Soil biodiversity and biogeochemical cycles

Alain Brauman

Jean Trap, Claude Plassard, Chotte Jean Luc, Tiphaine Chevallier et Eric Blanchart

Launch of the Global Soil Biodiversity Atlas in France, 28th November 2016

European Commission

GLOBAL SOIL BIODIVERSITY ATLAS

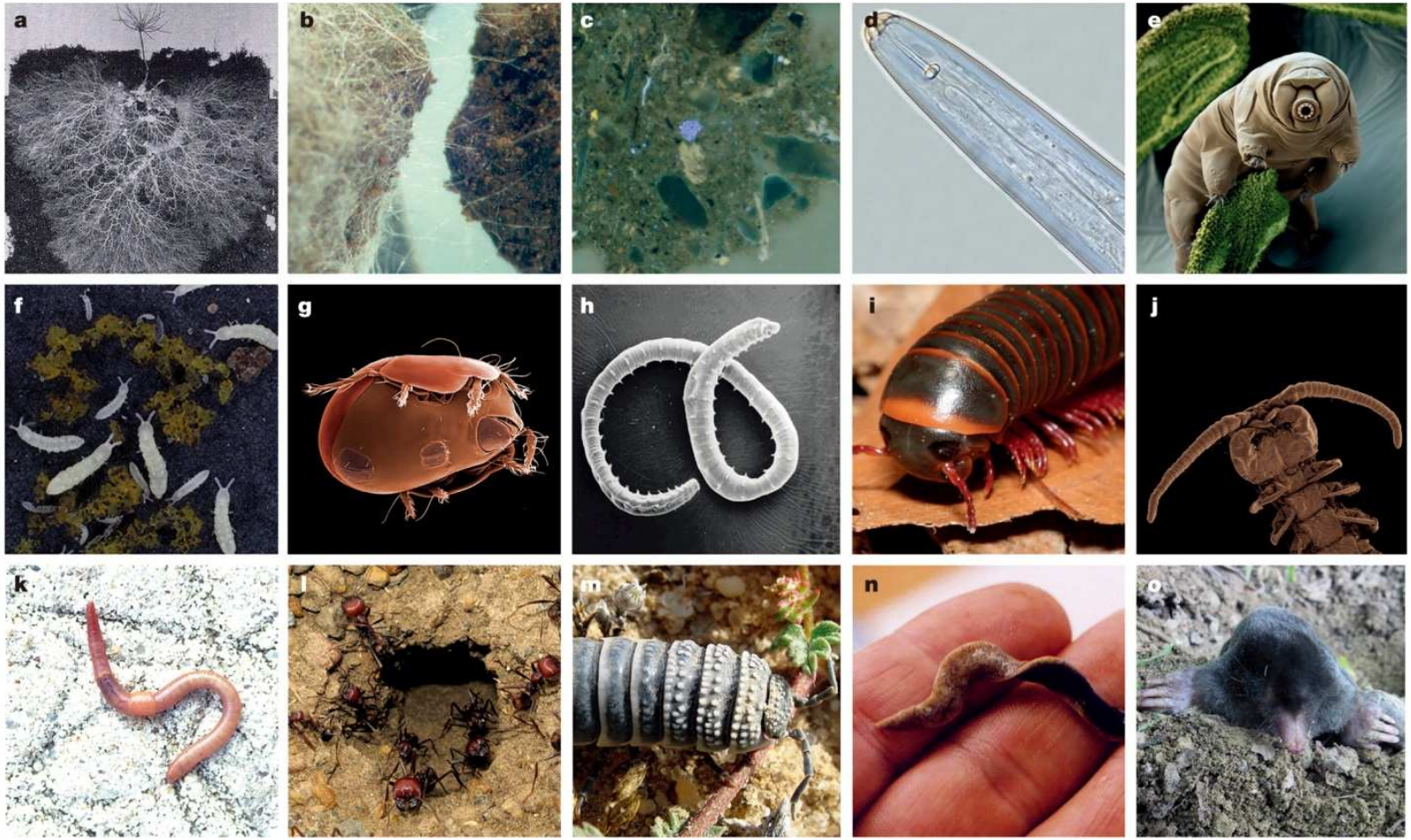
2015 International Year of Soils

GLOBAL SOIL BIODIVERSITY INITIATIVE

Joint Research Centre

Introduction

Fascinating biodiversity of the soil



RD Bardgett & WH van der Putten Nature 528, 305–311 (2014) doi:10.1038/nature16099

eco&sols

nature

Introduction

Biodiversity need iconic species

Introduction

We found our soil star !!

Tardigrades
are the cutest invertebrate.

moss piglets

Water bear

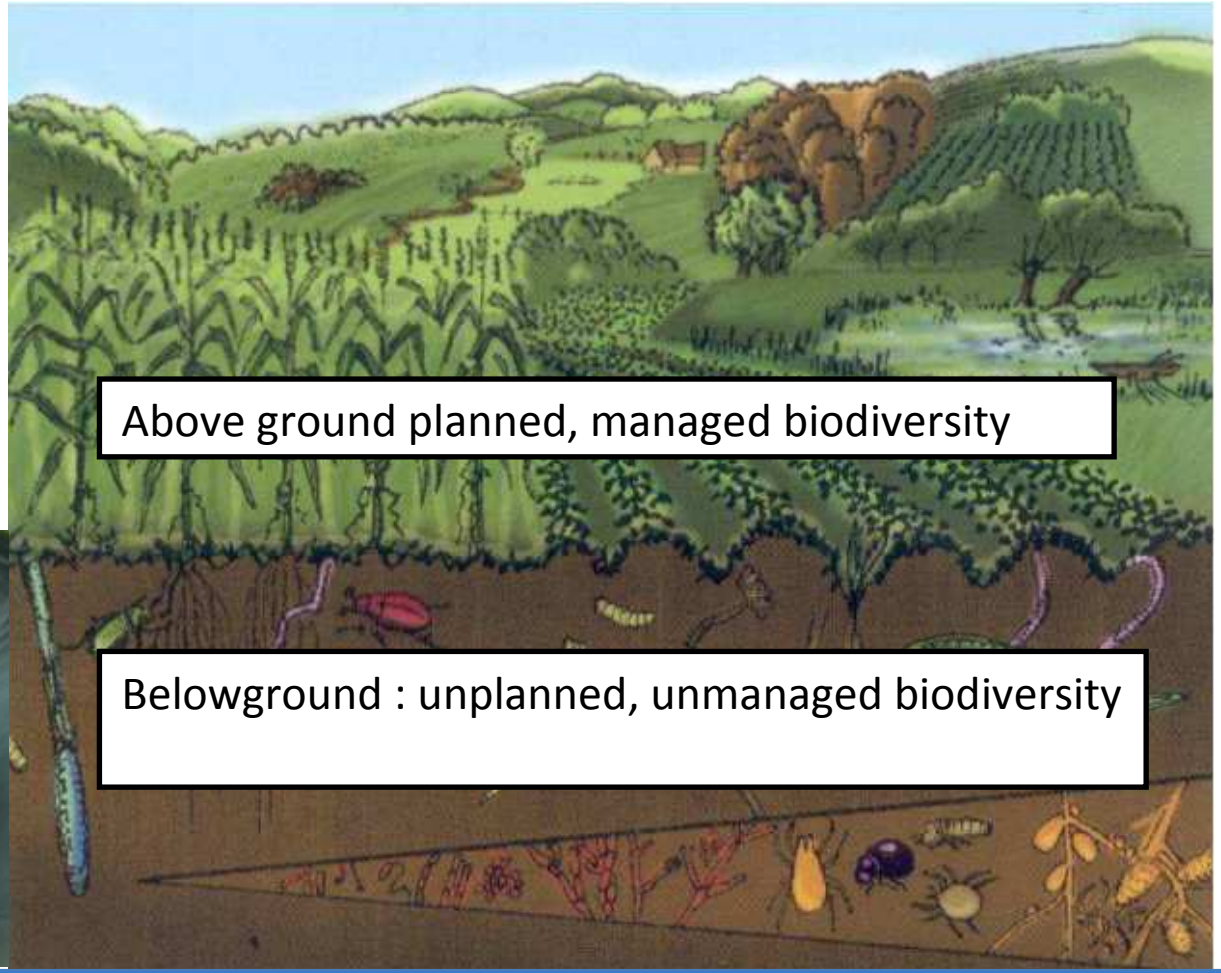
Nice but useful ???

Pygmy rhinoceroses

100 à 200 µm

Introduction

Question of this talk !



Is it feasible, necessary, useful, to study soil biodiversity for agriculture?

Brussaard, 2010, ESA

Problematic: Is it useful to study soil biodiversity?

The soil specificity and complexiity

Soil a new biotic frontier

Giller (1996), Brussaard (1997), Behan-Pelletier (1999), André (2001), Wall, André (2002), Decaëns et al. (2008)

1 – Abyssal communities

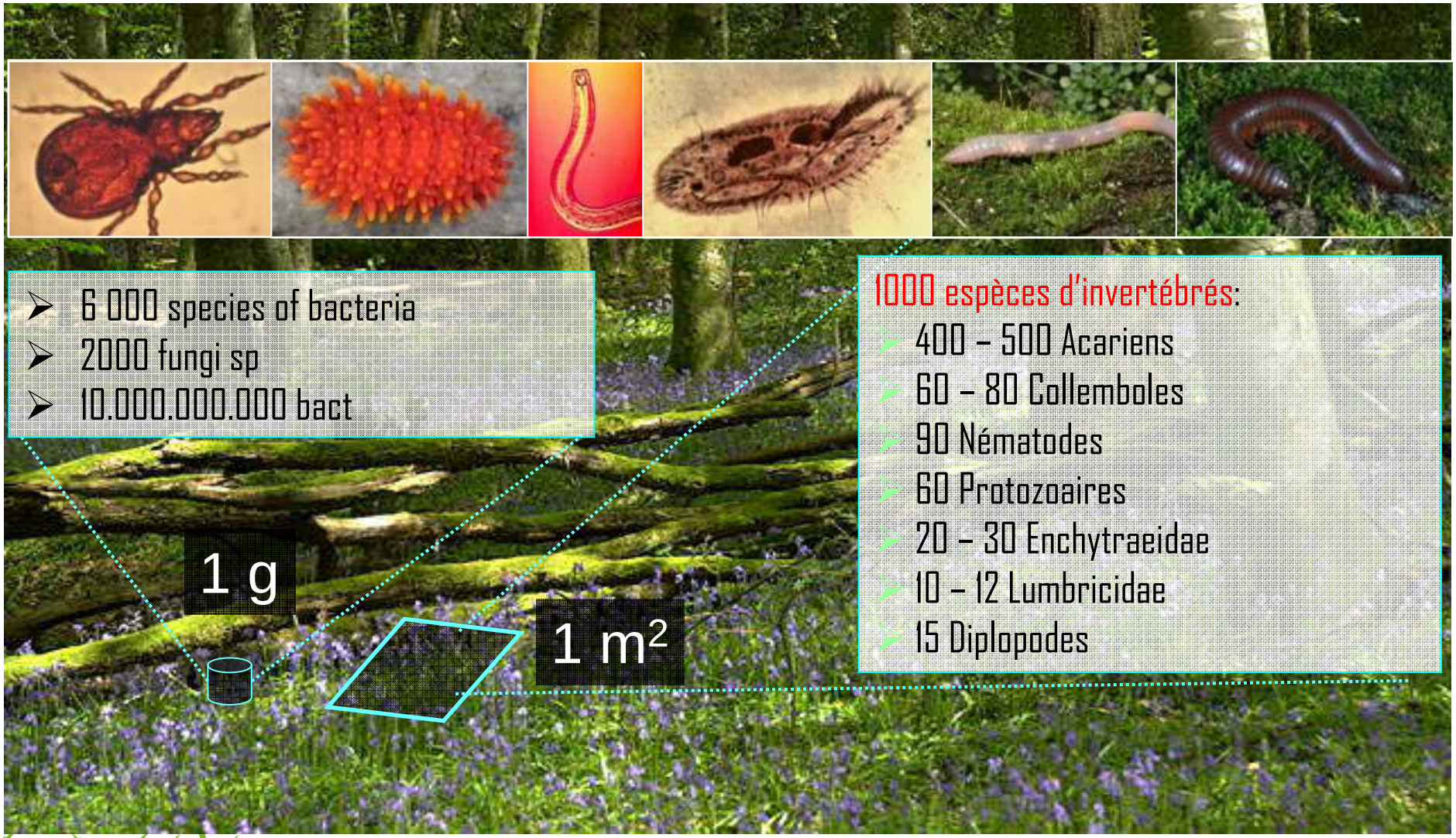
2 – Communities from the rainforest canopies

2 – Soil communities

- > 25 % of global biodiversity
- but difficult to access and study
- Less than 10% of species already described
- Lack of specialists
- High threats of degradation in some situations

Problematic: Is it useful to study soil biodiversity?

Soil a hot spot of diversity

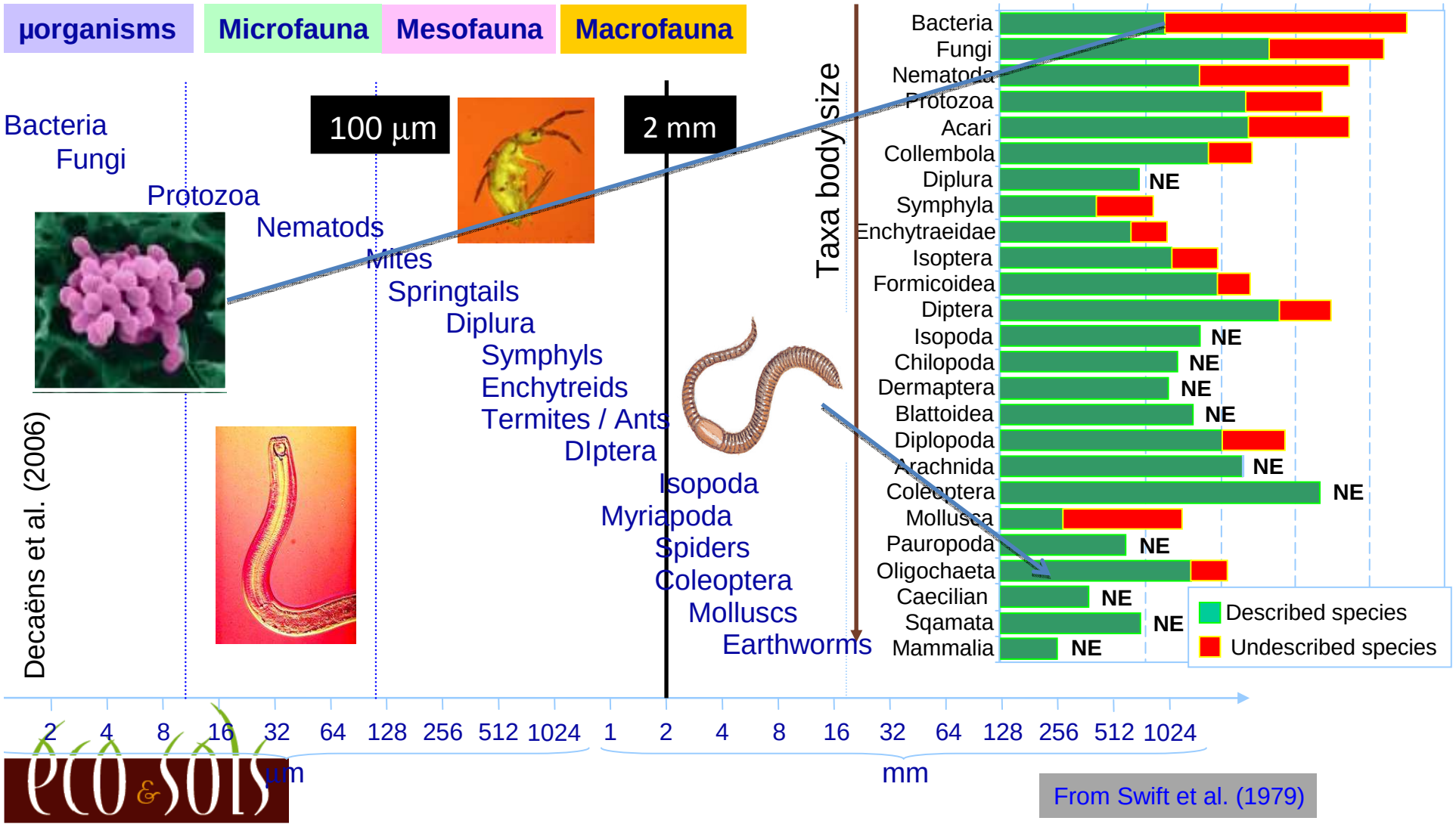


Torsvick et al. (2002), Hawksworth (2001), Schaefer et Schauermann (1990)

Problematic: Is it useful to study soil biodiversity?

Size problem

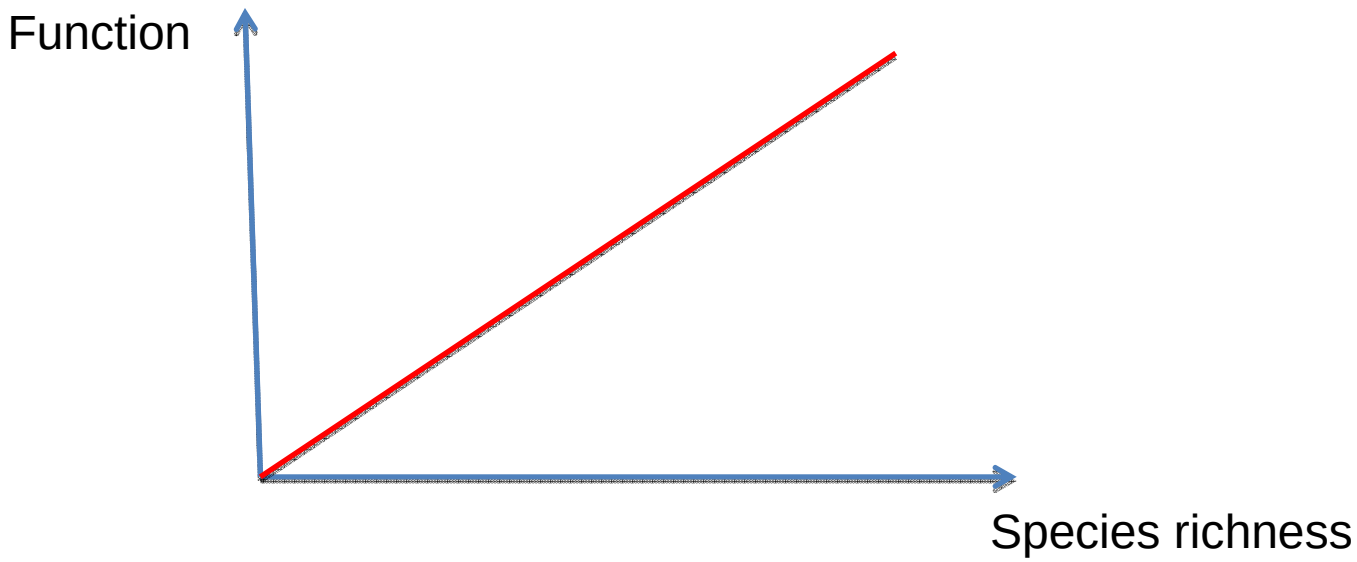
Size classification



From Swift et al. (1979)

Is it useful to study soil biodiversity?

Is there a link between soil biodiversity and functions ?



Problematic: Is it useful to study soil biodiversity?

Taxonomical vs functional classification ! which matter?

Fragment litter

Isopoda
3 species

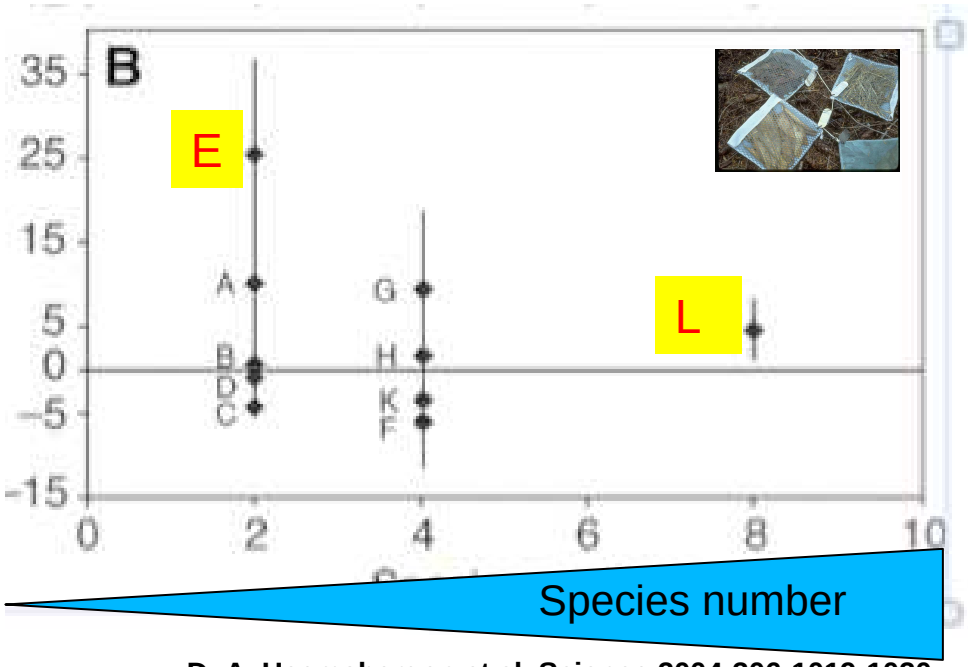
Diplopoda
2 Species

Transport litter and modify soil

Annelide (3 species)

Species combination

2 species	4 species	8 species
A	F	L= All of them
B	G	
C	H	
D	K	
E =		



D. A. Heemsbergen et al. Science 2004;306:1019-1020

Problematic: Is it useful to study soil biodiversity?

First take home message

Soil functioning depends on the maintenance of soil functional diversity rather than taxonomic group





D. A. Heemsbergen et al. Science 2004;306:1019-1020

Problematic: Is it useful to study soil biodiversity?

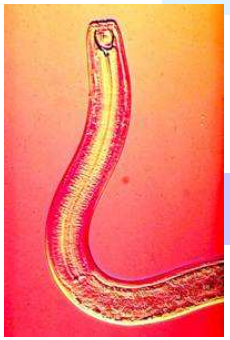
Functional classification of the soil biota

Microorganisms

Chemical engineers

N cycle: fixation, nit, denit
P cycle: phosphatases
C transformations, humification
Soil structure
Plant growth
Détoxication, bioremediation
Symbiotic or free-living

Microfauna: Protozoa and nematods



Regulation of microbial populations

Microregulators

Macrofauna (and roots)

Bioturbation,
OM decomposition
Activation of microbial activity
Hot spots of microbial activity
Nutrient and C cycling

Soil engineer

Predators

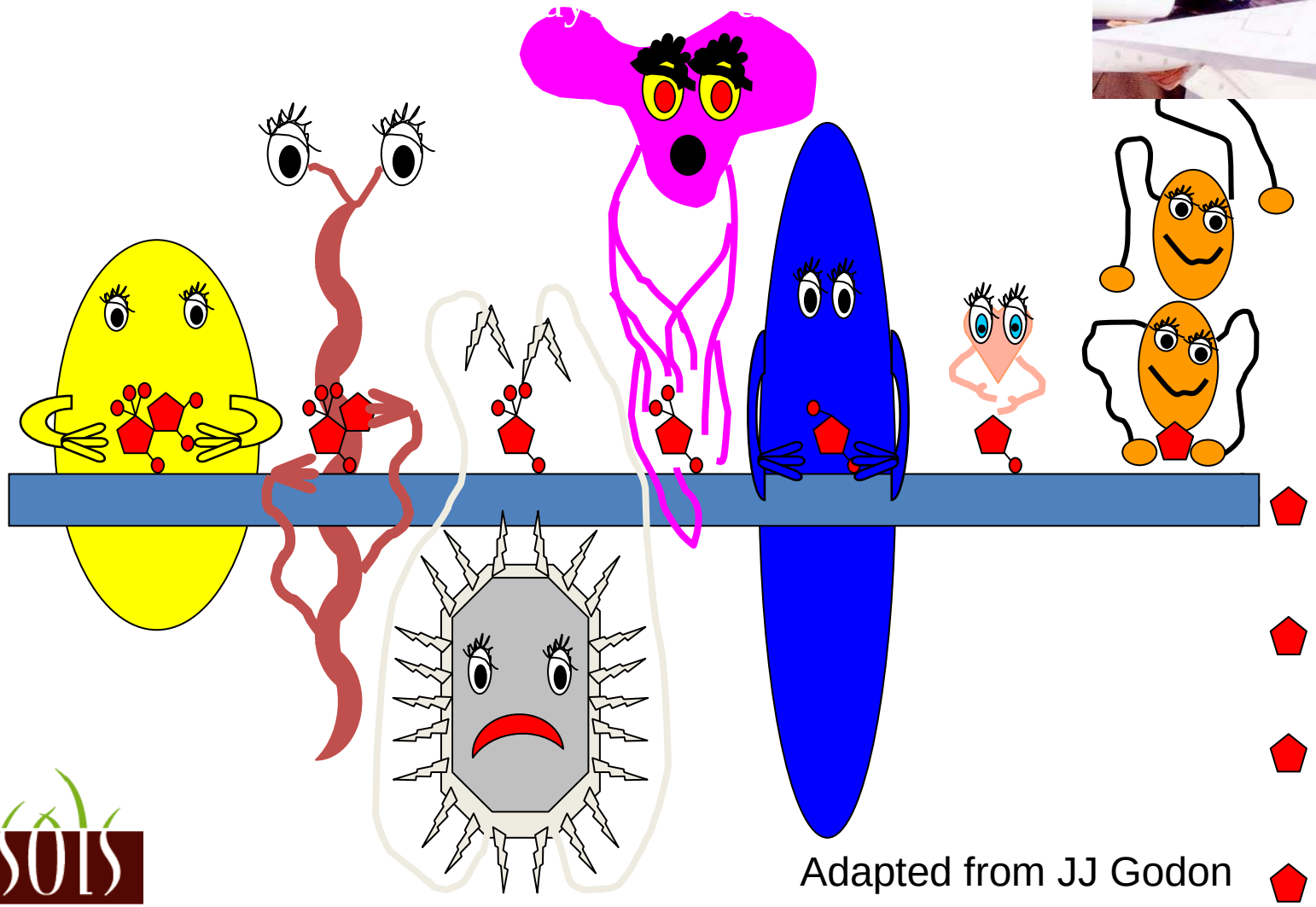
Regulation of invertebrate populations

Pests and disease
Harmful to plants

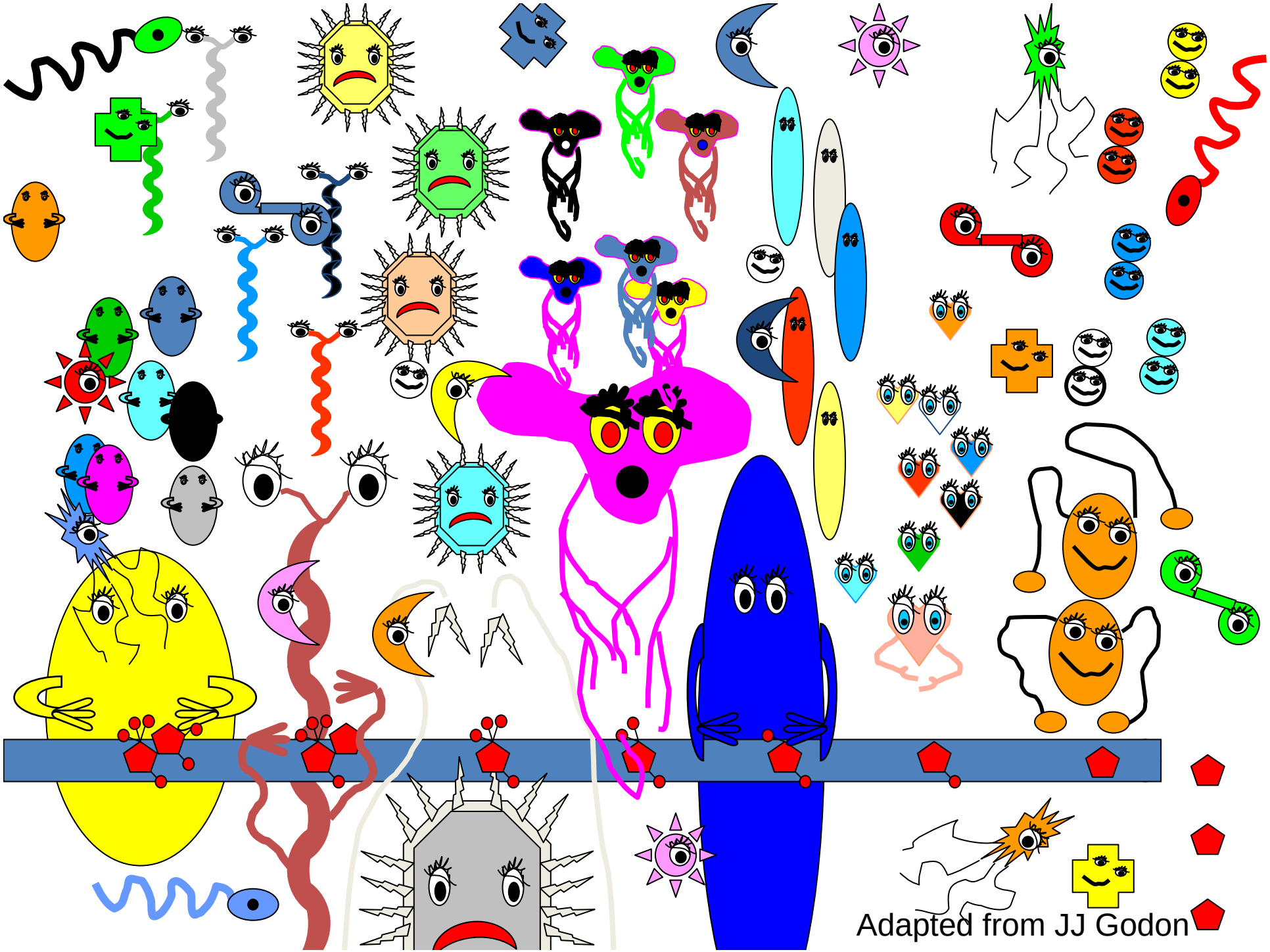
Pests

Problematic: Is it useful to study soil biodiversity?

Do we need just a functional diversity?



Adapted from JJ Godon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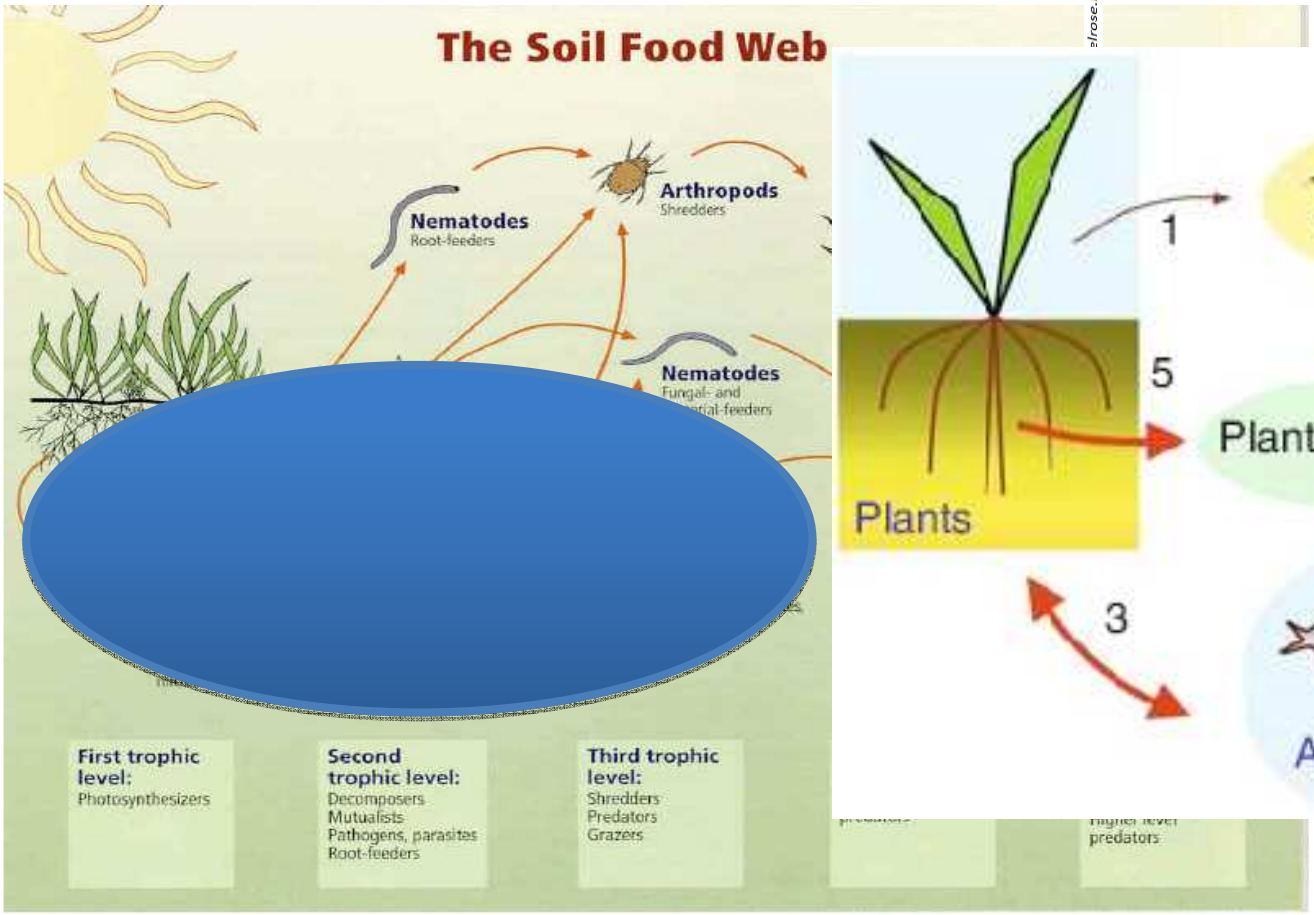
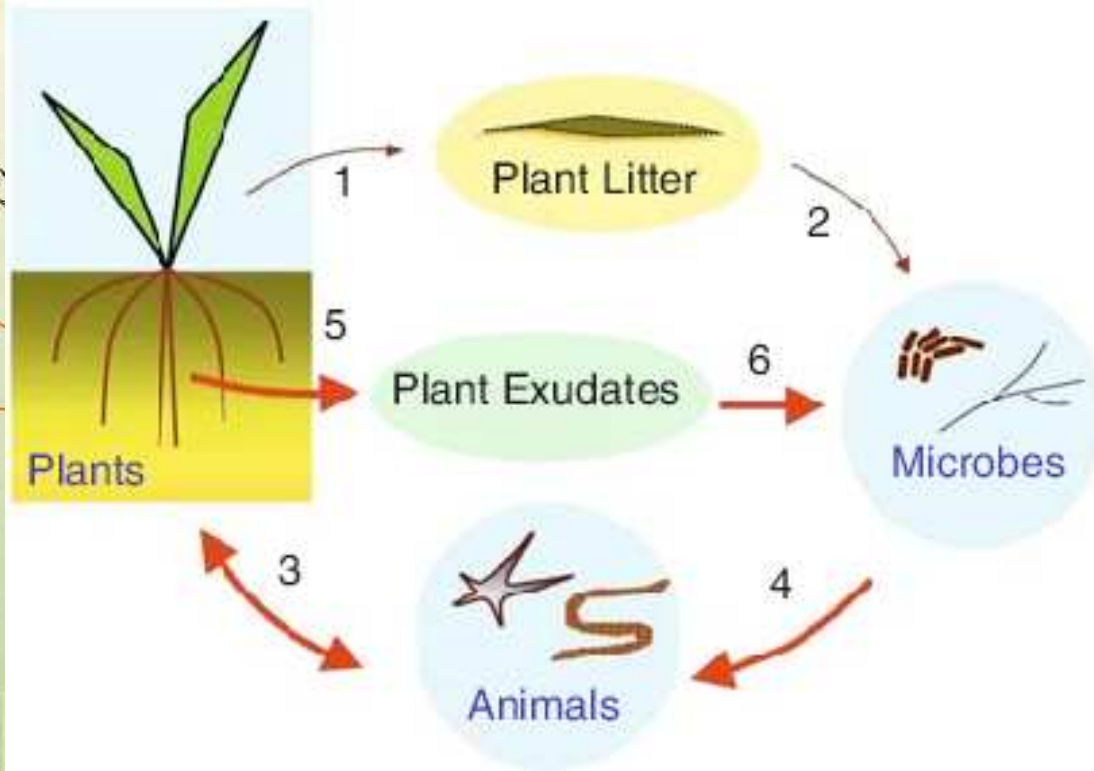
Problematic of the talk

Rather than who is there ? The key question is with who they interact?

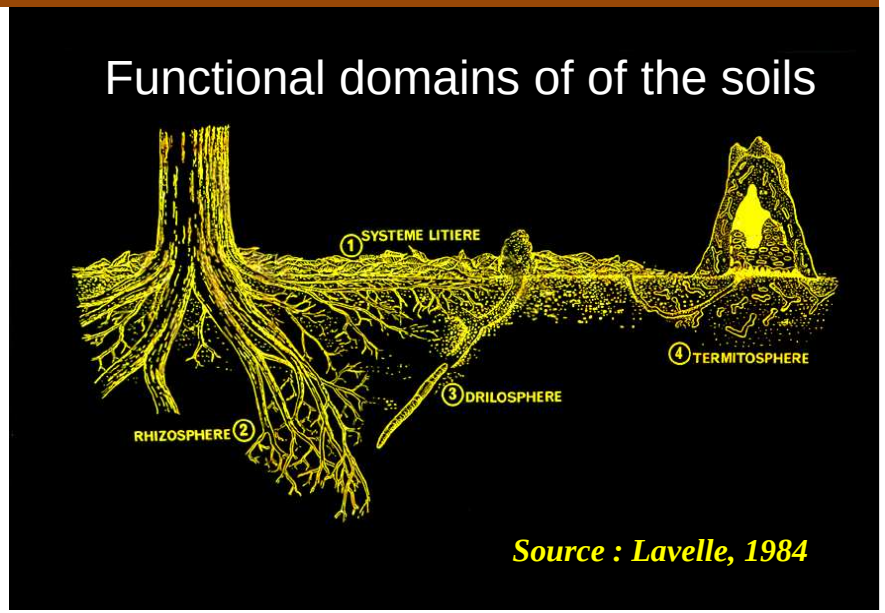
The soil food web





Problem link to this question

Soil complexity



- Interactions are not only trophic
- 1+1 >> 2 (facilitation)
- Methodological difficulties

Role of the soil biota → challenging question!

Objective of the talk

Demonstrate the link between soil functions and soil biological assemblages

The 4 main ecological functions

Nutrient cycling
- Capture
- Dynamics
- N and P availability

Carbon transformations
- Decomposition
- OM dynamics

Maintenance of soil structure
- Water retention
- Erosion
- Habitat provision

Population regulation
- Pest control

ECOcSYSTEM SERVICES

Plant growth, erosion, carbon sequestration, water filtering…

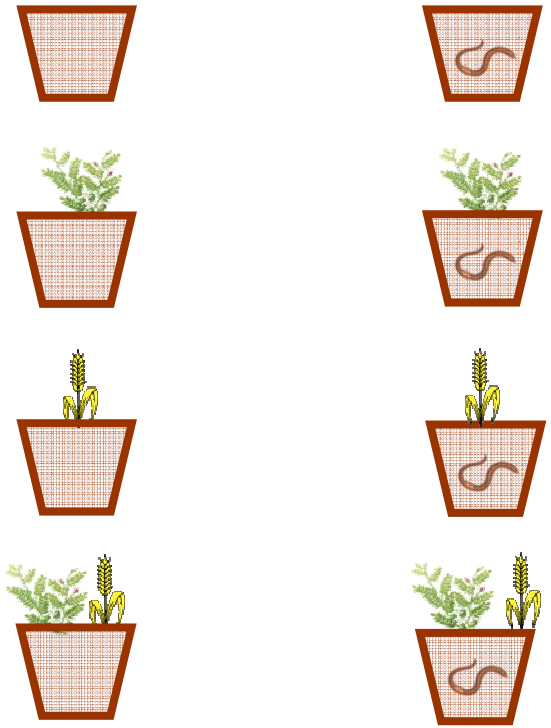
Biological interactions and ecological functions

Macrofauna impact on plant growth and nutrient cycle

Earthworms, P availability, plant growth and plant interactions

Without earthworms | **With earthworms (8 worms/pot)**

5 replications



Control

Chickpea

Durum wheat

Intercropping

Containers 1.5 L

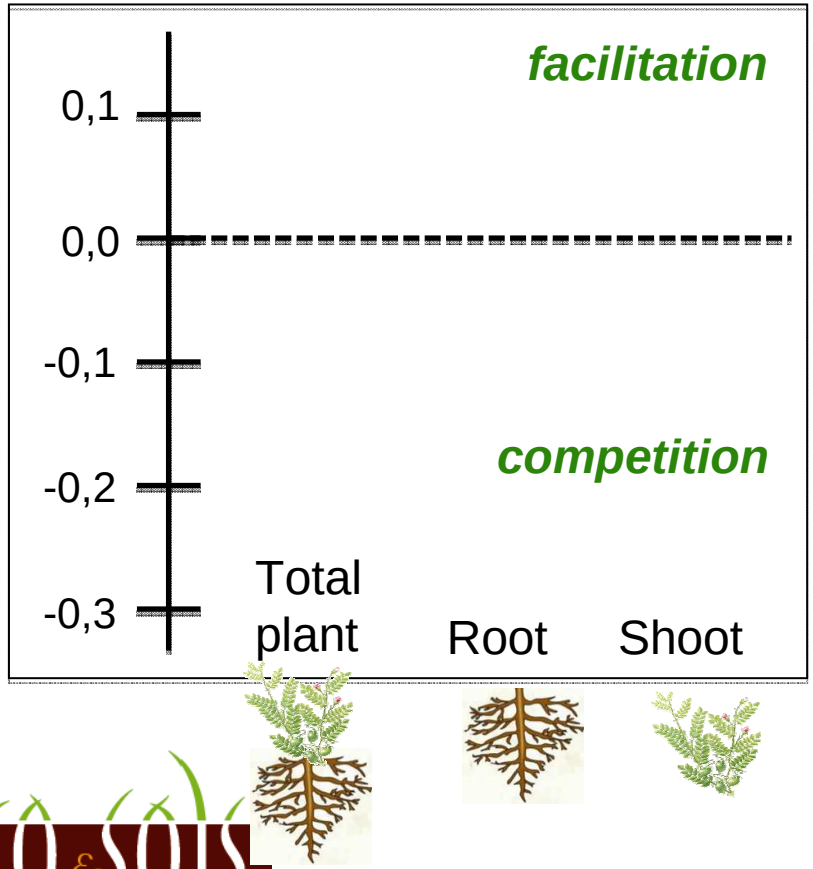
Coulis et al., 2014

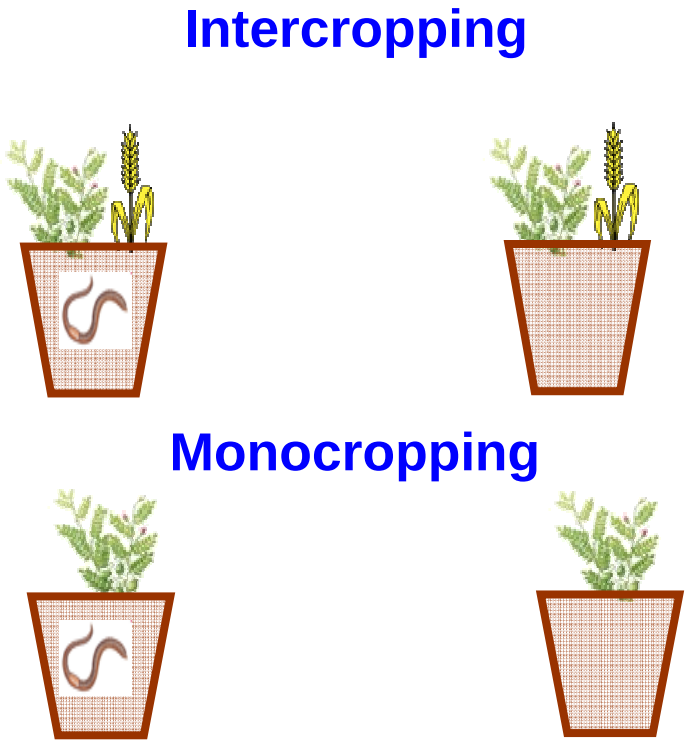
Biological interactions and ecological functions

Macrofauna impact on plant growth and nutrient cycle

Earthworms, P availability, plant growth and plant interactions

$$\text{Relative Interaction Index} = \frac{\text{Biomass inter} - \text{Biomass pure}}{\text{Biomass inter} + \text{Biomass pure}}$$





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Biological interactions and ecological functions

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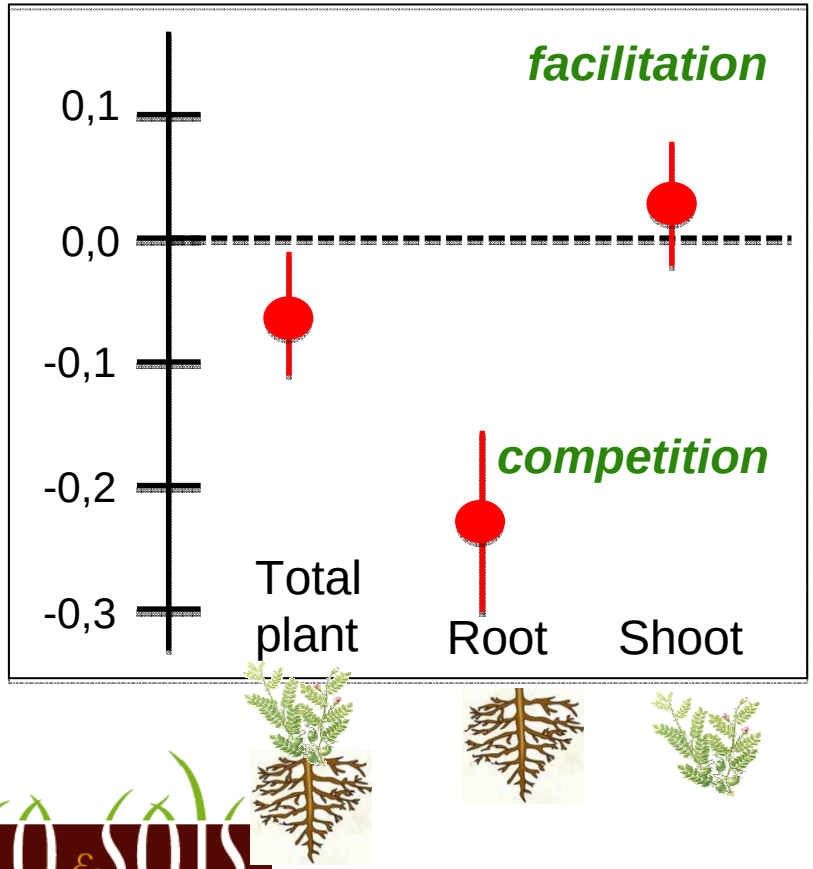
Biomass production (chickpea)



Without earthworms

Intercropping

Monocropping

Coulis et al., 2014

Biological interactions and ecological functions

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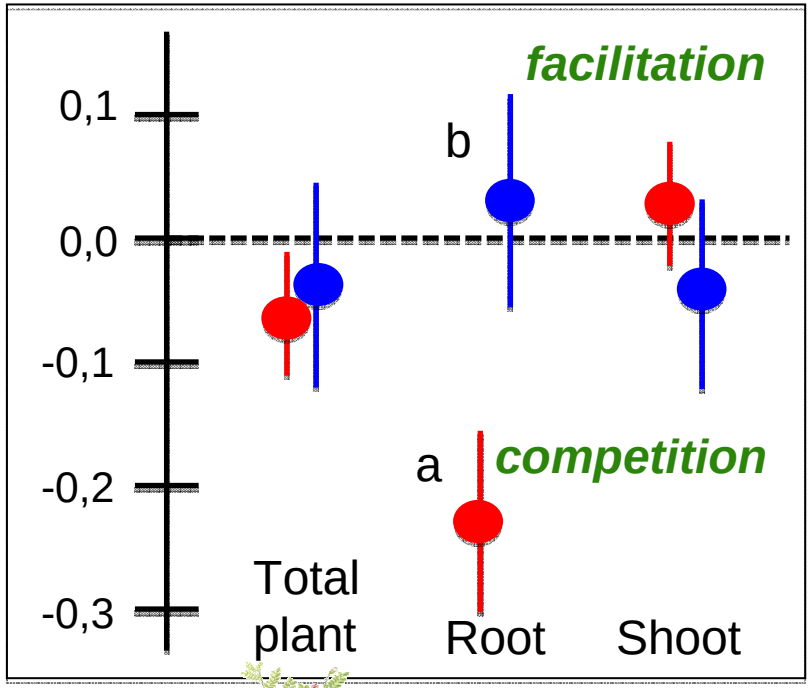

Without earthworms
With earthworms

Monocropping

Earthworms modify competition between plants

Coulis et al., 2014

Biological interactions and ecological functions

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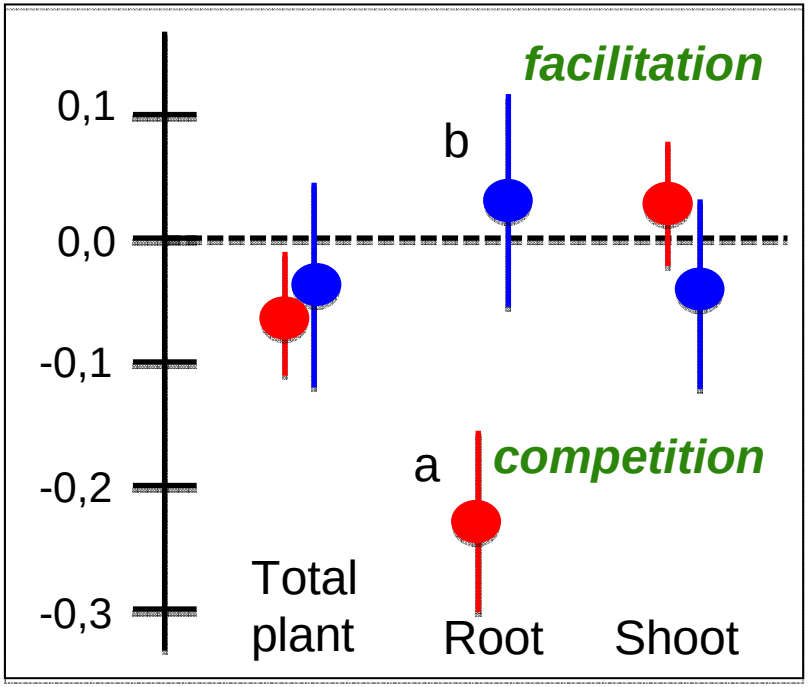
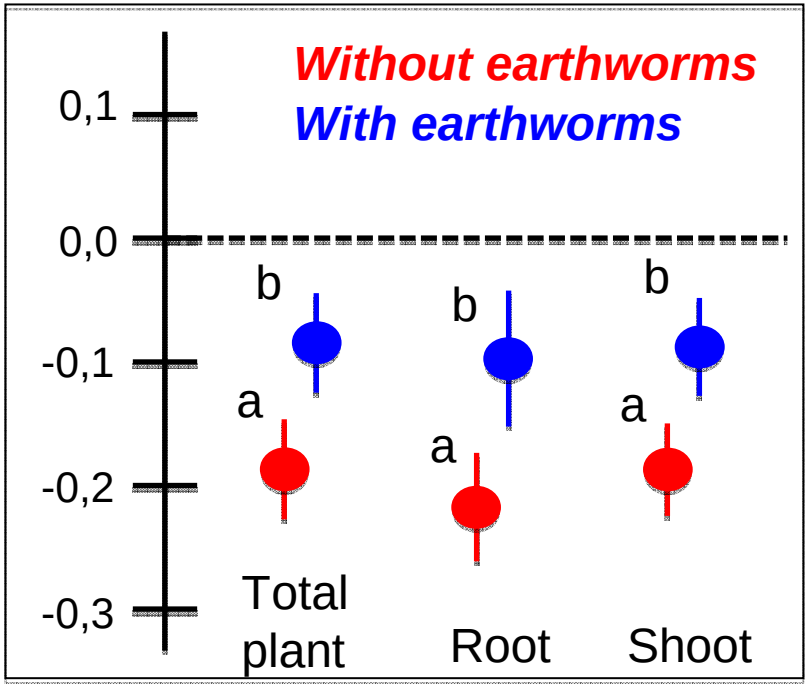


Phosphorus accumulation (chickpea)



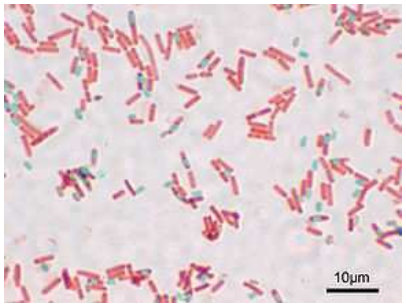
Earthworms modify competition between plants

Earthworms improve plant nutrition by modifying P forms in soil

Coulis et al., 2014

Biological interactions and ecological functions

What happen when we increase the trophic diversity?

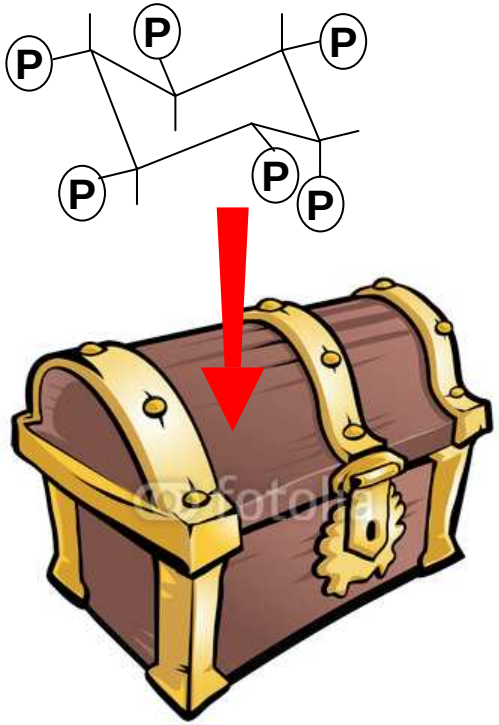


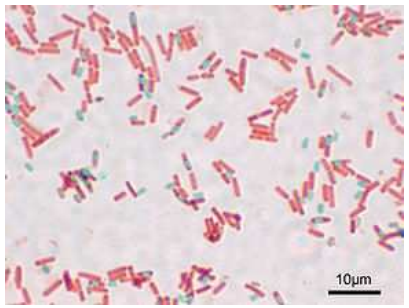
Phosphorus accumulation

Biological interactions and ecological functions

Phosphore cycle – case of phytate

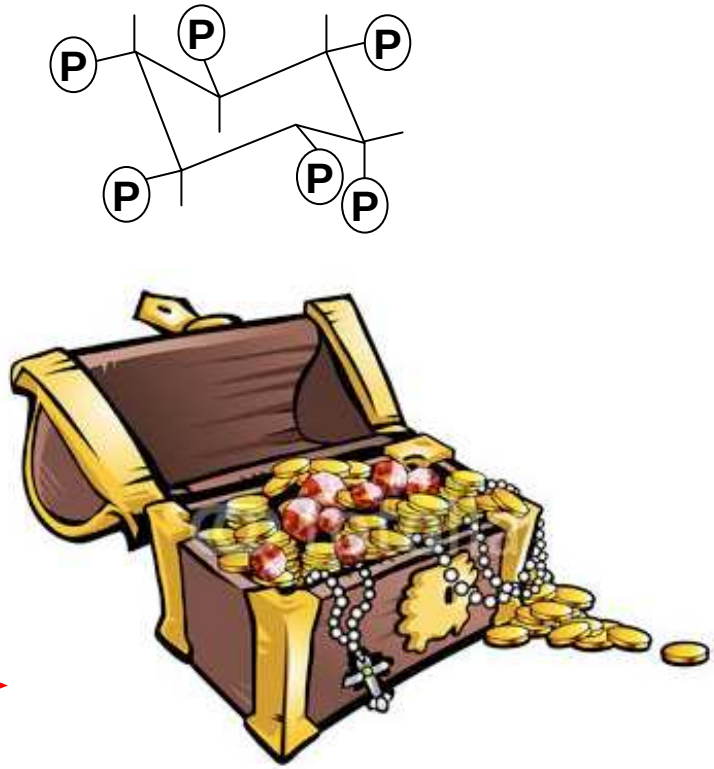
myo-inositol hexakis-phosphate
(phytate)
~ 80% of total organic P in soil





Phytate mineralizing bacteria

Phytases



From C. Plassard

Biological interactions and ecological functions

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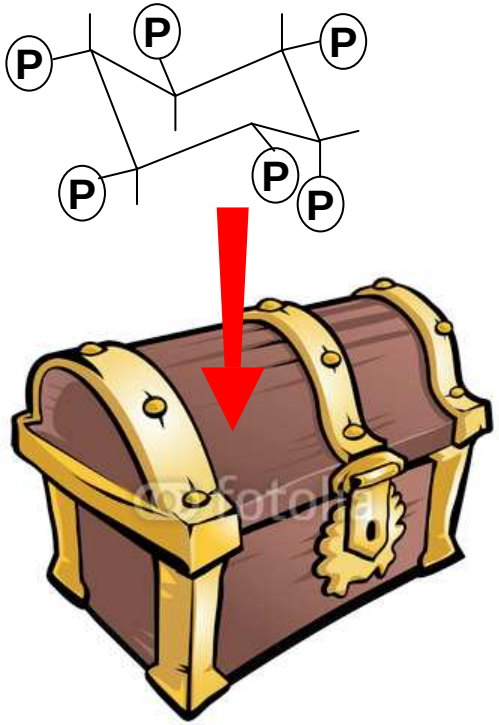

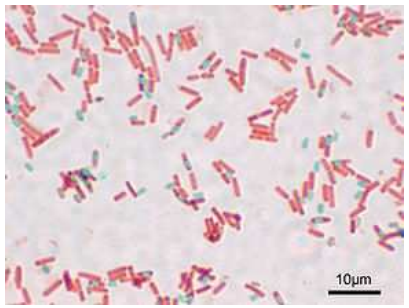

Phytate mineralizing bacteria

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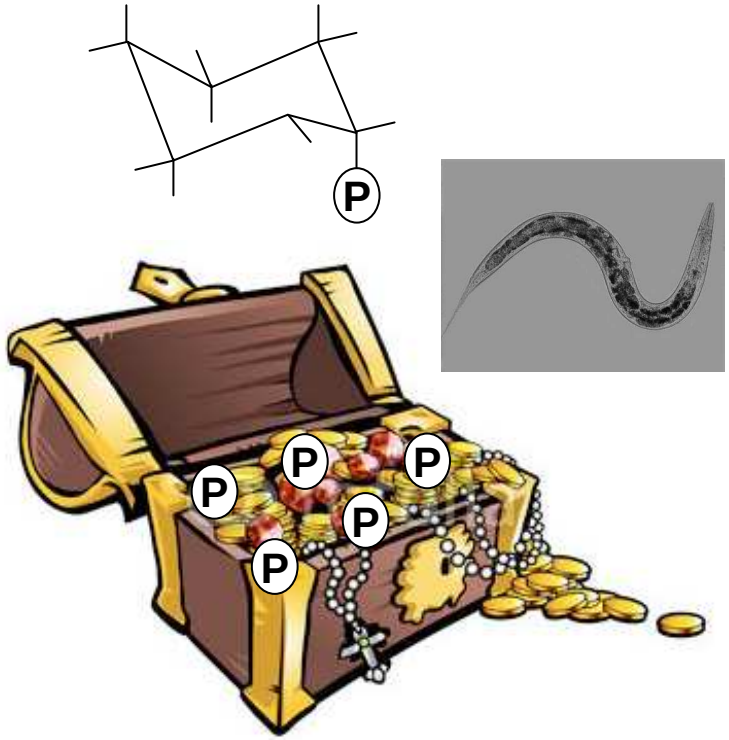


From C. Plassard

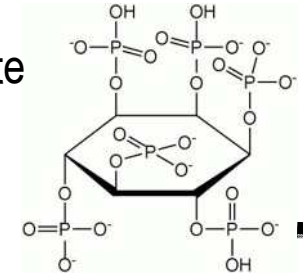
Biological interactions and ecological functions

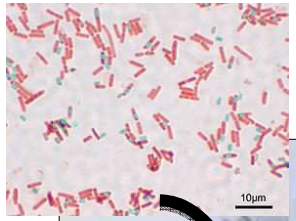
Detritivore food web and nutrient cycle

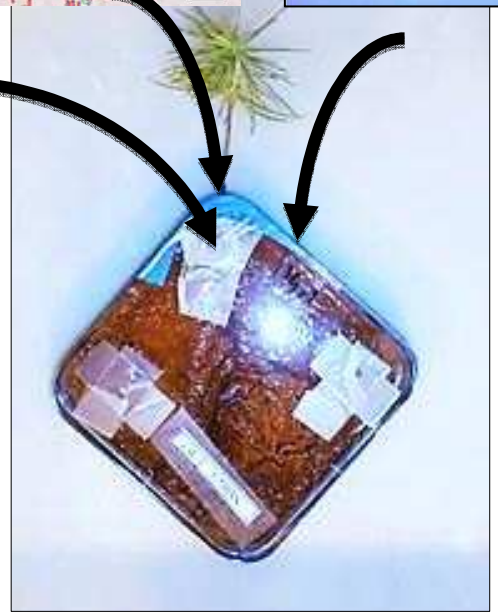
✓ **Roles of trophic interactions involving roots, bacteria and bacterivores nematodes**

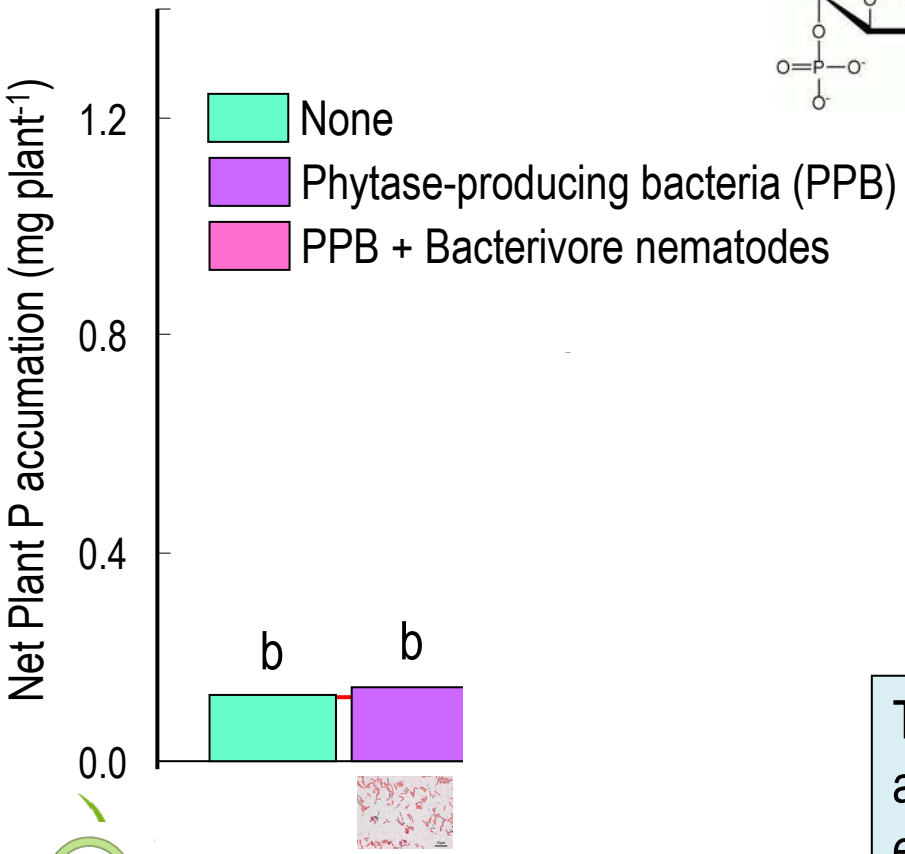
Example with Pinus pinaster growing on phytate

Phytate







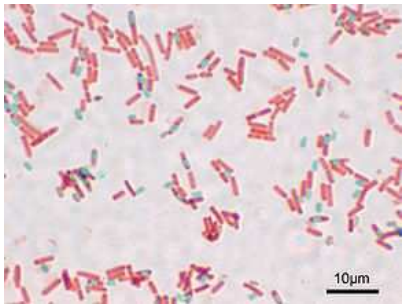


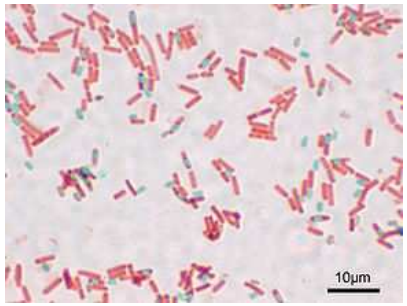
Trophic interaction between bacteria and nematodes increased plant P use efficiency from a recalcitrant P source.

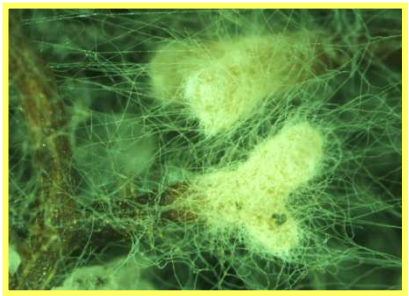
Unlock-P

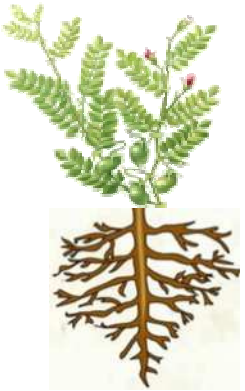
Biological interactions and ecological functions

What happen when we increase the trophic diversity?









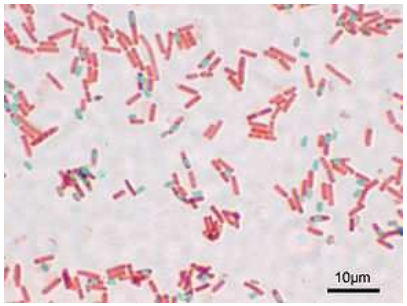
Phosphorus accumulation

Biological interactions and ecological functions

Detritivore food web and nutrient cycle

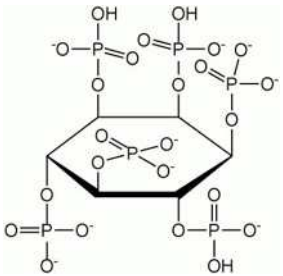
Mutualist

Bacillus subtilis

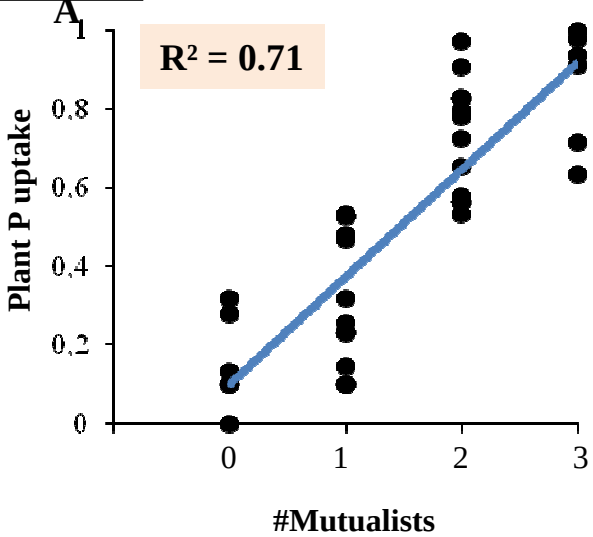


Hebeloma cylindrosporum

Rhabditis sp.



Case A



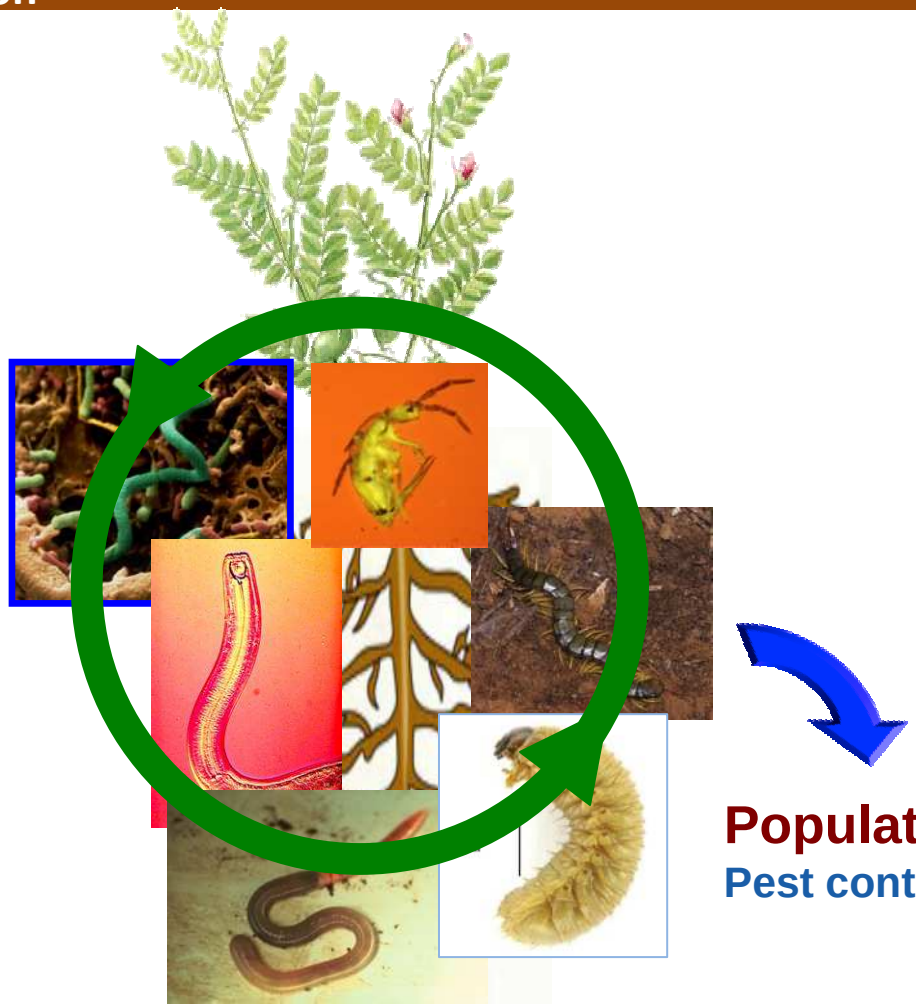
Organic P → Mineral P

P forms

Trap & Plassard, Unpublished

Biological interactions and ecological functions

Pest regulation



Population regulation

Pest control

Biological interactions and ecological functions

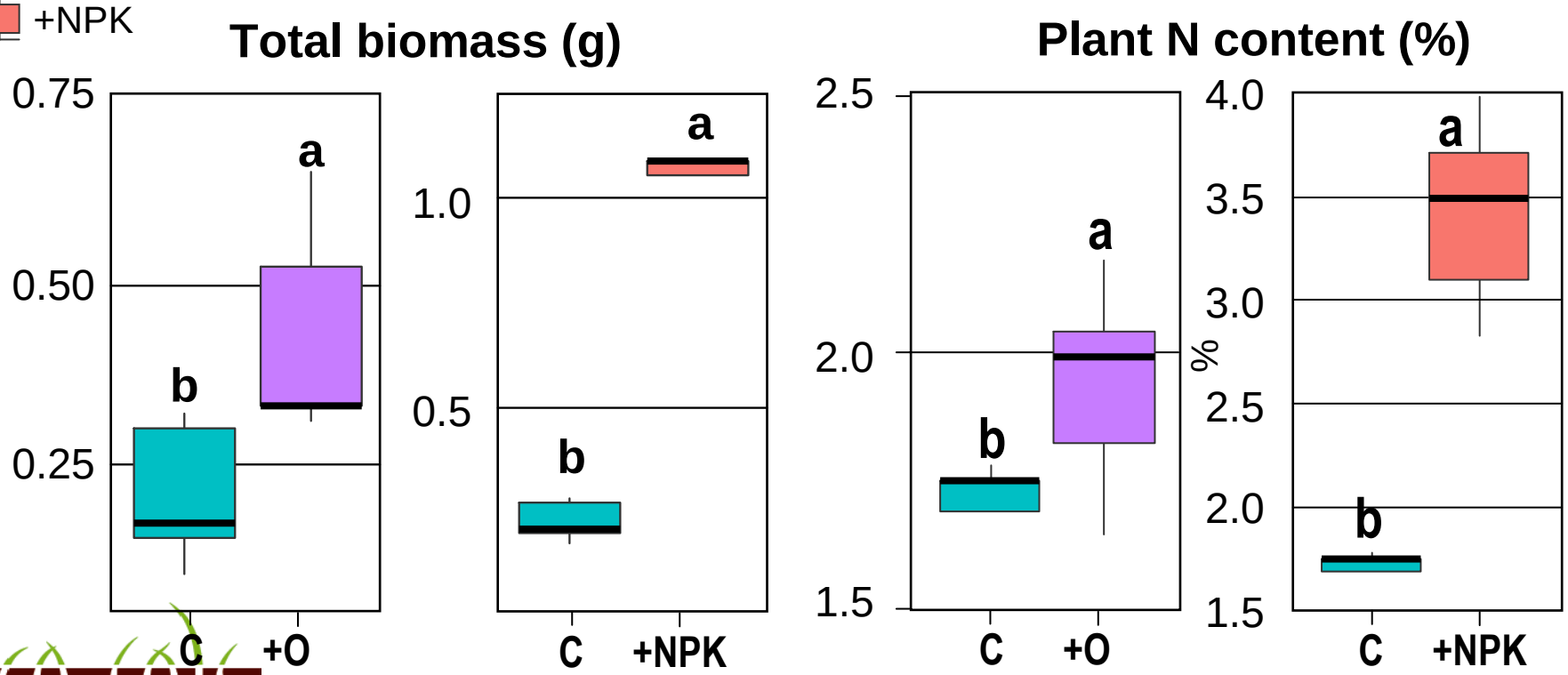
Pest regulation: role of soil biota on rice tolerance (pyriculariose fungi disease)

Mineral Fertilisation *versus* biologic (earthworms + nematodes)

- Moderate but significative effect of soil organisms (O) on biomass and % N
- Important effect of mineral fertilisation (NPK) on biomass and %N

Legend

- Control (C)
- O= Earthworm and Nematodes
- +NPK



Trap et al., Unpublished

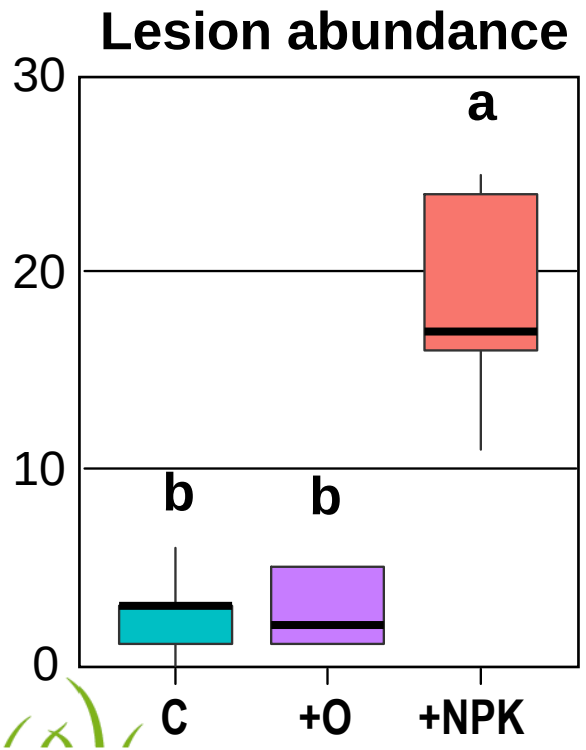
Biological interactions and ecological functions

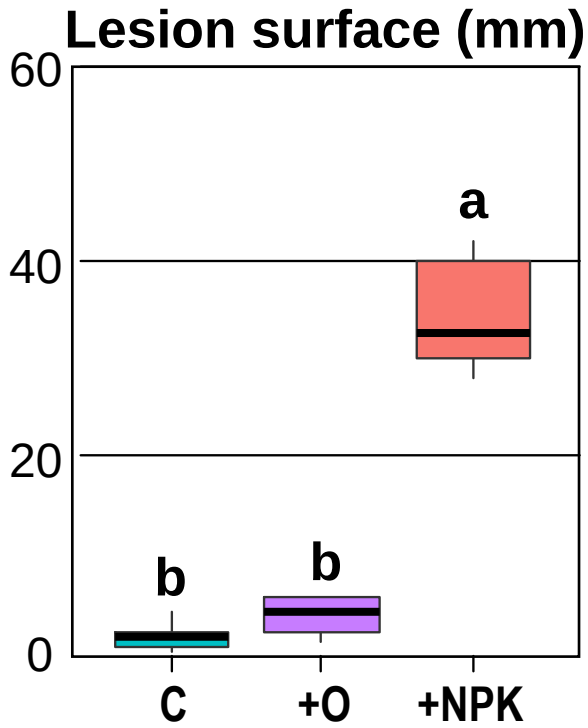
Pest regulation : Role of soil biota on rice tolerance (pyrucurlariose)

- No effect of soil organisms (O) on disease increase
- HIGHT effect of NPK on disease increase

Legend

- Control (C)
- + Earthworm and nematodes
- +NPK

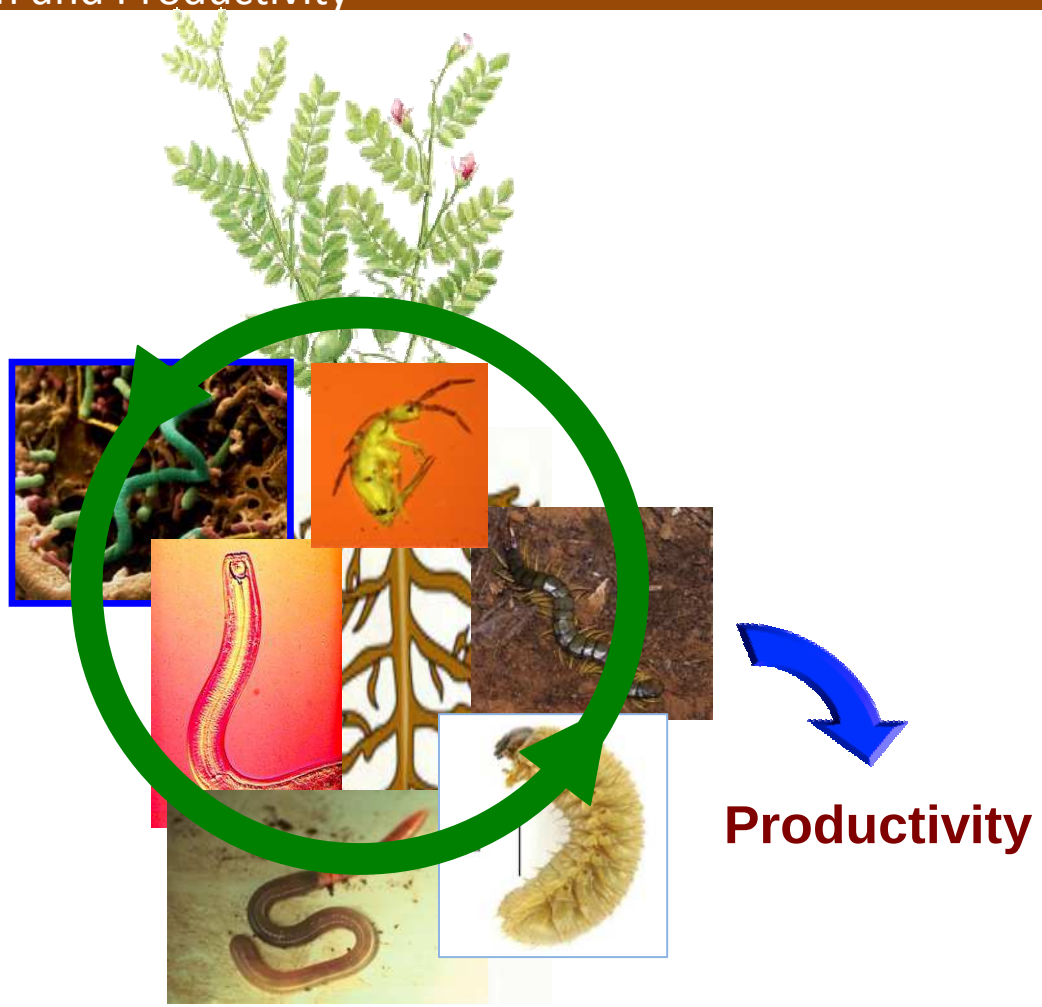




Trap et al., Unpublished

Biological interactions and ecological functions

Plant nutrition and Productivity

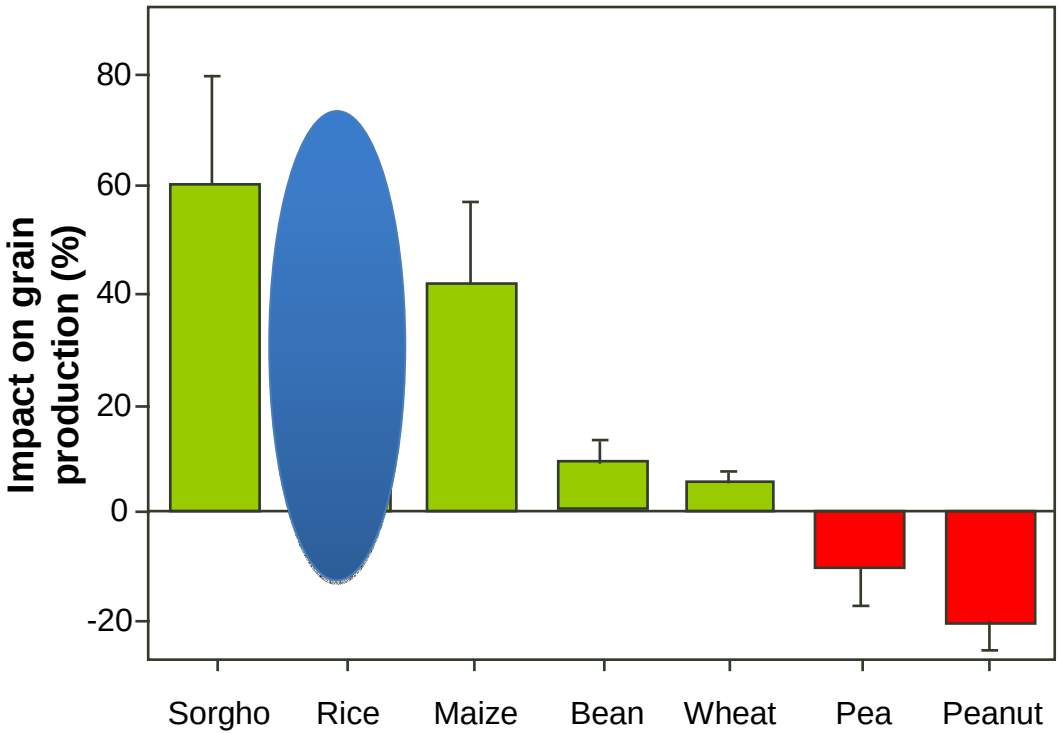


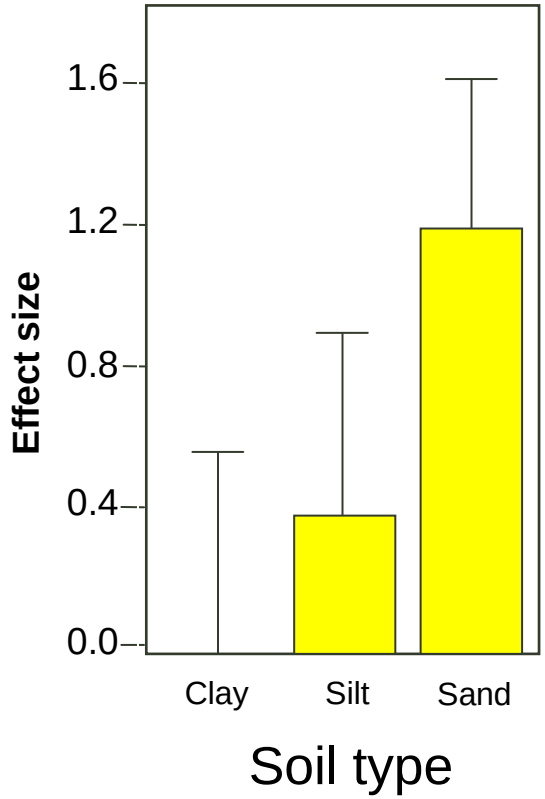
Biological interactions and ecological functions

Plant productivity

- Impact of earthworms on primary productivity

Brown *et al.* (1999), Laossi *et al.* (2010)





Adapted from T. Daecans

Does this soil biota-plant interaction vary with plant variety

Biological interactions and ecological functions

Plant productivity

8 different rice variety

Optimale
culture 700-1200m

Sensitive to
pyriculariose

Sensitive to
STRIGA

Tolerant to
STRIGA

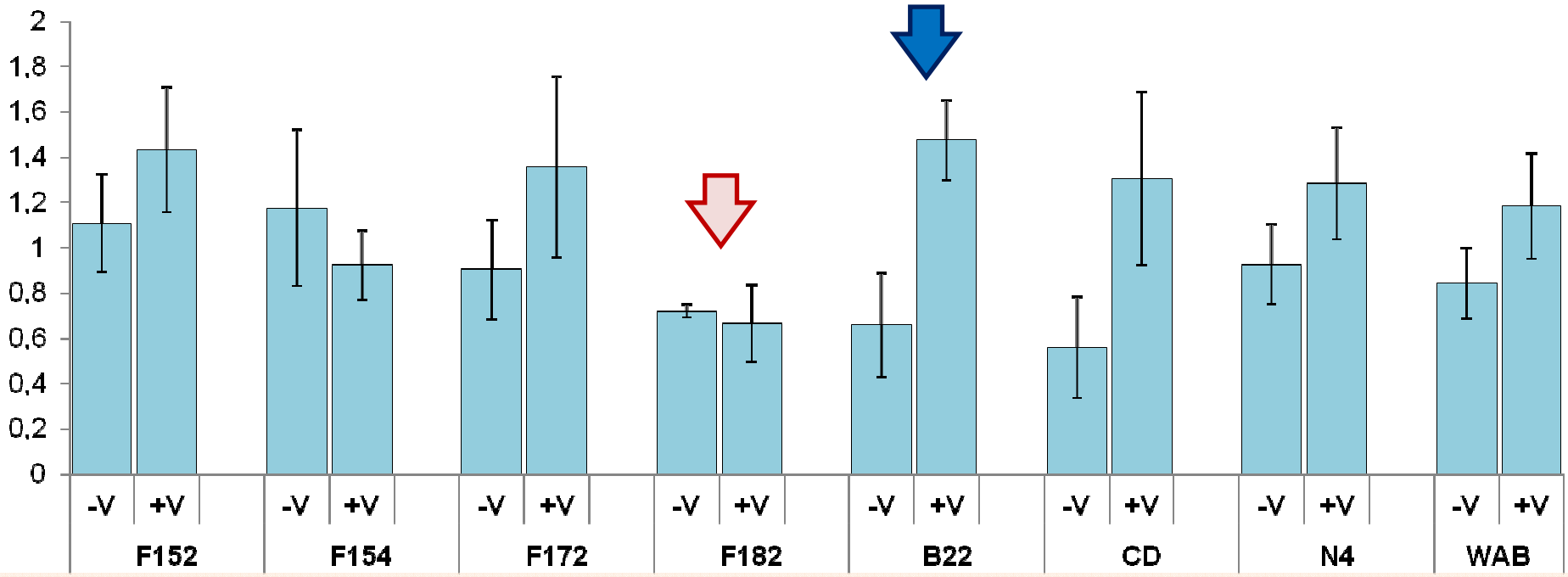
Resistant to
pyriculariose

Trap & Blanchart, Unpublished

Biological interactions and ecological functions

Plant productivity

Shoot-root ratio

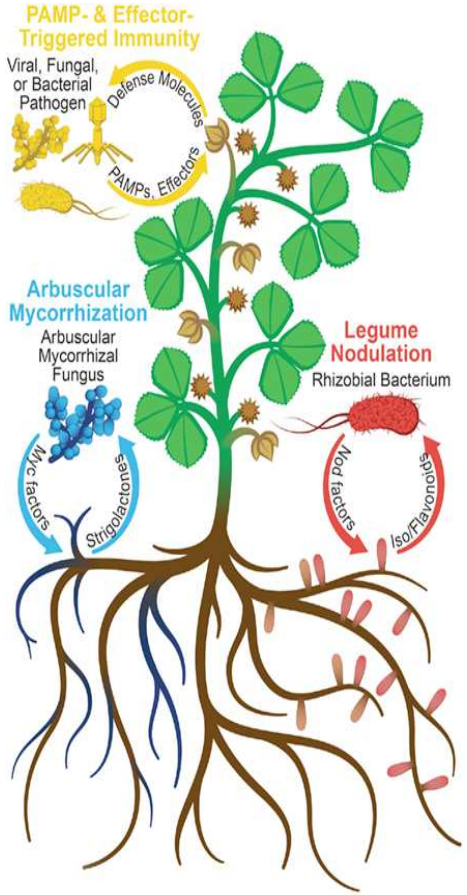


Soil organisms, such as earthworms, have a central effect on the functions of the crop plant, BUT, this effect is dependent on the genetic deterministic response potential of the plant.

Trap & Blanchart, Unpublished

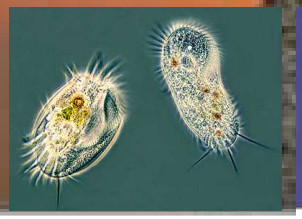
Take home message

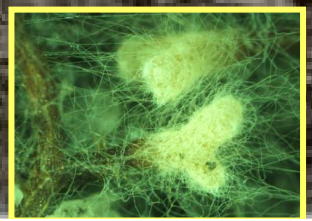
Soil biological interactions:
a driver to improve soil functioning and soil sustainability

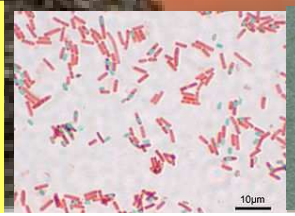


How plant could develop without irrigation fertilization etc..
The answer is in the study of symbiotic mycorhizae and
Symbiotic nitrogen bacteria (Guillaume Becard, Toulouse)

We are also the future of agriculture !







Thank you for your attention

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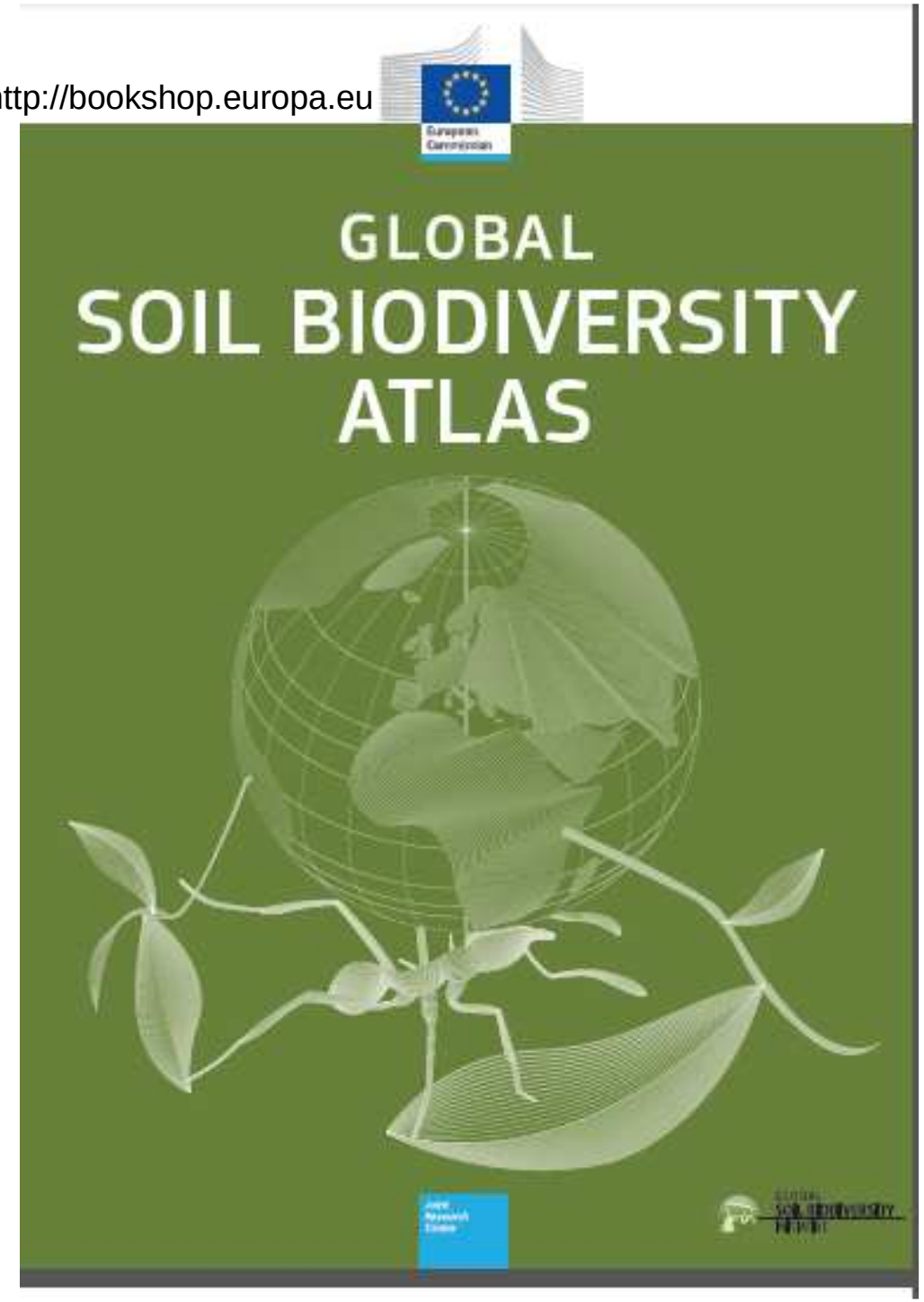


Ecological intensification of crop production

↓

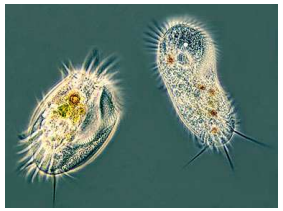
Intensification of ecological processes

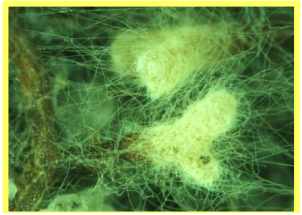
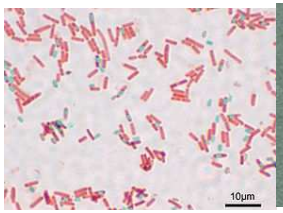
↓

Especially biotic interactions, in order to optimize their potential and to limit the use of inputs while maintaining or improving crop productivity" (INRA)

↓

How could we measure at field scale the functions driven by soil biota?

Introduction

Main questions link of this talk

Why its so difficult to study soil biodiversity

Is biodiversity studies are sufficient to understand how the soil functions Soil b