Resilient and sustainable farming systems

From theory to practice

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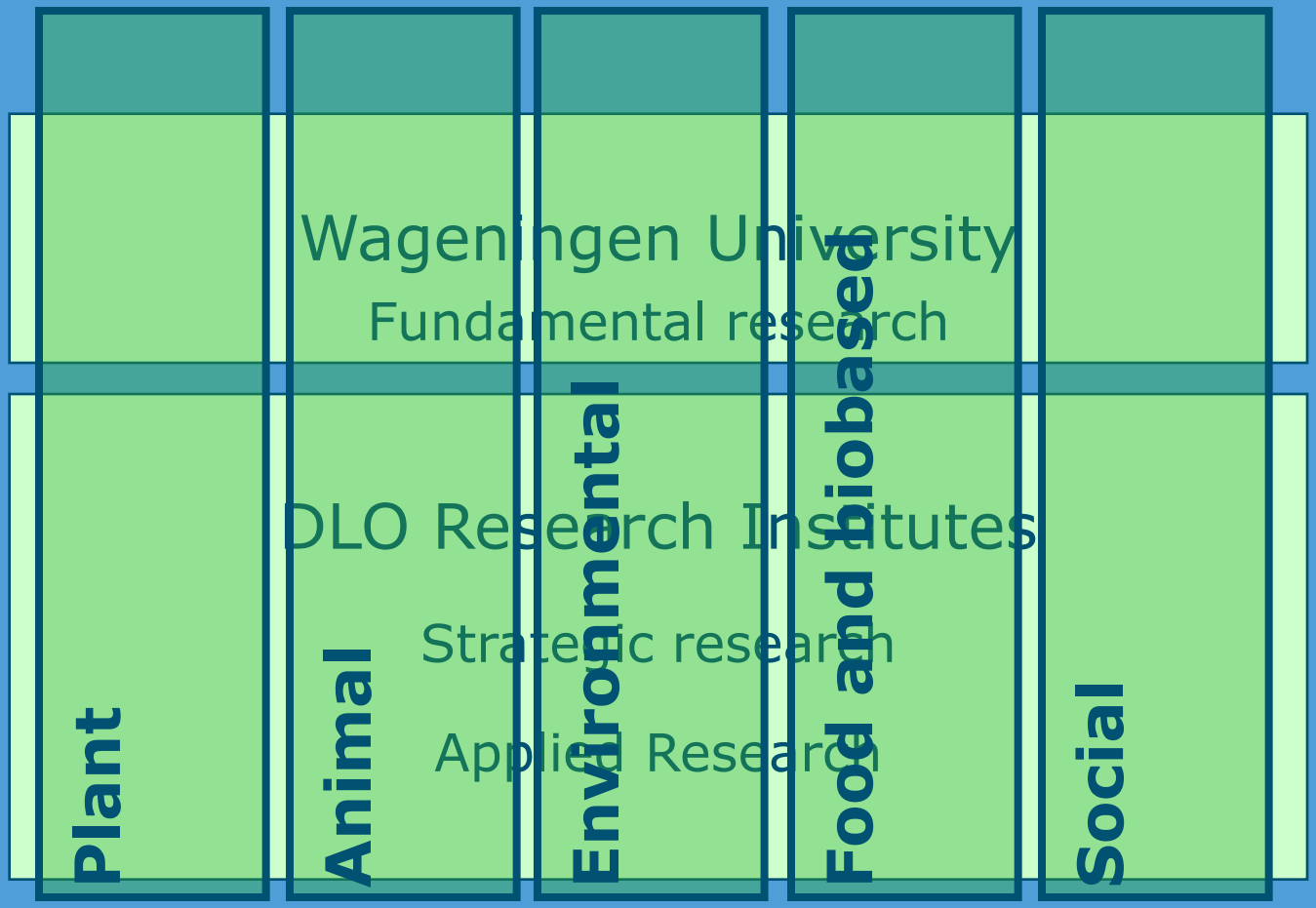
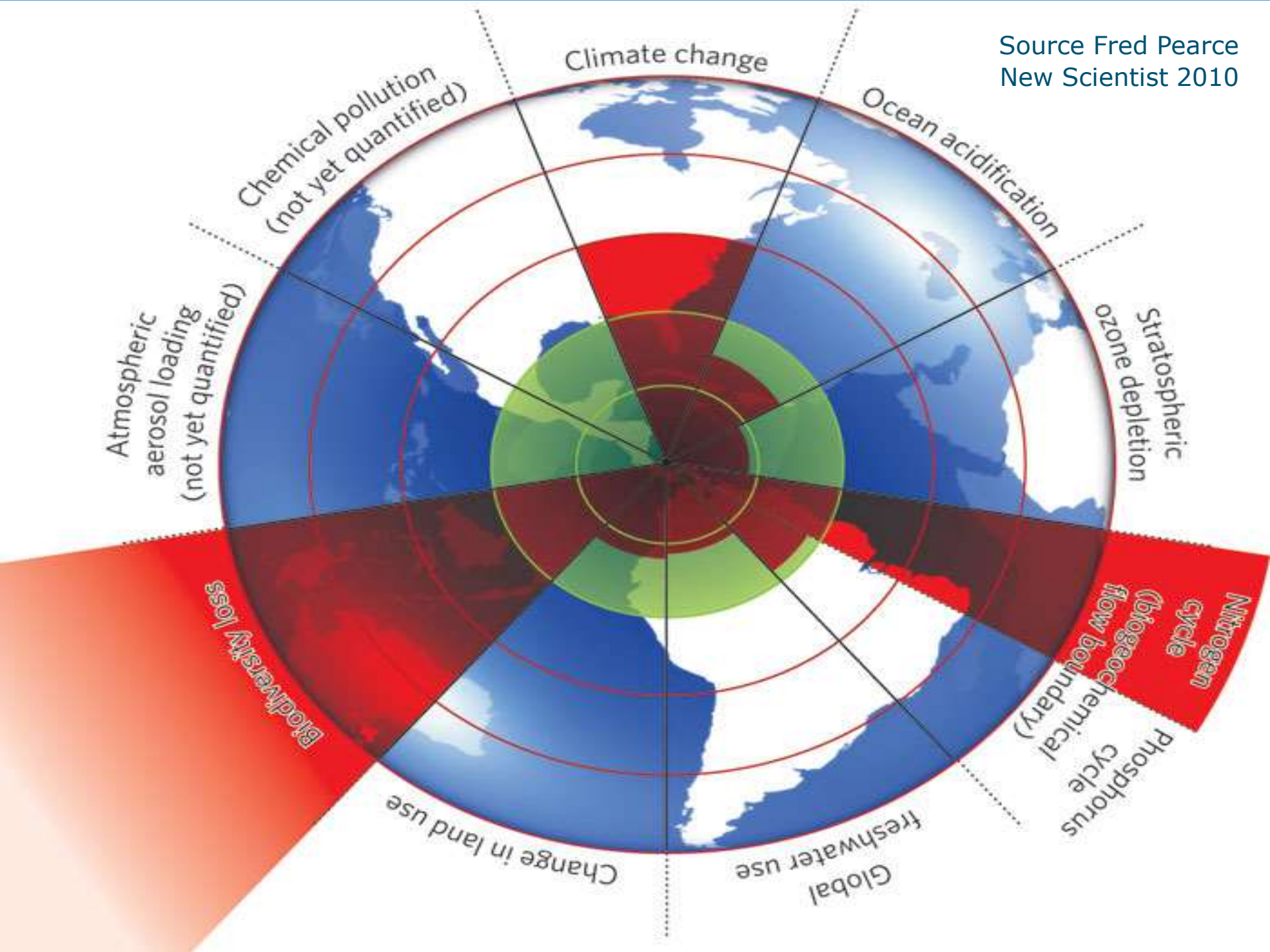
Structure Wageningen UR



Plant Sciences Group


9 billion
people
70% increase
in food

Source Fred Pearce
New Scientist 2010



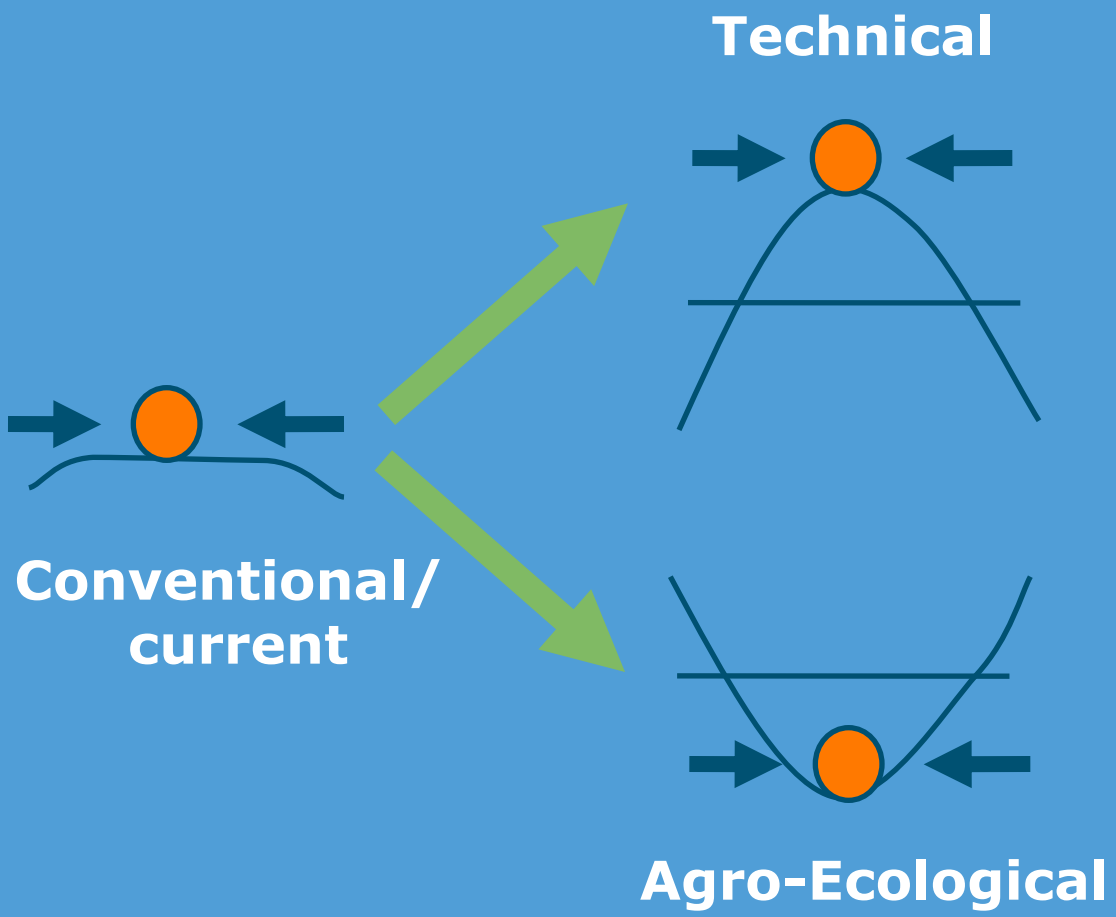
Global developments in agriculture

- Larger scale, more monocultures
  - loss of spatial + temporal diversity
- High/increasing amounts of inputs
- Decreasing availability and quality of resources
  - soil, biodiversity, water, phosphorus, energy
- Decreasing robustness/resilience of agro ecosystems

A central tenet of epidemiology is that both the number of diseases and the incidence of disease should increase proportionally to host abundance (Tilman et al. 2002).

Production of food in an ecosystem or in a factory?

Two visions



- Maximum control
- Maximum yield
- Low diversity
- Monoculture
- Market oriented
- High value crops

- High diversity
- Resilient
- Stable yield
- High diversity
- Environmental oriented

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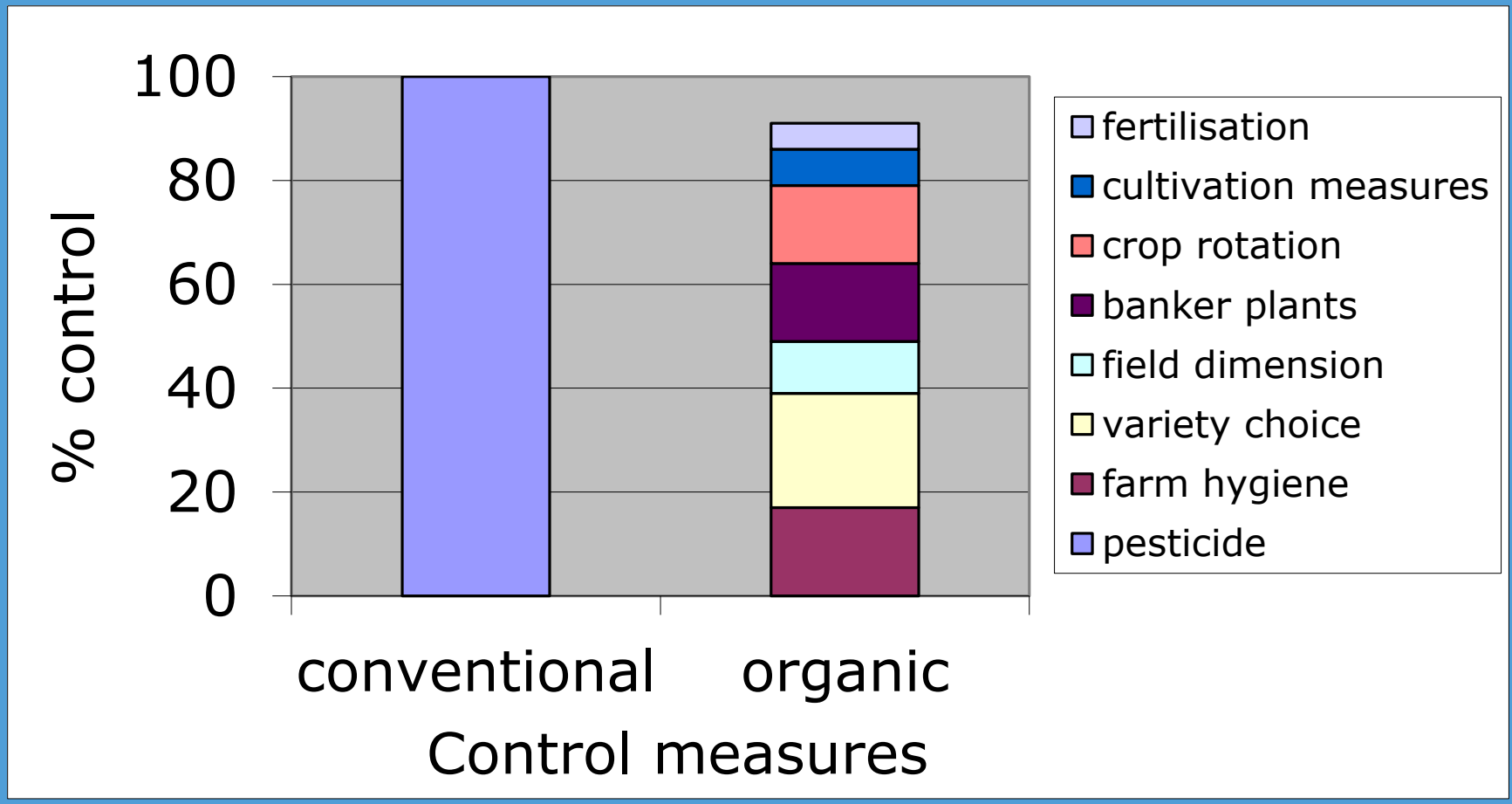
Complex and multi-objective methods



Control pest x (+ landscape + biodiversity + …)

Conflicting objectives in agricultural production?

- Market demands uniformity
- Mechanisation and field operations demand uniformity
- Economy and policy (subsidies) promote uniformity
- Reductionist research focusses on G-M-E solutions

- Resilient agro-ecosystems
- Attractive Landscape
- Conservation Biodiversity

Stress factors of agro-ecosystems

- Physical/chemical
  - drought
  - excess of water
  - temperature
  - erosion
  - wind
  - pollution
  - compaction
  - nutrients
- Biological
  - pests
  - diseases
  - weeds

We do need resilience

- Increase in stress factors: climate change
- Increasing vulnerability in modern agriculture
- Economical and environmental costs of control
- To fulfil all ecosystem services
  - production
  - water management
  - climate
  - biodiversity
  - landscape
  - …

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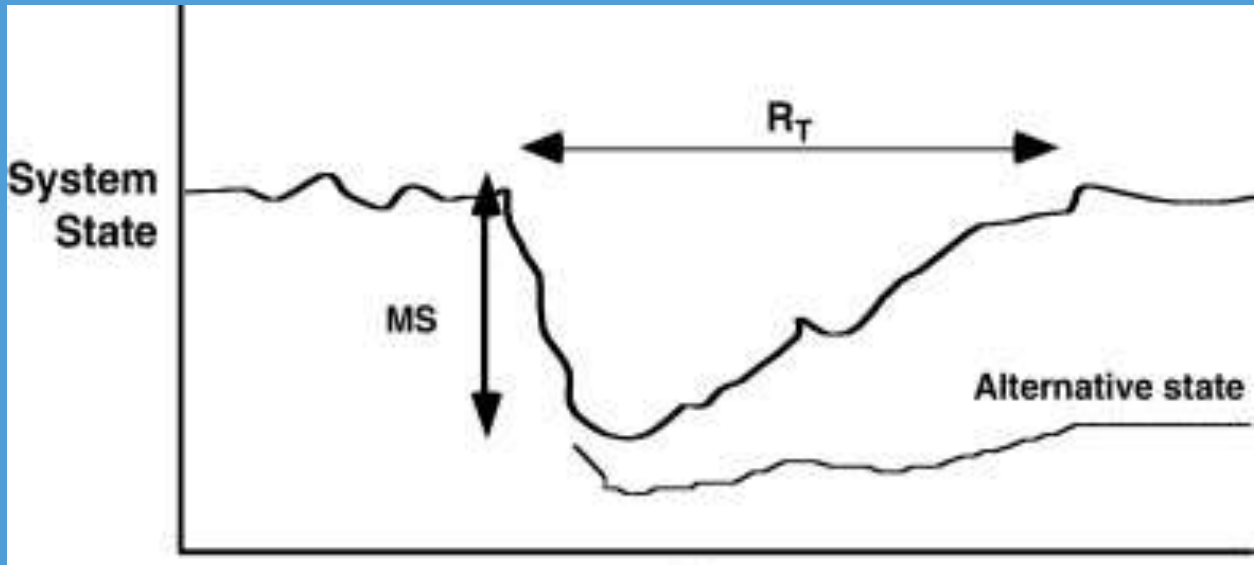
Definition Ecological Resilience

- The amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures (Holling, 1973)
- The capacity for self-repair or adaptive renewal and reorganization of social-ecological systems following perturbation.

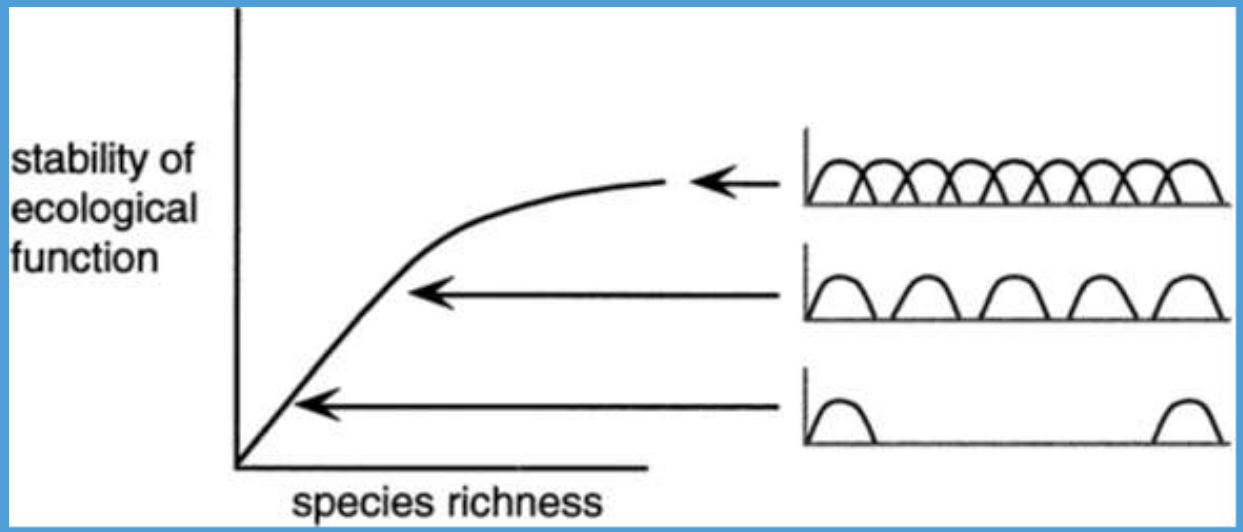


(Costanza et al., 1992): Resilience = MS / R_T

Key elements for resilience in agro ecosystems

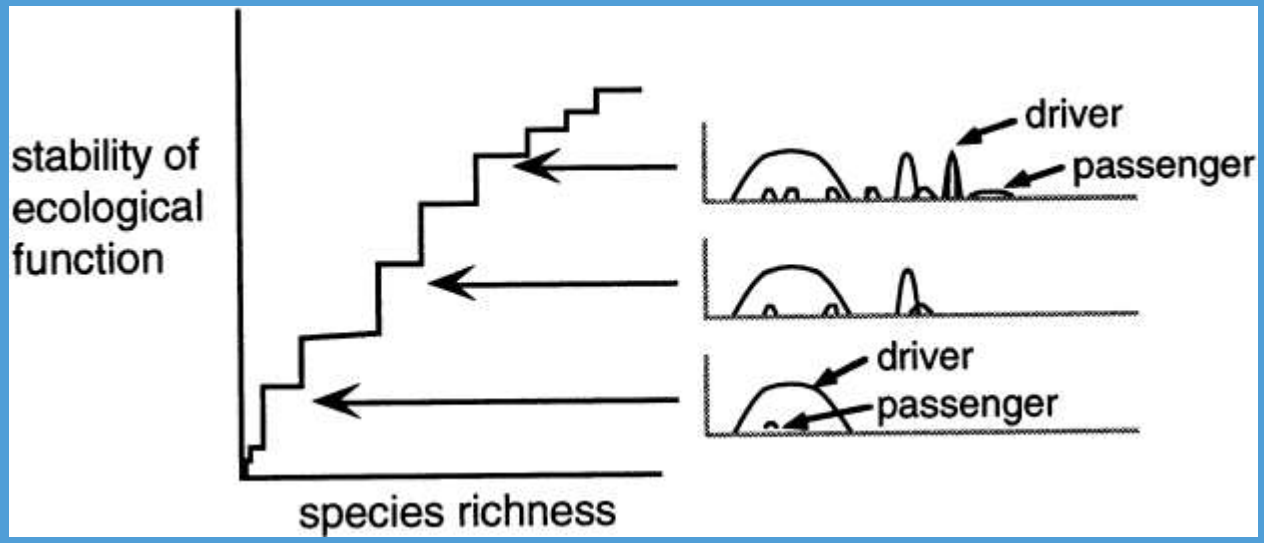
- Soil quality
  - Buffering capacity water and nutrients
  - Biodiversity
- Biodiversity in time and space and on different scales
  - Different niches and functions
  - Redundancy and overlapping functions
  - Spare capacity for changing conditions
- Well balanced mix of control and guidance

Biodiversity and resilience

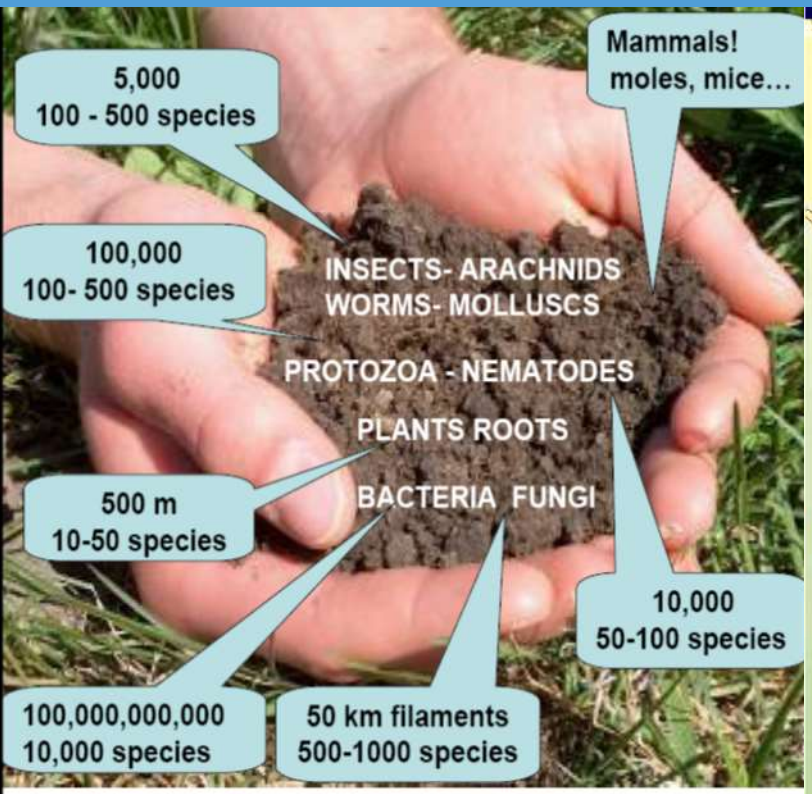


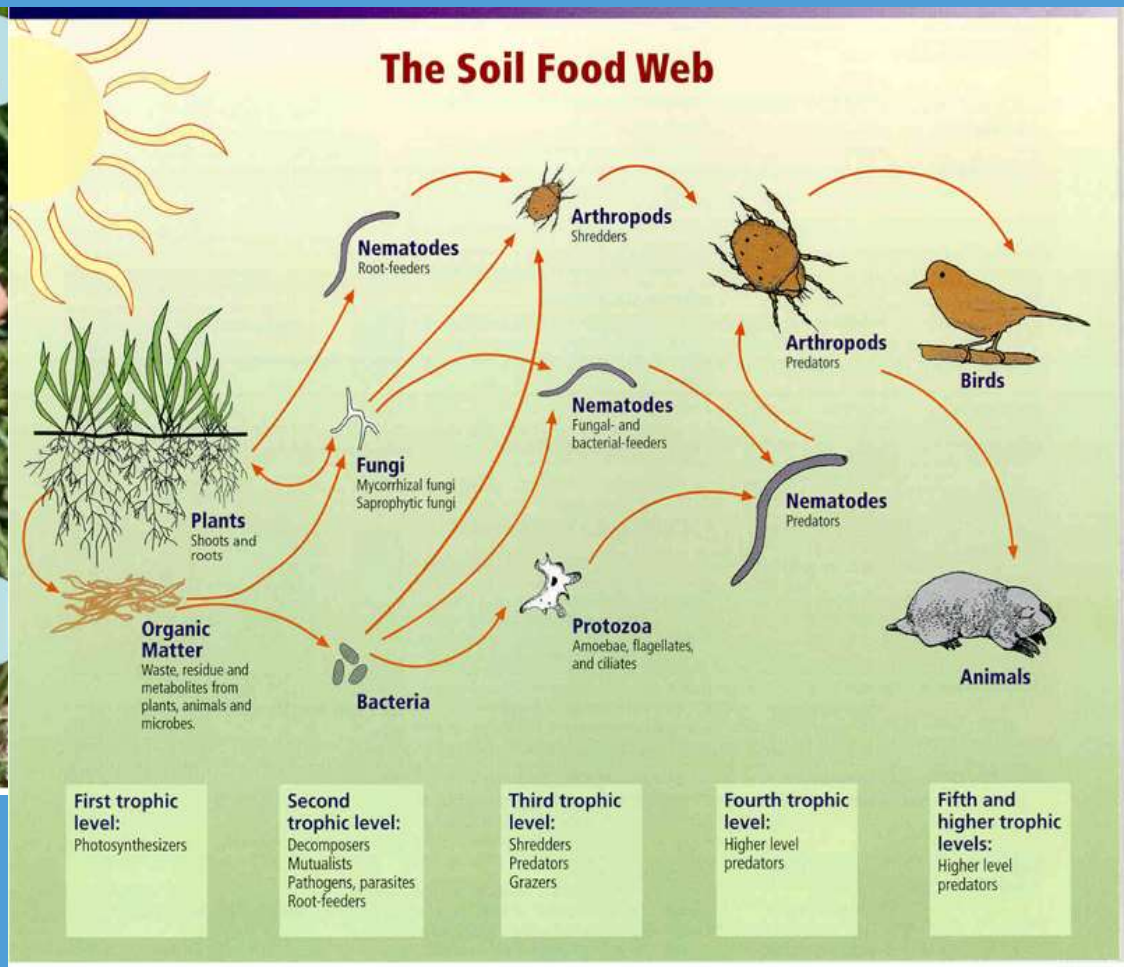
Ehrlich and Ehrlich (1981)

Walker (1992, 1995)



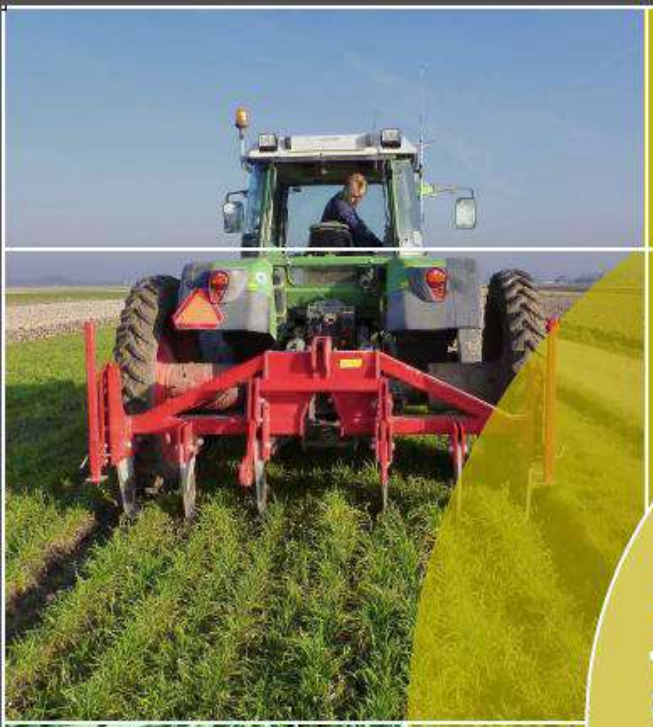
Soil is the basis
Organic matter plays a central role





Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.

Vruchtbare gronden



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For quality of life

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Organic matter input

Conventional		Organic
Low EOM input	***Average EOM input***	***High EOM input***
AF	MAN	BIO
800 kg eom/ha/yr	1550 kg eom/ha/yr	2750 kg eom/ha/yr
crop residues, catch crops	slurry, crop residues, catch crops	FYM, slurry, crop residues, catch crops
Fertilization: chemical fertilizers	Fertilization: chemical fertilizers, slurry	Fertilization: FYM, slurry

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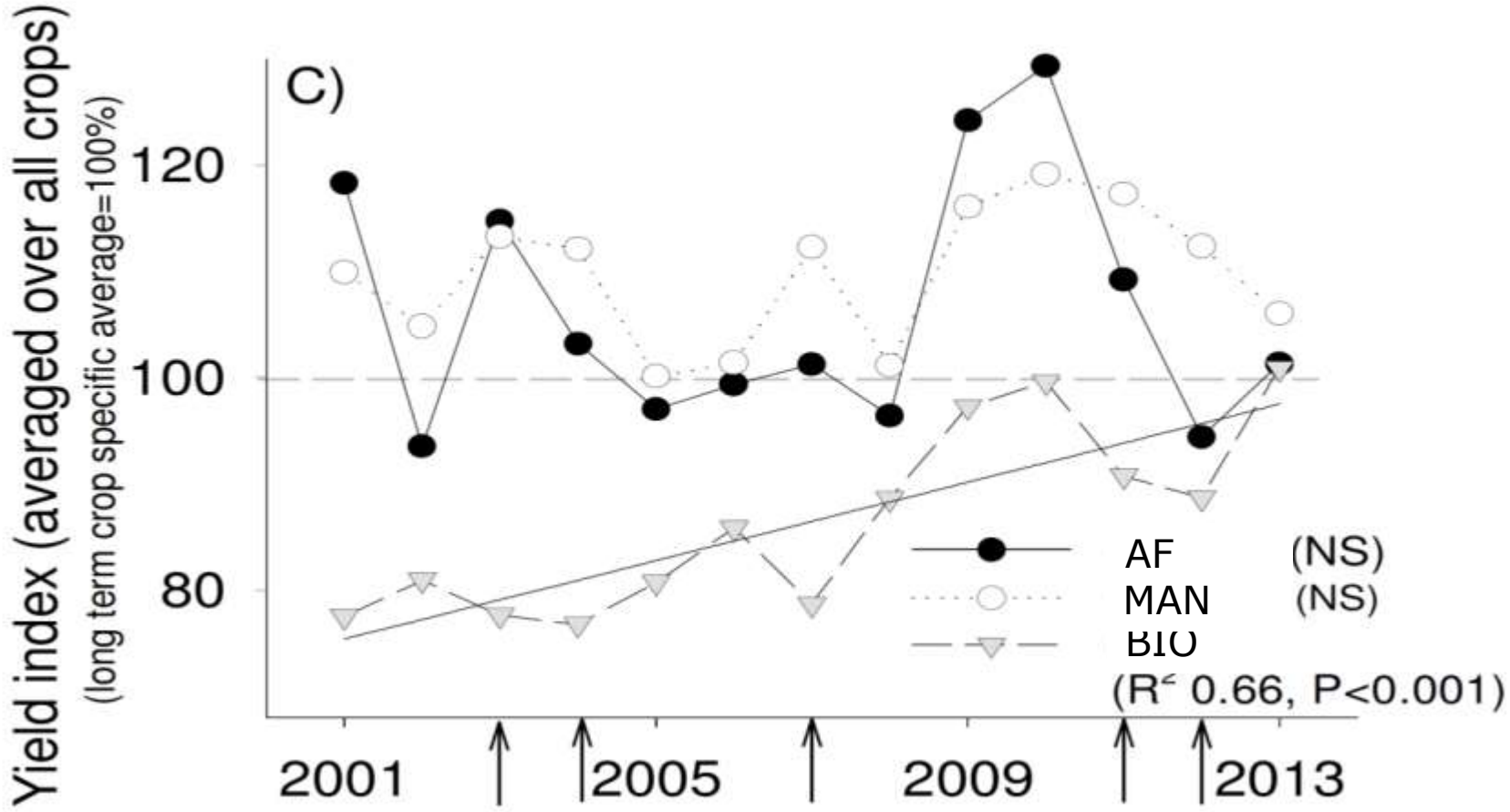
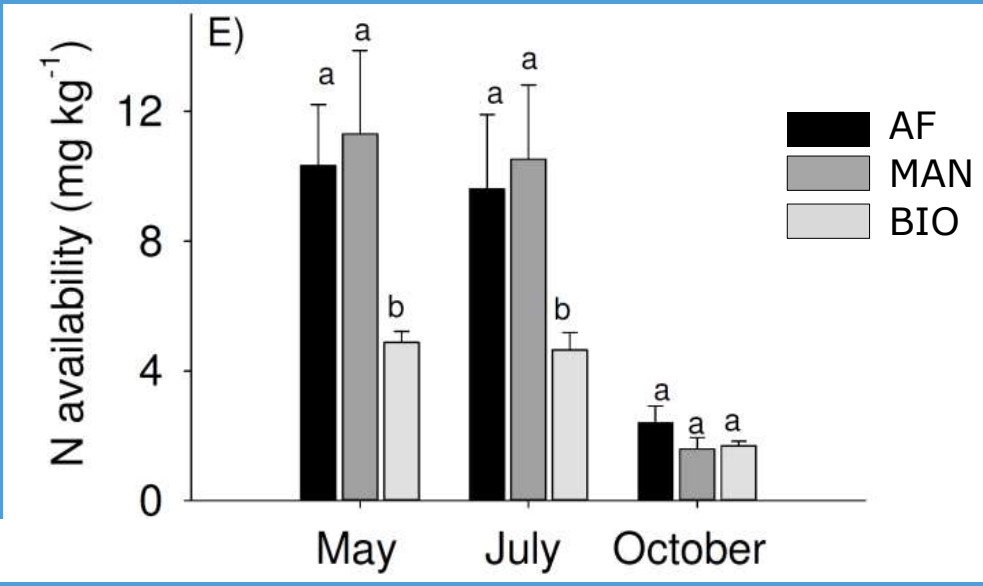
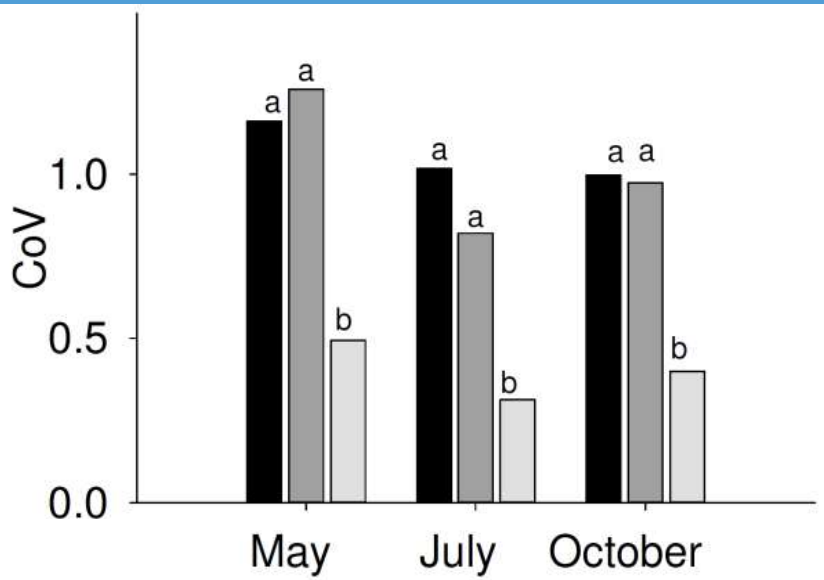
Difference in crop condition: MAN and AF

Crop yield trend 2001-2013



Spatial variation of mineral nitrogen





Management for biological resilience

Create **continuity** for functional biodiversity

- Food, shelter and habitat

Create **discontinuity** in hosts for pathogens (plant, crop, field, landscape)

- Crop rotation, cropsurface, genetic diversity, plant resistance

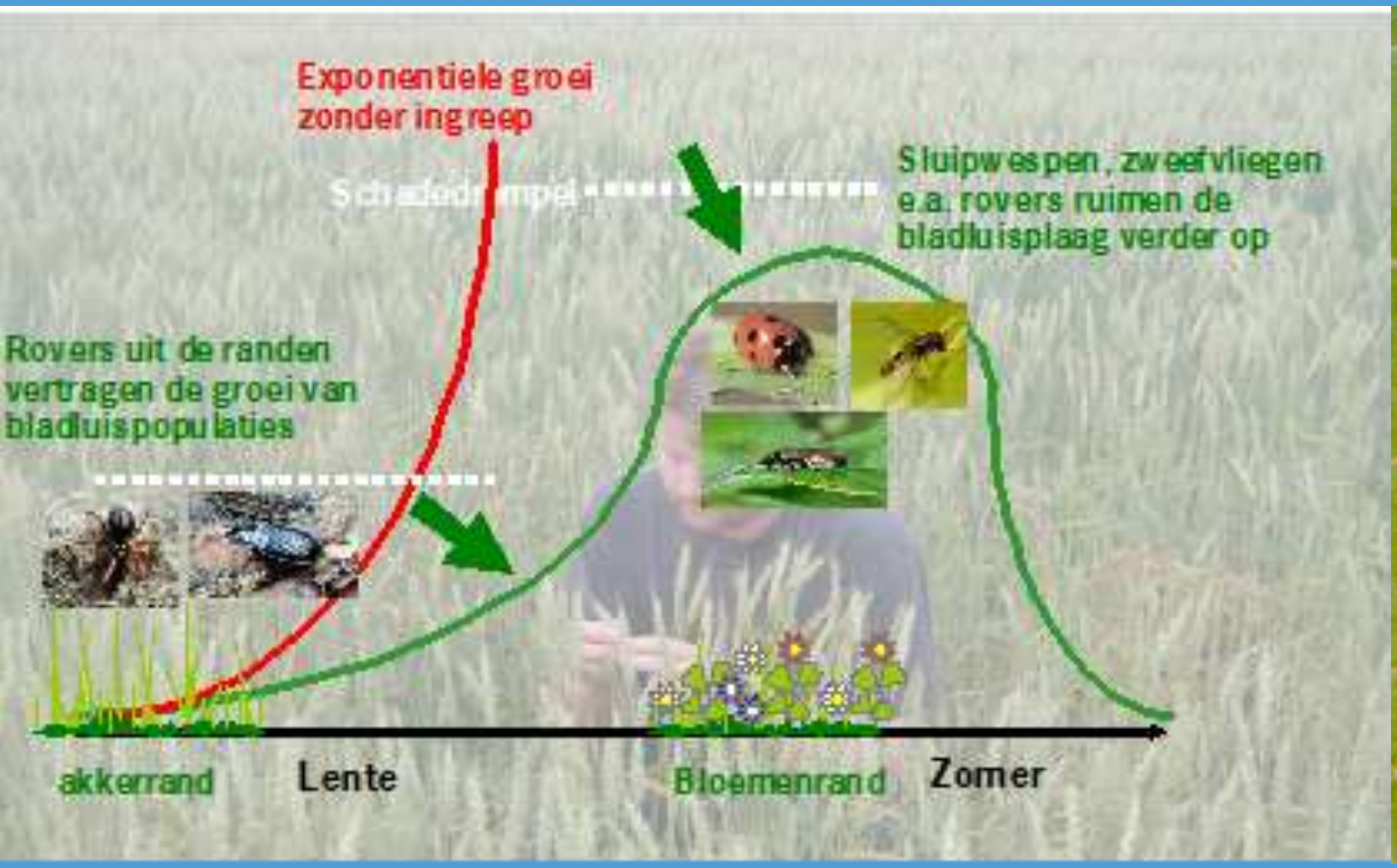
Spatial and temporal!

Continuity for beneficials
Food, shelter and habitat

- Landscape: ecological infrastructure, natural elements
- Field margins (presence and management)
- Soil management
    - reduced tillage, organic matter, mulch
- Field size and dimensions
- Alternative food sources
- Flower strips
- Crop management

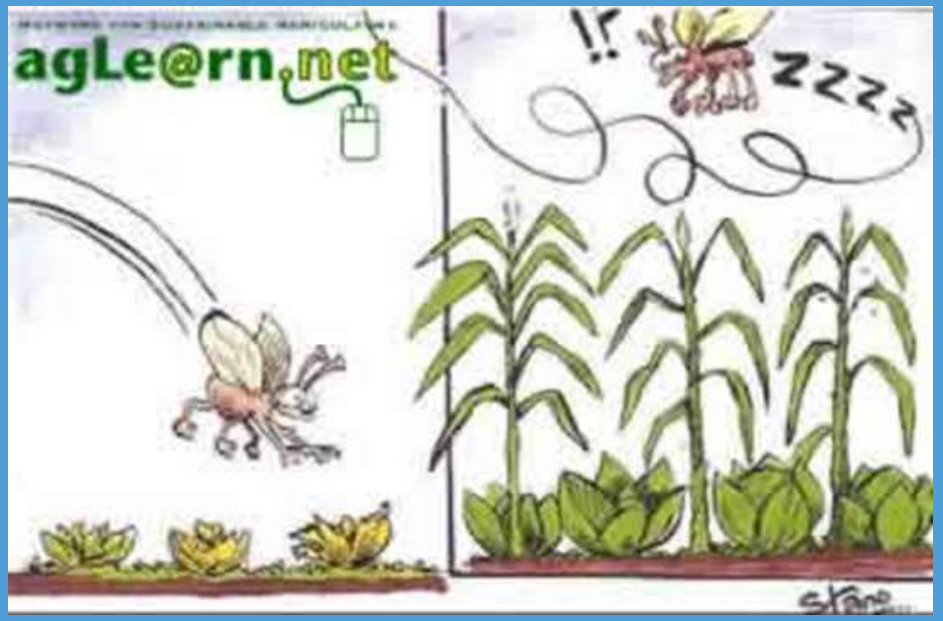
Ecological infrastructure
Field margins, field size

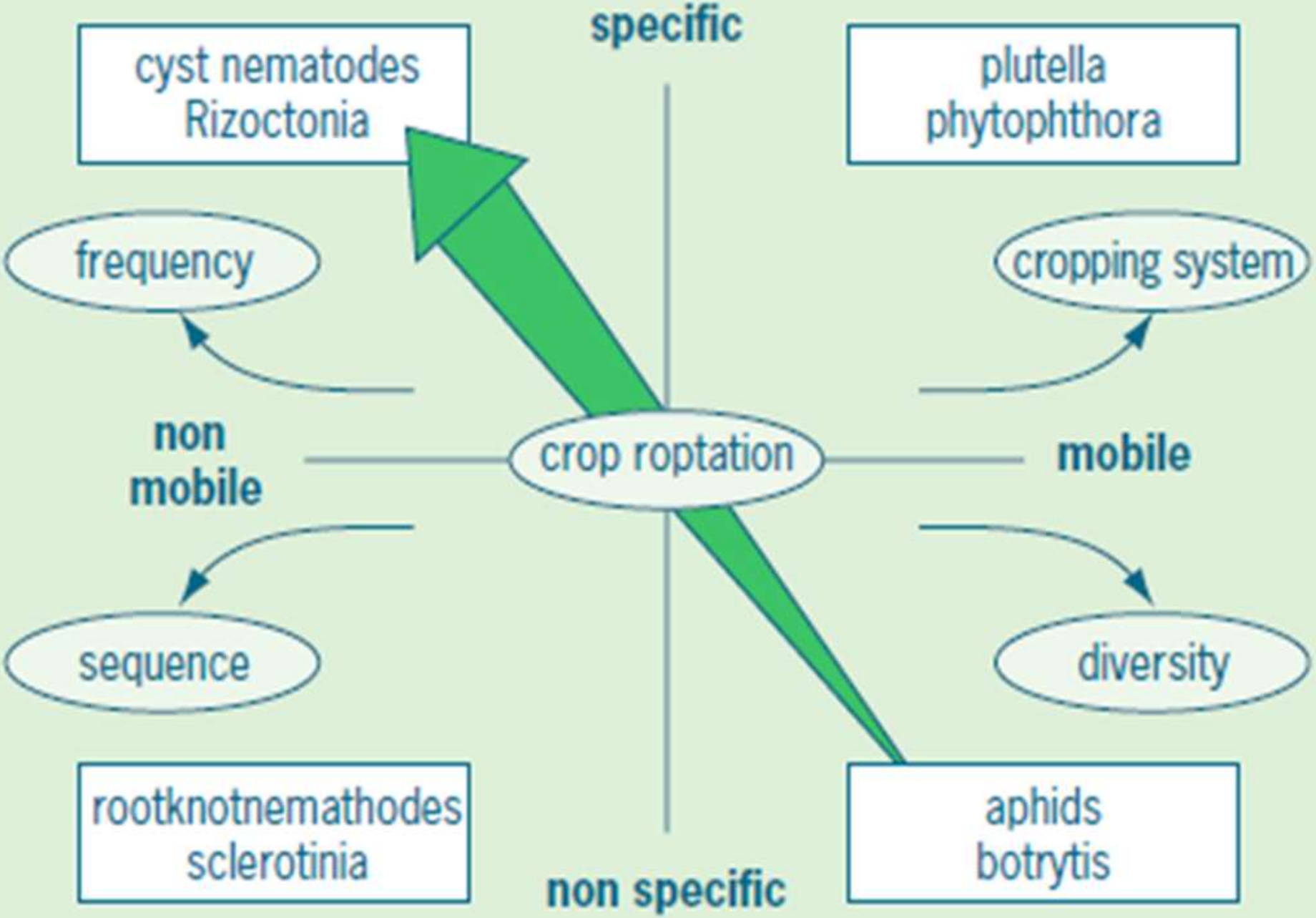
Effects Spiders and beetles from margins



Discontinuity for pathogens

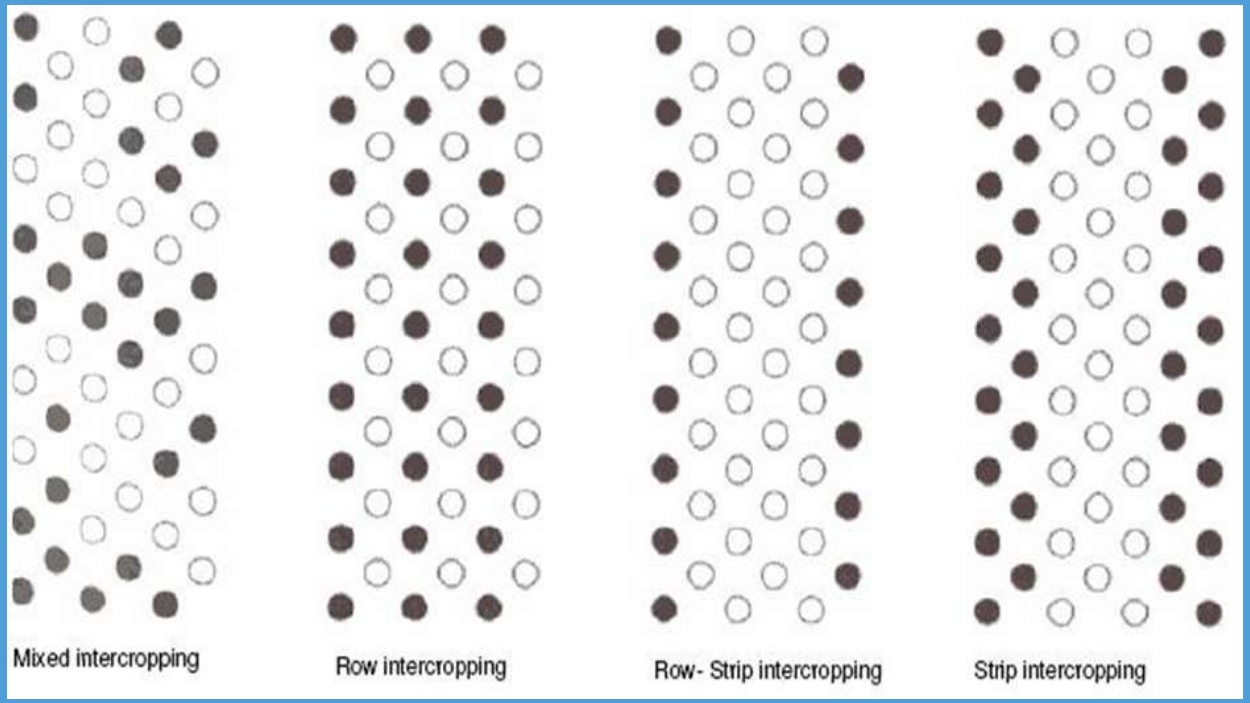
- Host scarcity, repellent, confusion, unfavourable habitat
- Crop Rotation
  - Frequency, sequence, field adjacency
- Intercropping
  - Strips, Rows,
  - Crop mixtures
  - Under sowing
  - Agroforestry




specific
cyst nematodes
Rizoctonia
plutella
phytophthora
frequency
cropping system
non
mobile
crop roptation
mobile
sequence
diversity
rootknotnemathodes
sclerotinia
aphids
botrytis
non specific

Intercropping

- Making more efficient use of resources
  - light, water, nutrients
- In general higher production
- Positive/negative crop interactions
- Reducing host abundance






Undersowing clover

Strip cropping system research Lelystad

Barriers for the adoption of diverse agro-ecosystems

- Economy, costs, policy, suppliers
- Reductionist research focused on G-M-E interactions
- Management (depending on mechanisation rate)
    - Mechanisation
    - Harvest
    - Weed control
    - Pest and disease control
    - Fertilisation
    - Irrigation

Where do we stand

Already applicable

- Field margins
- Flower strips
- Reduced tillage
- Cover crops
- Positive org matter balance
- Mixed cropping fodder crops
- Undersowing cover crops
- Multifunctional crop rotation
- Variety mixes

Needs further paradigm shift, research, technology

- Strip cropping
- Agroforestry
- Intensive crop mixes
- Genetically heterogeneous varieties

Knowledge, research and adoption

- Some knowledge about general principles available
  - Further knowledge development needed
  - Design and testing for local conditions
  - Interdisciplinary approaches
  - Development techniques (sensors, ICT, GPS, robots, ...) to solve the conflicting objectives

- Combine with on farm research, farmer field schools, stakeholder involvement, ...

Wrap up

- Increased resilience is crucial for agro-ecosystems
  - Food security, biodiversity and other ecosystem services combined
  - Balance between control and resilience management
  - Various management options for increased resilience already applicable
  - Needed: Improved knowledge, technology development; paradigm shift, policy

Some references and contacts

- Tillage and crop diversity effects on overwintering of natural enemies – willemien.geertsema@wur.nl
- Earthworm diversity and soil functions in reduced tillage systems and field margin strips – mirjam.pulleman@wur.nl
- Disease suppresiveness of soil amendments – joeke.postma@wur.nl
- Soil health and soil management – gerard.korthals@wur.nl
- Reduced Tillage and soil Biodiversity – derk.vanbalen@wur.nl
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- Soil management and soil biodiversity – marjoleine.hanegraaf@nmi-agro.nl
- Organic matter management – janjo.dehaan@wur.nl