

The perspective of science(s) on sustainable wheat farming

PR PIERRE DELAPLACE

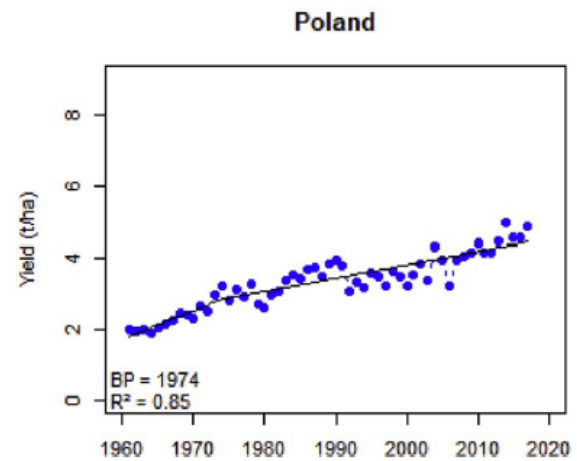
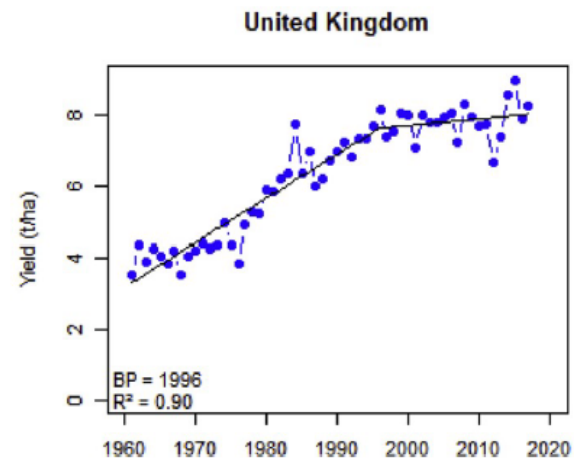
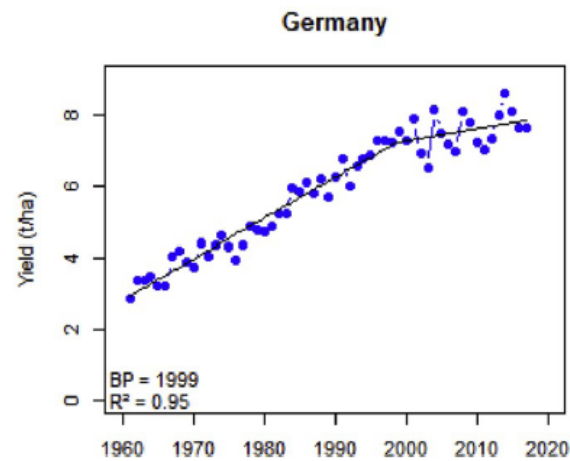
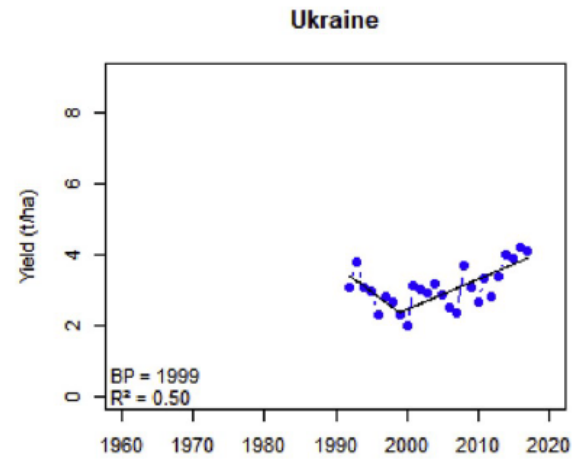
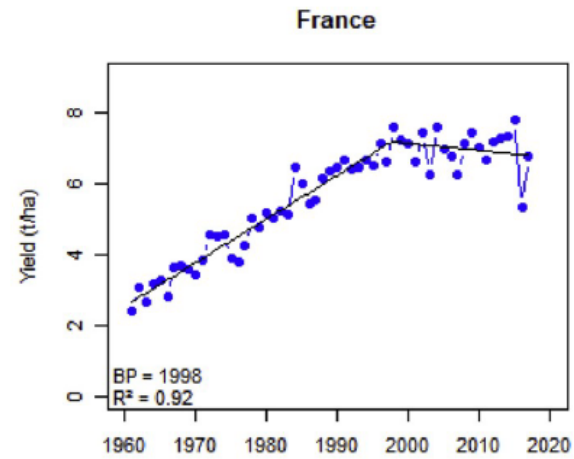
University of Liège – Gembloux Agro-Bio Tech - Belgium

Sustainable Wheat Initiative Europe – June 5th 2025

Setting the scene

Why should we aim for low carbon (equivalent)-emitting farming practices?

Wheat yields in Europe reached a plateau since the mid-1990s



This trend can be explained by several conflicting factors.

Positive effects of breeding

vs

Negative effects due either to the evolution of agricultural practices or climate change

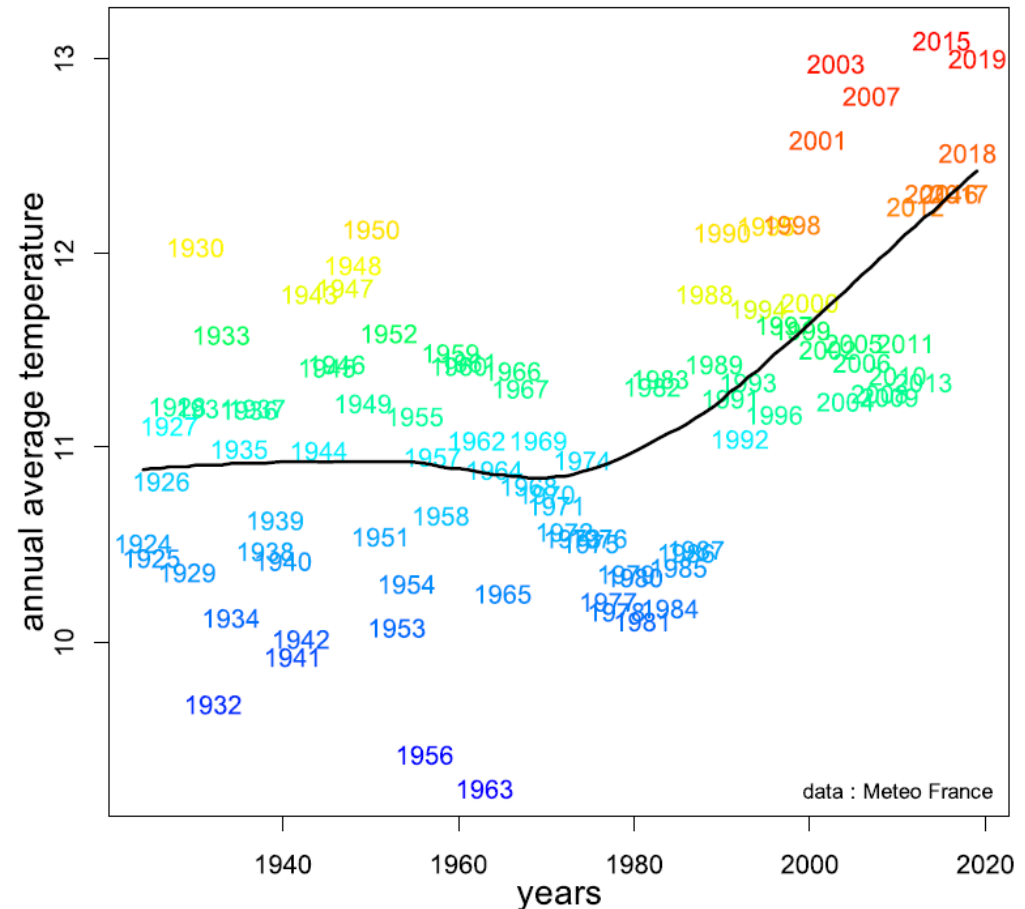
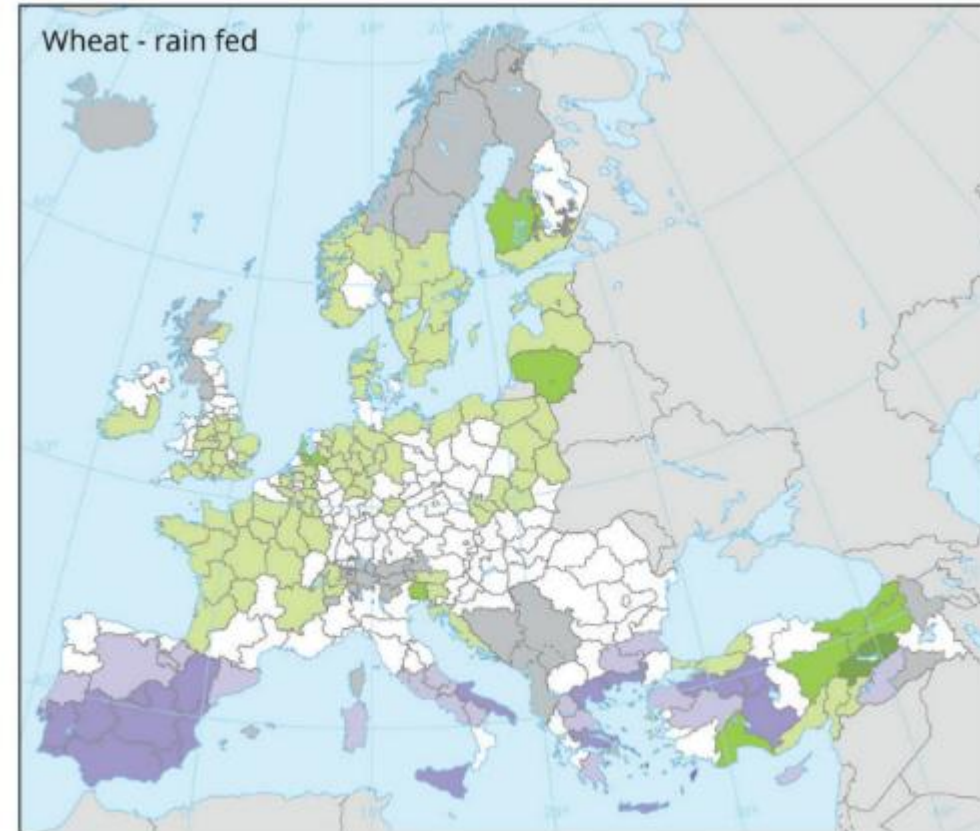
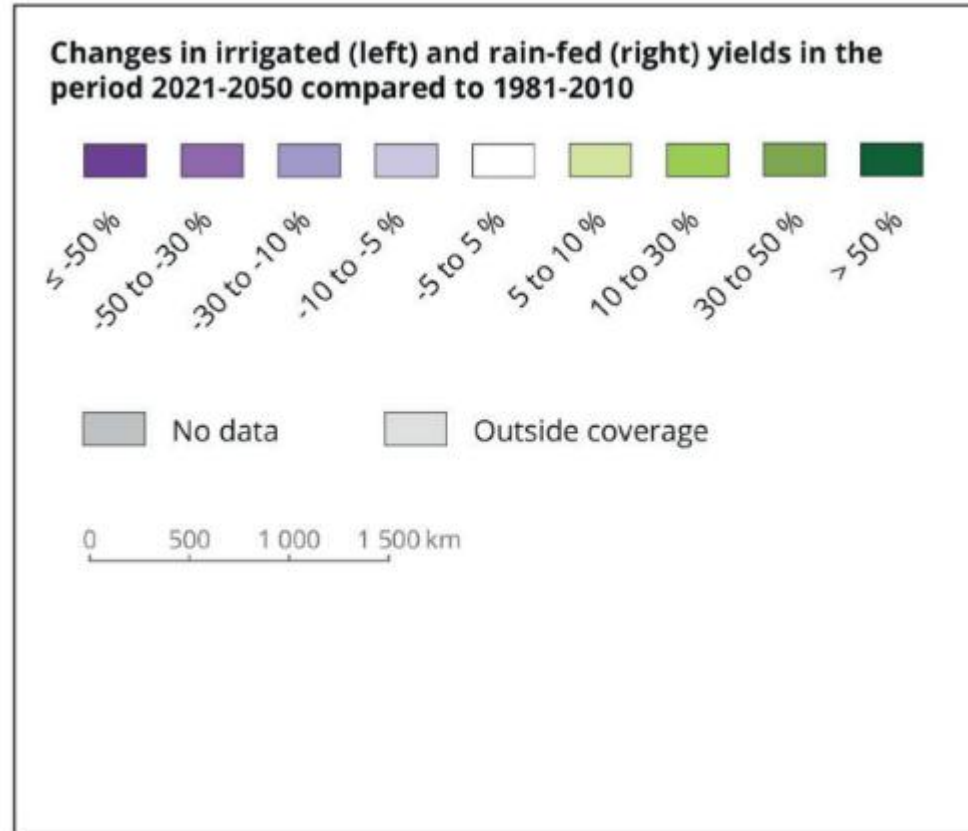


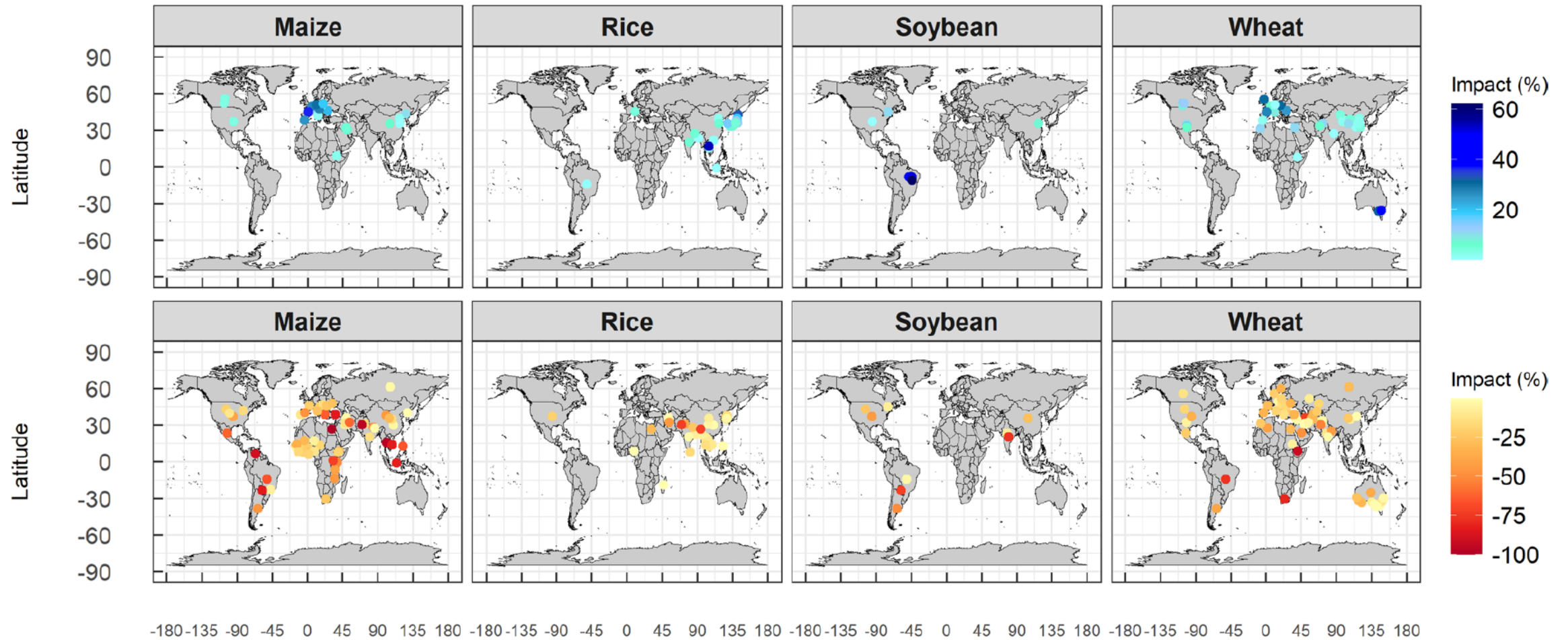
Fig. 3. Evolution of the annual average temperature (°C) from 1924 to 2019 at Clermont-Ferrand, France.

Wheat yields using RCP8.5 scenario for the first half of the XXI century - Europe -



Wheat yields using RCP8.5 scenario for the first half of the XXI century

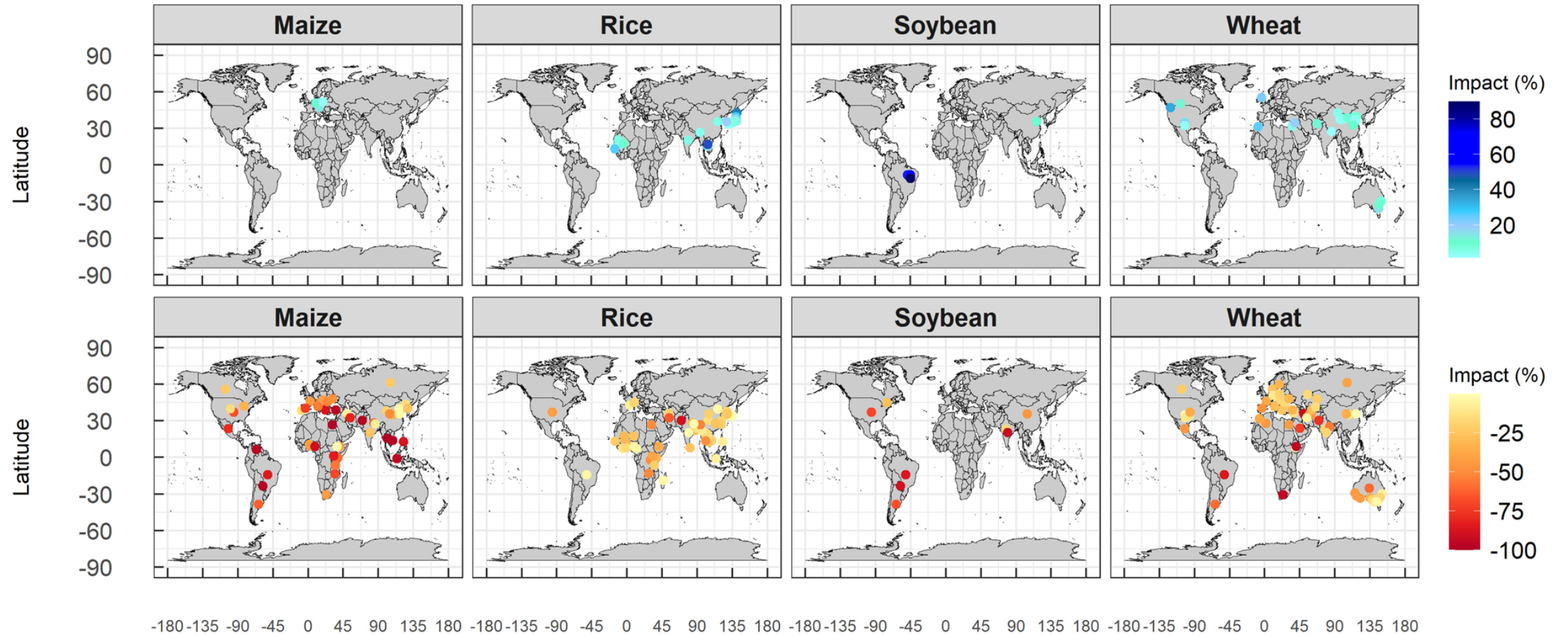
(a) RCP8.5 Mid-Century



Wheat yields using RCP8.5 scenario for the **second** half of the XXI century

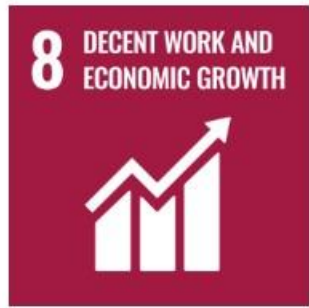
Longitude

(b) RCP8.5 End-Century

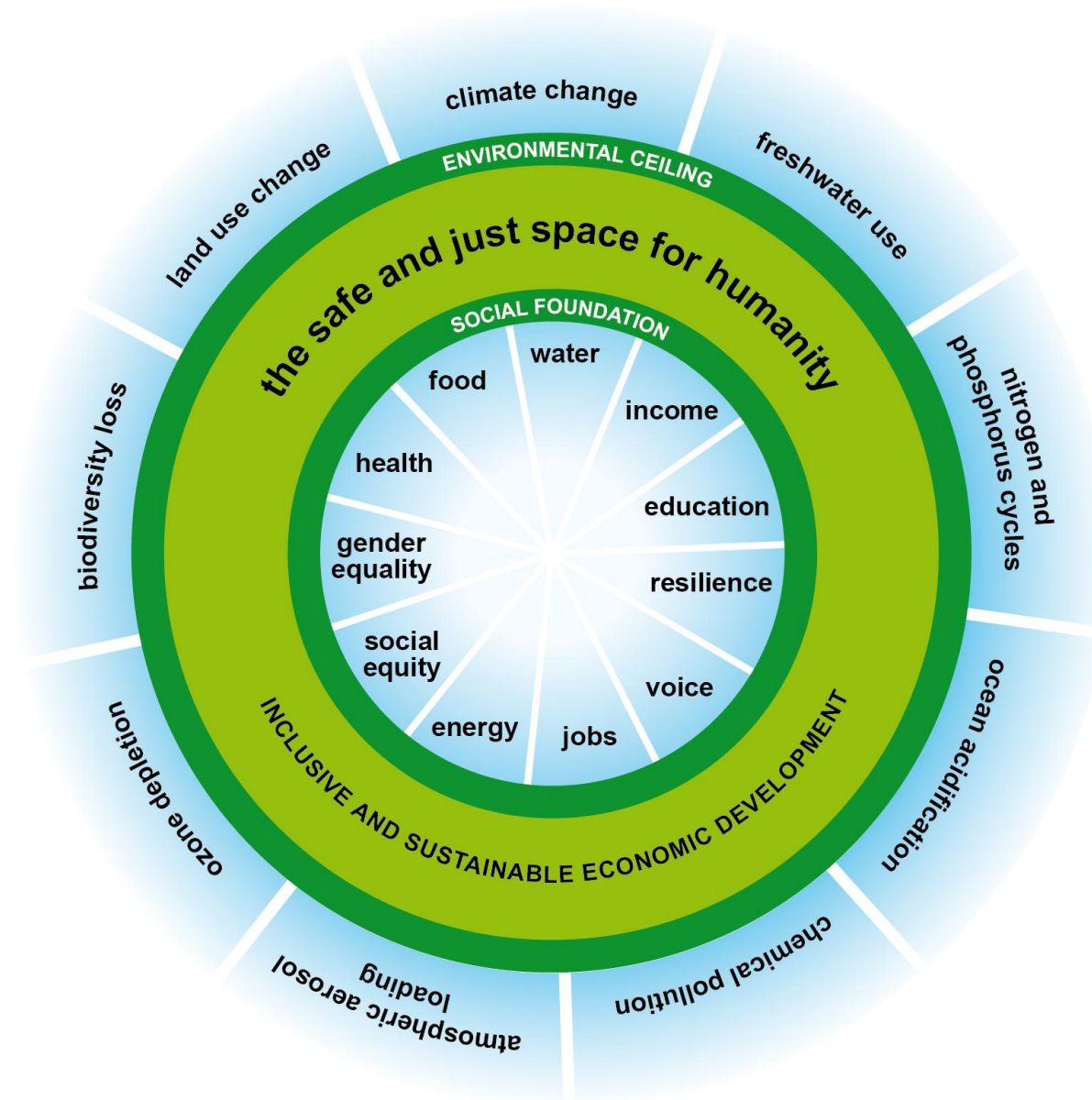


Setting the scene

The UN Sustainable Development Goals (SDGs)



Social foundation vs Environmental ceiling



SDGs (directly) related to the wheat agrosystem management

2

End hunger, achieve food security and improved nutrition and promote sustainable agriculture

6

Ensure availability and sustainable management of water and sanitation for all

12

Ensure sustainable consumption and production patterns

13

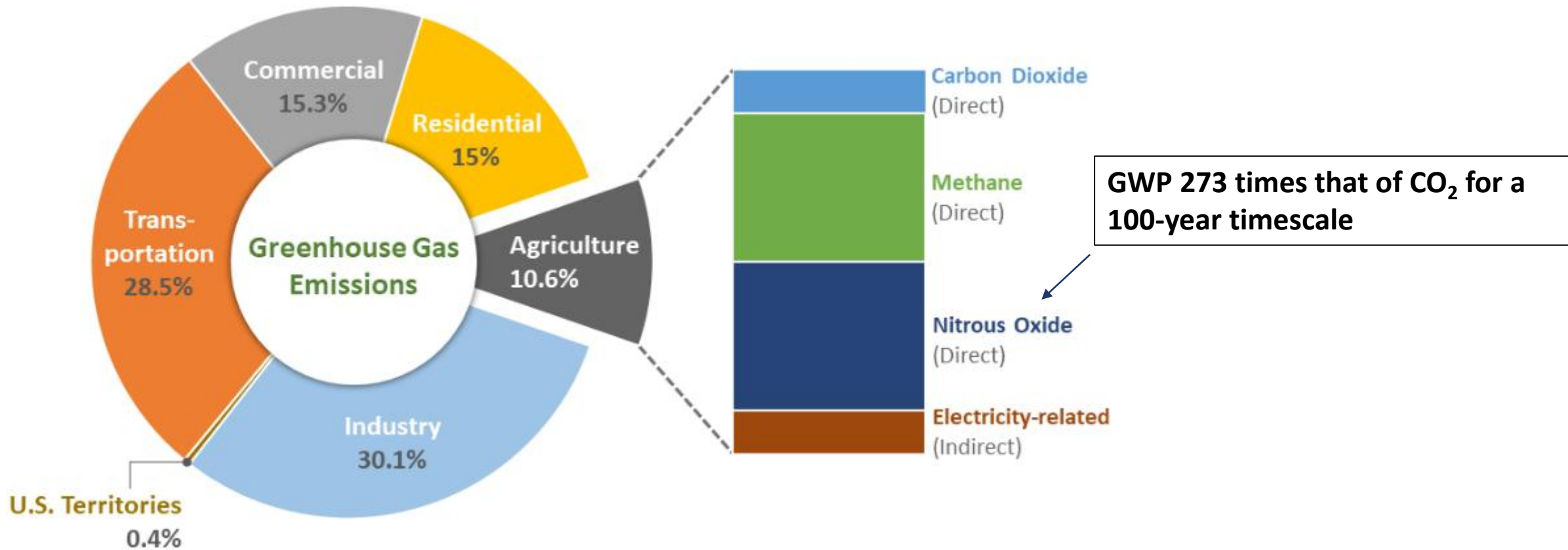
Take urgent action to combat climate change and its impacts

15

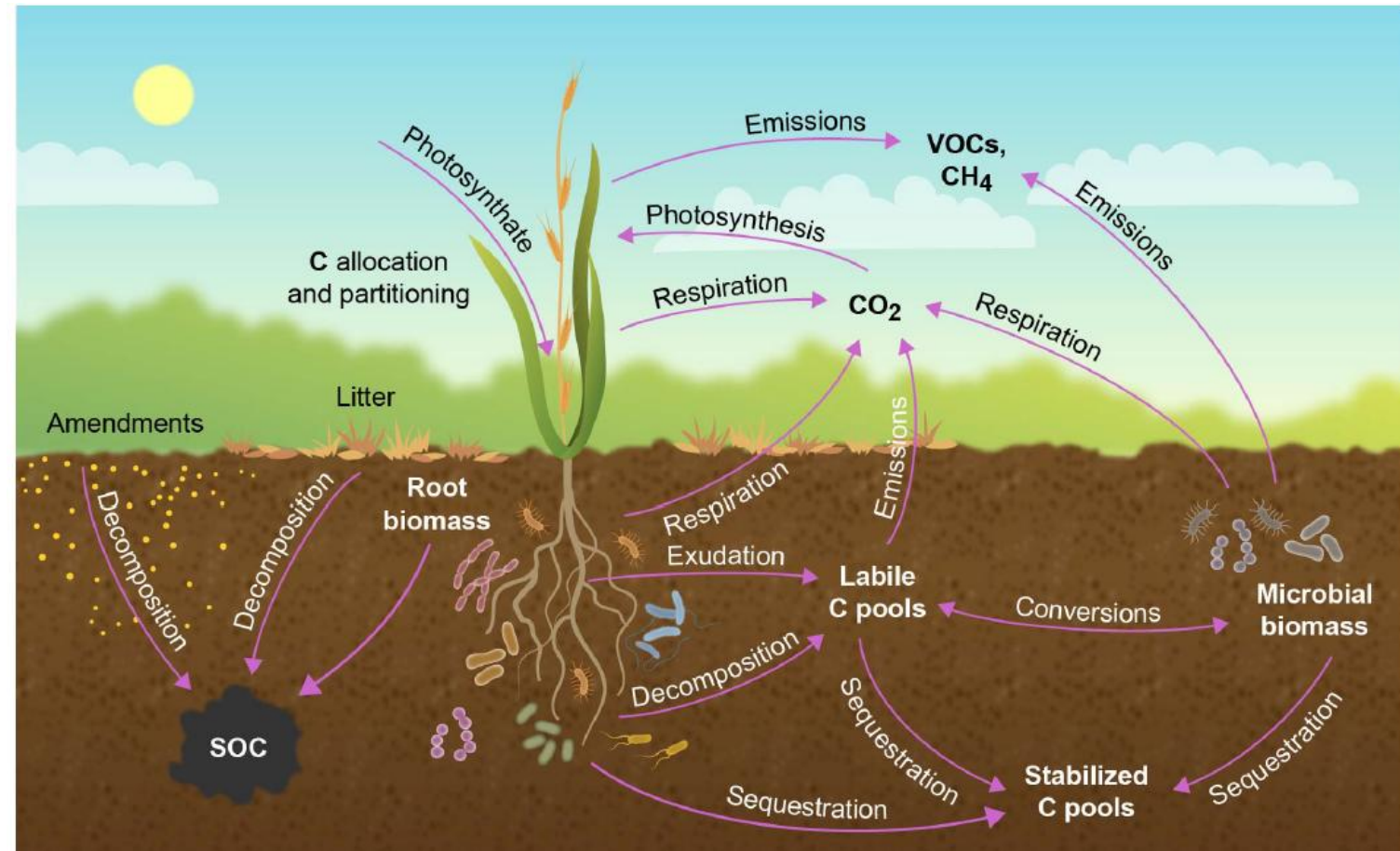
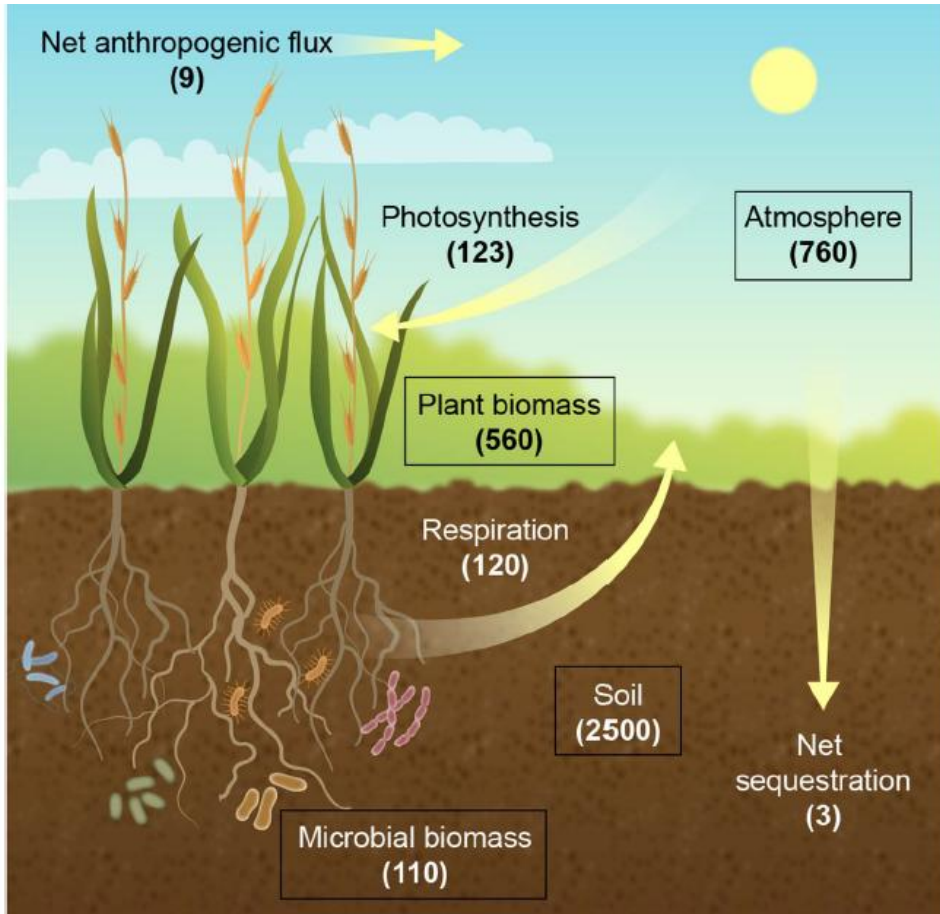
Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Setting the scene

C and N-cycling in agrosystems

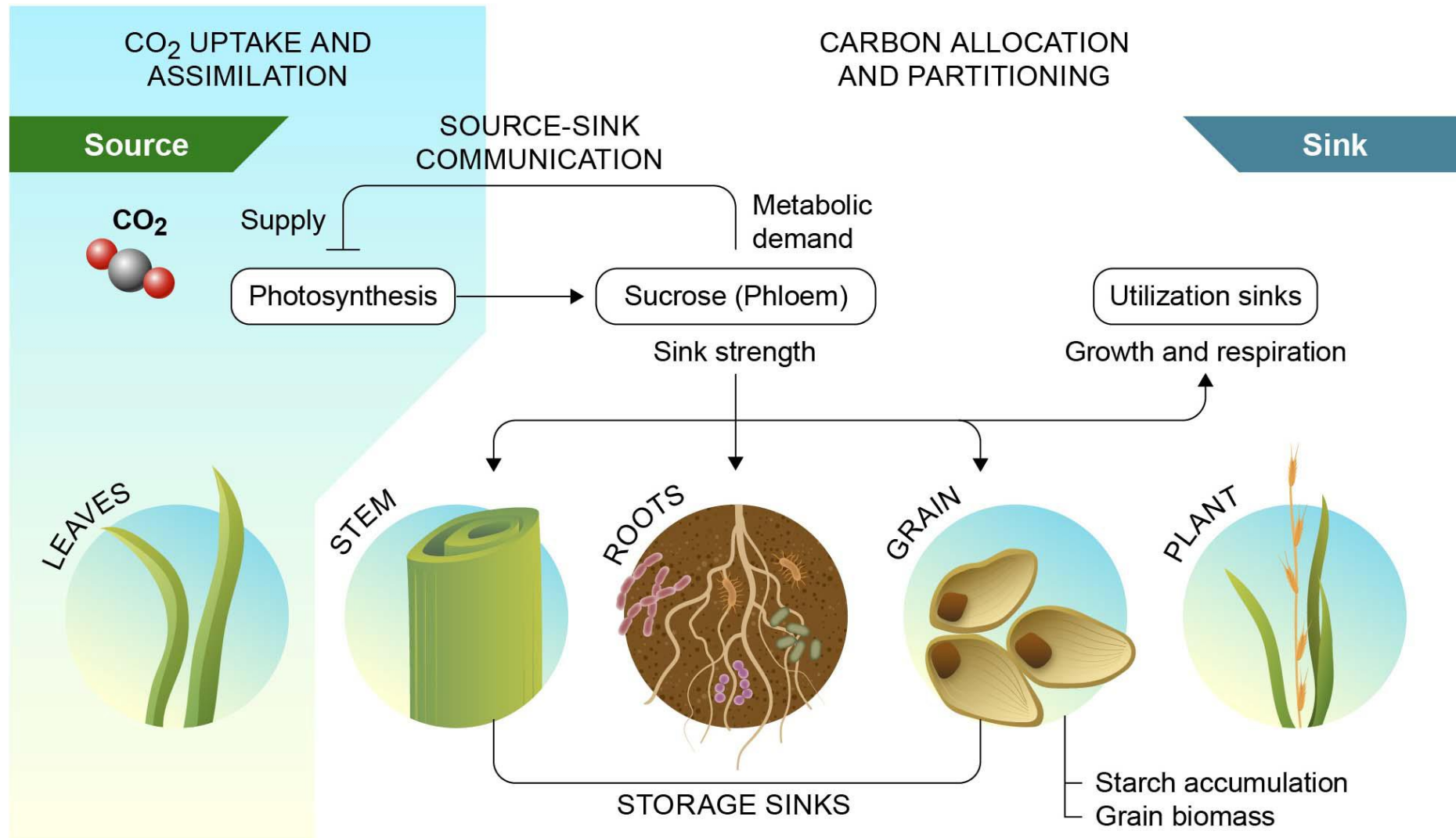


“Agriculture is the ONE sector that has the ability to transform from a net emitter of CO₂ to a net sequesterer of CO₂ —there is no other human managed realm with this potential”

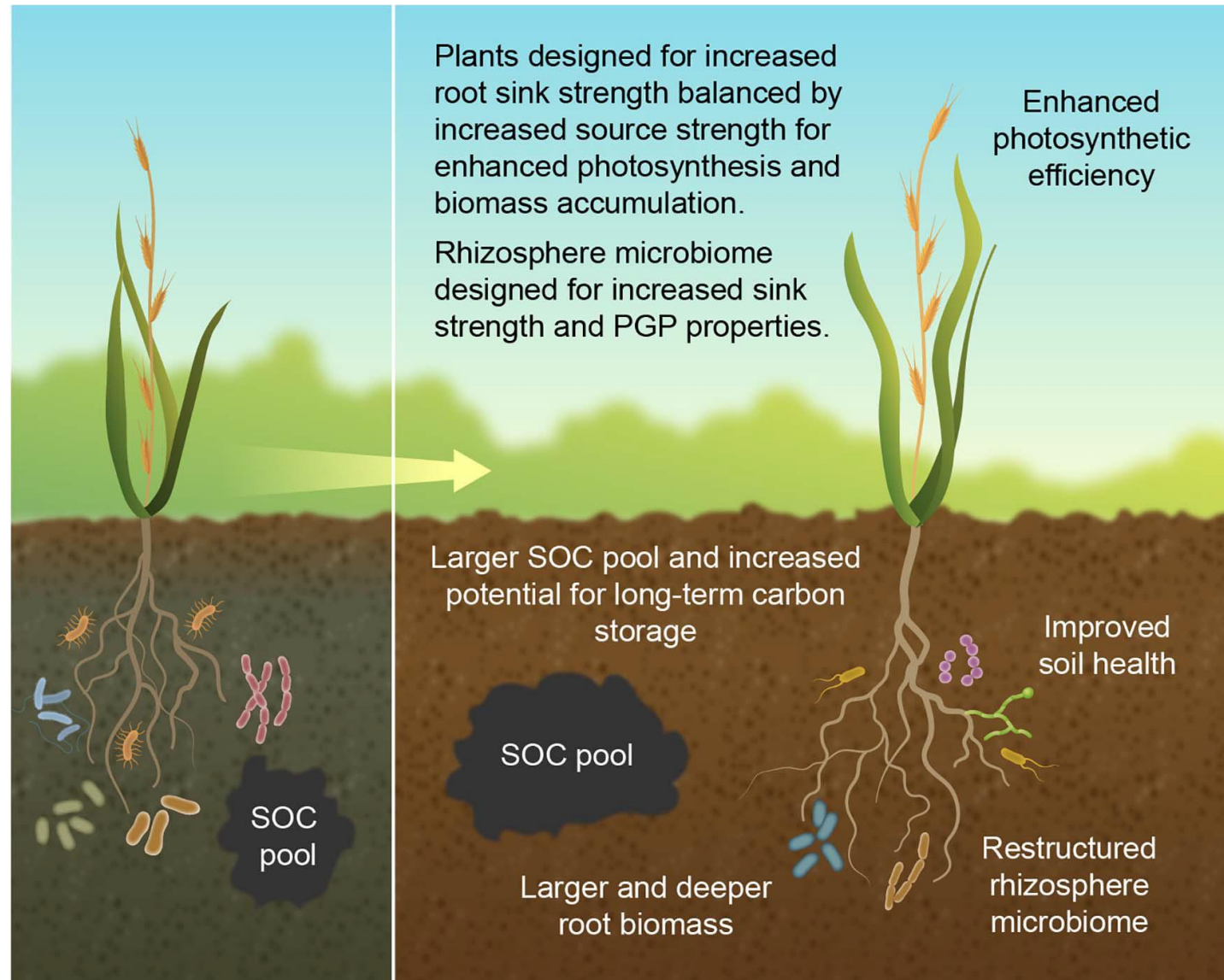


Rhizosphere: region of soil directly formed and influenced by roots and associated microorganisms that are part of the plant microbiota.

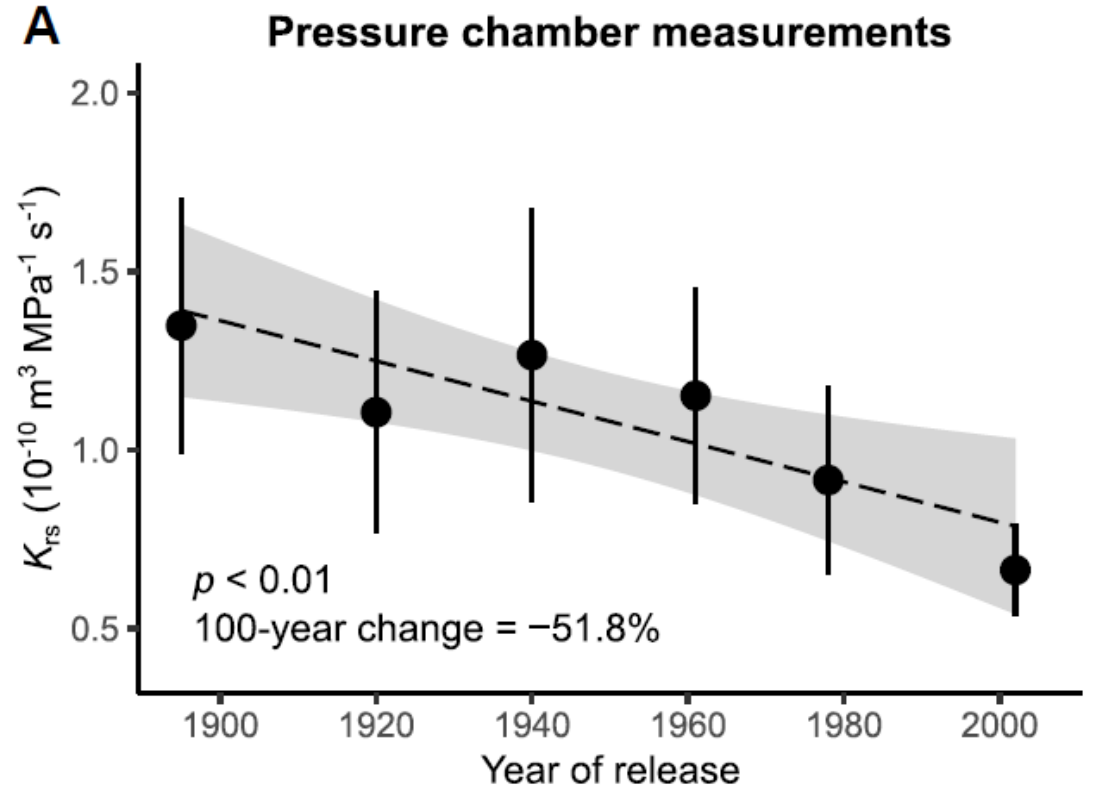
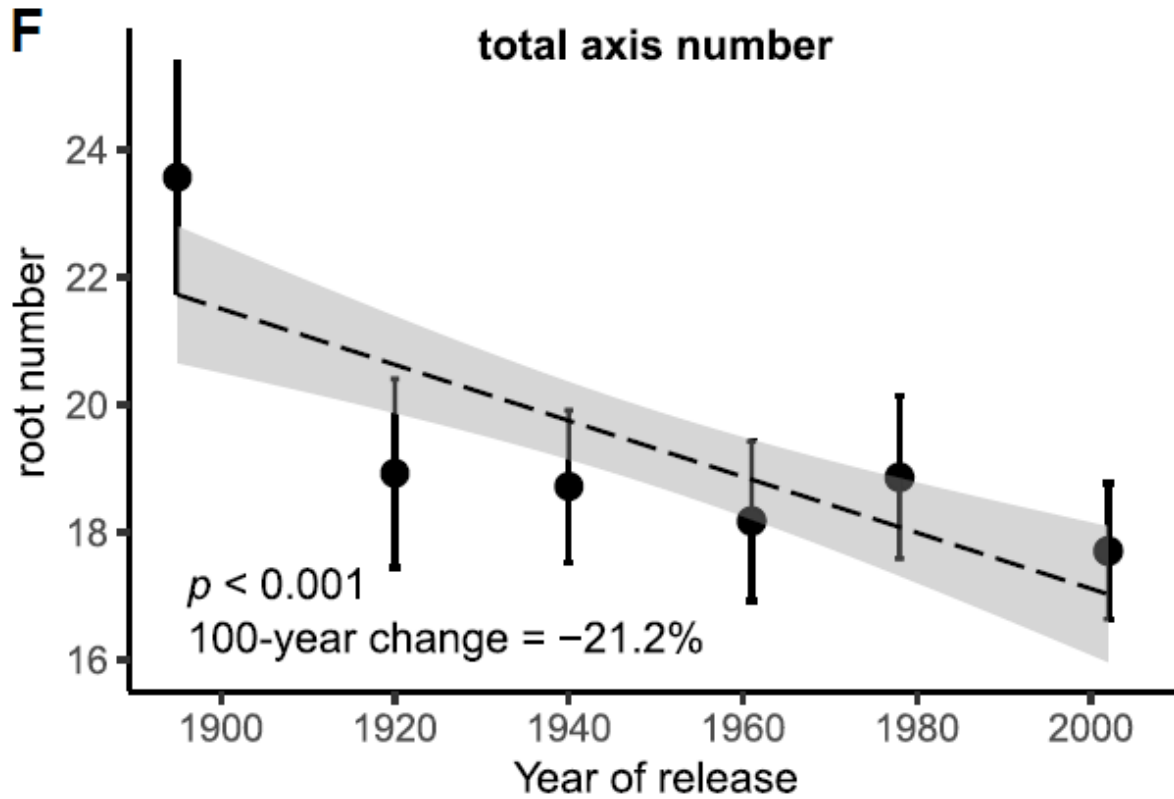
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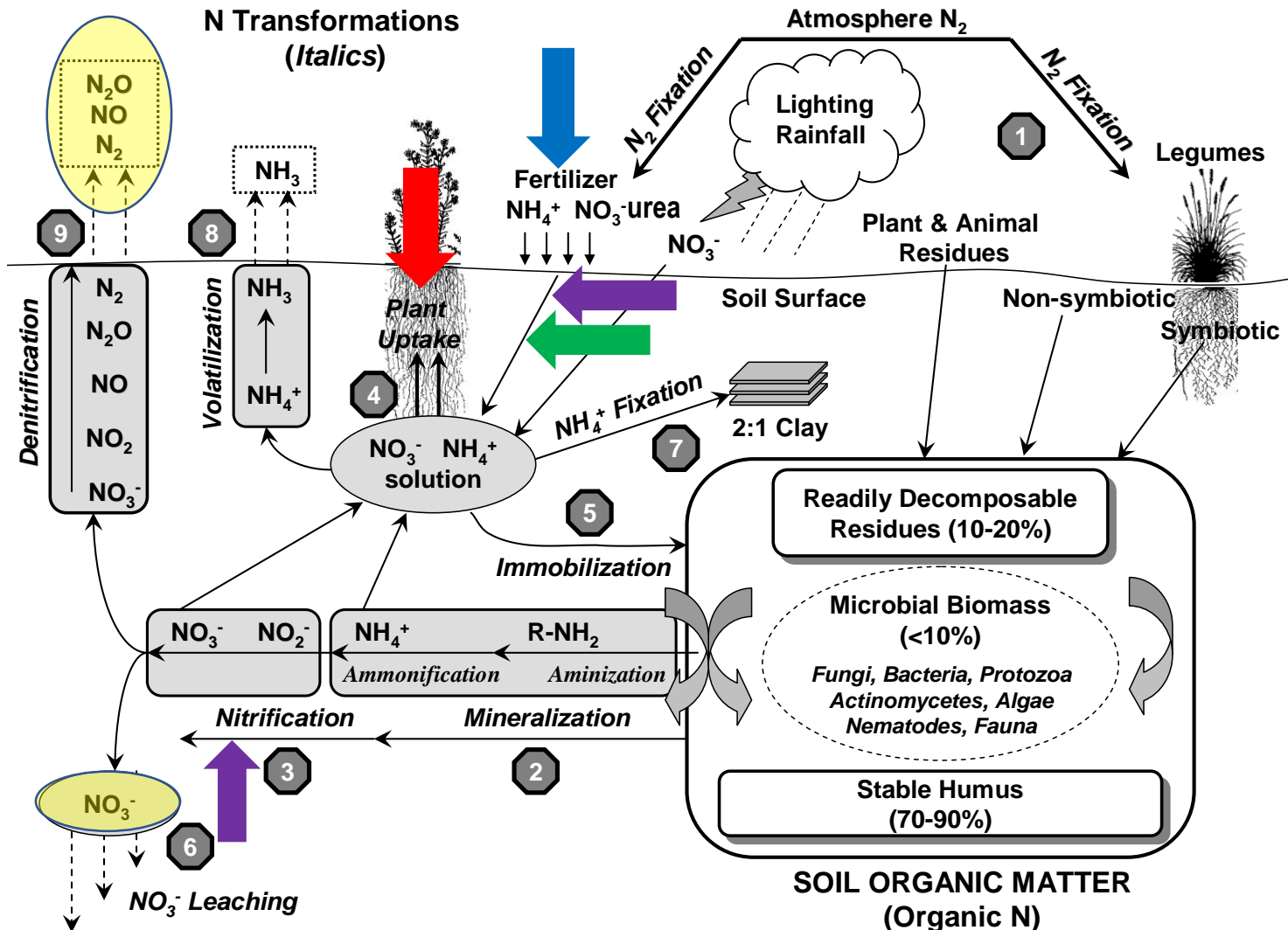
“Agriculture is the ONE sector that has the ability to transform from a net emitter of CO₂ to a net sequesterer of CO₂ —there is no other human managed realm with this potential”



However, the root number and root hydraulic conductance have been drastically reduced by breeding



Nitrogen cycling and Nutrient Use Efficiency



✓ Precision agriculture

✓ Slow and controlled release fertilizers

✓ Fertilizers additives (urease and nitrification inhibitors)

✓ Biostimulants

The conceptual levers

Agroecology principles and transitioning

Agroecology Concept

From this :

*Agroecology is the application of **ecological concepts and principles** to the design and management of **sustainable agroecosystems**, or the science of sustainable agriculture. (Altieri 1995; Gliessman 1990, 1997, 2013).*

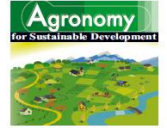
To this :

*Agroecology is the **integration** of research, education, action and change that brings **sustainability to all parts of the food system**: ecological, economic, and social. It's transdisciplinary in that it values all forms of knowledge and experience in food system change. It's participatory in that it requires the **involvement of all stakeholders from the farm to the table and everyone in between**. And it is action-oriented because it confronts the economic and political power structures of the current industrial food system with alternative social structures and policy action. The approach is grounded in ecological thinking where a holistic, systems-level understanding of food system sustainability is required. (Gliessman, 2018)*

Agroecology principles and transitioning

Agron. Sustain. Dev. 29 (2009) 503–515
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Review article

Agroecology as a science, a movement and a practice. A review

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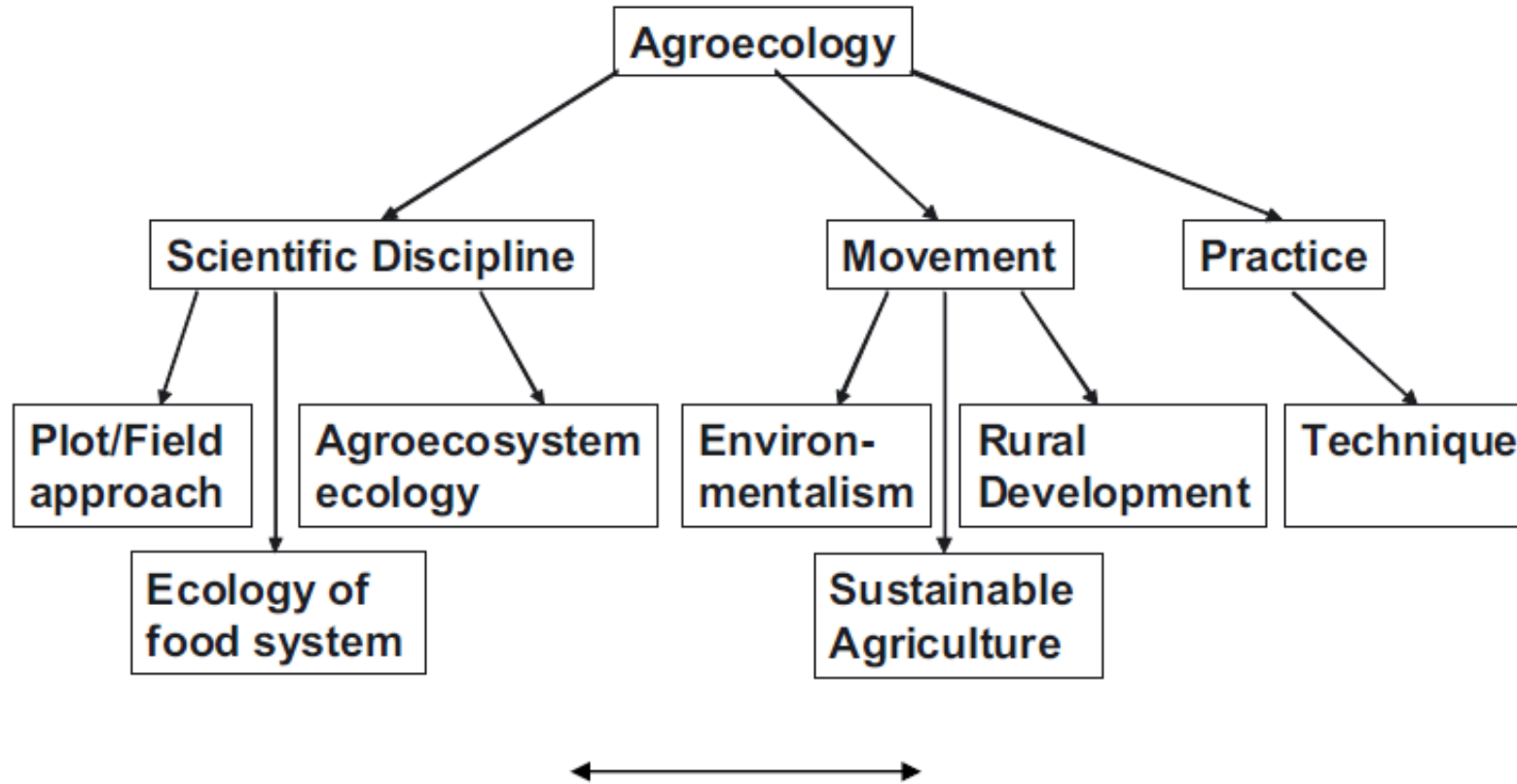


Figure 1. Diversity of current types of meanings of agroecology.

TRANSFORMATIONAL

LEVEL 5
Rebuild the global food system so that it is sustainable and equitable for all

LEVEL 4
Re-establish connections between growers and eaters, develop alternative food networks

LEVEL 3
Redesign the whole agroecosystem based on ecological processes

LEVEL 2
Substitute alternative practices and inputs

LEVEL 1
Increase efficiency of industrial inputs

LEVEL 0
No agroecological integration

INCREMENTAL

FOOD SYSTEM

AGROECOSYSTEM



Choosing your practice based on its potential and scope of action

Agron. Sustain. Dev.

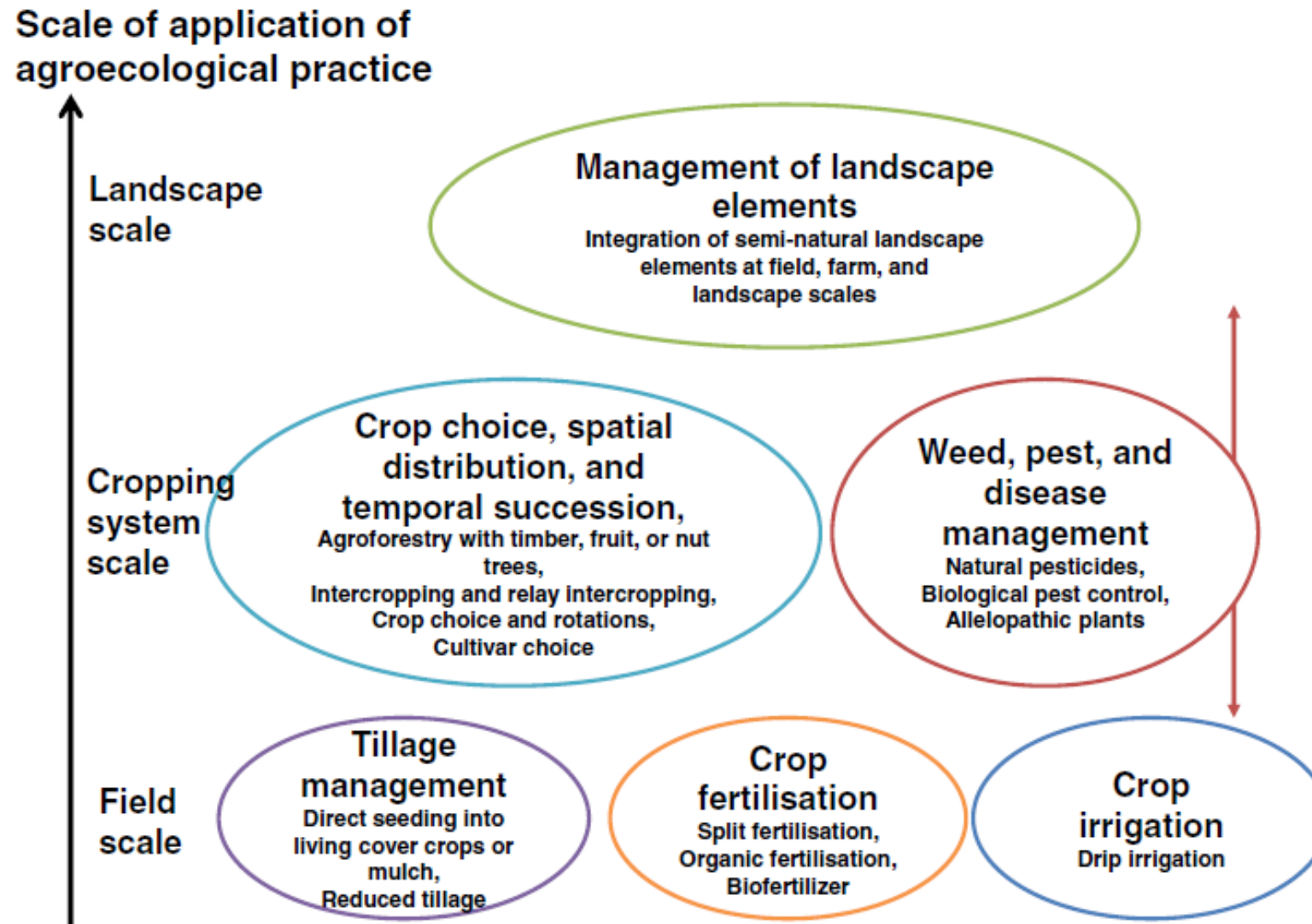
DOI 10.1007/s13593-013-0180-7

REVIEW ARTICLE

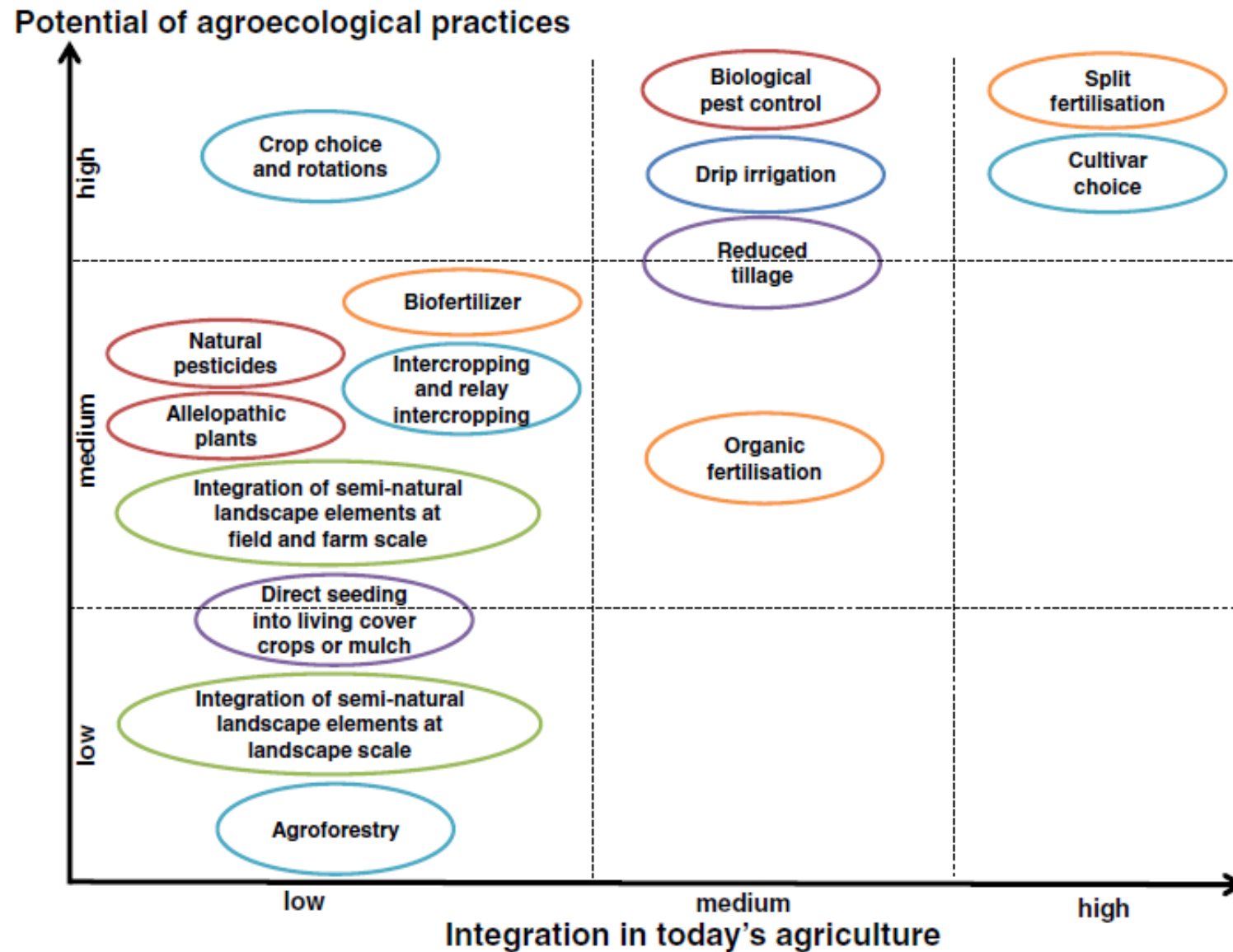
Agroecological practices for sustainable agriculture. A review

**Alexander Wezel • Marion Casagrande • Florian Celette •
Jean-François Vian • Aurélie Ferrer • Joséphine Peigné**

Choosing your practice based on its potential and scope of action



Choosing your practice based on its potential and scope of action



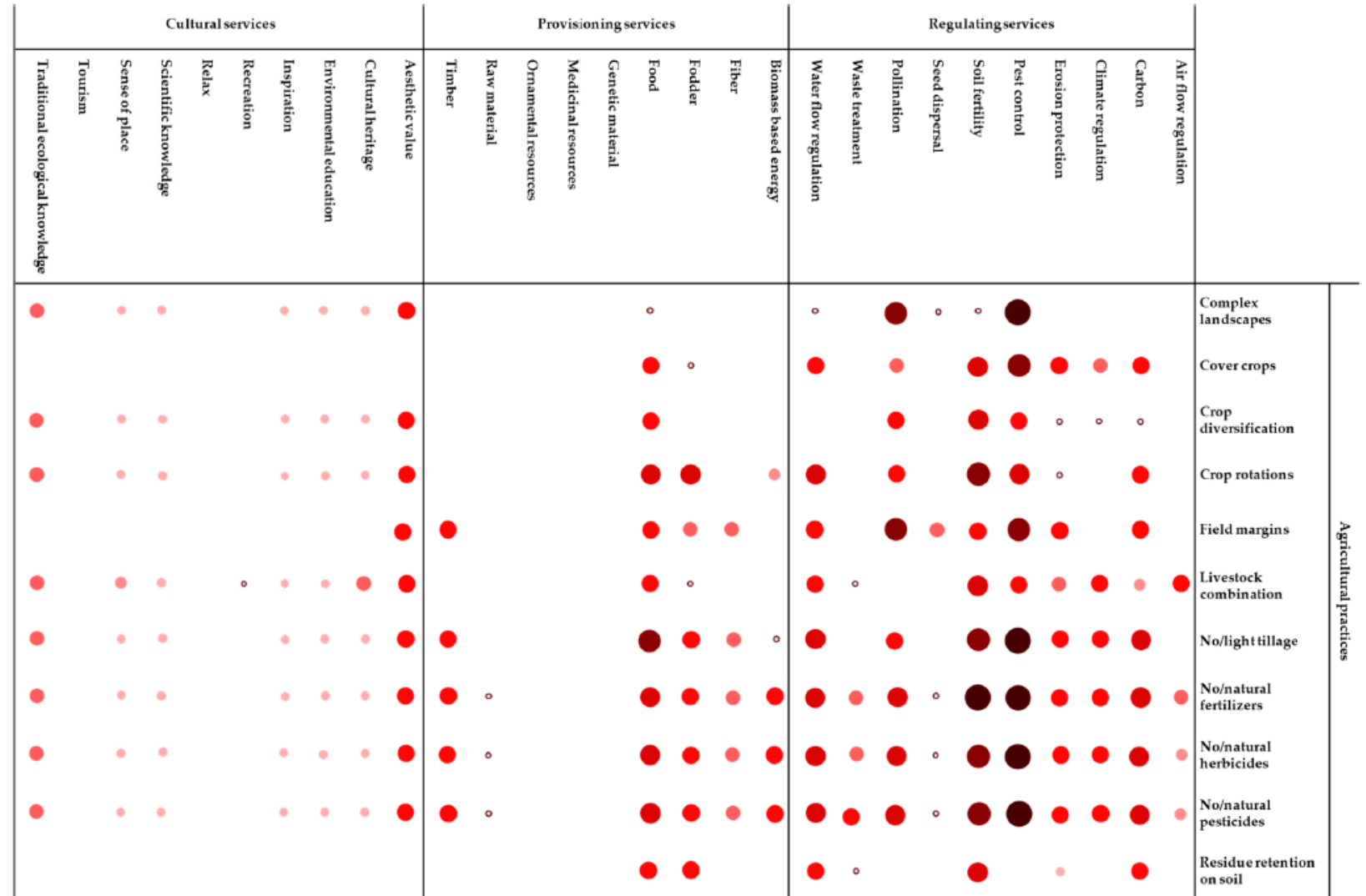
Choosing your practice based on its potential and scope of action

➤ One practice can provide multiple services

➤ One services can be provided by multiple practices

➤ At each intersection, the intensity will be different !

No. of times that every relationship between each agricultural practice and ecosystem service has been analyzed

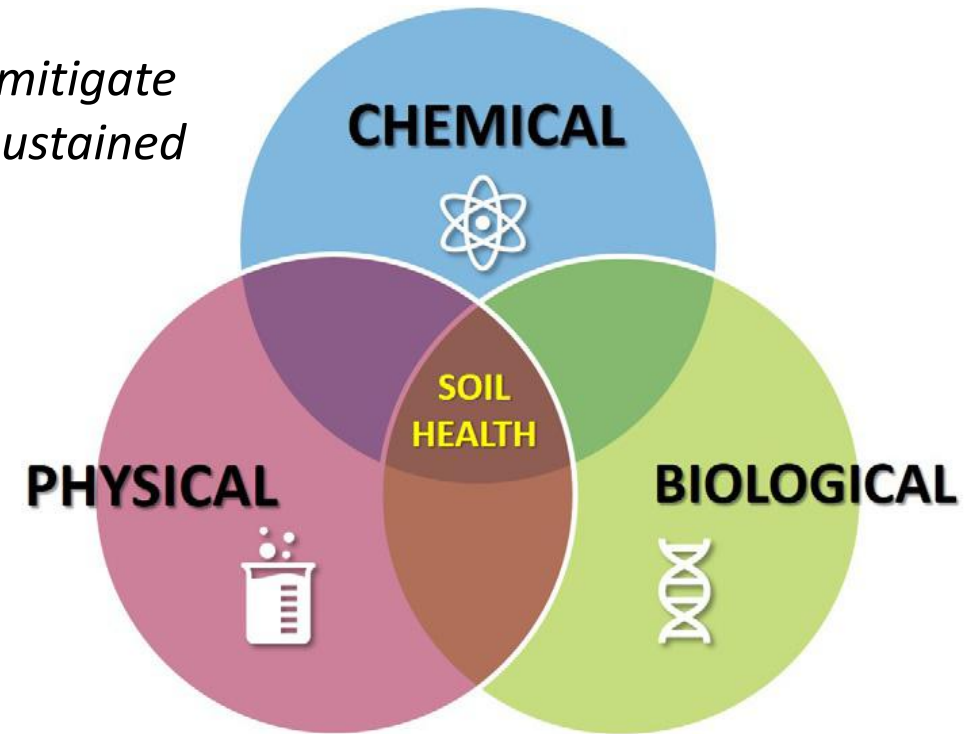


The conceptual levers

Soil health and quality concepts

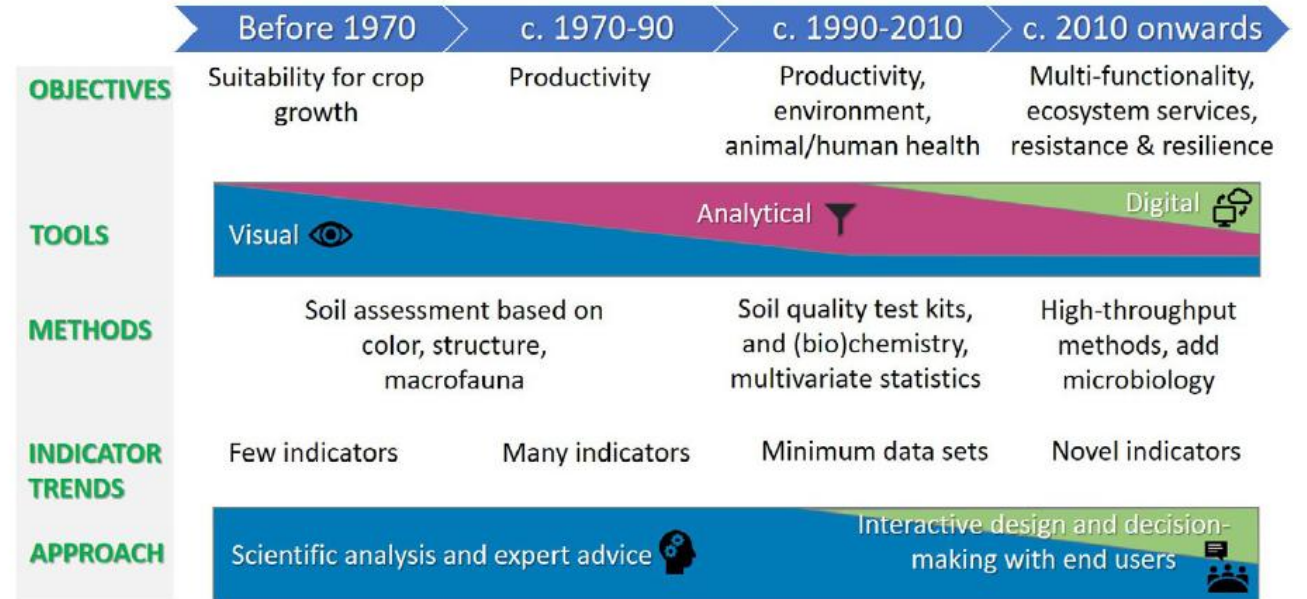
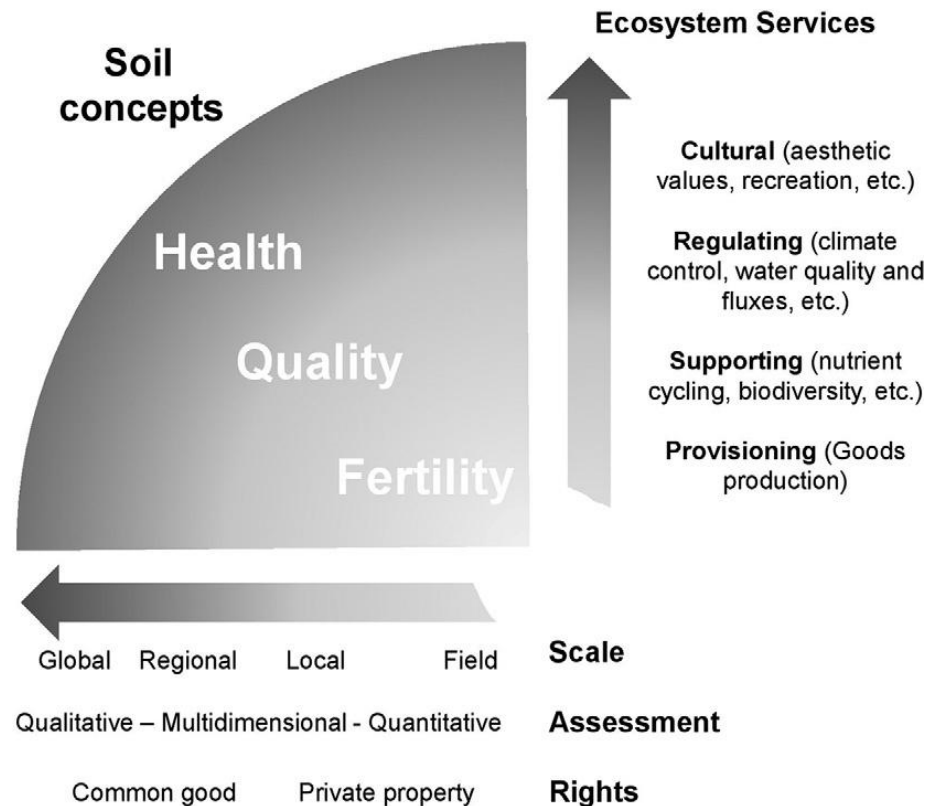
The conceptual levers

*“**Soil health** is the capacity of soils to provide a sink for carbon to mitigate climate change and a reservoir for storing essential nutrients for sustained ecosystem productivity”.*

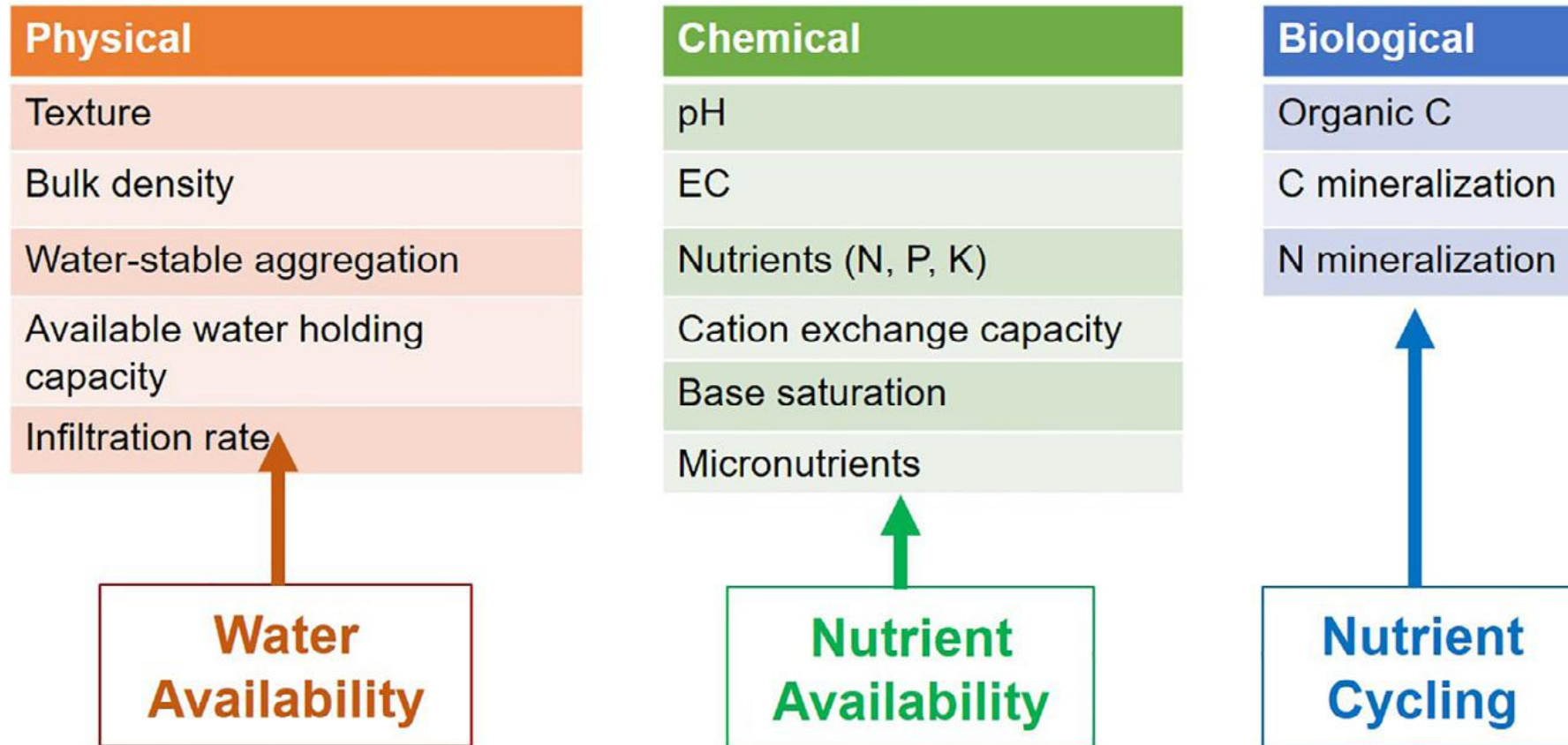


*“**Soil health** can be defined as the ability of the soil to respond to agricultural practices in a way that sustainably supports both agricultural production and the provision of other ecosystem services”.*

Evolution of soil fertility-quality-health assessment over time



Indicators/Properties to Assess Soil Health:



Tier 1

- Effective indicators
 - Defined regionally and by soil grouping across United States
 - Thresholds exist to at least indicate “Poor”, “Adequate”, “Good” that are outcome based (yield, environmental goals, etc.)
 - Management can be suggested to improve soil functioning
- Examples: Standard soil test, SOC, aggregation

Tier 2

- Effective indicators
 - Trend/directionality are known, potential ranges may be known in some regions but not nationally
 - Thresholds in various regions are either unknown or not outcome-based
 - Management can be suggested to improve soil functioning
- Examples: Active C, bioavailable N, PLFA, CASH, Haney, SMAF

Tier 3

- Not yet effective indicators
- Indicators may be useful if its relationship to soil health-related processes can be clarified
- Before it can be widely used, methods development must improve laboratory implementation, interpretation, regional application, and linkage to management impacts

Knowledge gaps



Lack of soil diversity information

Need to build a database of soil health studies across varied soil types



Lack of correlation between soil health and crop yields

Measure soil health values to climate, soil, management, and disease parameters



Lack of consistent sampling techniques and protocols

Need to have consistent sampling protocols in soil assessment procedure



Lack of objective and trusted measures

Need to have a deliberate effort to ensure that communication effectively articulates

The proposed Tier 1, Tier 2, and Tier 3 indicators for characterizing soil health by the Soil Health Institute

The future:

Time travelling with Triticum, a question of trade-offs?



*BIOdiversity of soils and FArming Innovations for improved
Resilience in European wheat agrosystems*

BIOFAIR

Coordinated by

Liège University and Université Libre de Bruxelles, BELGIUM

FiBL Switzerland – Frick – SWITZERLAND

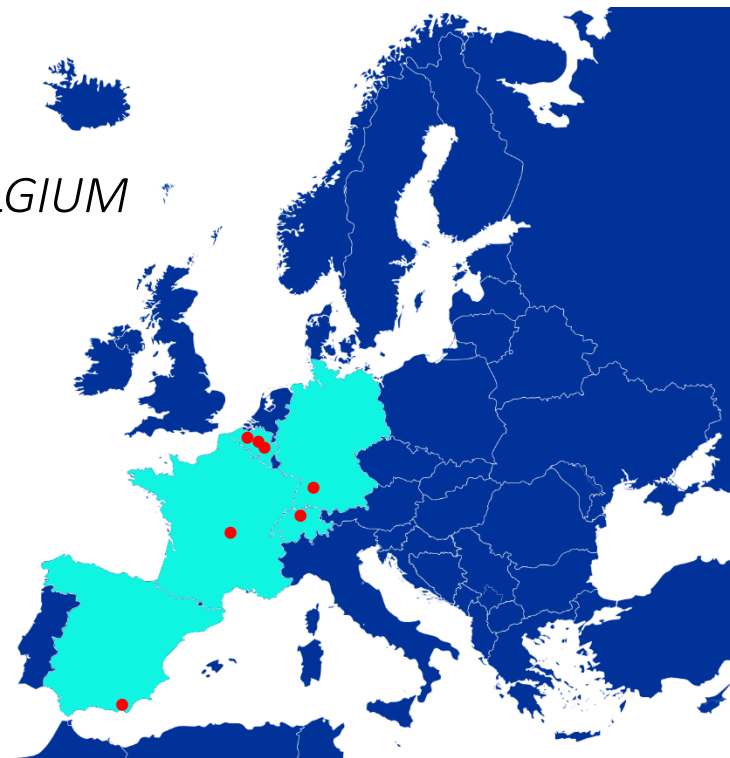
FiBL Europe – Brussels – BELGIUM

Hohenheim University - Stuttgart – GERMANY

Ghent University – Ghent – BELGIUM

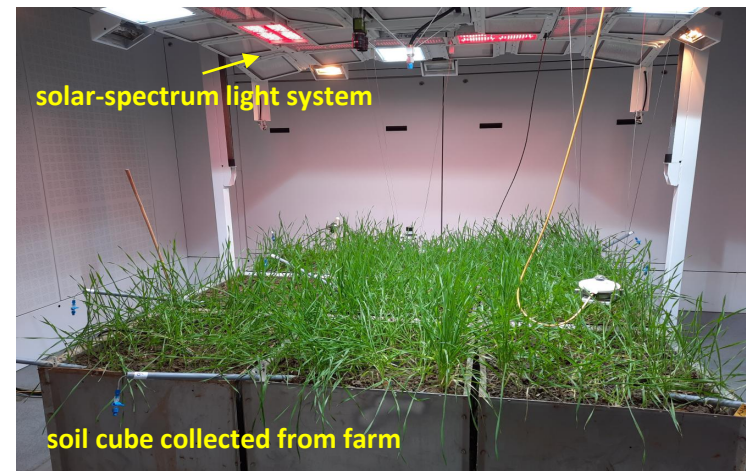
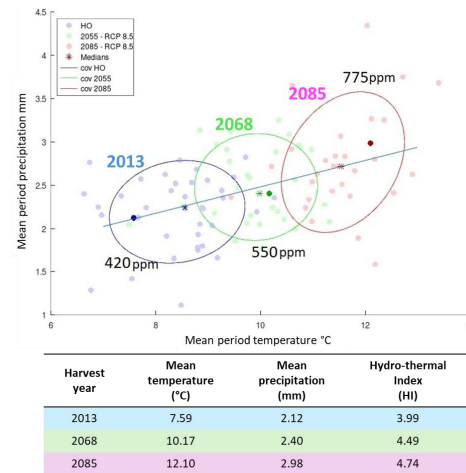
CSIC – Almería – SPAIN

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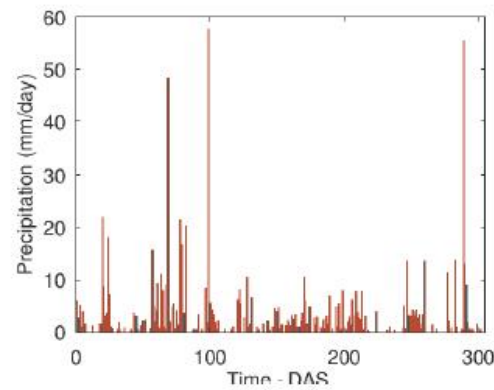
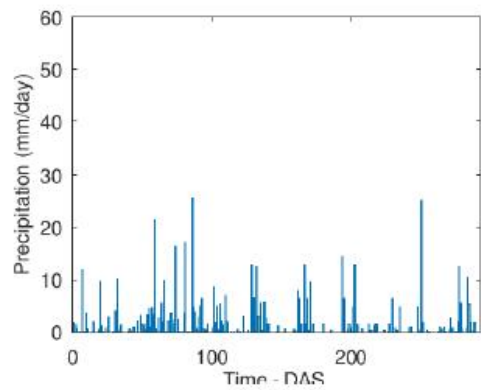
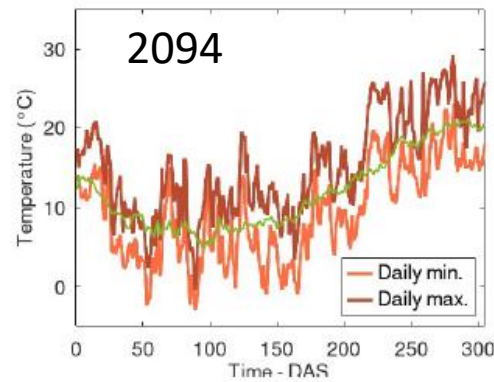
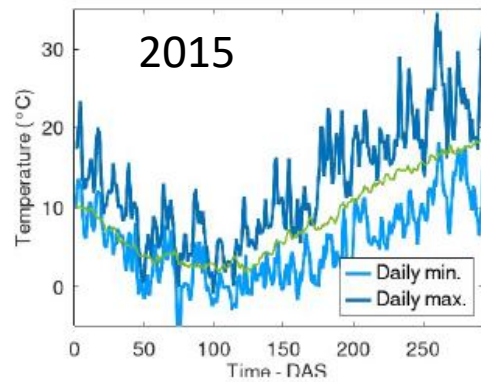
Goals & Methodology

- Assessing the impacts of **climate change** and **innovative farming practices** on plant productivity, nutritional quality and fitness.
- Studying the **soil functioning** and the related soil microbiome as well as micro- and meso-fauna **biodiversity**.
- Understanding the reported changes in **productivity, quality** value of the cereal grains and the **suppressiveness capacity** of such soils against **(a)biotic stresses**.



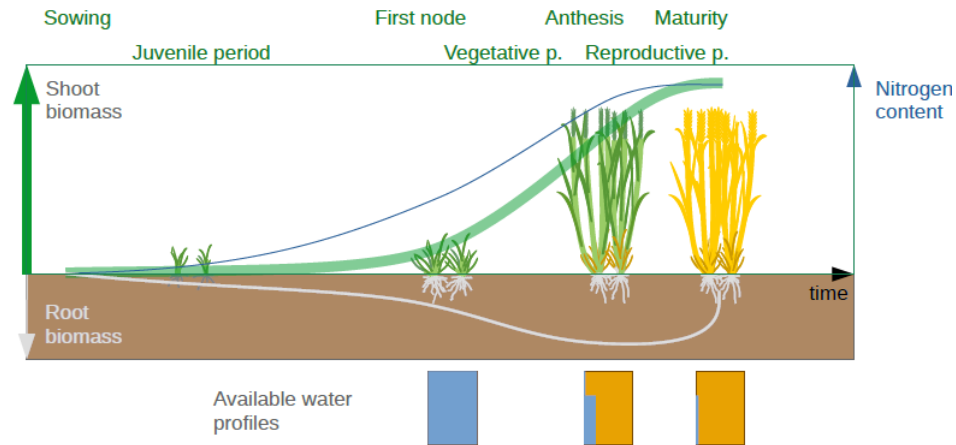
SCIENTIFIC OUTCOMES

The Seminal Ecotron Experiment

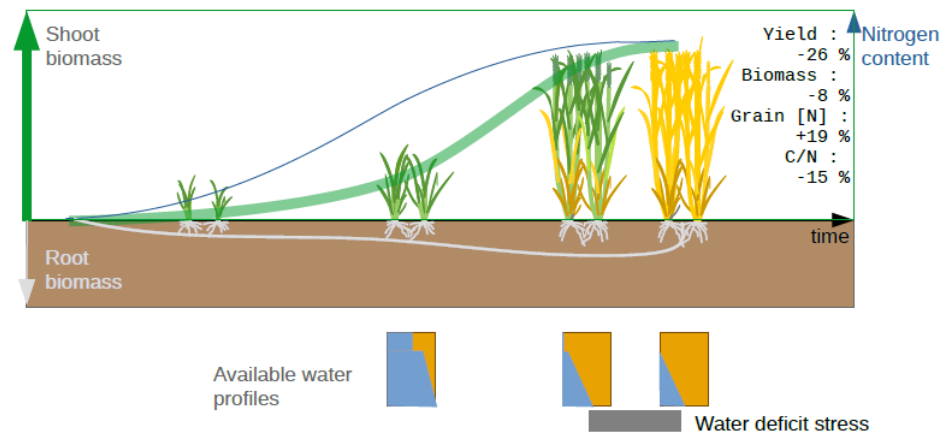


SCIENTIFIC OUTCOMES

Present Meteorological Conditions



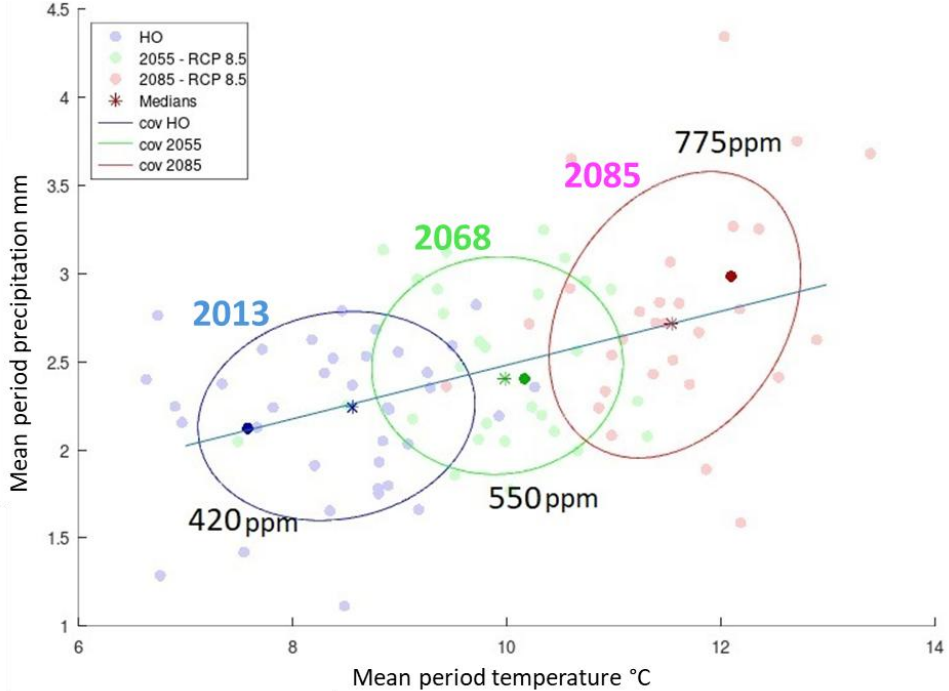
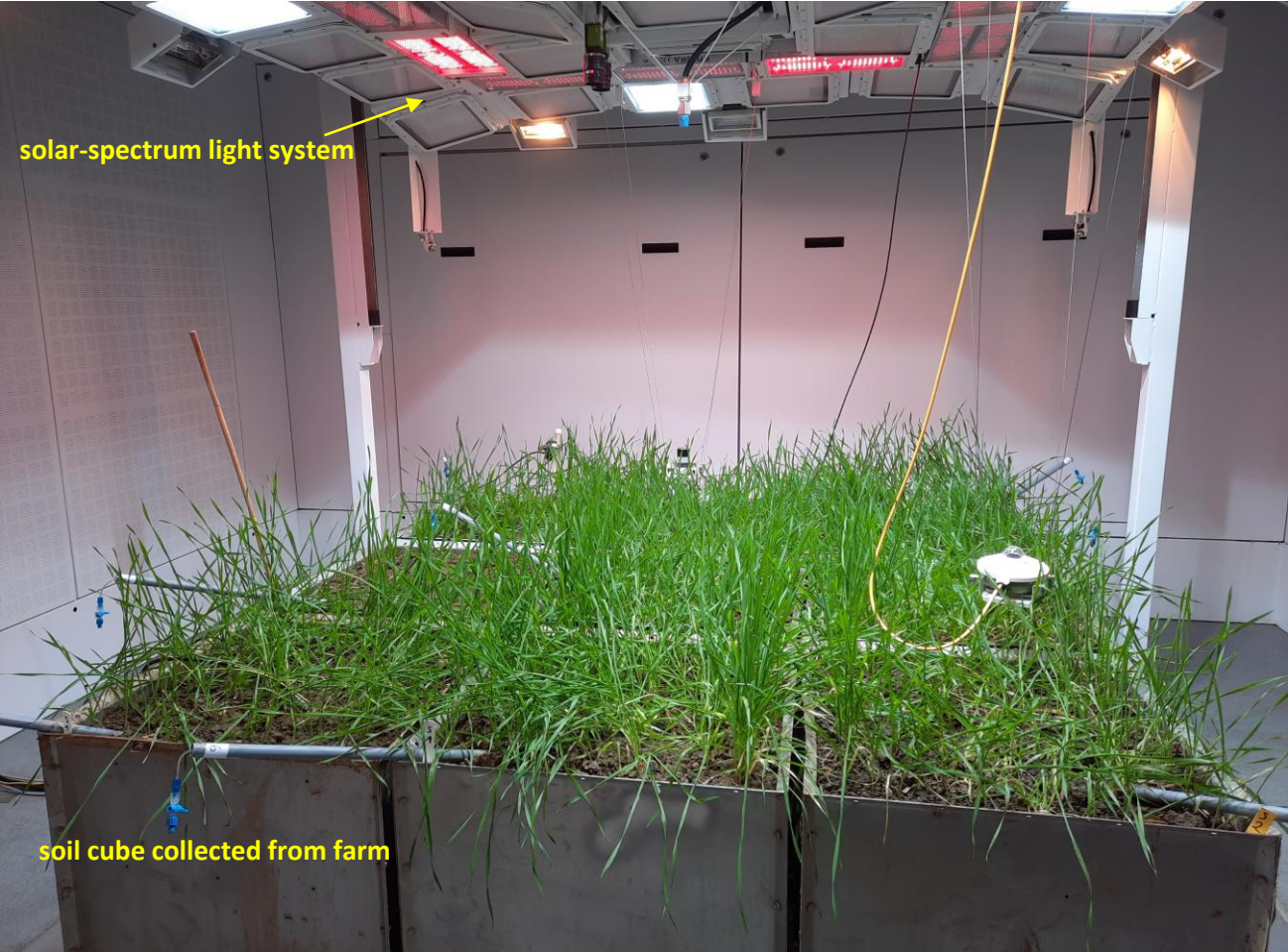
Future Meteorological Conditions



- Higher temperatures in Winter allowed a higher biomass production that limited the tillers number due to the competition for light and thus the amount of ears and nodal roots.
- Larger availability of soil water and nitrogen during the juvenile and vegetative periods under future climate conditions
- Higher sensitivity to water deficit stress due to a limited root growth

SCIENTIFIC OUTCOMES

BIOFAIR Ecotron experiment at Gembloux Agro-Bio Tech



Harvest year	Mean temperature (°C)	Mean precipitation (mm)	Hydro-thermal Index (HI)
2013	7.59	2.12	3.99
2068	10.17	2.40	4.49
2085	12.10	2.98	4.74

SCIENTIFIC OUTCOMES

Two soil types

Two geographically close soil types with identical soil classification^a (Aba(b)0), silty loam, C:N = 10.5, pH = 8) but **long-term contrasting management history** were compared. Soil One is «low input» and conventionally managed, while Soil Two is «high input» and increasingly adapting organic farming principles.

a www.geoapps.wallonie.be



50°38'35.1474"N
4°37'22.0123"E

50°39'12.8668"N
4°38'10.7664"E

Physicochemical characterisation of the two soil types at the beginning of the experiment

	C (g kg ⁻¹)	N (g kg ⁻¹)	C:N	P (mg 100g ⁻¹)	K (mg 100g ⁻¹)	Mg (mg 100g ⁻¹)	Ca (mg 100g ⁻¹)	pH (H ₂ O)	Humus (%)	Clay (%)	Silt (%)	Sand (%)	Classifi- cation
Soil One (S1) "low input"	9.92	0.94	10.5	13.60	31.20	8.37	218.31	8.04	1.98	12.15	67.13	20.72	Silt loam
Soil Two (S2) "high input"	22.01	2.09	10.5	39.79	72.51	14.70	534.42	8.08	4.23	13.55	78.85	7.60	Silt loam

SCIENTIFIC OUTCOMES

Yield (t ha⁻¹)

2013

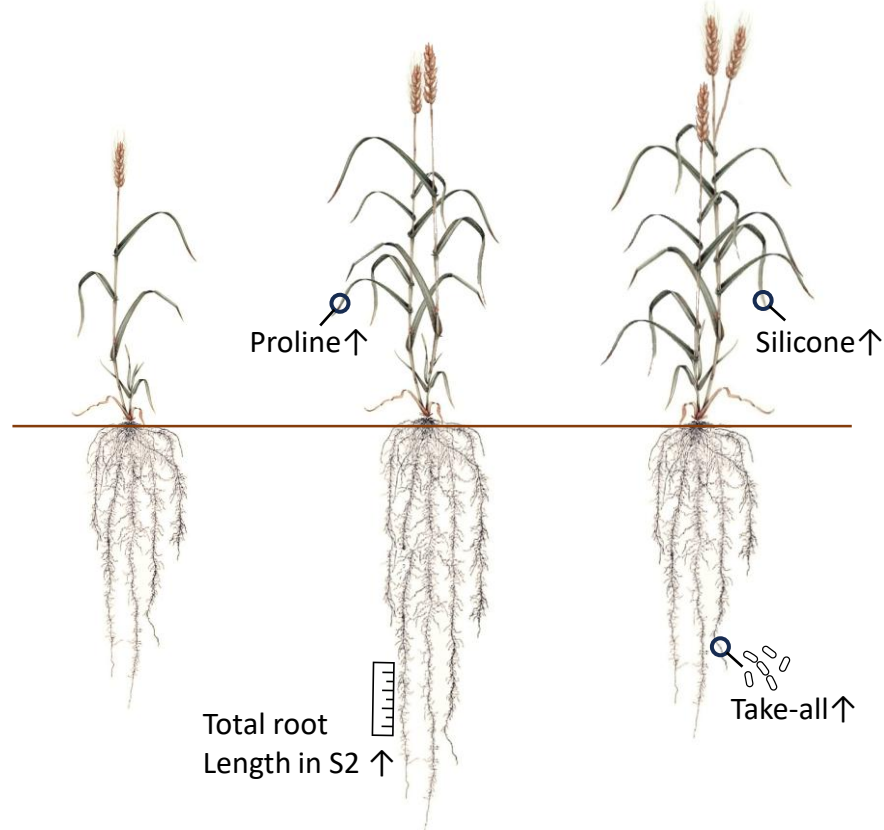
S1: 3.79±0.51
S2: 3.50±0.34

2068

S1: 4.76±0.37 (+26%)
S2: 3.71±0.32 (+6%)

2085

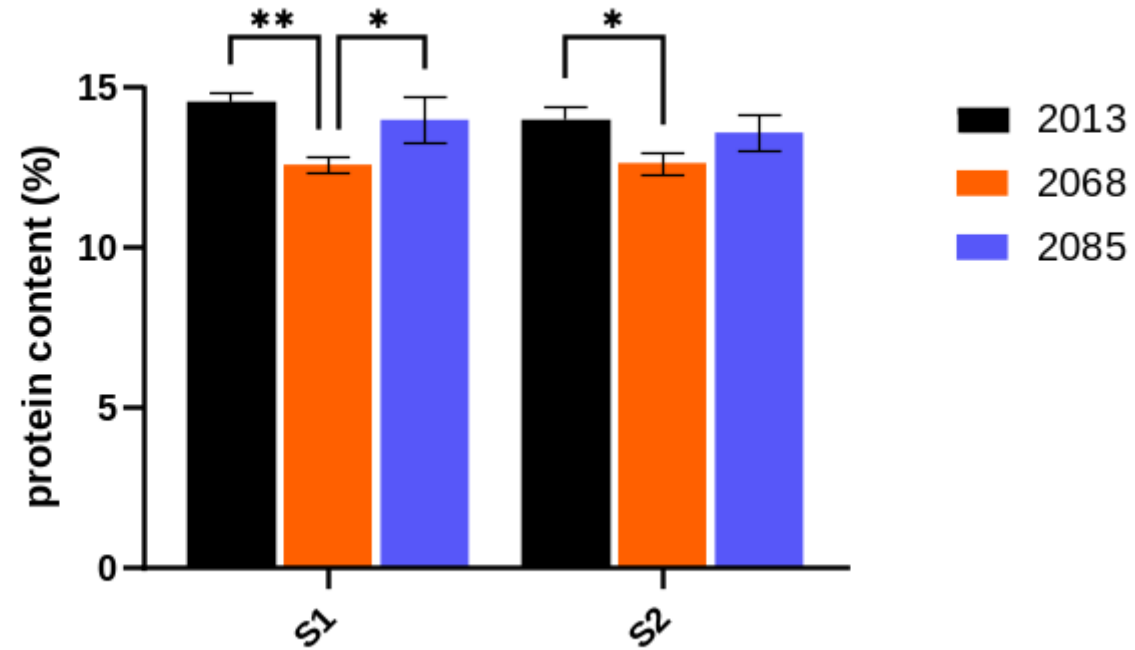
S1: 5.09±0.50 (+34%)
S2: 3.05±0.59 (-13%)



Agronomic performance & environmental impact

- Wheat plants grew faster, taller and with larger leaves in the future (phenological advance)
- Total root length was mostly increased in 2068 in S2
- Yield constantly increased in the future for soil S1 (always S1>S2)
- Abiotic stress was defeated with increased foliar proline and silicone in 2068 and 2085 respectively
- Take-all disease (*Gaeumannomyces graminis* var. tritici) increased in the future, most strongly in soil type 1 in 2085
- Potential soil CO₂ emissions increased (always S2>>S1), N₂O decreased
- Increased risk of nitrate leaching in the future (esp. S1)

SCIENTIFIC OUTCOMES

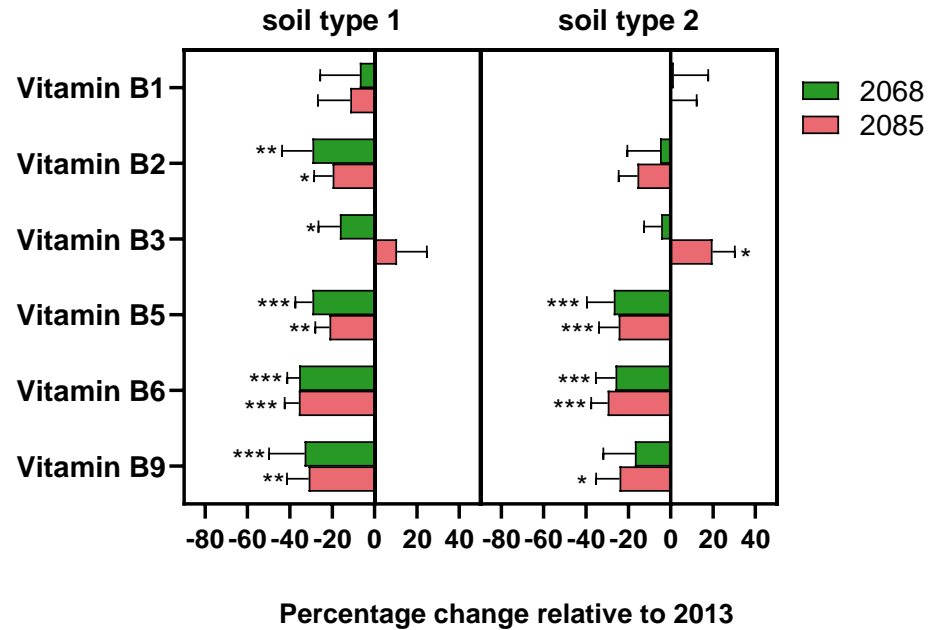


- Significant decrease in protein content in 2068 (vs 2013), whatever the soil type

SCIENTIFIC OUTCOMES

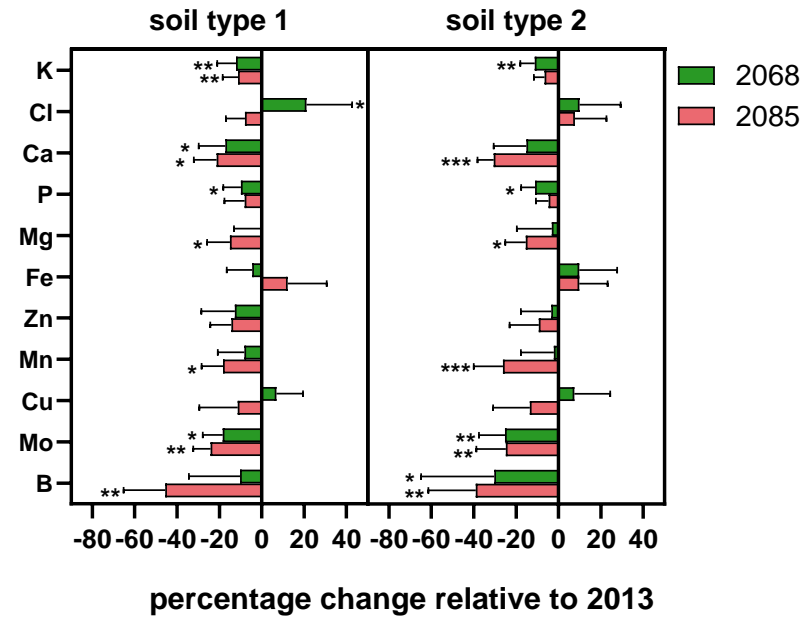
Relative changes of B vitamins and mineral contents in wheat grains harvested under three different meteorological conditions.

a



- Overall decline in B vitamin content

b



- Overall decline in mineral content

Key Findings of the BIOFAIR Project

Key Scientific Findings

Reduced wheat yields under drought; minor gains from elevated CO₂
Grain micronutrient & B-vitamin content decreased under climate change
Higher root disease risk in future climates (e.g. take-all fungus)
Soil biodiversity shifts with climate; more activity ≠ more productivity

Farming Practices & Soil Health

Reduced tillage improves biodiversity but may reduce yield
SOC-enhancing practices increase microbial activity but risk CO₂ emissions
Organic systems show better drought resilience in some contexts

Stakeholder Impact

3 co-creation workshops shaped experimental design
Baking tests confirmed lab results with industry stakeholders

Policy & Practical Relevance

Informs EU policies on soil health, food security, and climate adaptation

What's next?!

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