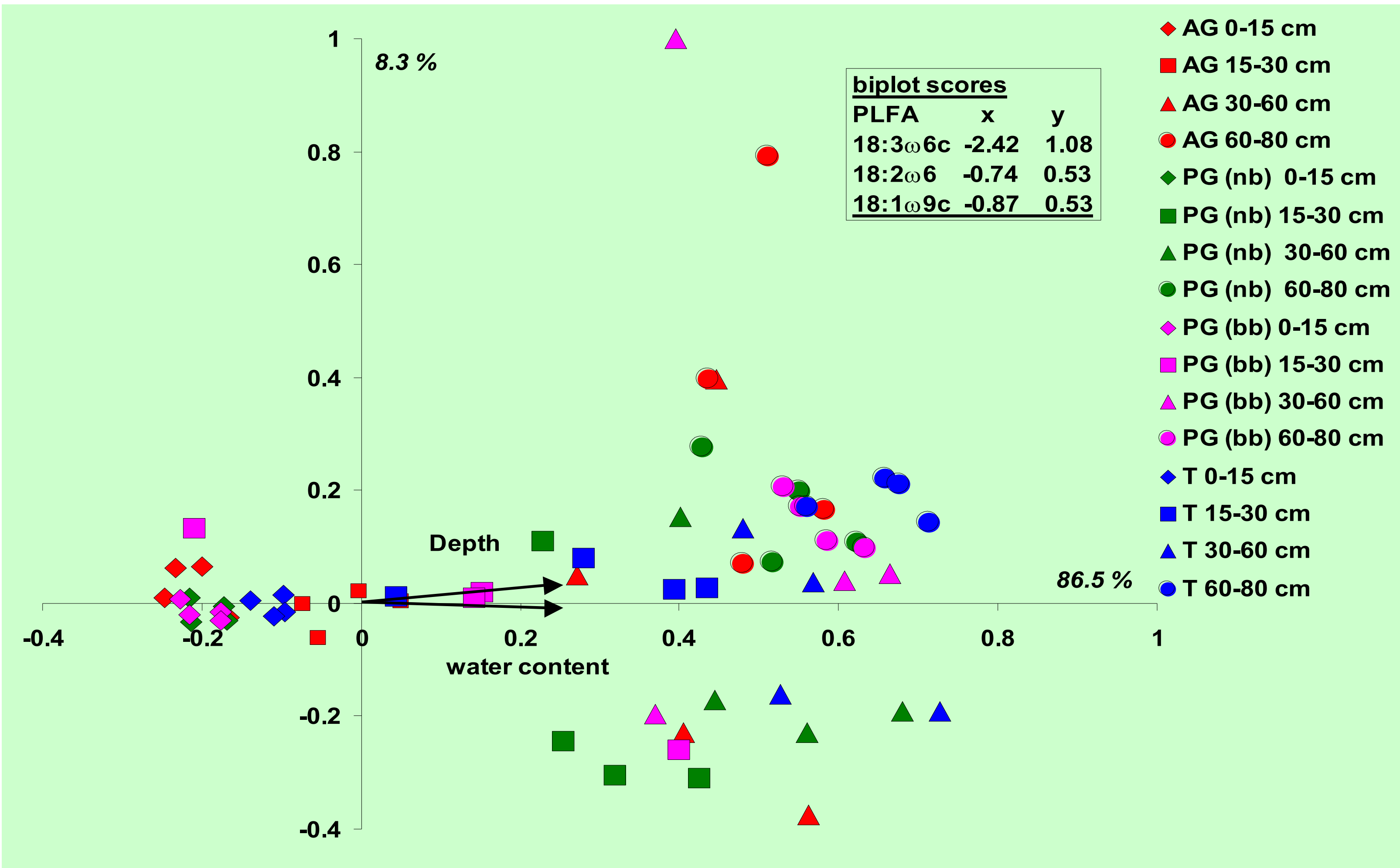
Atmospheric enrichment of CO_2 and soil microbial biomass

Results from FACE experiments in forest and grassland plots

(3) Mostly no effect of FACE was detected for SMB-C even under increasing primary production
(4) SMB-C never decreased
(5) Microbial turnover for C and N often increased
(6) Effects strongly depend on soil characteristics
(7) N availability is ruling the effects
(8) Microbial N-fixation is supported under FACE in low N soils
(9) More information on effects at the community level are needed

Some snapshots from current science (6)

Soil biological properties and plant communities



Potthoff et al. 2004

Some snapshots from current science (7)

Atmospheric enrichment of CO_2 and nematodes

Abunance of Bacterial feeding nematodes increases

Yeates et al. 1999, Nematology 1:285-293

N limitations support plant feeding taxons in FACE experiments,
N supply supports predator/omnivores

Hoeksema et al. 2000, Pedobiologia 44:725-735

Total abundance of nematodes <u>decreases</u> in elevated CO_2

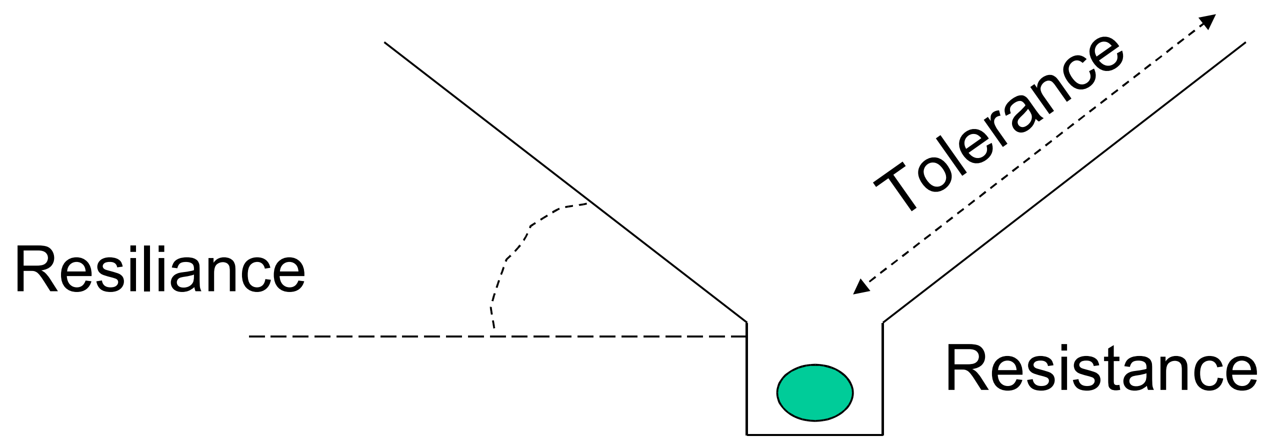
Neher et al. 2004, Functional Ecology 18,584-591

Total abundance of nematodes <u>increases</u> in elevated CO_2

Yeates et al. 2003, Biology and fertility of soils 38, 319-326

Summary of snapshots

- Current science gives a difuse picture of soil biological properties due to environmental changes
- We are far away from predictable scenarios in the soil system
- Multidiciplinary thinking and communication is needed in identifying risks to ecosystem functions



Outlook and research needs

- Linking community structures to functions
- Identifying factors that put key functions at risk
- Management of soil biota of forest floors that are degrading or damaged
- Resistance and resilience of soil communities and soil functions to disturbance
- Identifying indicators to assess soil quality in terms of habitat conditions

Soil biology as covered in this symposium

Diversity of soil organisms (*Kulhankova, David*)

Mangagement of soil fertility and soil organisms
(*Ranger*, *Meklaoui, Ferreira)*

Nutrient pools and transformations (*Xu, Martinez,*
Tewksbury & van Miegroet, Maquère, Andrade)

Many thanks to all contributors and listeners