Food and Agriculture Organization of the United Nations

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UNITED NATIONS ESCAP Economic and Social Commission for Asia and the Pacific

Webinar III - Climate Smart Agriculture

Loss of Biodiversity and the Uncertainties associated with Climate Change

Soil biodiversity a major challenge for the multiperformance of agroecological systems

Philippe Lemanceau
UMR Agroécologie, Dijon, France

INRAE

Wednesday 27 May, 2020

Current intensive conventional agricultural systems are not sustainable

- Increase of inputs: fossil energy, fertilizers, pesticides, water
- Resource erosion:
    - Arable lands (desertification, salinization, soil sealing,…) with soils being not renewable at our human time scale
    - Biodiversity
    - Water: quantity and quality
- Global change to which agriculture contributes but also to which agriculture is submitted.

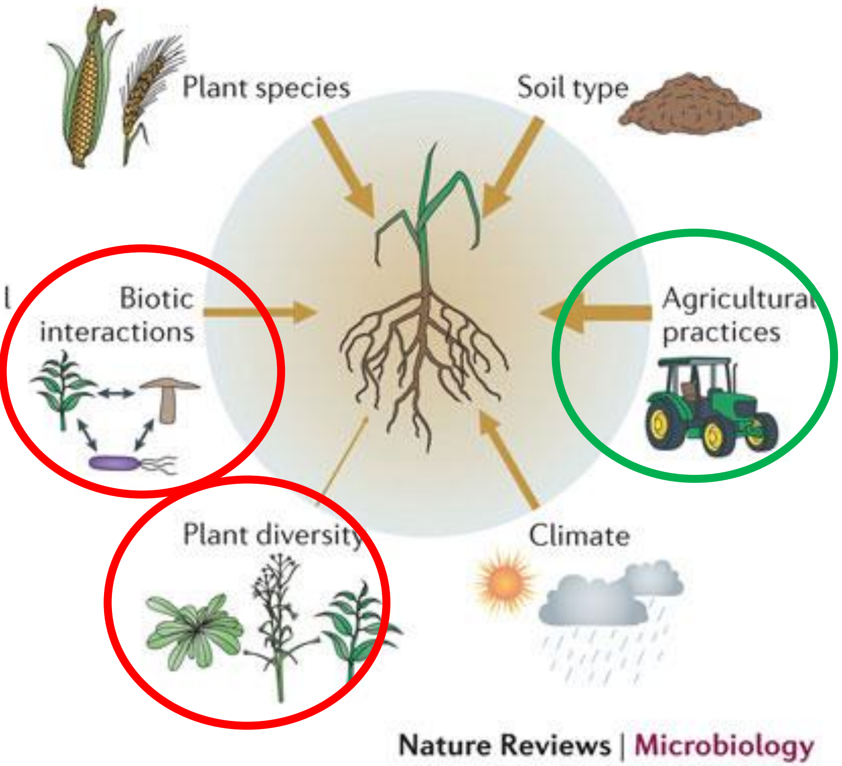
Agricultural systems should:

- Provide food of adequate quantity and quality
    - Prevalence of people undernourished (822 Mo - 2018) = 10.8%
    - Malnutrition: 'Hidden Hunger' 2 Ma
    - Increase of the world population: 7.79 Md, 2030 ~ 8.5, 2050 ~ 9.7 Md
- Contribute to climate mitigation
- Preserve resources: soil, water, biodiversity

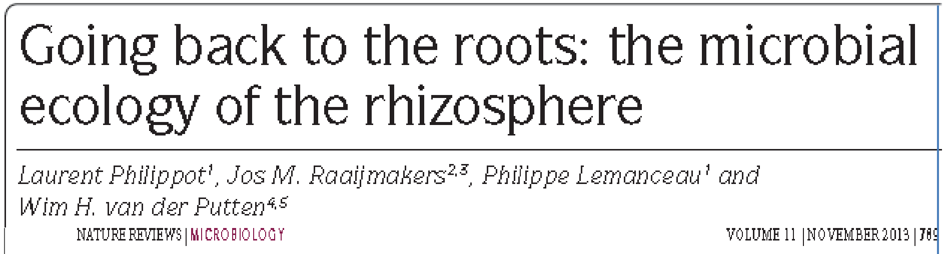
➯Move from intensive conventional agriculture to ecological intensification with agroecology

- Ecological intensification: Integrate ecological processes into land-management strategies to enhance ecosystem service delivery and reduce anthropogenic inputs Bommarco et al. 2013. Trends Ecol. Evol.
- Agroecology: Apply ecological concepts and principles to optimize interactions for a sustainable that (i) support food production and food security and nutrition and (ii) deliver ecosystem services including climate mitigation http://www.fao.org/agroecology/overview/eg/

Conventional agricultural systems



Paradigm shift: Harness biodiversity and biotic interactions


Going back to the roots: the microbial ecology of the rhizosphere

Laurent Philippot[1], Jos M. Raaijmakers[2,3], Philippe Lemanceau[1] and Wim H. van der Putten[4,5]

NATURE REVIEWS | MICROBIOLOGY VOLUME 11 | NOVEMBER 2013 | 789

Living soils

- Huge quantity of organisms
  - Fauna: 1-5 T/ha
  - Fungi: 3.5 T/ha
  - Bacteria: 1.5 T/ha

F. Ippolito

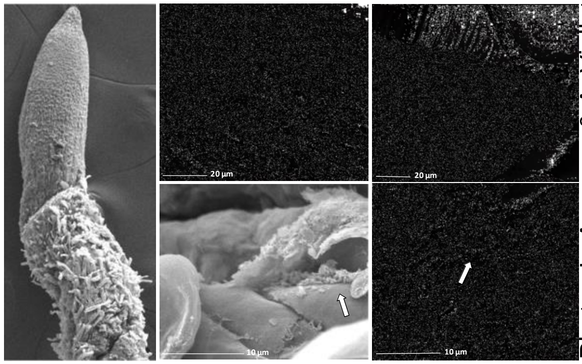
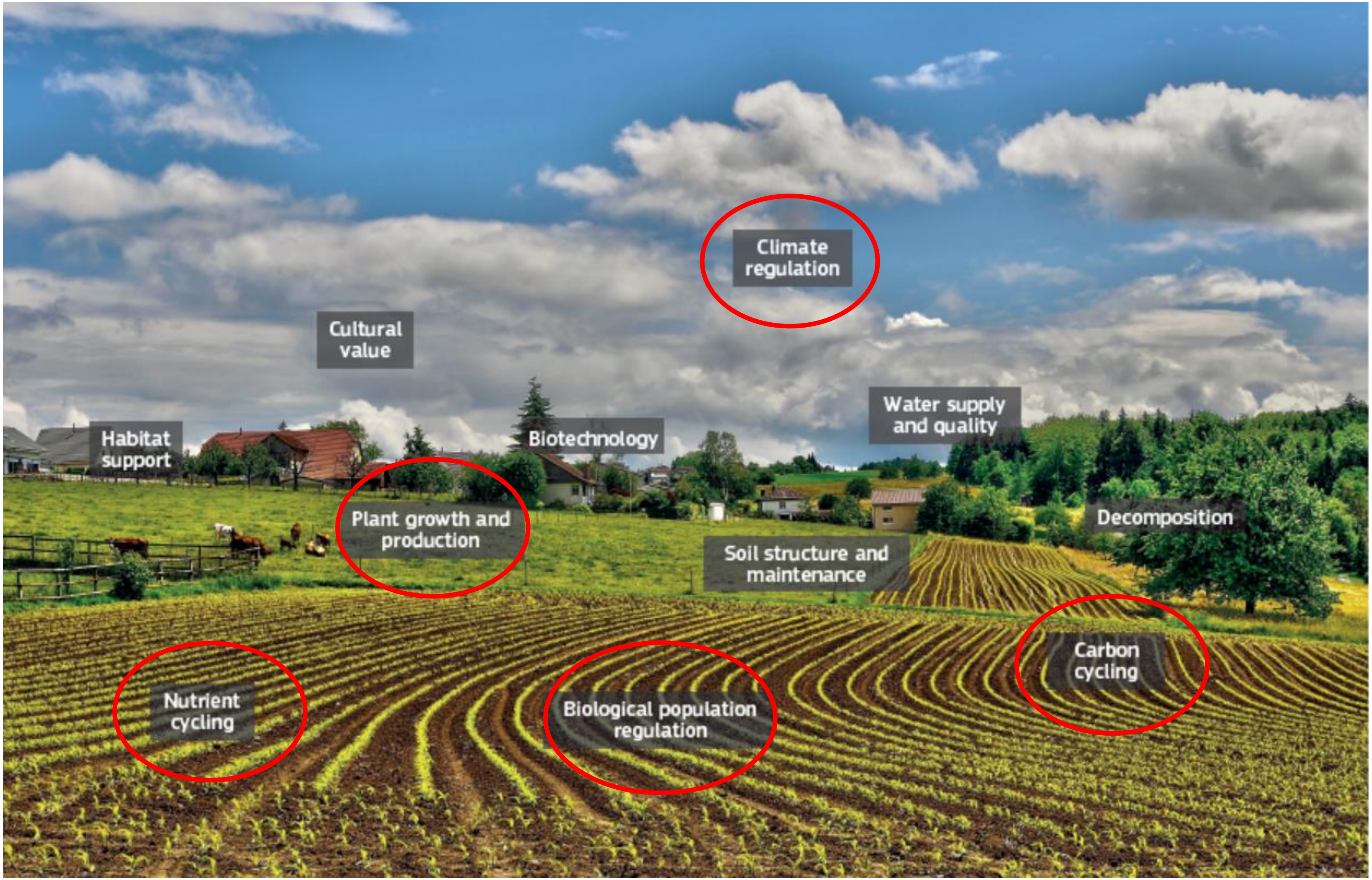


Photo : L. Avoscan & A. Violet

- Fantastic diversity

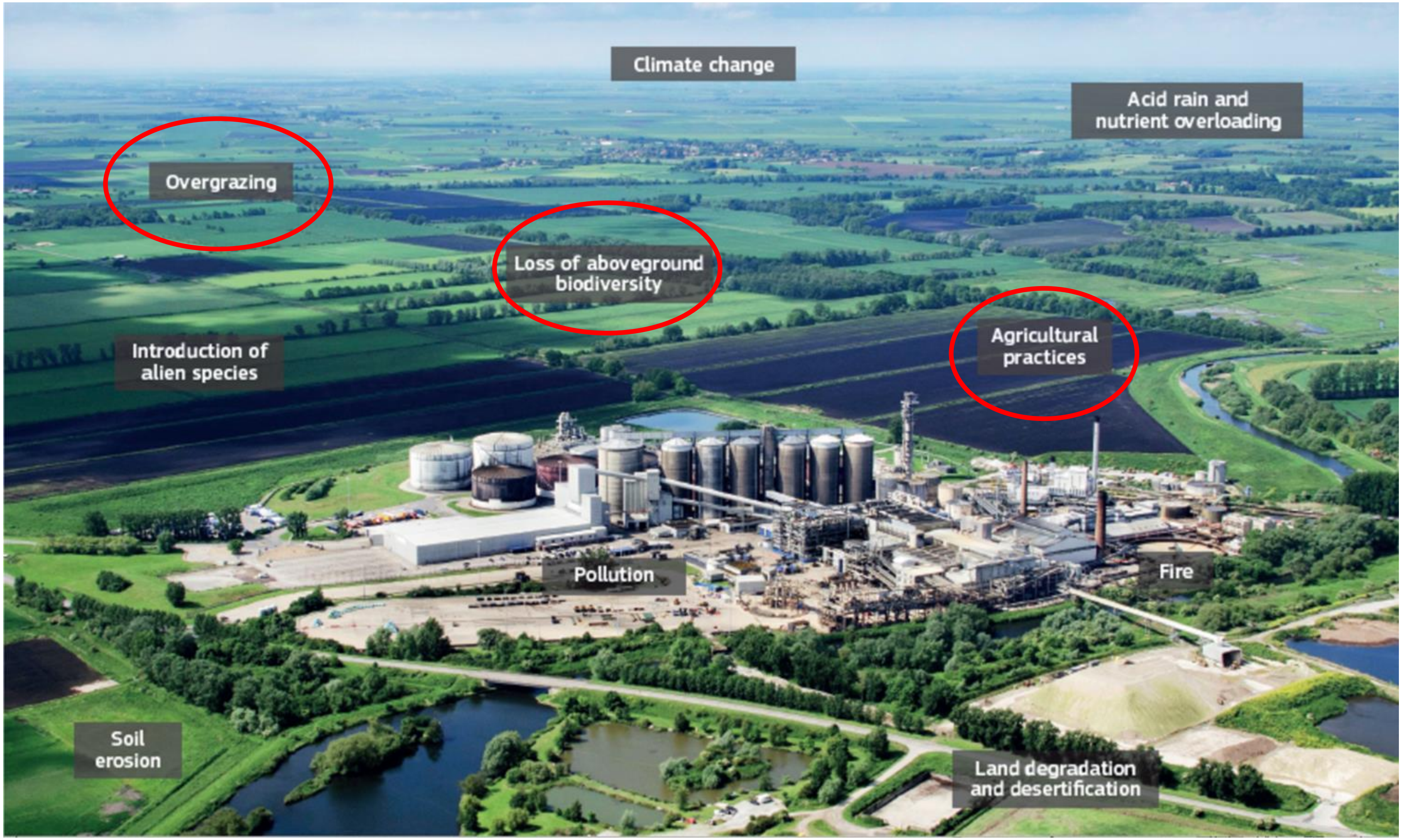
Gesein et al. 2019. Curr Biol. Rev.

Soil biodiversity delivers a range of ecosystem services



Global Soil Biodiversity Atlas. European Commission, Publications Office of the European Union, Luxembourg. 176 p.

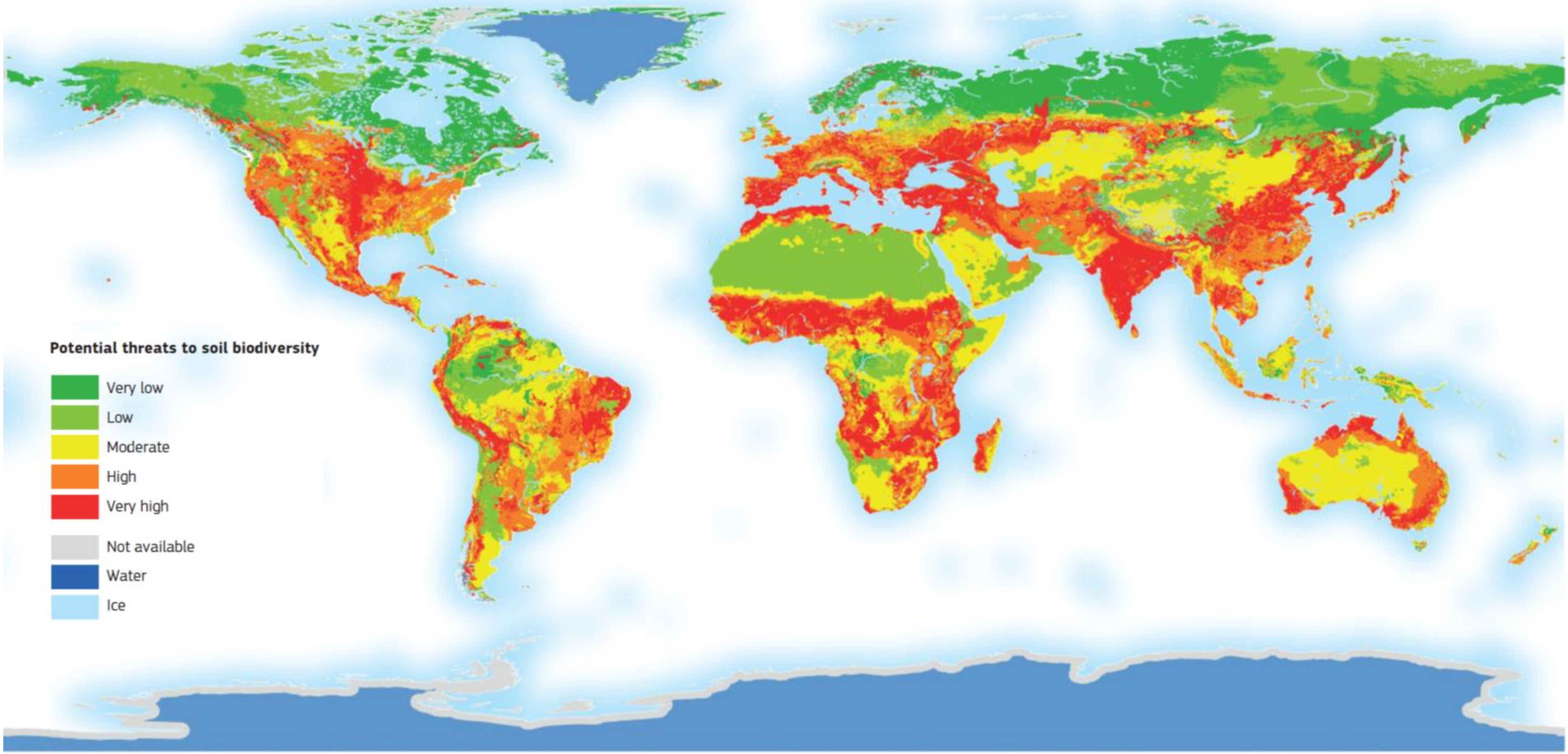
Soil biodiversity is submitted to major threats



Global Soil Biodiversity Atlas. European Commission, Publications Office of the European Union, Luxembourg. 176 p.

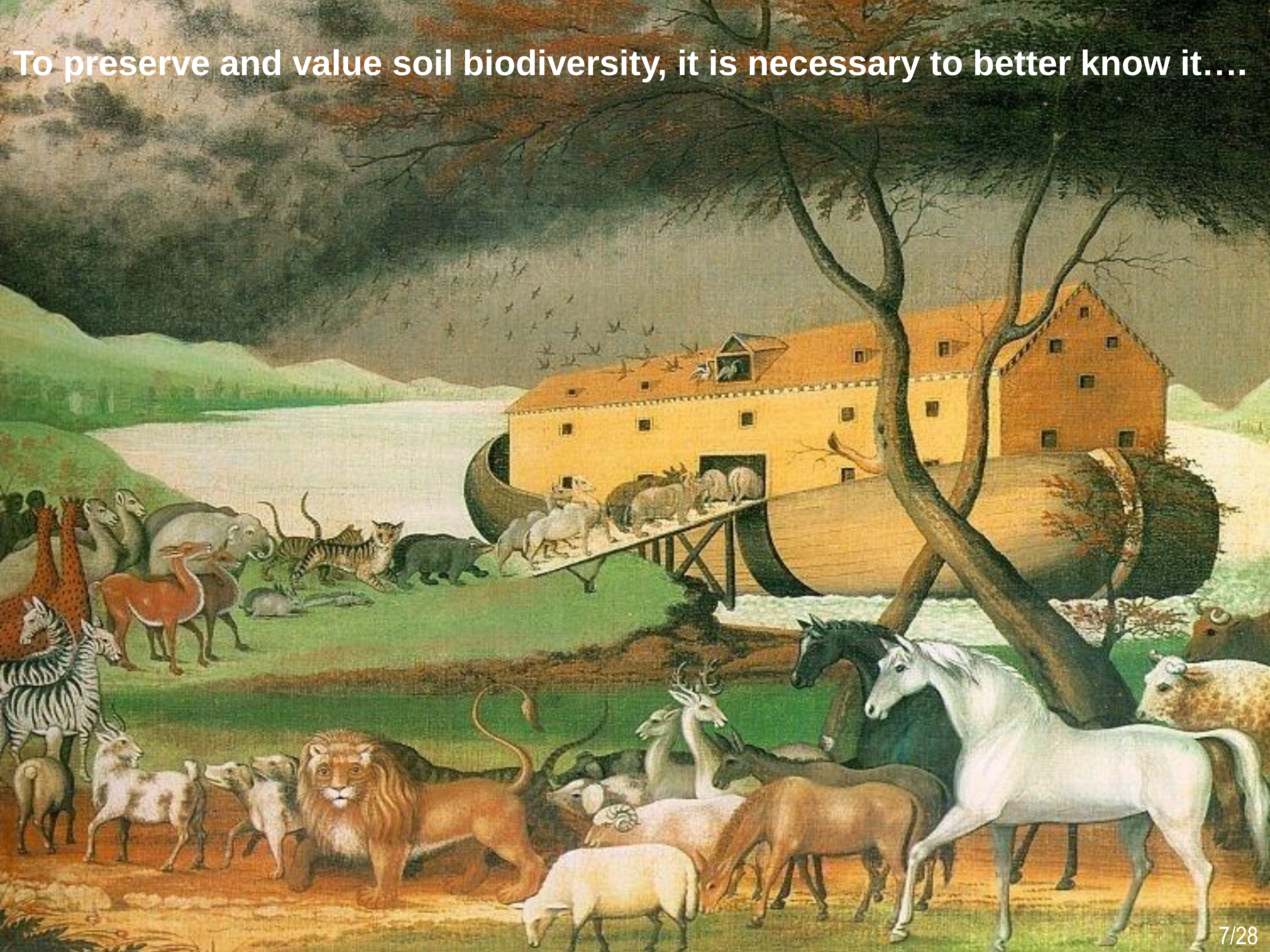
Soil biodiversity is submitted to major threats

Potential threats to soil biodiversity



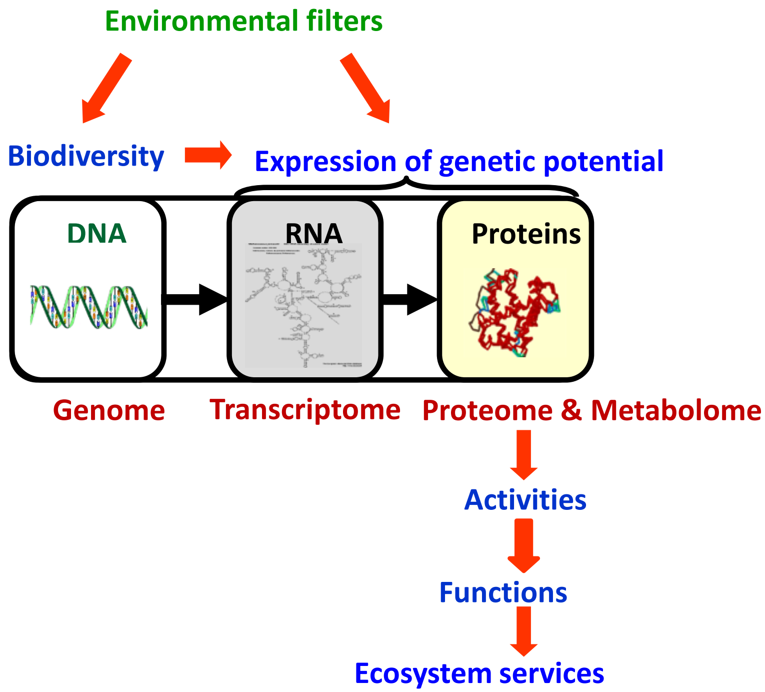
Global Soil Biodiversity Atlas. European Commission, Publications Office of the European Union, Luxembourg. 176 p.

To preserve and value soil biodiversity, it is necessary to better know it….

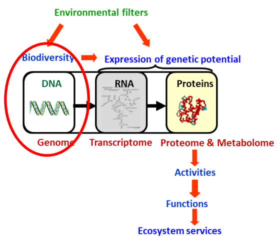


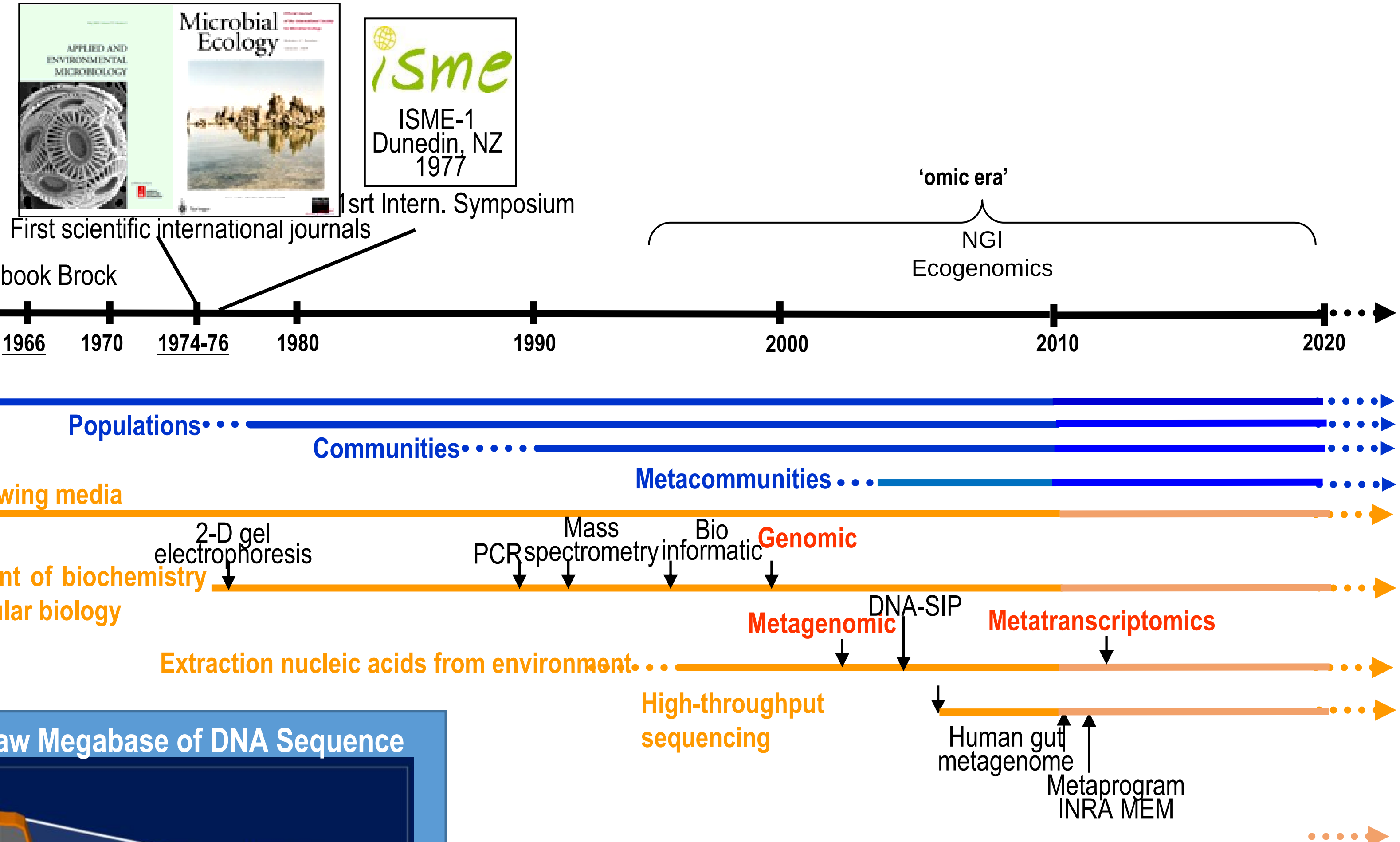
This requires a better knowledge in:

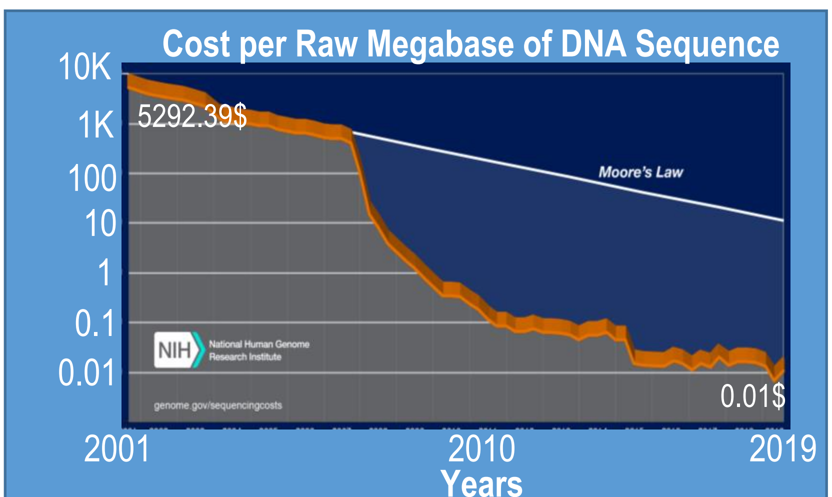
- Soil biodiversity
- Relationships between soiil biodiversity-functions-ecosystem services
- Impact of the variety of environmental situations



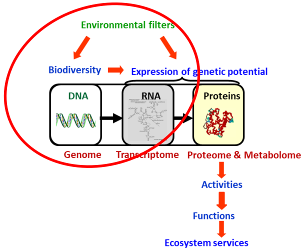
Soil microbial diversity: fantastic methodological developments







Adapted from Maron et al. 2007. Microbiol. Ecol.



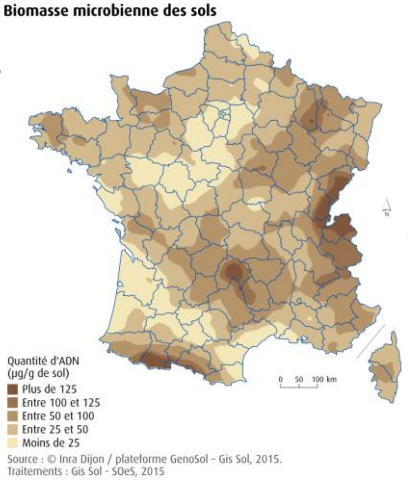
Soil microbial diversity: Diagnosis

Molecular biomass

RMQS

Gis Sol

Biomasse microbienne des sols



Dequiedt et al. 2011 Glob Ecol Biogeogr

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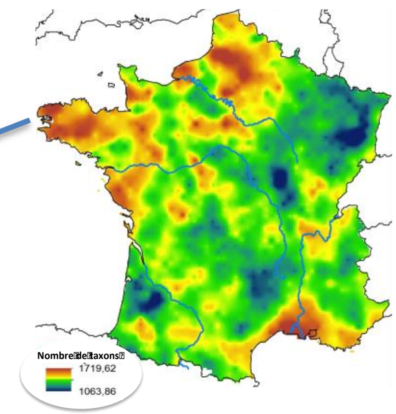
ADEME

Strong impact of the soil type

Significant impact of the land use

Bacterial diversity



GENOSCOPE

Ranjard et al., 2013 Nature Com

Predictive model

$$Y=\beta 0+\sum(\beta jXj+ \beta jX^2j)+\sum\sum \beta jkXjXk+\varepsilon$$

ONB Observatoire National de la Biodiversité

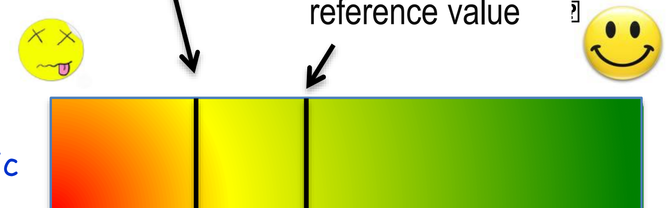
« National indicator for soil »

ONB Observatoire National de la Biodiversité

« National indicator for soil »

treshold value

reference value



Horrigue et al., 2016 Ecol Indic

Terrat et al., 2017 Plos One

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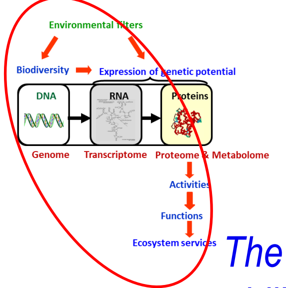
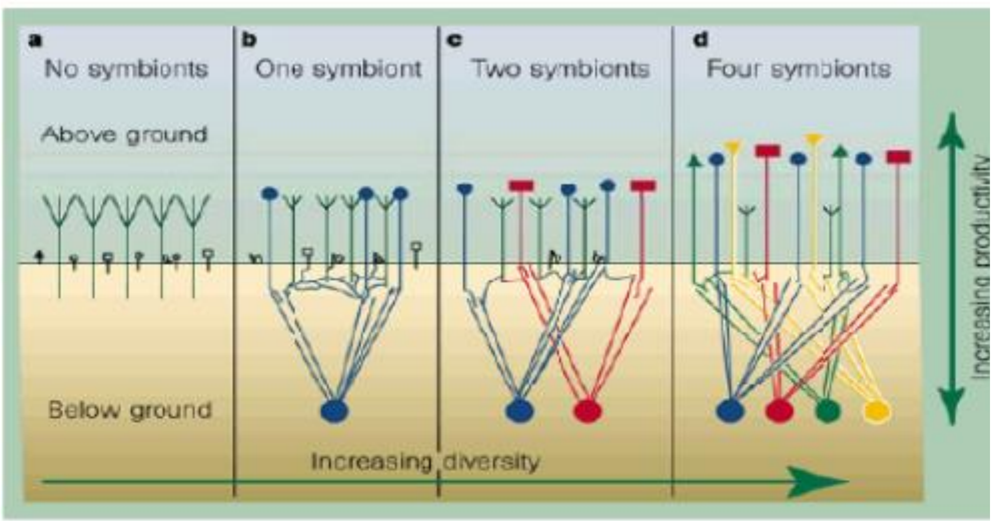
Courtesy of L. Ranjard INRAE Dijon

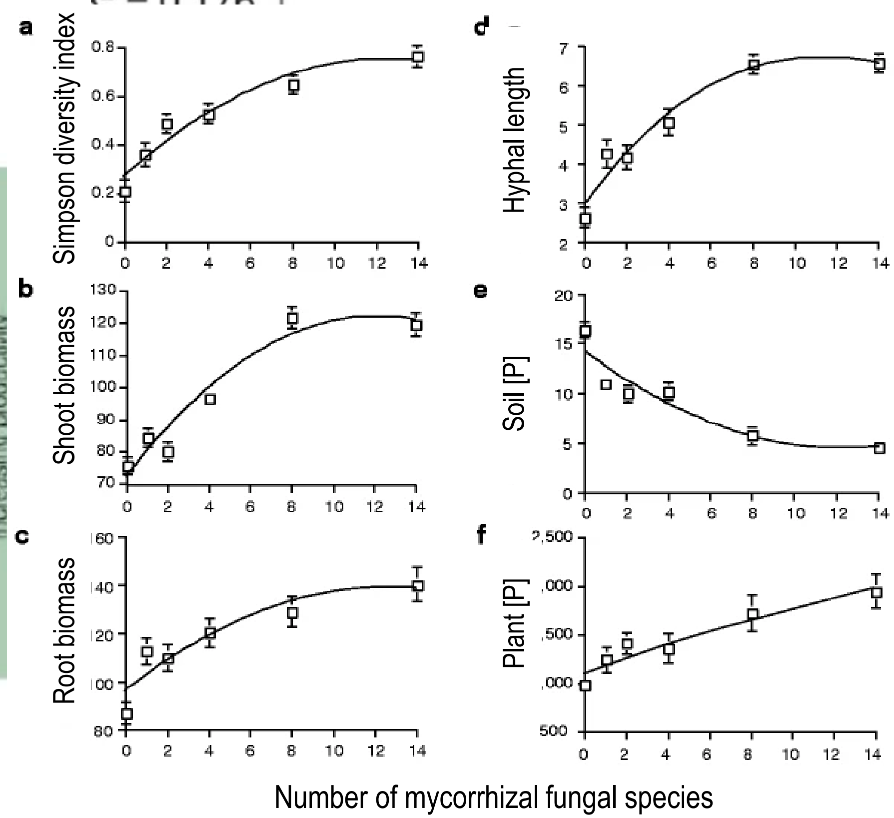


Relations between biodiversity and functioning

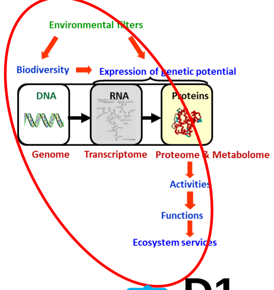
The question of how such loss of biological diversity will alter the functioning of ecosystems and their ability to provide society with the goods and services needed to prosper (Cardinal et al. Nature 2012)



Courtesy of Van der Heijden, Agroscope, Zurich

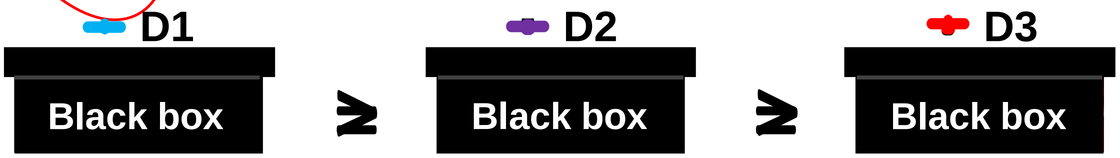


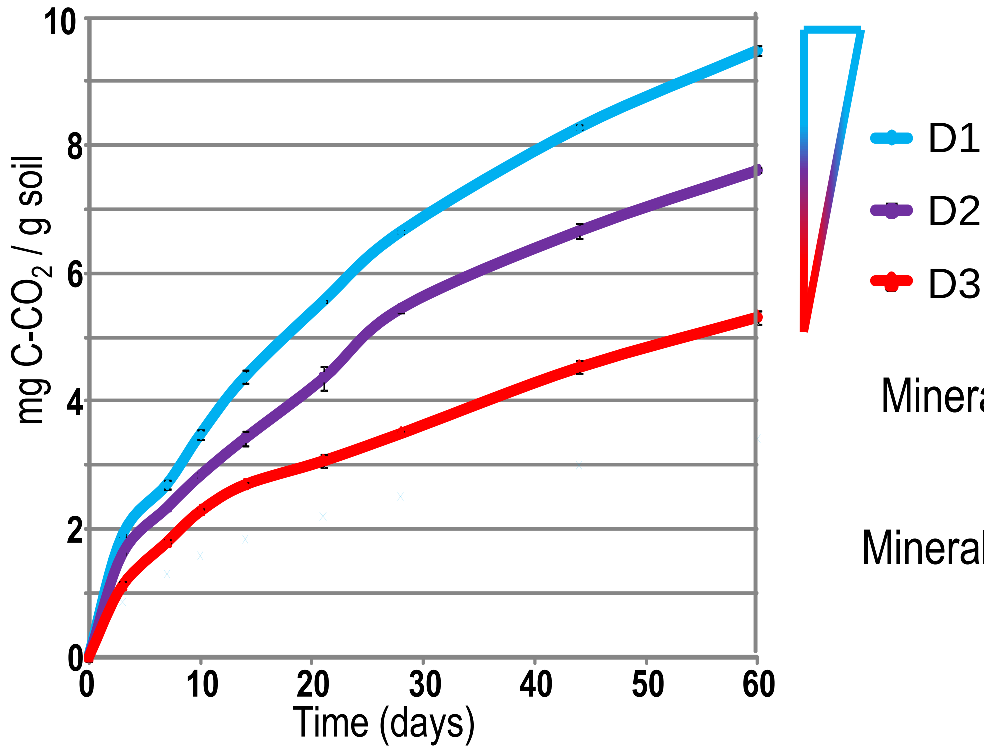
Van der Heijden et al. 1998. Nature 396:69-72



Relations between biodiversity and functioning

Carbon cycle – Mineralization



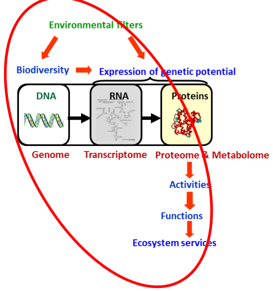


Mineralization D1 > D2 >D3

Mineralization SOM = f (Microbial diversity)

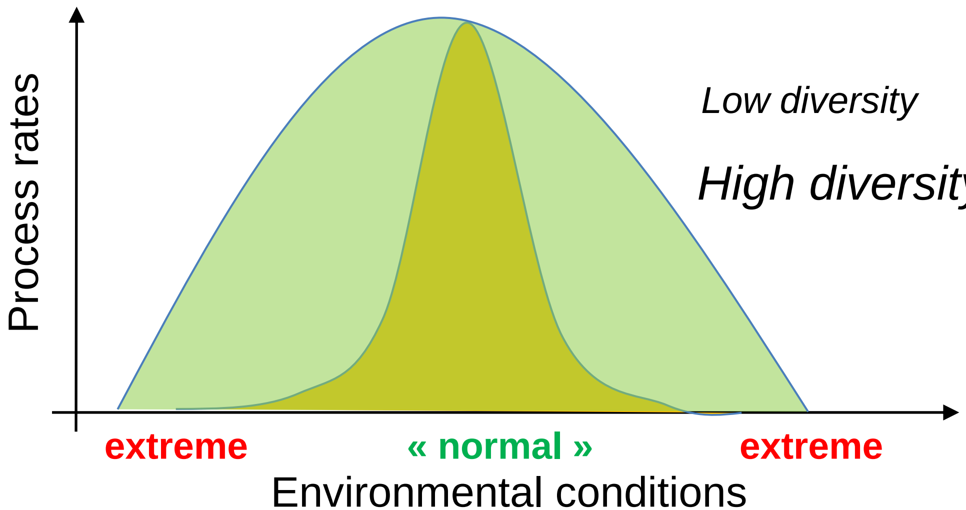
Maron et al. 2018. Appl. Environ. Microbiol.

Courtesy of P.-A. Maron, INRAE Dijon



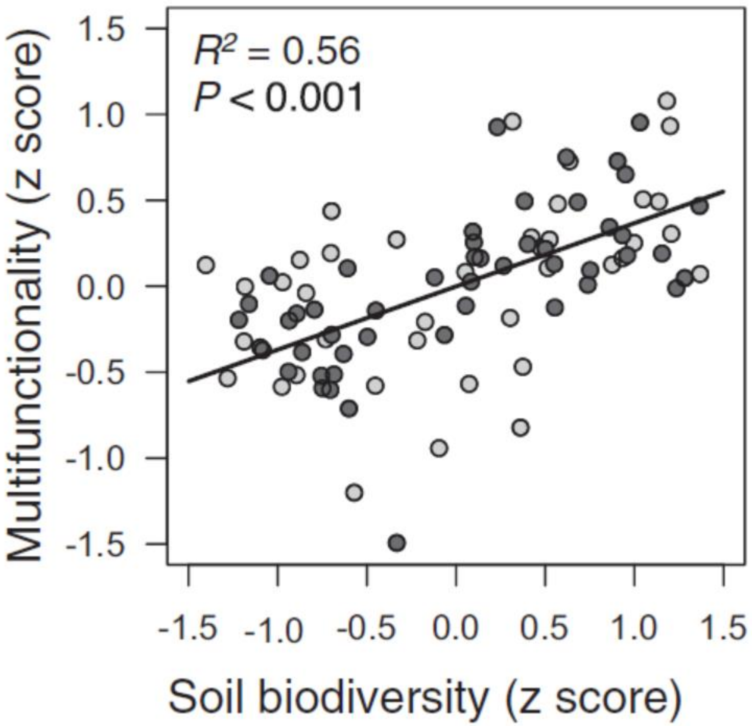
Relations between biodiversity and functioning

Expression of each function under changing environmental conditions



Courtesy of L. Philippot INRAE Dijon

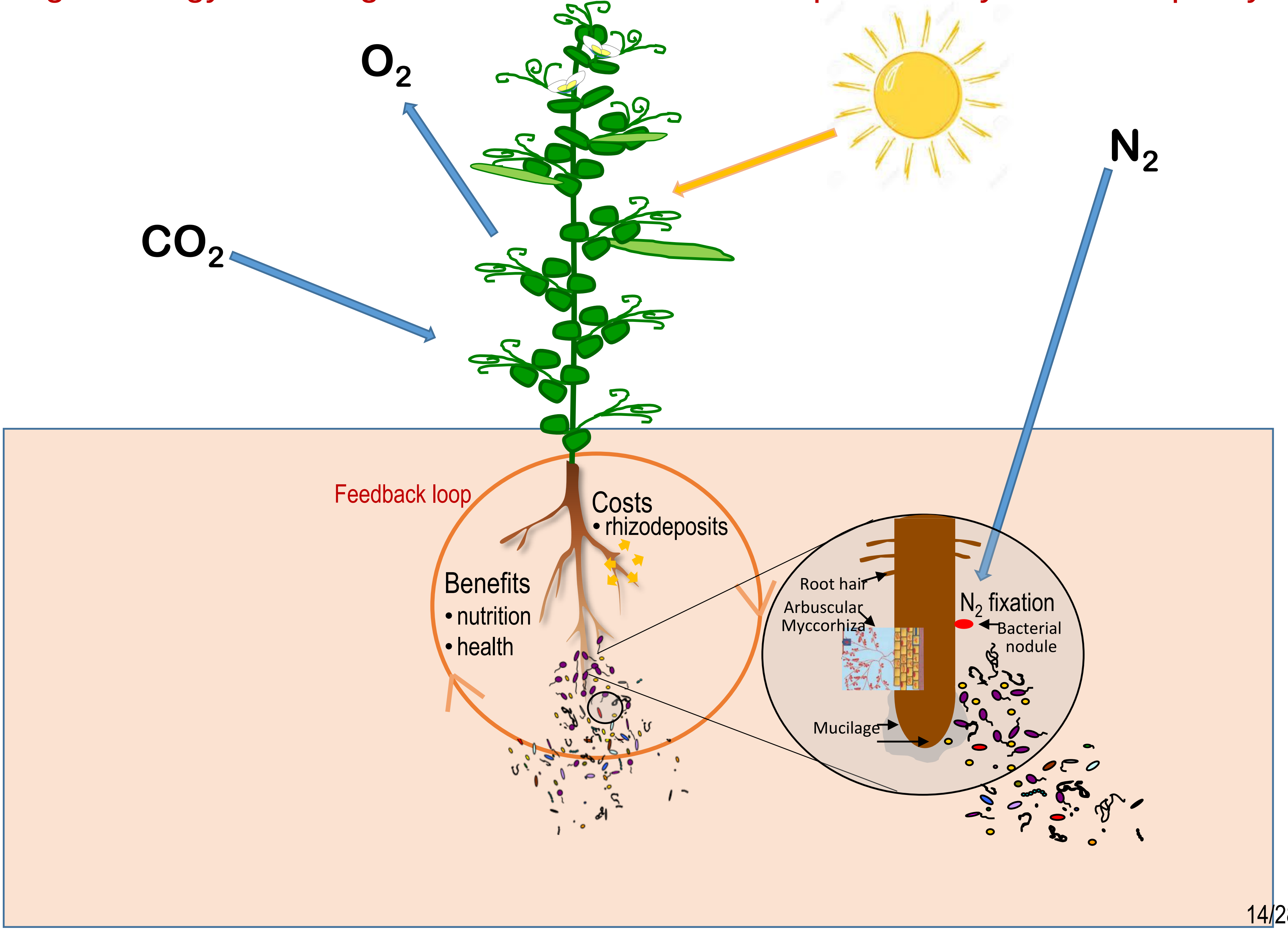
Expression of a range of functions



Wagg et al. 2014. PNAS 111:5266-5270

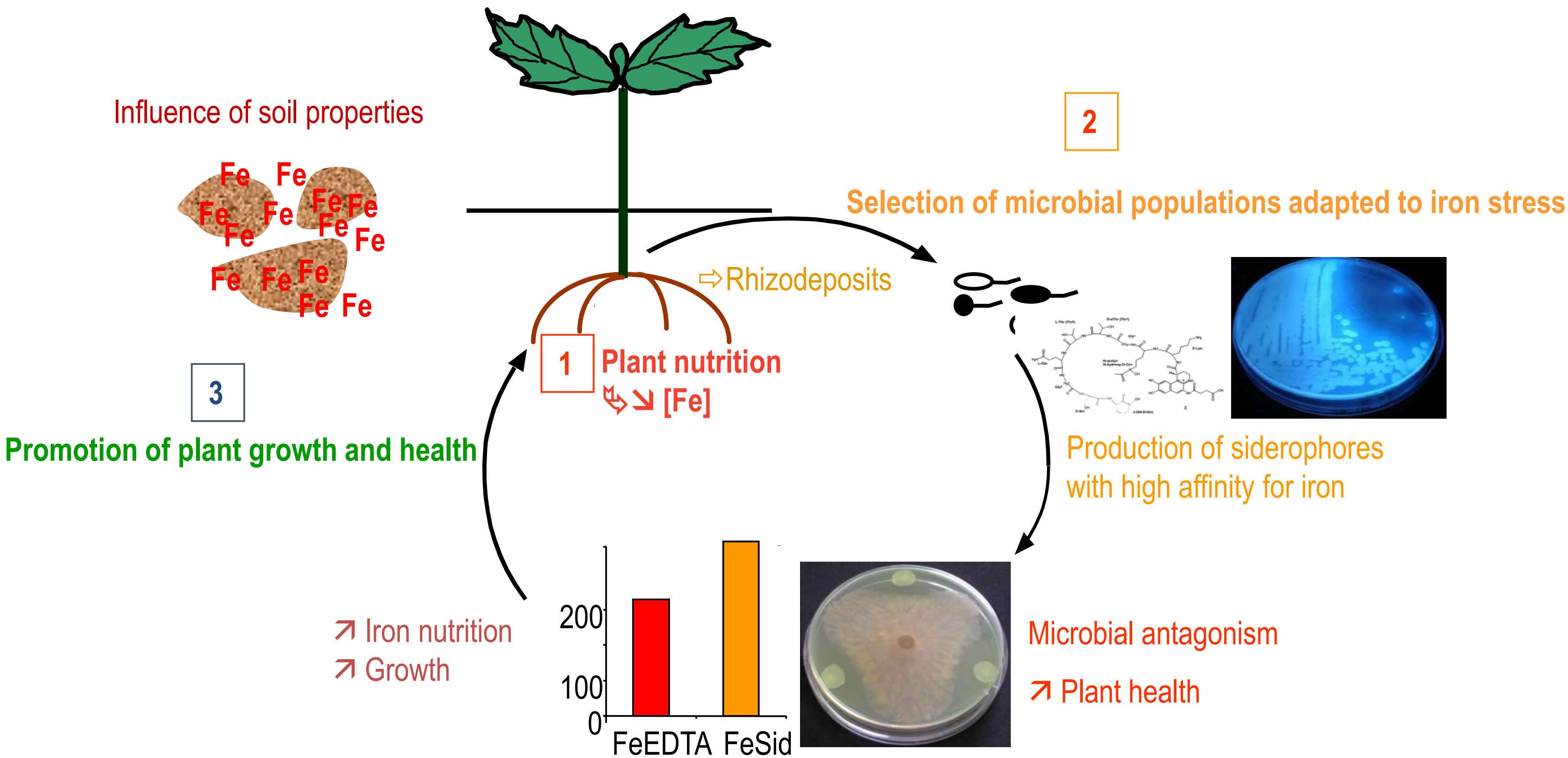
Agroecology can play an important role in building resilience and adapting to climate change. http://www.fao.org/agroecology/overview/eg/

Agroecology: Steering microbial communities for productivity and food quality



Agroecology: Steering microbial communities for productivity and food quality

Iron dynamics impact crop productivity and quality



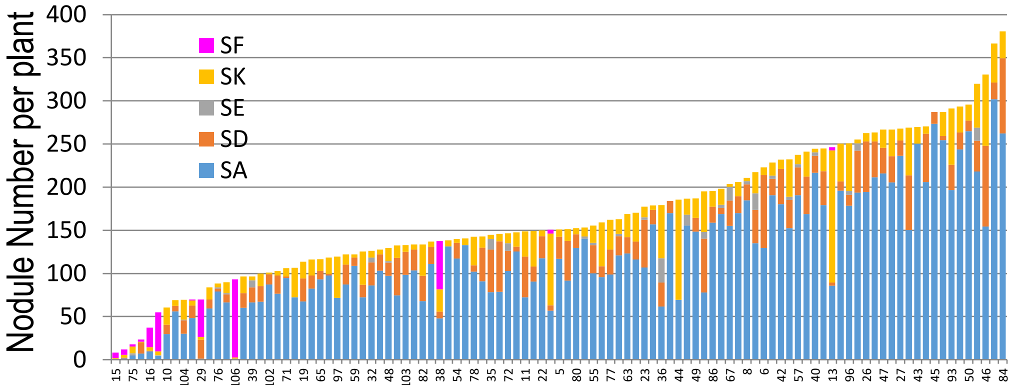
Courtesy of S. Mazurier, INRAE Dijon

Lemanceau et al. 2009. Adv. Bot. Res.

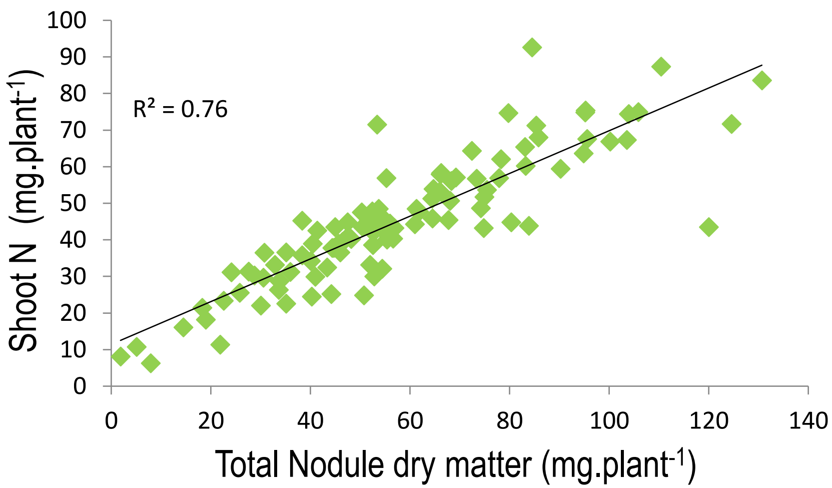
Agroecology: Steering microbial communities for productivity and food quality

Promoting nitrogen fixation

104 pea accessions inoculated with a mixture of 5 *Rhizobium* strains



High variability of the number of nodules and the composition of Rhizobia in nodules according to the pea accession



Bourion et al 2018. Front. Plant Sci.

SYMBIOPEA & GRaSP Projects
UMR Agroécologie Dijon
UMR LSTM Montpellier

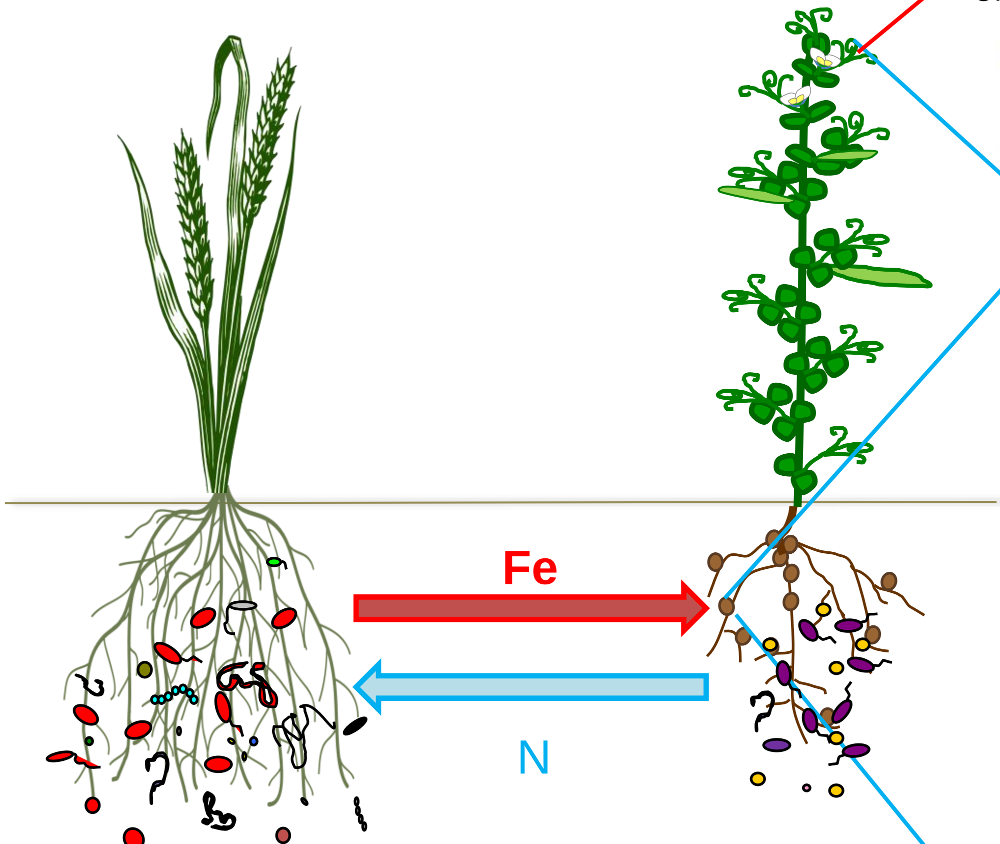
Courtesy of V. Bourion, INRAE Dijon

Agroecology: Steering microbial communities for productivity and food quality

Crop associations increase productivity and food quality

Graminaceous - Strategy II

Legume - Strategy I



Grain content in AA and Fe

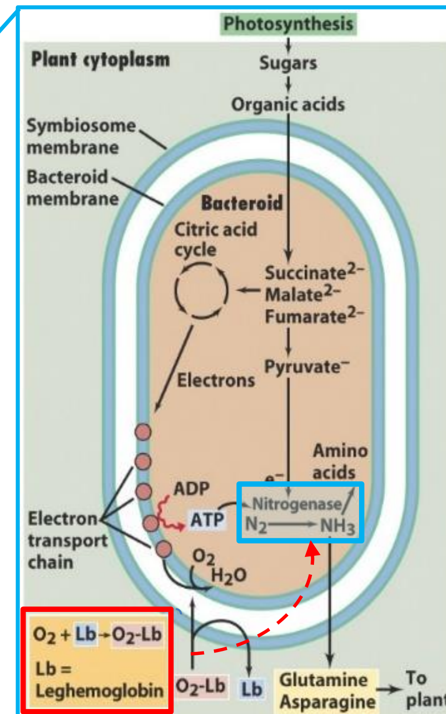
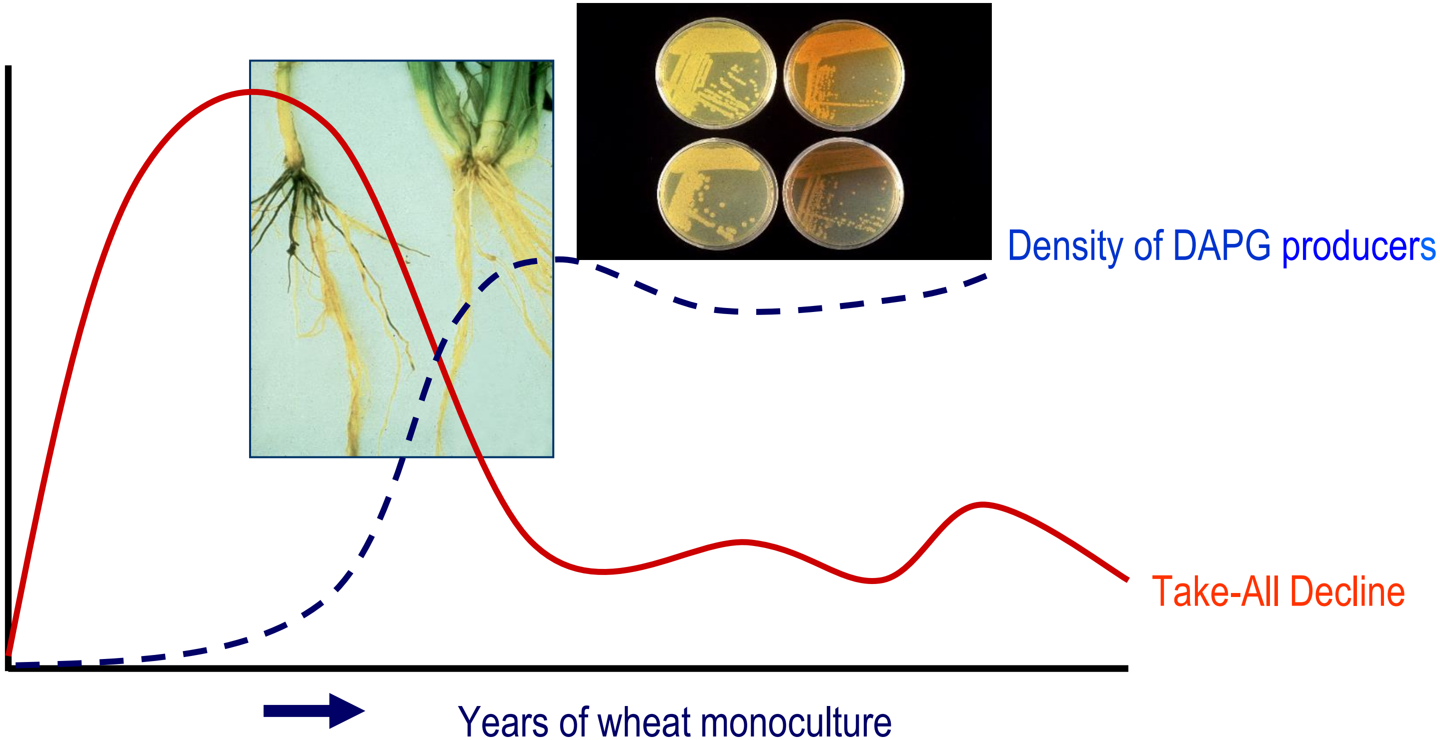


Figure 19-67 Brock Biology of Microorganisms 11/e
© 2006 Pearson Prentice Hall, Inc.

Courtesy of B. Pivato, INRAE Dijon

Agroecology: Steering microbial communities for productivity and food quality

Pathogen regulation

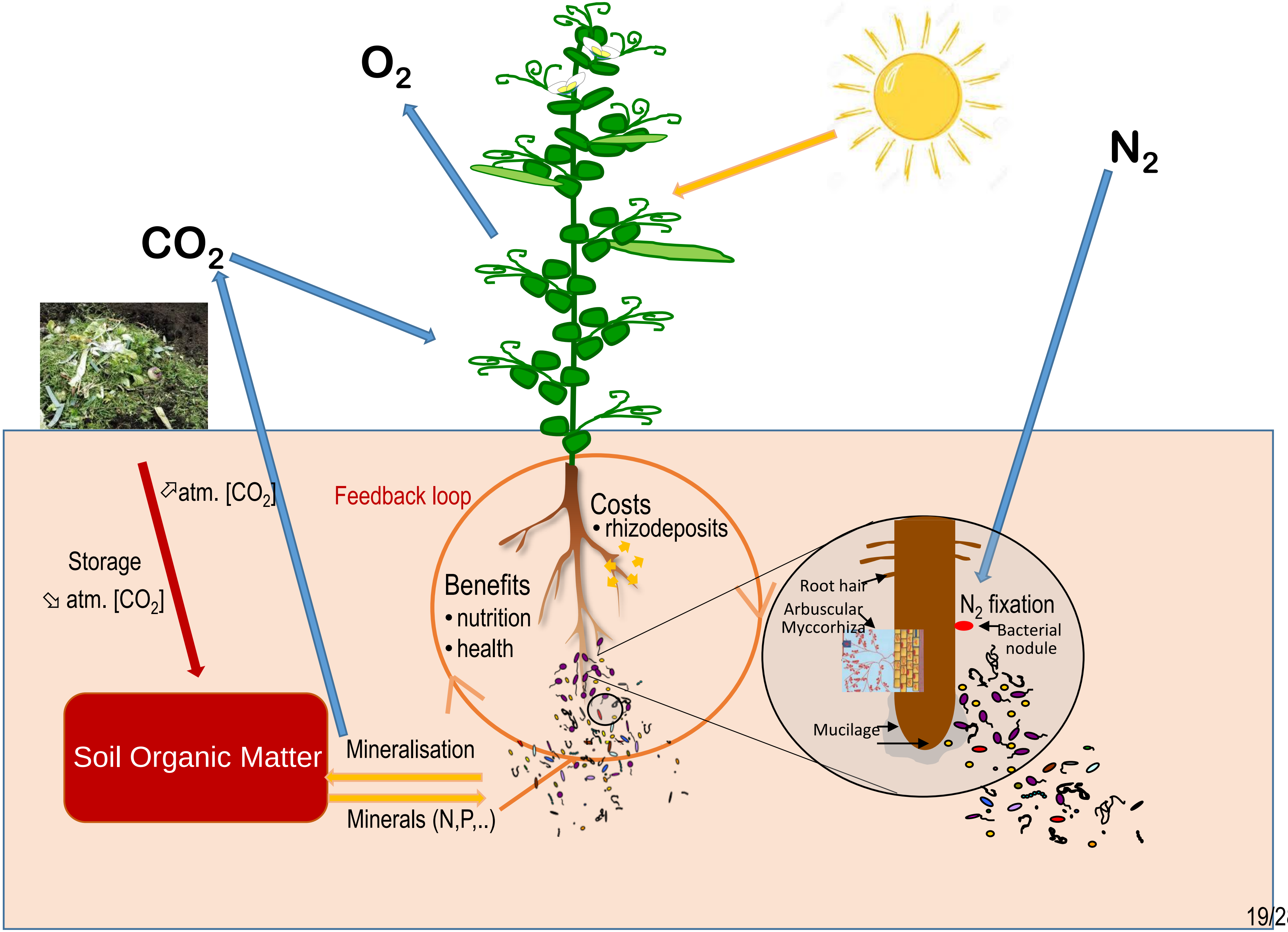


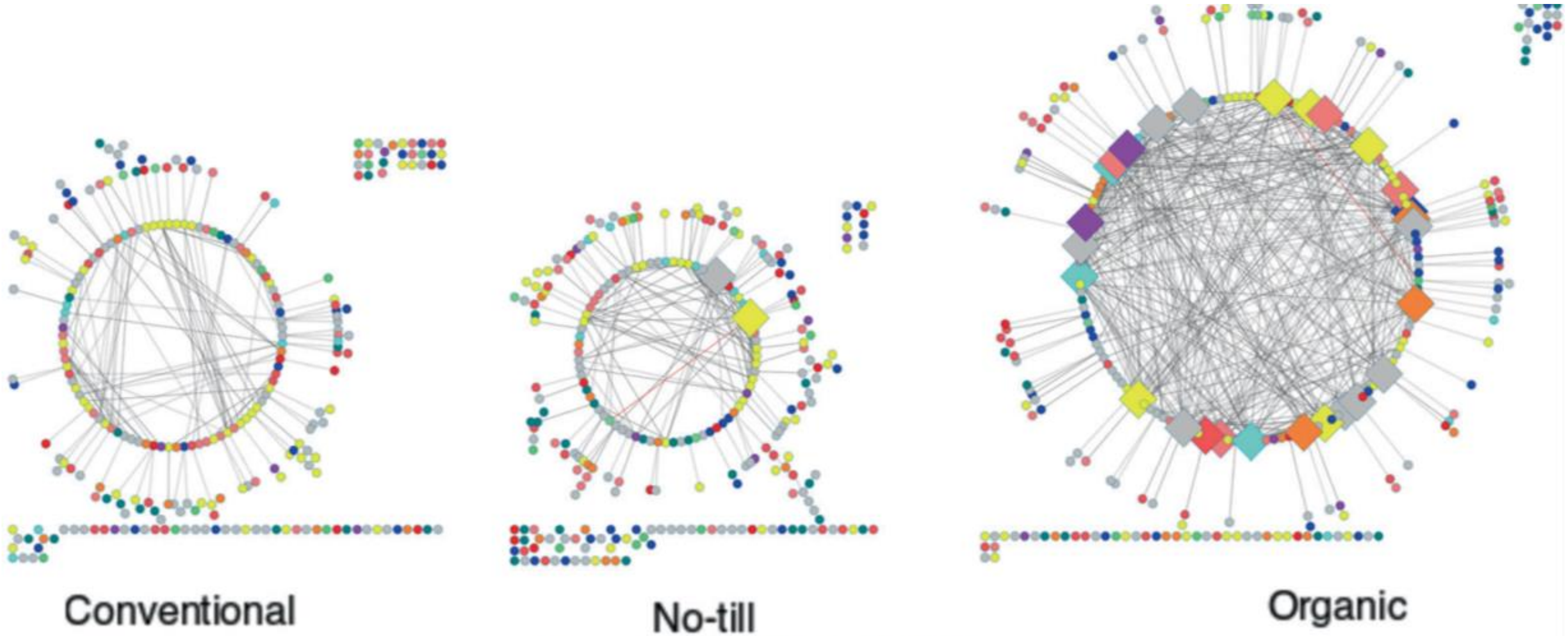
Recruitment by wheat roots infected by *Gaeumannomyces graminis* var. *tritici* of antibiotic producers leading to take-all decline in all soils tested.

Mendes et al. 2011. Science 332:1097-1100

Courtesy of J. Raaijmakers, NIOO Wageningen

Agroecology: Steering microbial communities for climate regulation

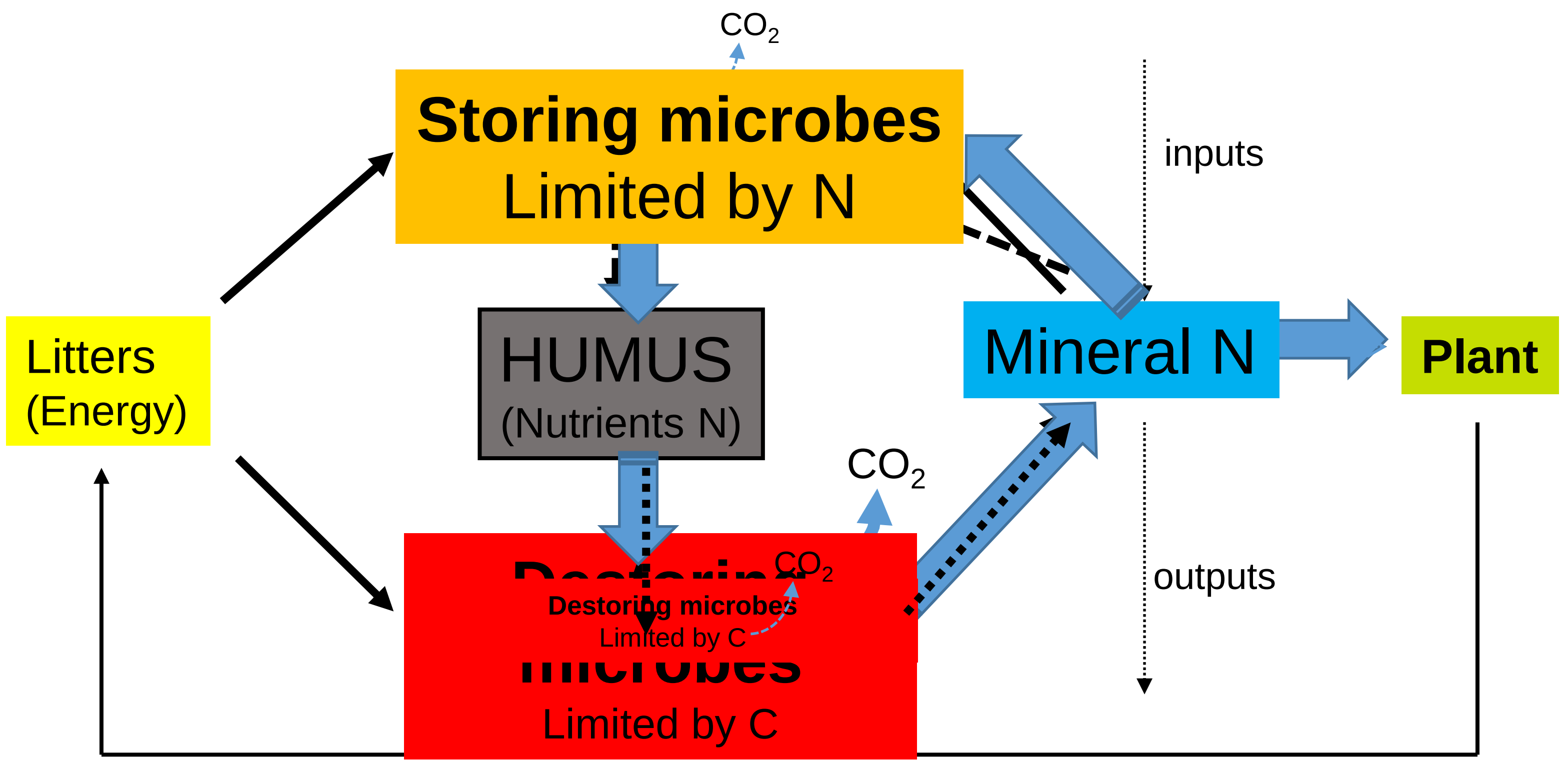




Banerjee et al. 2019. ISME J

Agroecology: Steering microbial communities for climate regulation

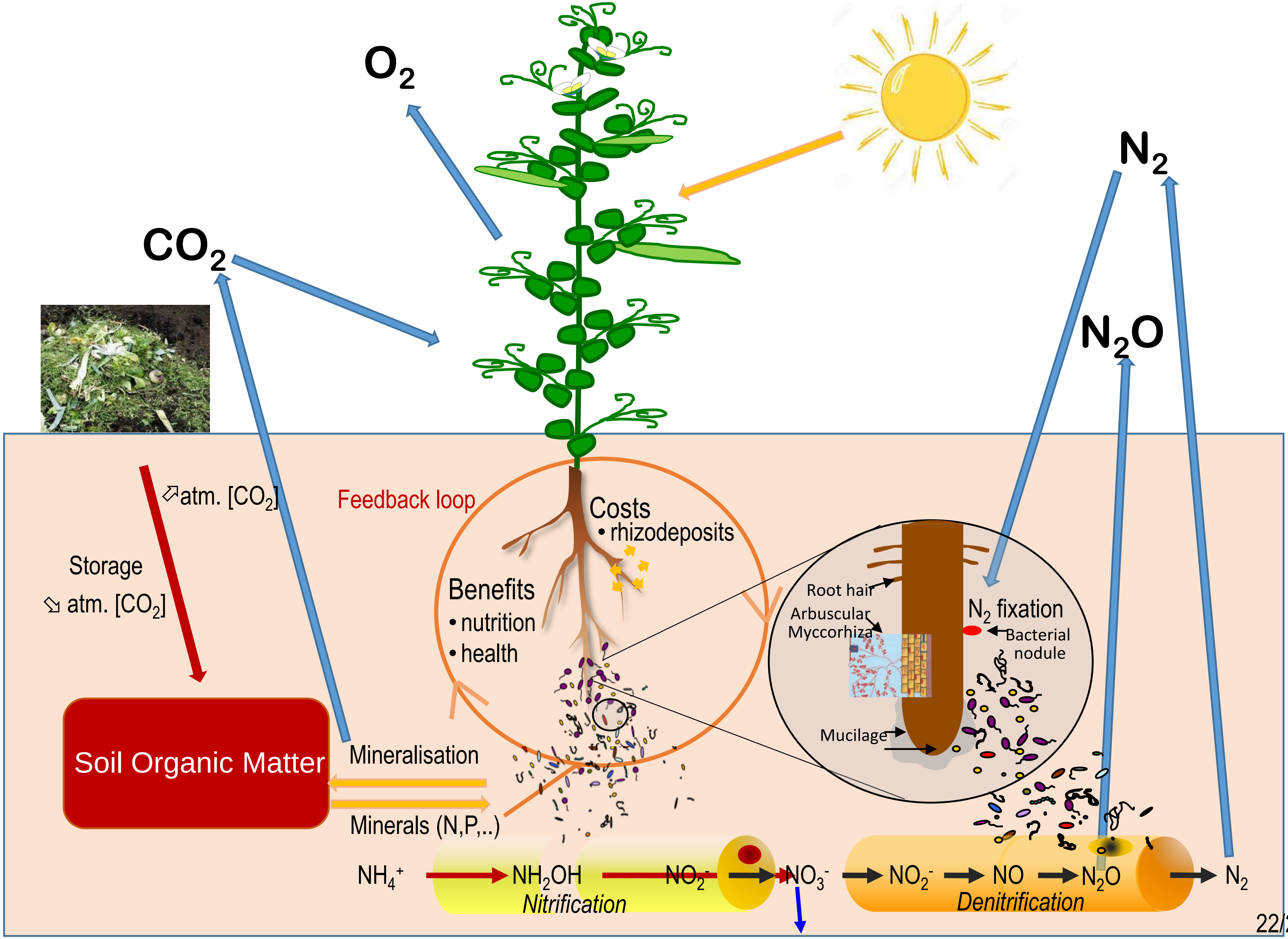
Tune SOM mineralization to plant nutrition to maximizing plant nutrition & soil C sequestration

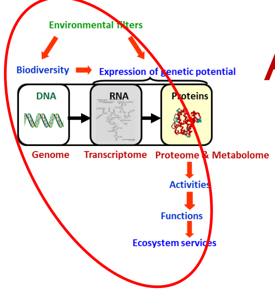


Perveen et al. 2014. Glob. Change Biol.

Courtesy of S. Fontaine, INRAE Clermont-Ferrand

Agroecology: Steering microbial communities for climate mitigation

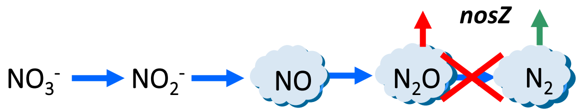




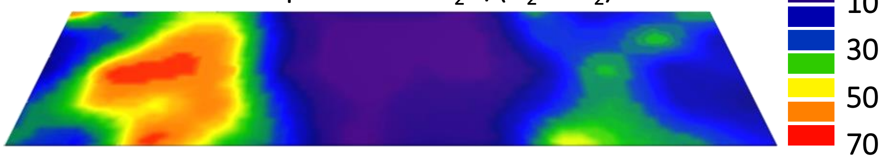
Agroecology: Steering microbial communities for climate mitigation

Nitrogen cycle – Denitrification

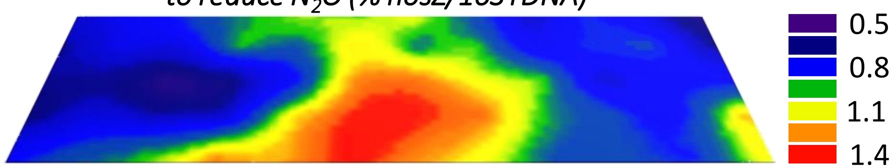
Spatial distribution of the denitrifiers



Denitrification end products % $N_2O/(N_2O+N_2)$



Proportion of bacteria genetically capable to reduce N_2O (% nosZ/16S rDNA)



Negative correlation between the % of bacteria capable to reduce N_2O and the $N_2O/(N_2O+N_2)$

Philippot et al. 2009. Environ. Microbiol.

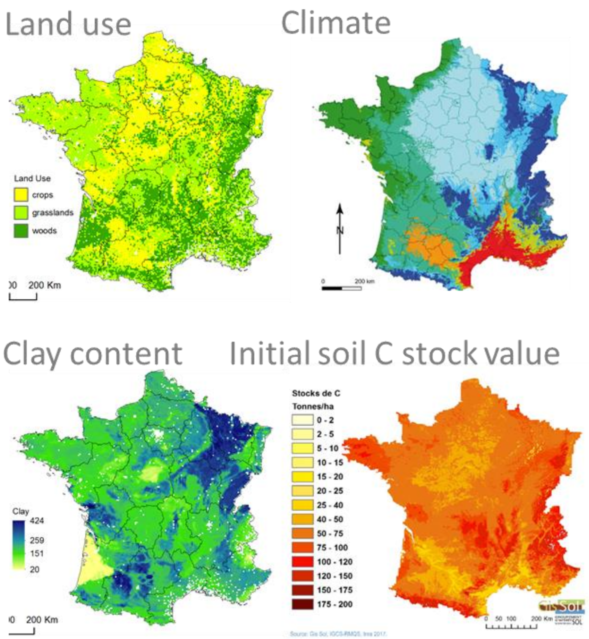
Courtesy of L. Philippot INRAE Dijon

Multiperformance of agroecology in practice

An annual growth rate of 0.4% in the soil carbon stocks, or 4‰ per year, in the first 30-40 cm of soil, would significantly reduce the CO_2 concentration in the atmosphere related to human activities.
https://www.4p1000.org/

Potential for additional carbon storage in arable cropping systems

Assessed by a modelling approach at a fine spatial-scale resolution (≈1 km2)



	Additional C storage 0-30 cm soil layer	Potential applicability	Potential additional C storage at the national level 0-30 cm soil layer	Relative yearly increase of soil C stocks
	Kg C/ha/an	Mha	Mt C/year	‰ /year
Arable cropping systems				
Expansion of cover crops	**+126**	**16.03**	**+2.019**	
No tillage	**+60**	**11.29**	**+0.677**	
New carbon inputs	**+61**	**4.21**	**+0.257**	
Expansion of temporary grasslands	**+114**	**6.63**	**+0.756**	
Agroforestry	**+207**	**5.33**	**+1.102**	
Hedges	**+17**	**8.83**	**+0.150**	
Total for croplands			**+4.960**	**+5.2 ‰**

Courtesy of S. Pellerin, INRAE Bordeaux

Multiperformance of agroecology in practice

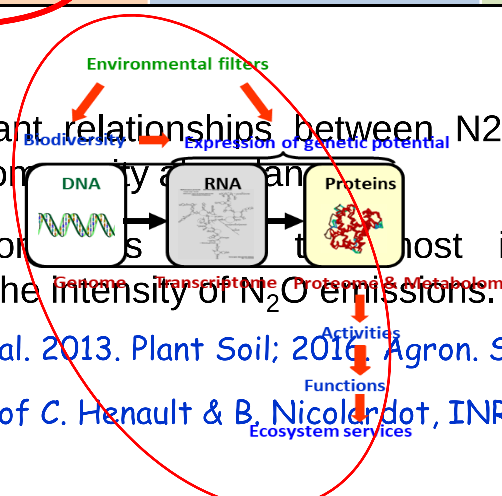
Effect of integrated weed management in cropping systems on N2O emissions from soils

Crop system	S1	S2	S3	S5
Type of system	Reference	IWM	IWM	IWM
Specific agricultural practices	Conventional	Minimum tillage Plowing, harrowing, mechanical weeding excluded	Mechanical weeding excluded Tillage allowed when necessary	Mechanical weeding and plowing allowed
Treatment frequency index	2,4	2,0	1,4	0
Plowing frequency	1 / year	-	0.4 / year	0.5 / year
Crop Rotation	Wheat/barley/rape	diversified	diversified	diversified
Cumul (g $N\text{-}N_2O\ ha^{-1}$)	326 ± 168^c	5226 ± 670^a	177 ± 172^c	777 ± 177^b


Long Term Experiment Bretenières, UE INRAE

No significant relationships between N2O emissions and microbial com[…]ty a[…]an[…]

↳ Soil co[…]s […] t[…]most important factors controlling the intensity of N_2O emissions.

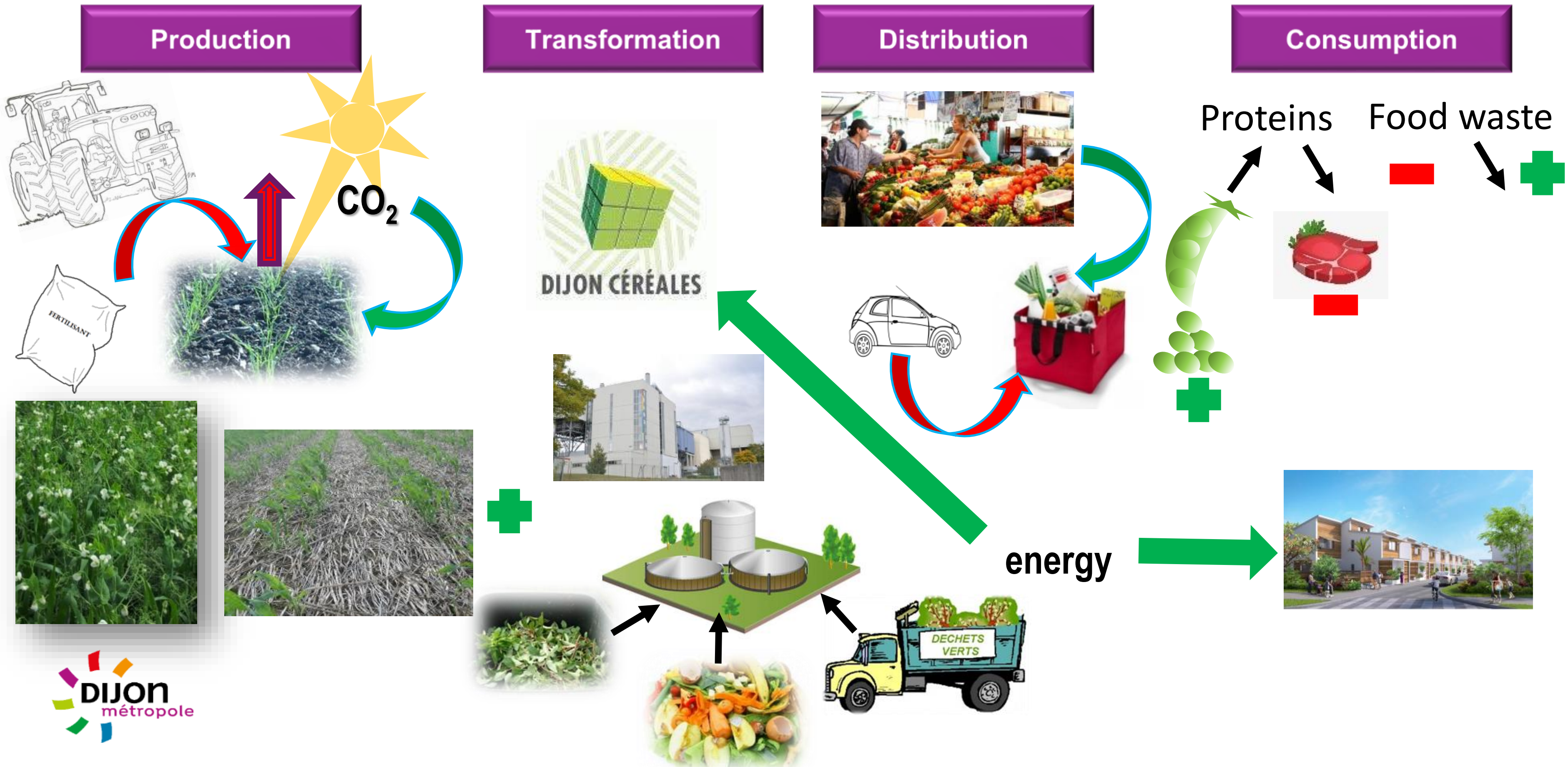


Vermue et al. 2013. Plant Soil; 2016. Agron. Sustain. Dev

Courtesy of C. Henault & B. Nicolardot, INRAE, AgroSup, Dijon

Territorial Initiative: Dijon Sustainable Agri-Food 2030

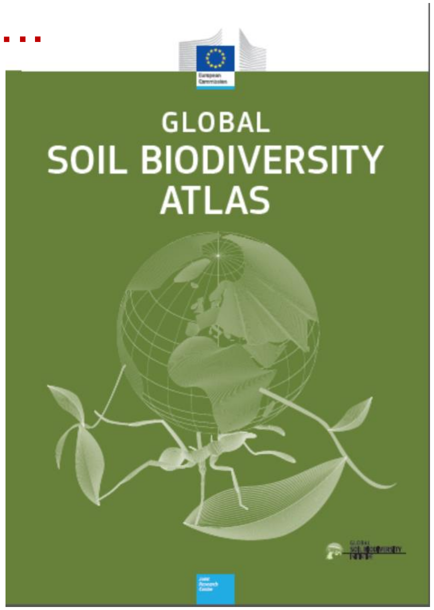
Linking farmers, food process-distribution, and end-users to promote local agroecology, transformation, distribution and consumption for a better food and environment quality, and a stronger social cohesion



For further information…..

GLOBAL SOIL PARTNERSHIP

Convention on Biological Diversity



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Science and Policy
for People and Nature

Global Initiative
Crop Microbiome and Sustainable Agriculture

https://www.globalsustainableagriculture.org/