INSTITUTE OF PLANT SCIENCES

Sant'Anna School of Advanced Studies – Pisa

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Key concepts in agrobiodiversity

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@GoAgroecology

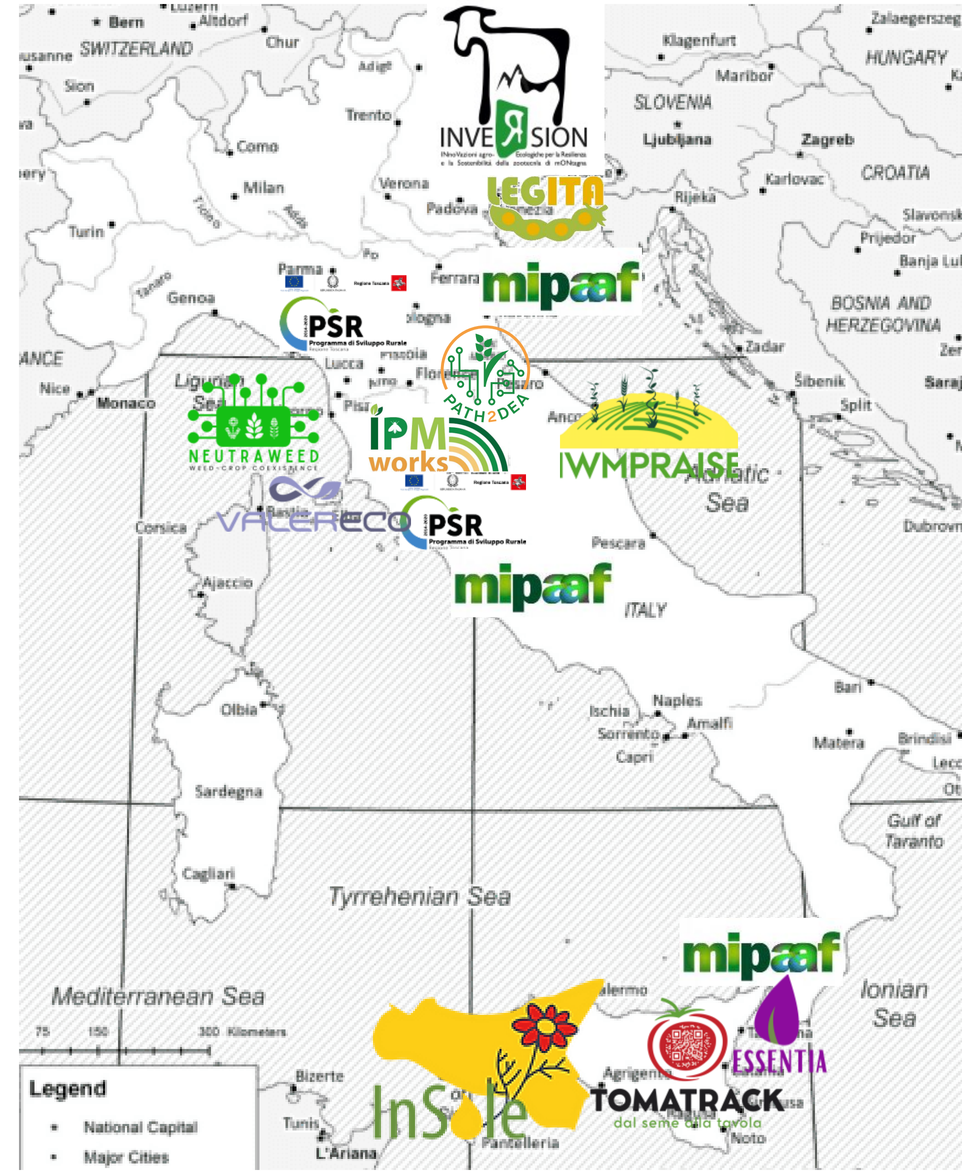
BREEDTECH project: 2nd Staff Training Workshop

23rd September 2025 - Scuola Superiore Sant'Anna, Pisa

Stefano Carlesi

Research Focus:

- •Optimizing use of **planned biodiversity** to enhance agroecosystem services
- •Developing integrated **weed management** strategies
- •Evaluating **cover crops** and **reduced tillage** in **organic** systems
- •Assessing effects of **crop diversification on weed communities**
- •Research on **using functional trait diversity** to manage **weeds**



Experience:

- •Over 17 years researching sustainable crop production systems in farm
- •Participated in major EU projects linked to farm trials: OSCAR, IWMPRAISE, IPMWORKS, PATH2DEA
- •Participated to 10 National or regional project involving farm trials
- •Co-design trials and projects with farmers and other stakeholders

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Today aims

1. Define the concepts of biodiversity and agroecology.

2. Explain how the agroecological approach helps to innovate agricultural systems towards greater economic, social and environmental sustainability.

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3. Present two examples of application of the functional use of biodiversity

Concept #1

Biodiversity and Agrobiodiversity

Biodiversity: what is it?

Biological diversity definition

Convention on Biological Diversity

the variability among living organisms from all sources including … terrestrial, marine and aquatic ecosystems and the ecological complexes of which they are a part.

This includes diversity

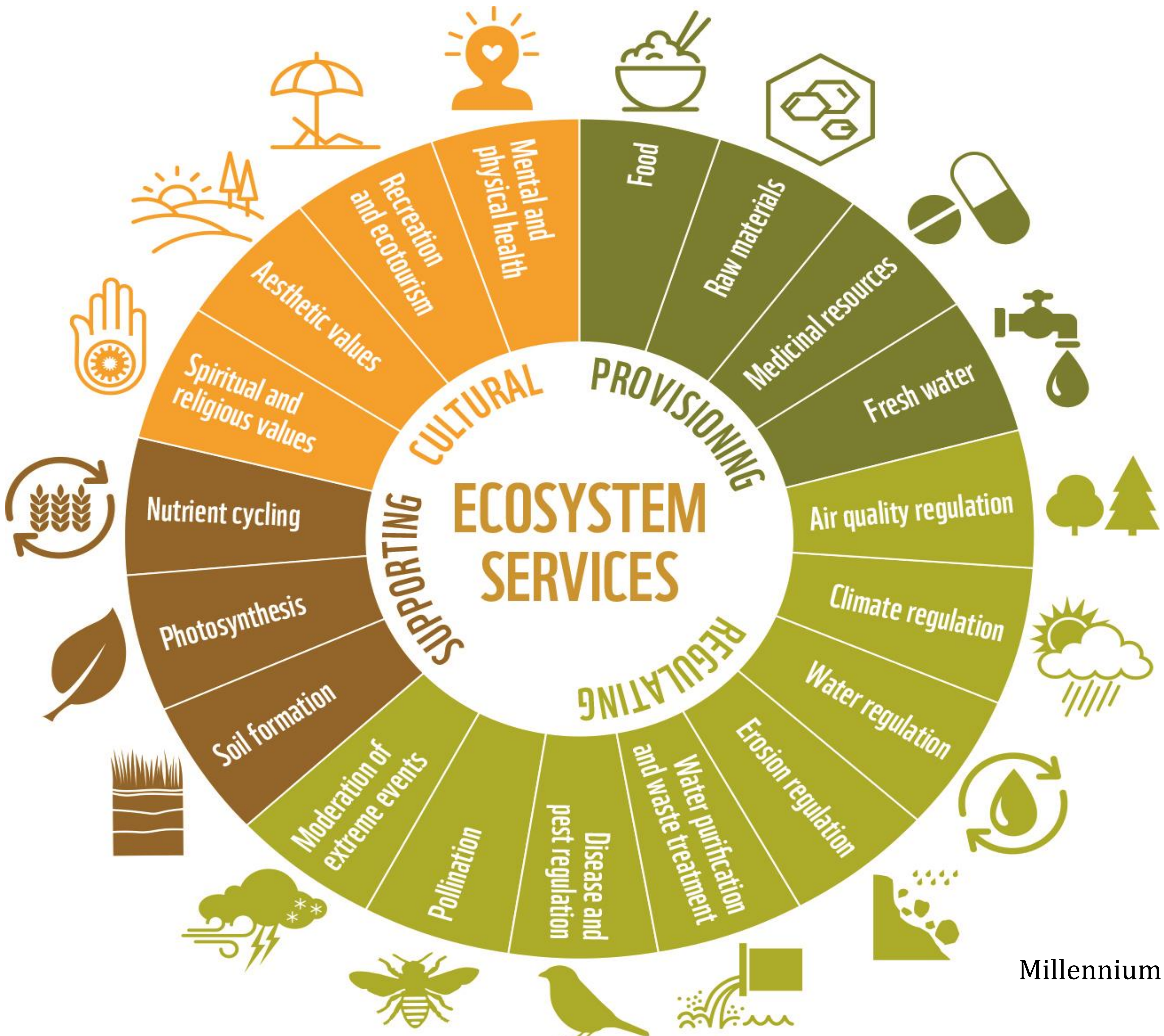
- within species
- between species
- of ecosystems

What is agrobiodiversity?

Agrobiodiversity is the **variability** of animals, plants and micro-organisms directly or indirectly utilized for agriculture and food production. Includes crops, livestock, trees and fishery. Includes the **diversity of genetic resources** (varieties and breeds) and of **species** utilized for the production of food, forage, fibre, energy and medicines. It also includes the **diversity of natural species** supporting production (e.g. soil micro-organisms, predators, pollinators) and the general diversity of organisms present in agroecosystems.

FAO (1999) and OECD/CBD (Parris, 2001), adapted.

Why does biodiversity matter?



Millennium Ecosystem Assessment (2005

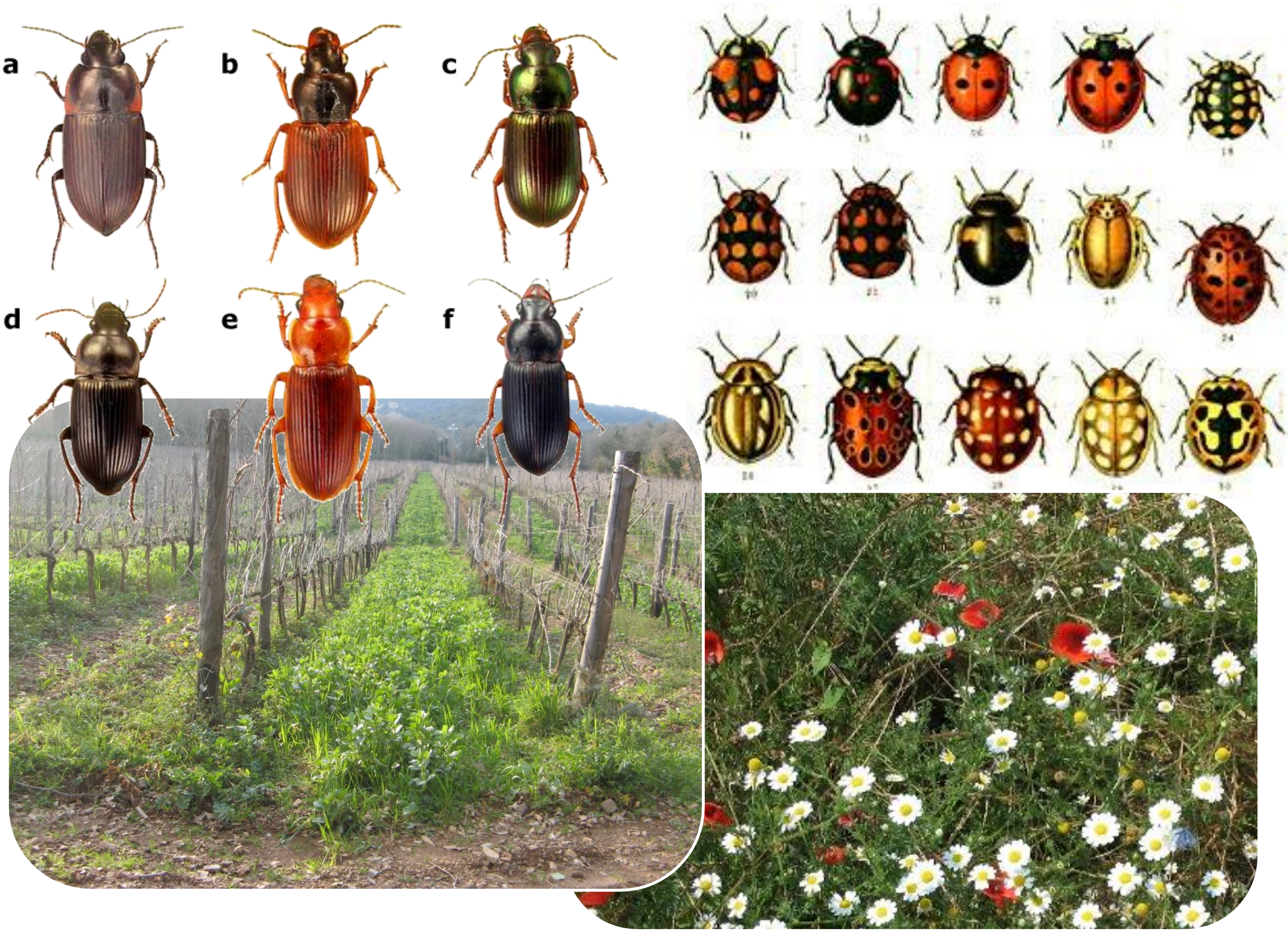
Agrobiodiversity: what is it?

Agrobiodiversity: what is it?

«Campbell's», Andy Warhol

Concept #2

The levels of Agrobiodiversity



a
b
c
d
e
f

The 4 dimensions of biodiversity (space and time): the variability between living organisms and the ecological complexes of which these organisms are a part.

Genetic diversity

Cultivated varieties and populations

Species diversity

crops, weeds, associated organisms

Habitat diversity

the elements and processes at various levels of scale

Management Diversity

Concept #3

Planned and Associated Agrobiodiversity

Planned and Associated Agrobiodiversity

Planned

- Farmers decide which and how many crop to grow
- Breeders select varieties
- **Other examples?**

Associated

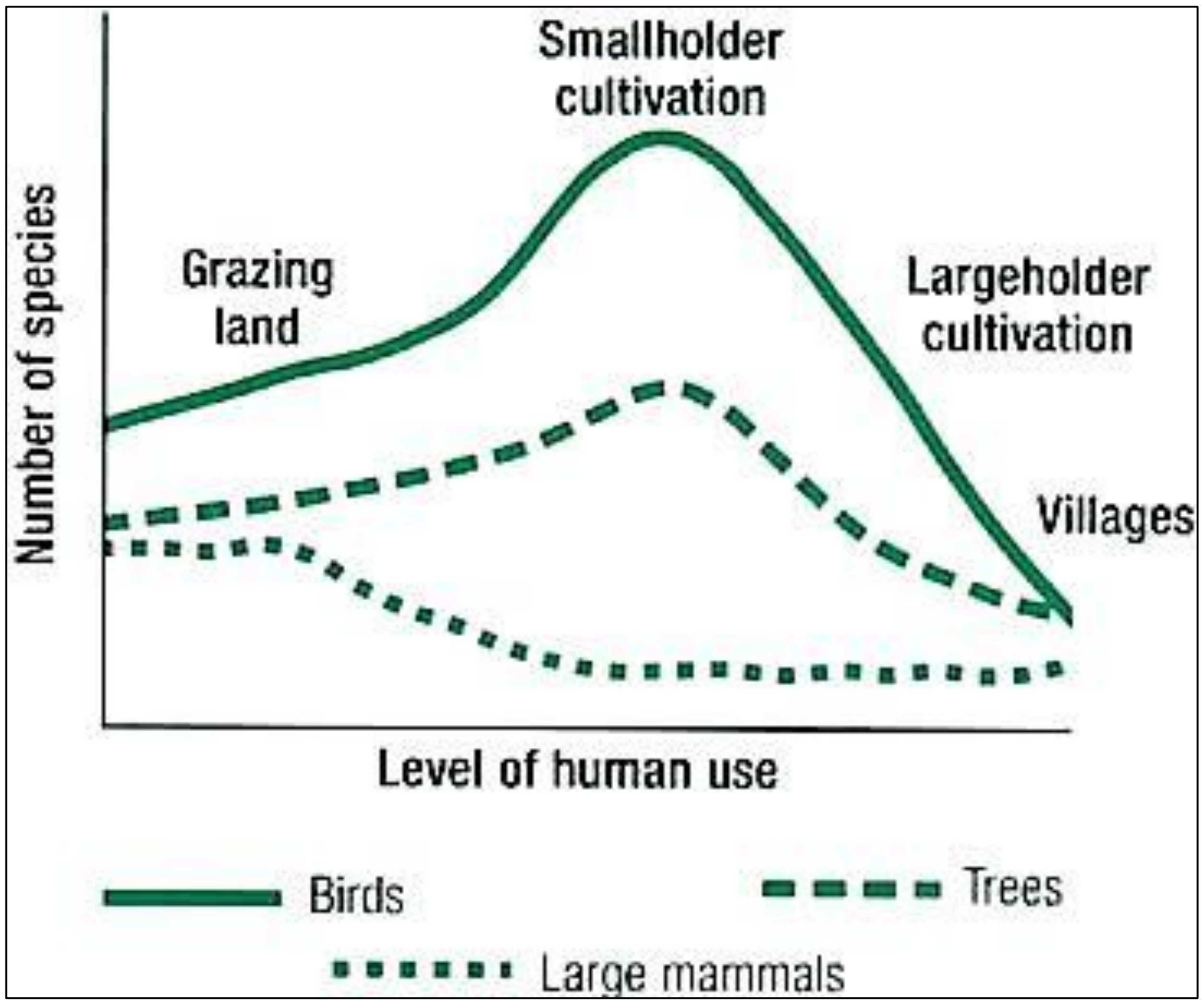
- Weeds grow in crop fields
- Insects reproduce in the agroecosystem
- **Other examples?**

CONCEPT #4

AGRICULTURE AND BIODIVERSITY

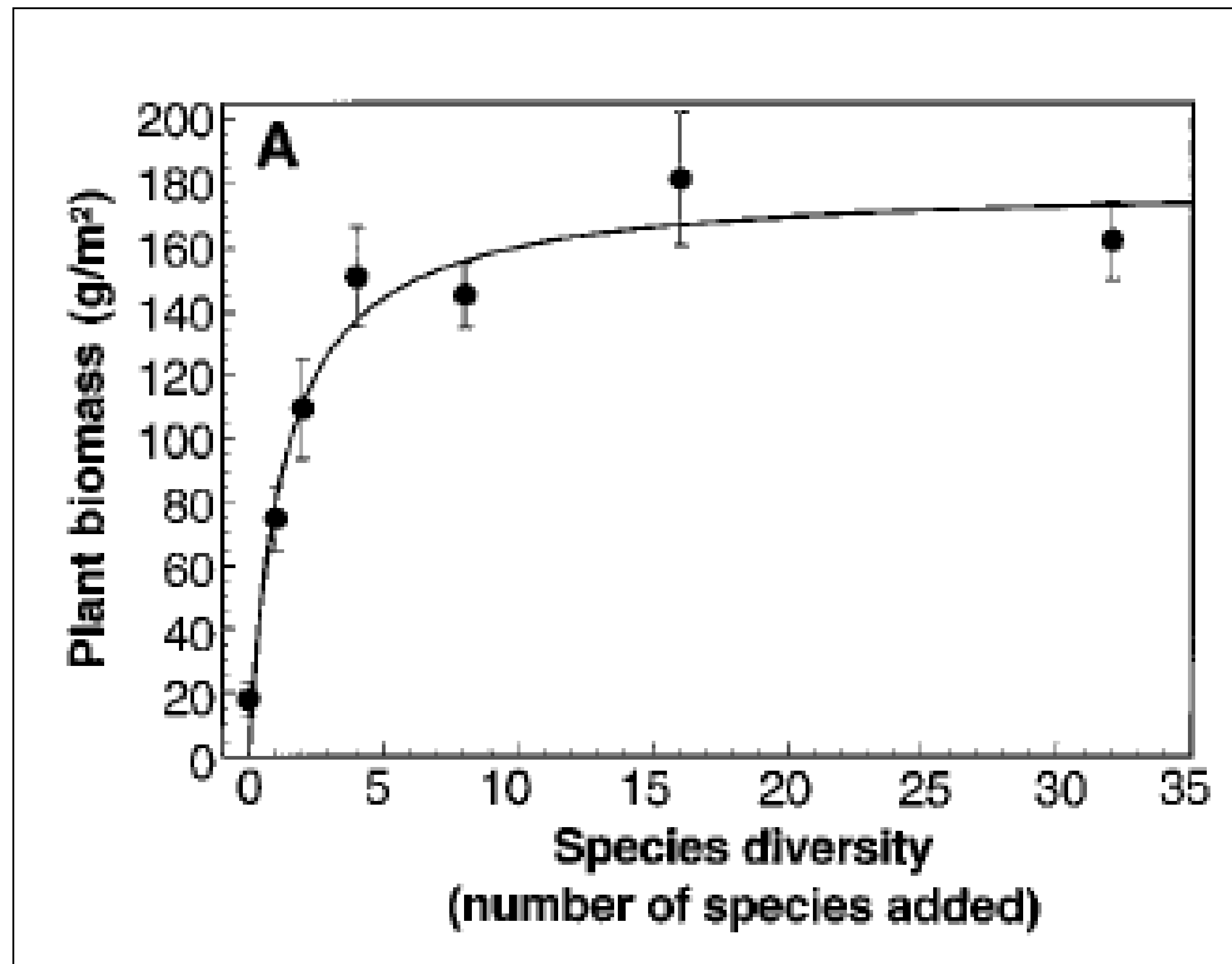
please observe these two graphs

Graph 1



http://www.fao.org/docrep/x5303e/x5303e09.htm

Graph 2



http://www.sciencemag.org/content/277/5330/1300

Concept #5

Biodiversity for Agriculture

Agriculture and Biodiversity

AGRICULTURE serving BIODIVERSITY (A for B)

- Non production-related ecosystem services (e.g. species/habitat conservation, cultural/amenity values): **CULTURAL** SERVICES

AND

BIODIVERSITY serving AGRICULTURE (B for A)

- Production-related ecosystem services (e.g. soil fertility, biological pest control, weed reduction): **PROVISIONING, REGULATING, SUPPORTING** SERVICES

Bàrberi et al. (2010). Weed Research 50, 388-401.

Can you find an appropriate title for this scheme?

Supporting
- Nutrient cycling
- Soil formation
- Primary production
- …

Provisioning
- Food
- Wood and fibre
- Fresh water
- …

Regulating
- Climate regulation
- Disease regulation
- Flood regulation
- …

Cultural
- Social well-being
- Aesthetics
- Educational
- Spiritual

Ecosystem Services

Supporting

- Nutrient cycling
- Soil formation
- Primary production
- …

Provisioning

- Food
- Wood and fibre
- Fresh water
- …

Regulating

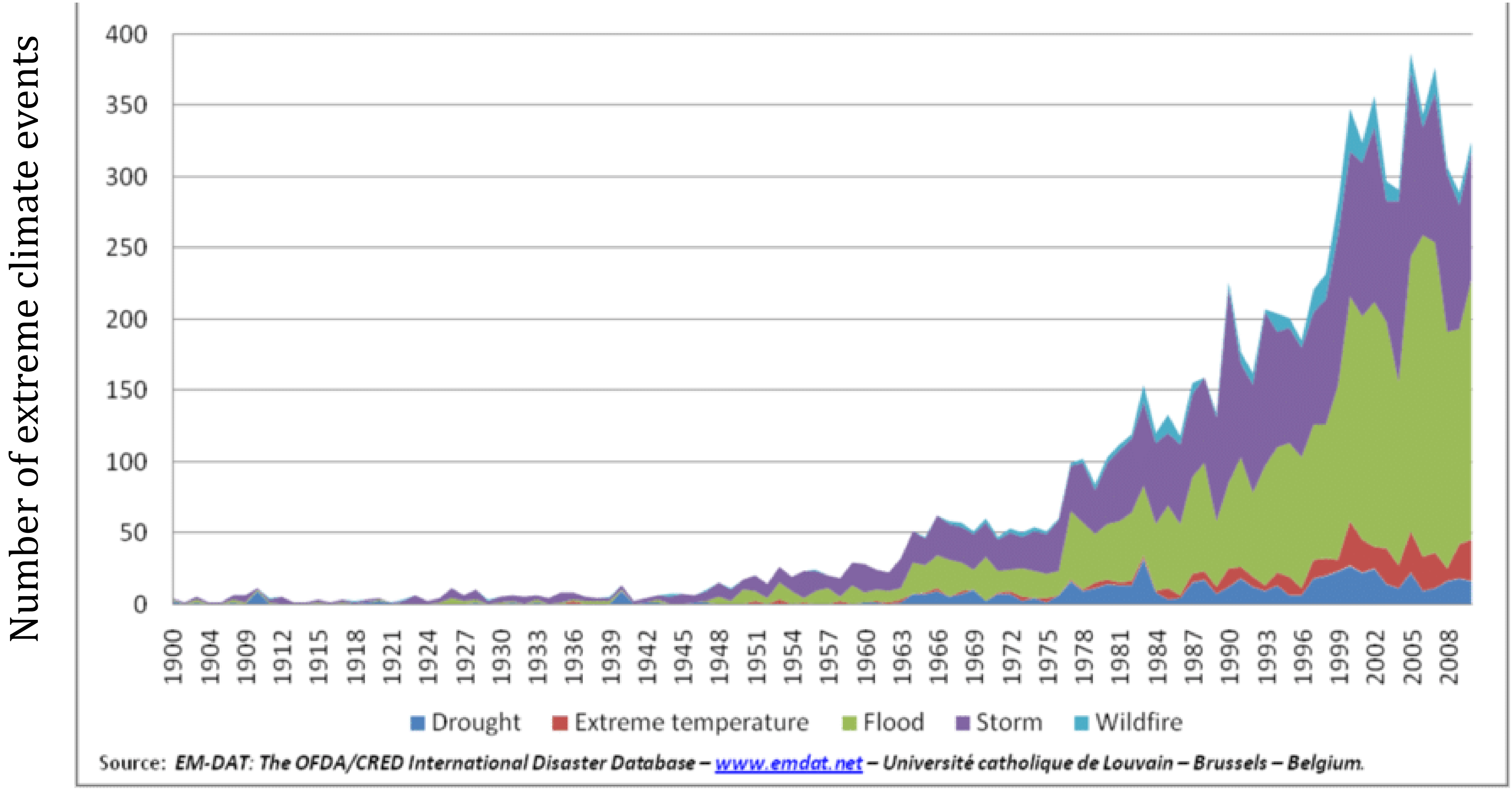
- Climate regulation
- Disease regulation
- Flood regulation
- …

Cultural

- Social well-being
- Aesthetics
- Educational
- Spiritual

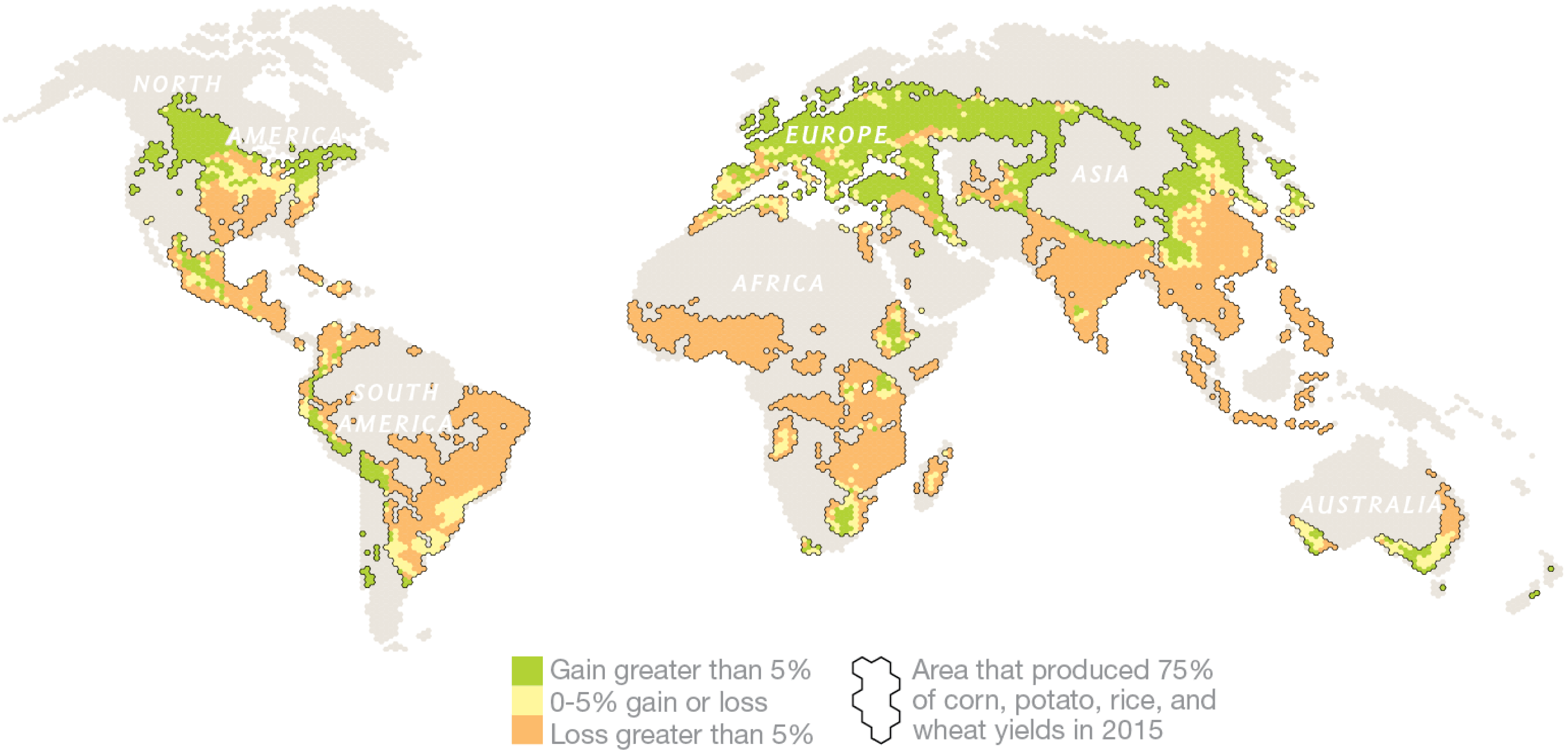
From Millennium Ecosystem Assessment

Drivers of change: climate crisis



Source: Simpson & Burpee (2015). MEAS Disc. Paper #3. DOI: 10.1007/978-3-642-38670-1_68

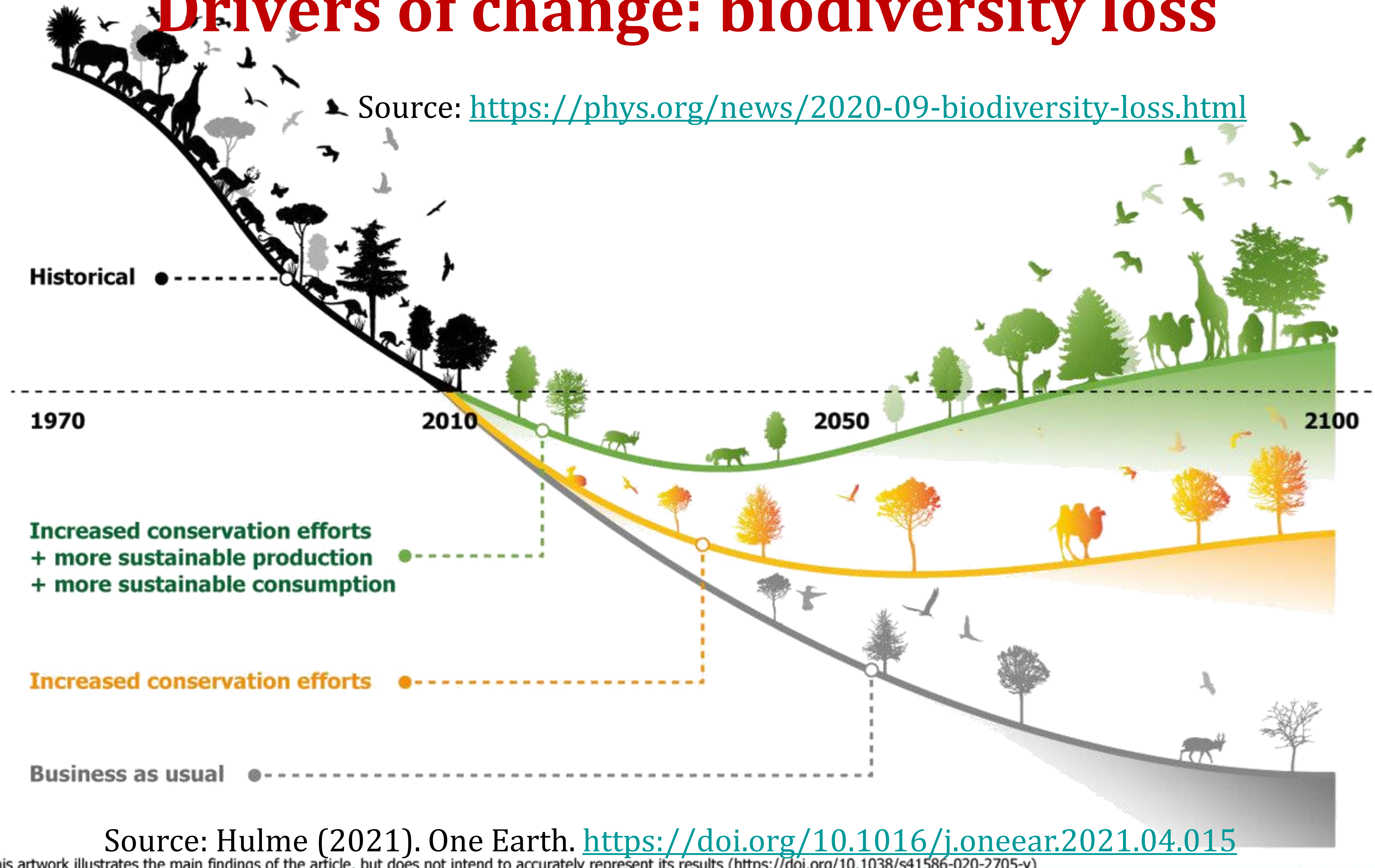
Drivers of change: climate crisis



Source: www.nationalgeographic.com/climate-change/how-to-live-with-it/crops.html

Drivers of change: biodiversity loss

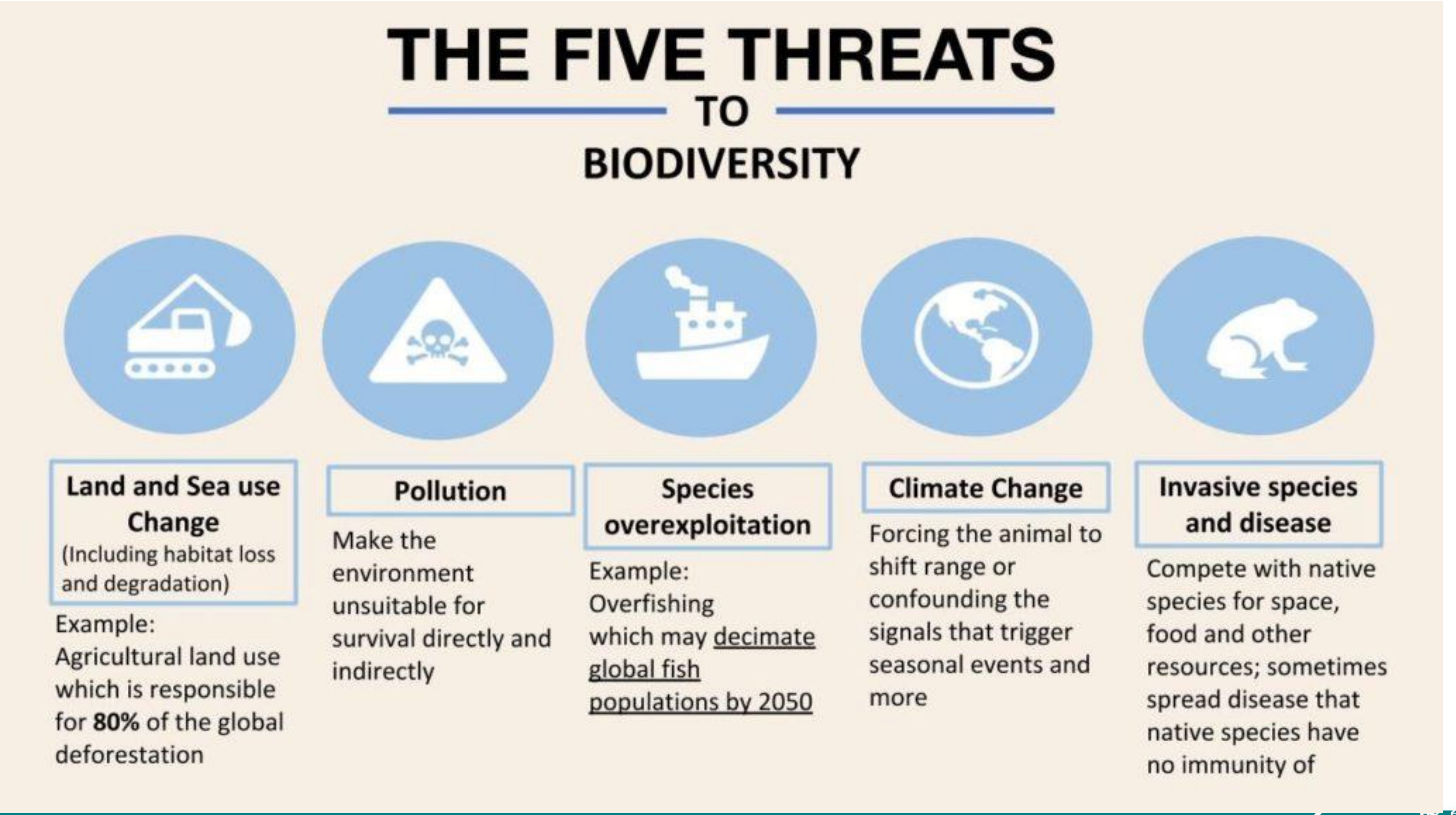
Source: https://phys.org/news/2020-09-biodiversity-loss.html



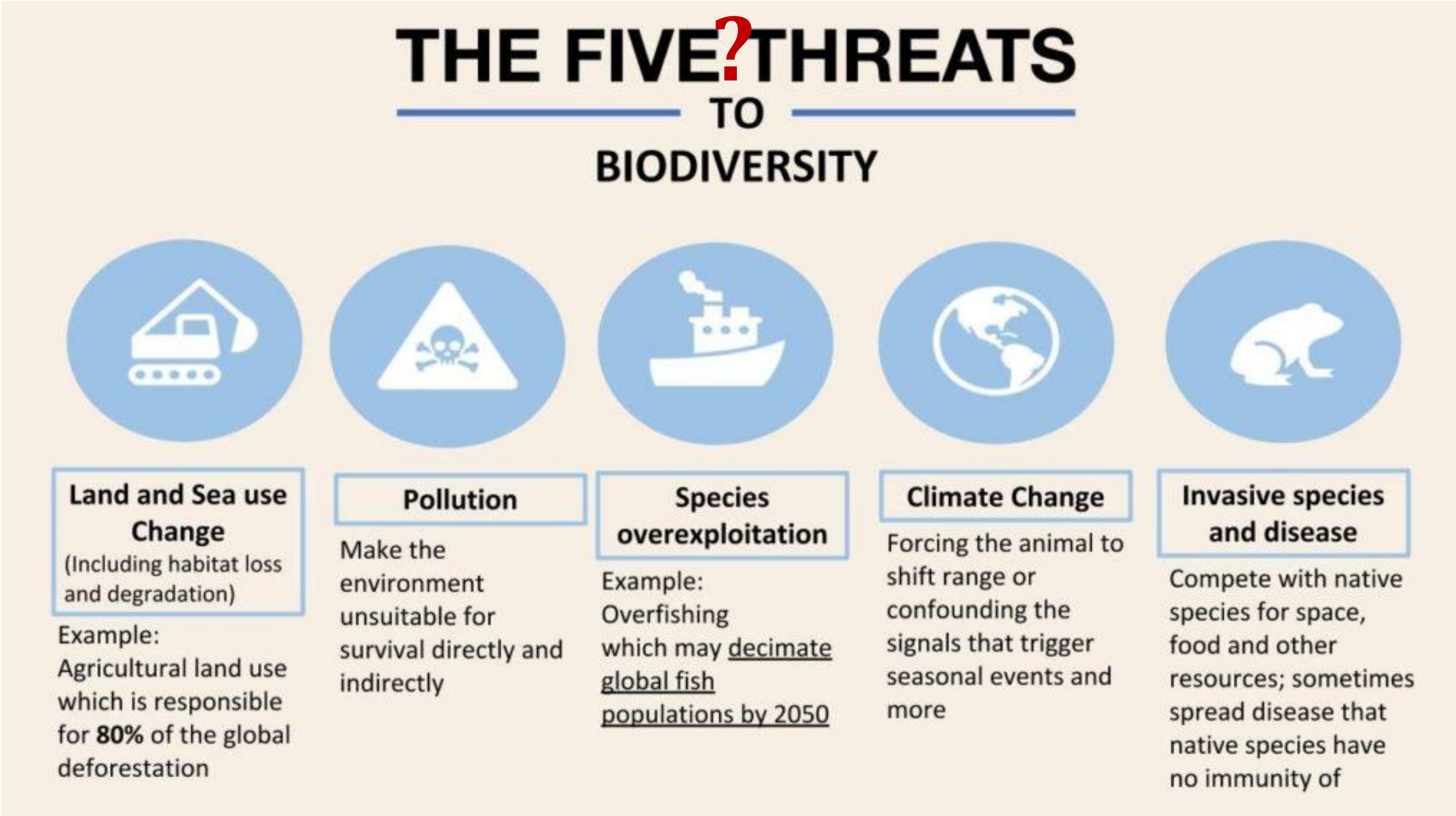
Source: Hulme (2021). One Earth. https://doi.org/10.1016/j.oneear.2021.04.015

Drivers of change: biodiversity loss

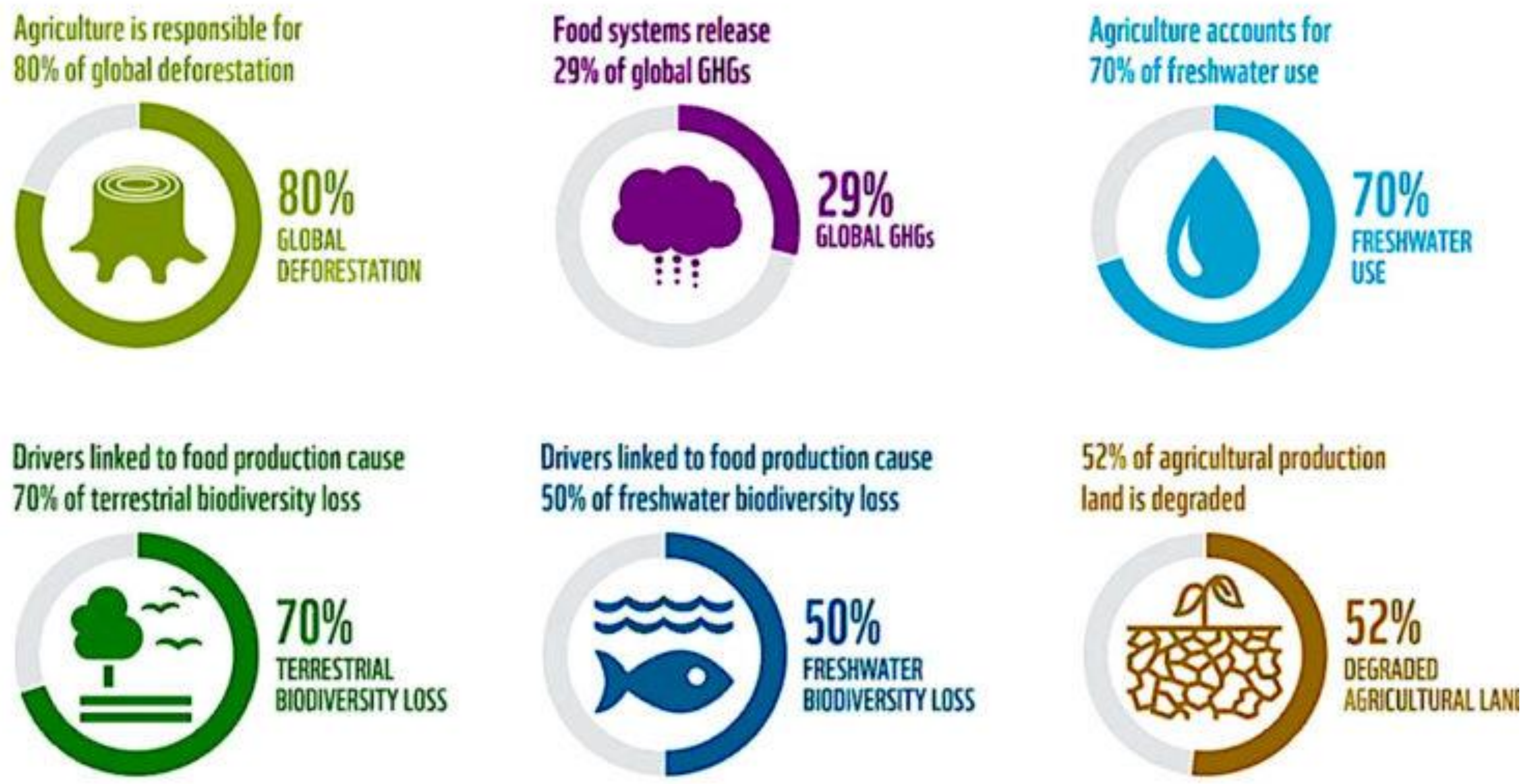
Source: www.earth.org



Could you give an example of agricutltural activities related to ?

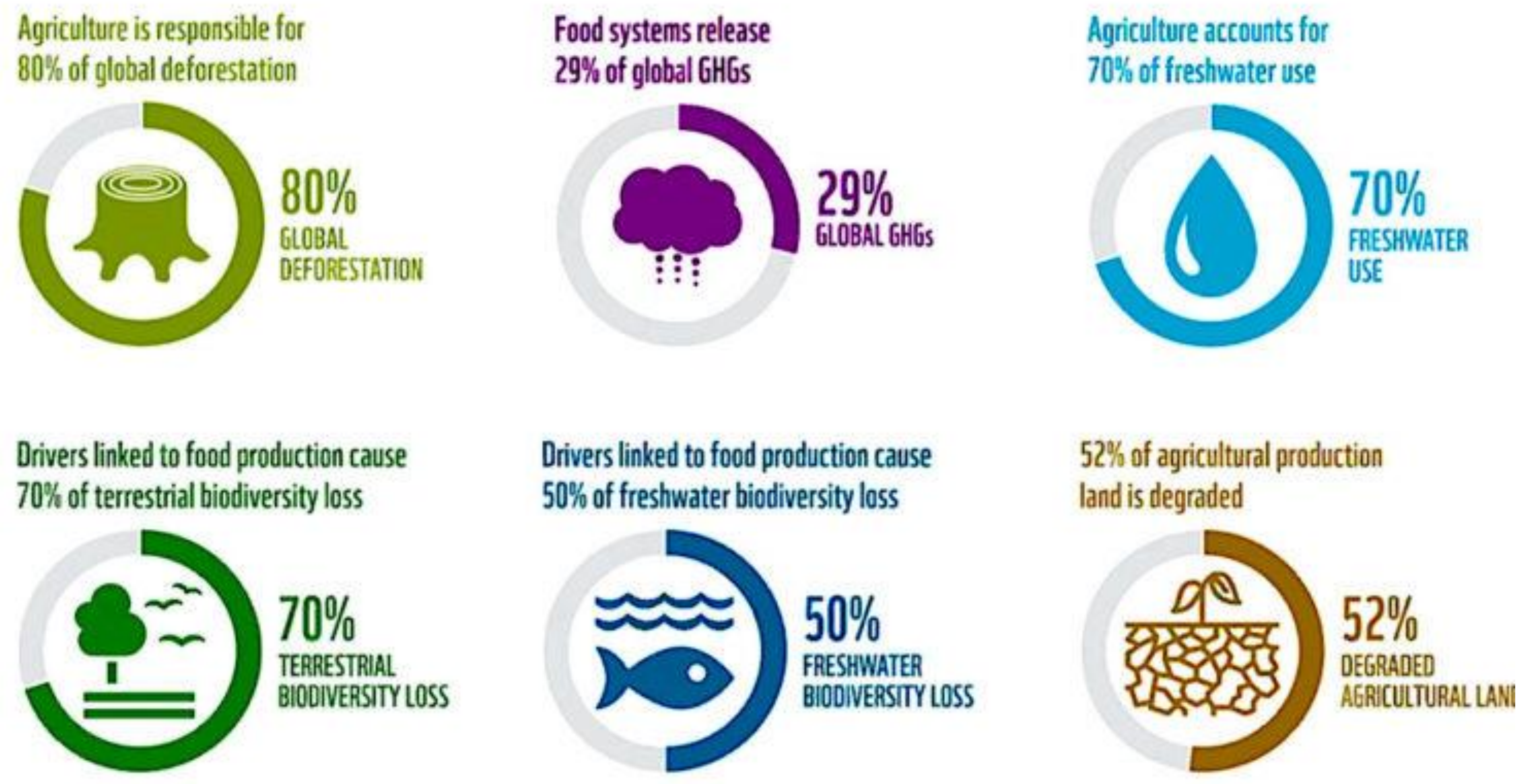


Drivers of change: biodiversity loss



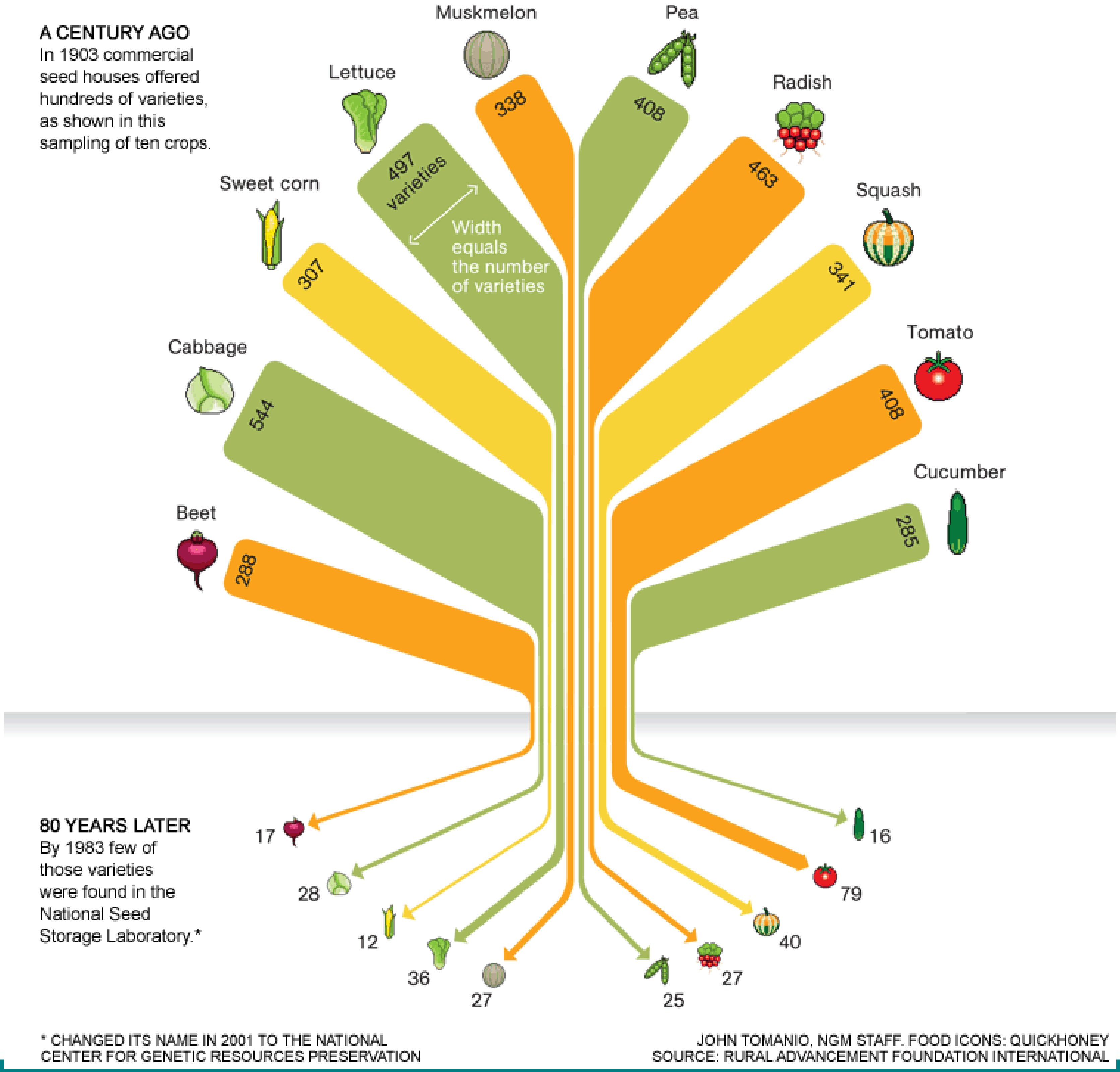
Source: https://india.mongabay.com/2020/09

Could you think to some measures that may mitigate agricultural negative externalities?



Source: https://india.mongabay.com/2020/09

Drivers of change: agrobiodiversity loss



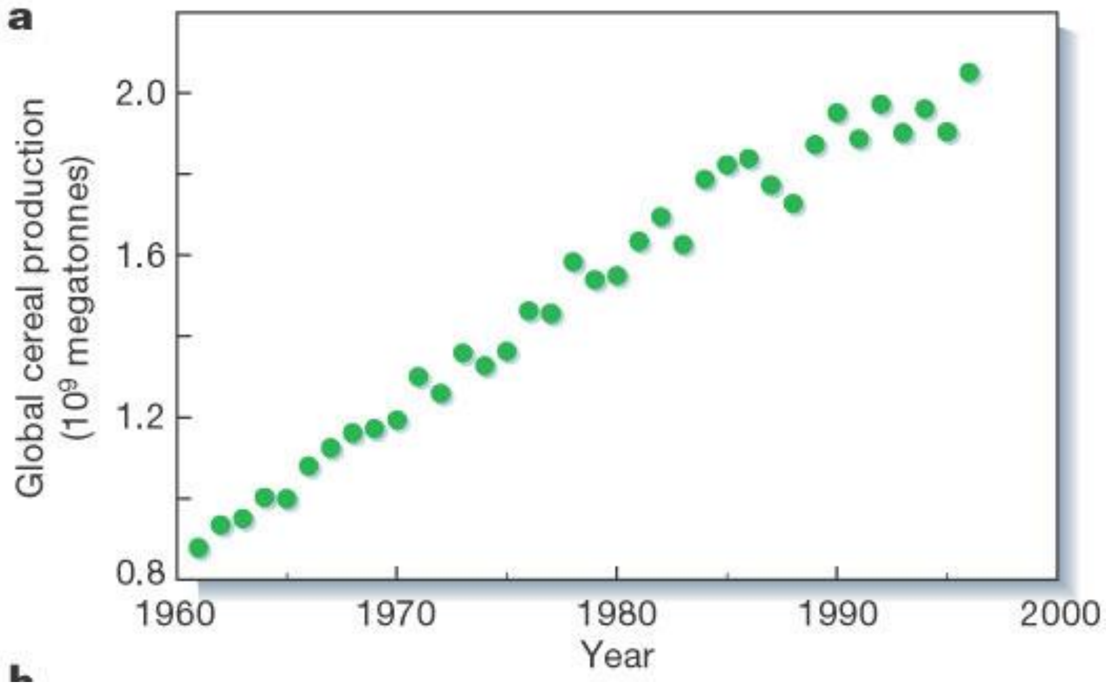
TOTAL # OF VARIETIES

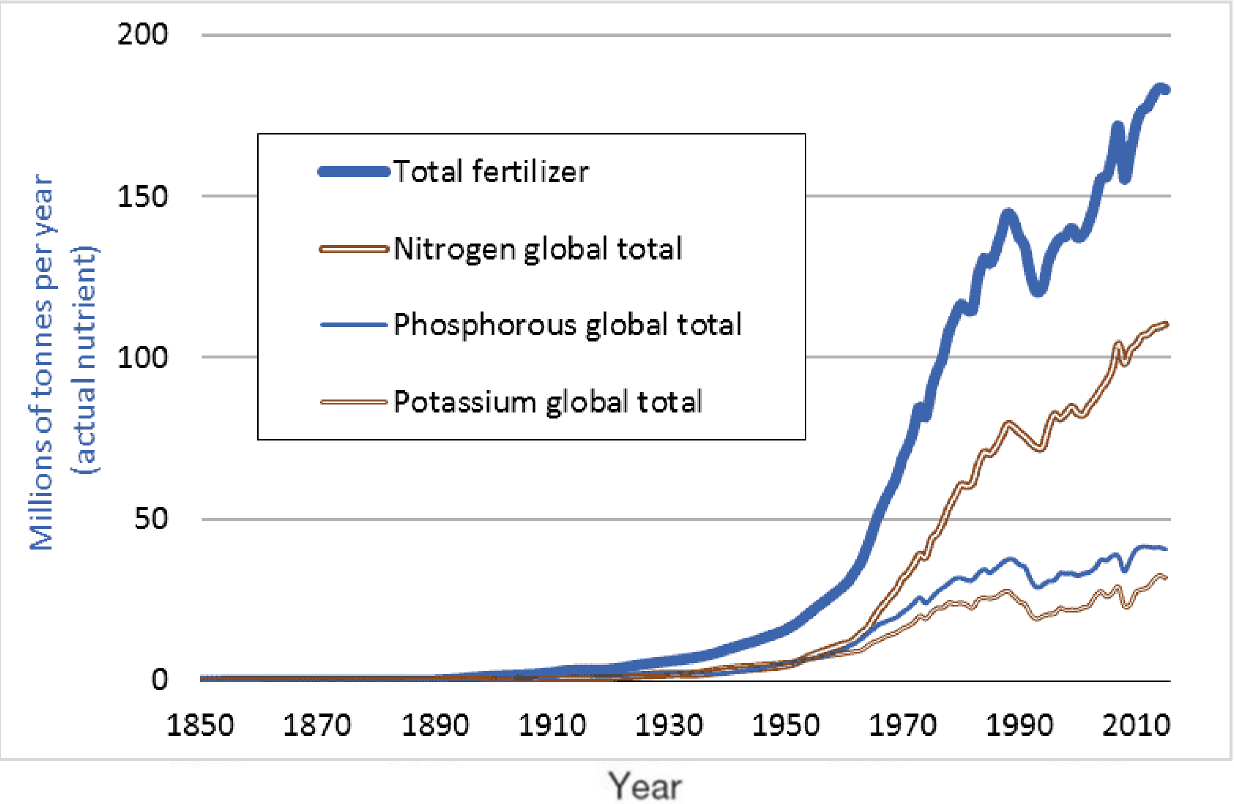
1903: 3879

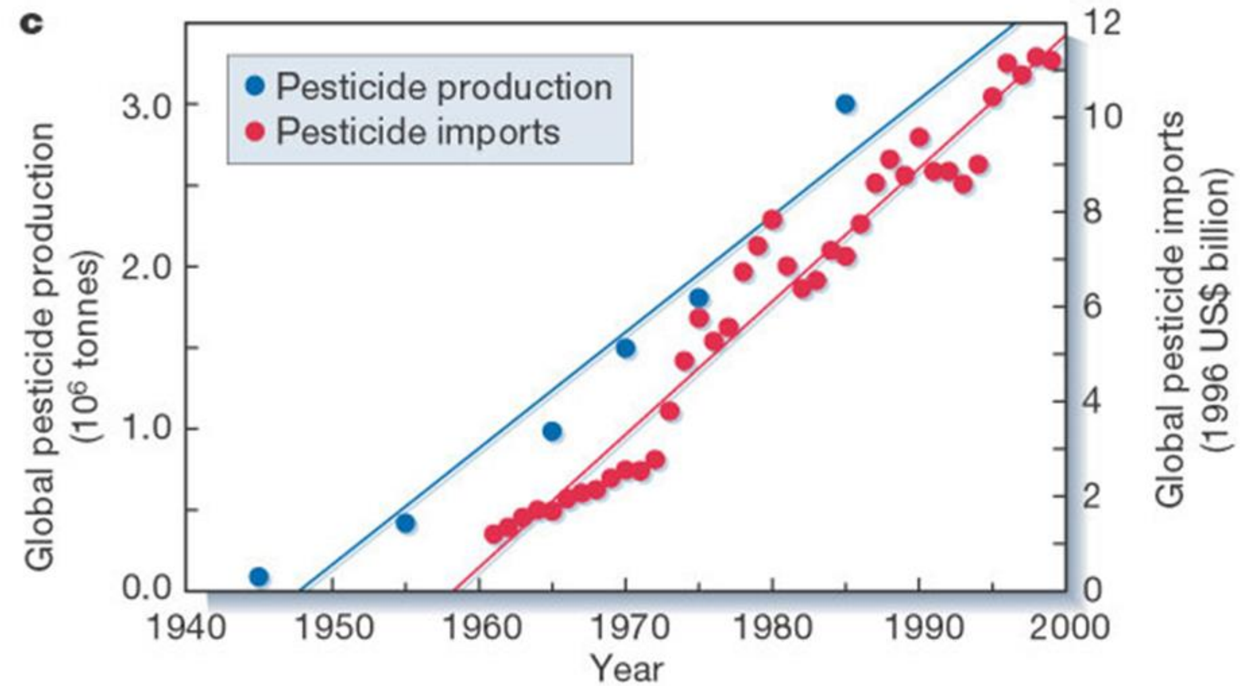
1983: 307

-92.1%

Come ci siamo arrivati?
Breve storicizzazione







Agricultural sustainability and intensive production practices,
Tilman et al., Nature 418, 671-677(8 August 2002) doi:10.1038/nature01014

Conventional Agriculture

hyper-Simplification → Control ecosystem services (provisioning

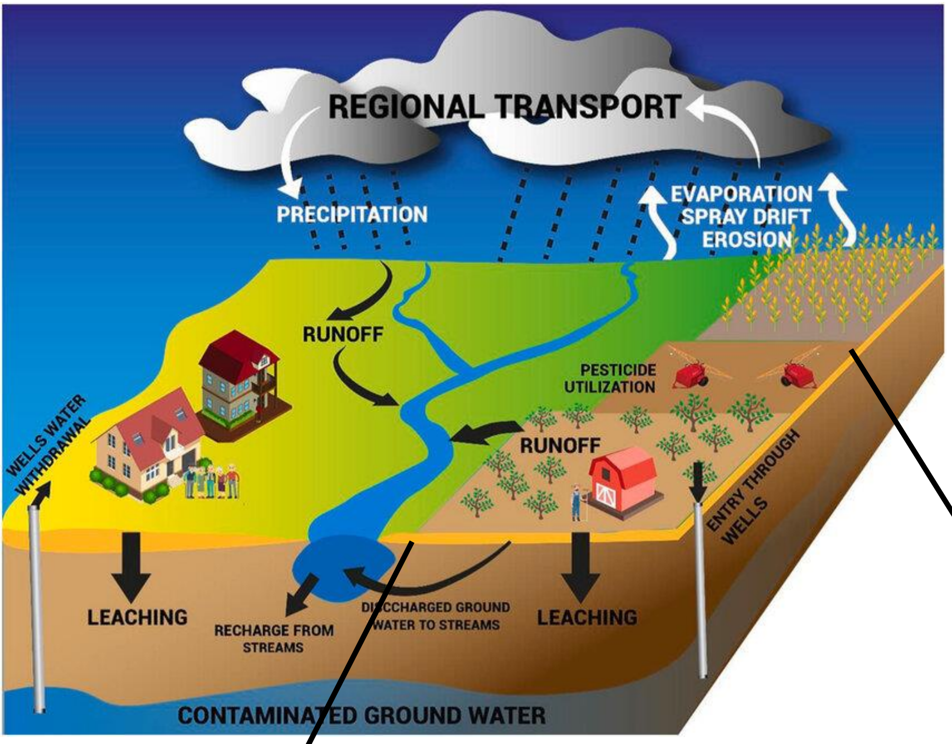
aiming at: increase of each single process efficiency

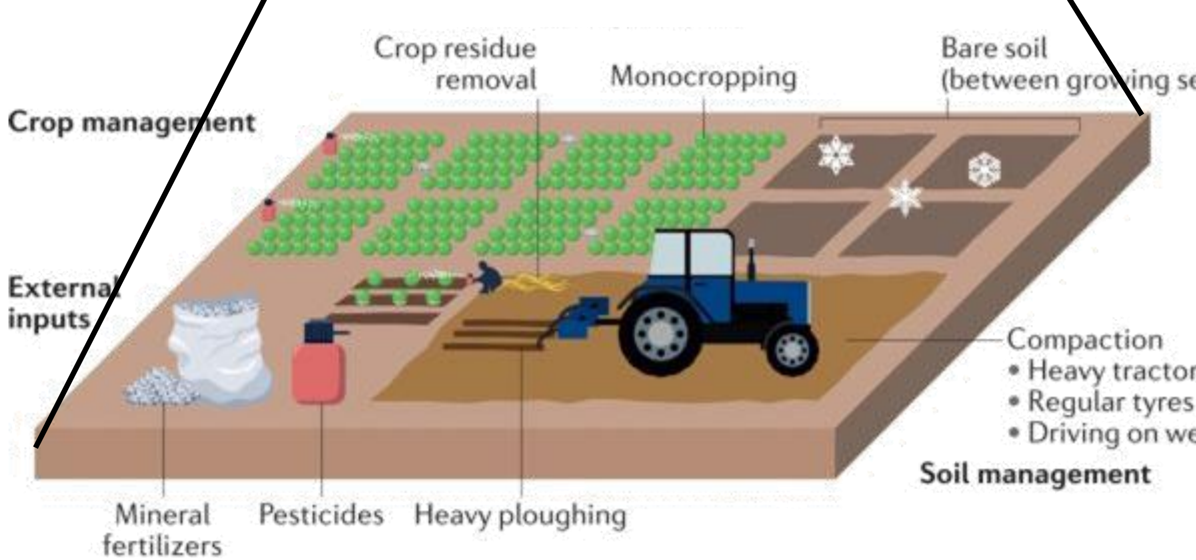
Supportingn and regulating ES substitution

Scaling-up means of material production:

- Meccanization
- Synthetic inputs
- Pesticide: (insecticides herbicides fungicides)
- Fertilizers.
- **Genetics selection developed in simplified context**

Conventional Agriculture Externalities





Water pollution from synthetic products and excess nutrients; over 38% of surface water bodies are affected by diffuse pollution, mainly from agriculture (EEA, 2018)

Pesticide residues in agricultural products have eroded public trust and raised concerns about food safety. EFSA reported that over 3.9% of food samples analysed contained pesticide residue levels above the legal limits (EFSA, 2023)

Greenhouse gases from agricultural activities accounts for around 10% of the European Union's emissions (EC, 2022)

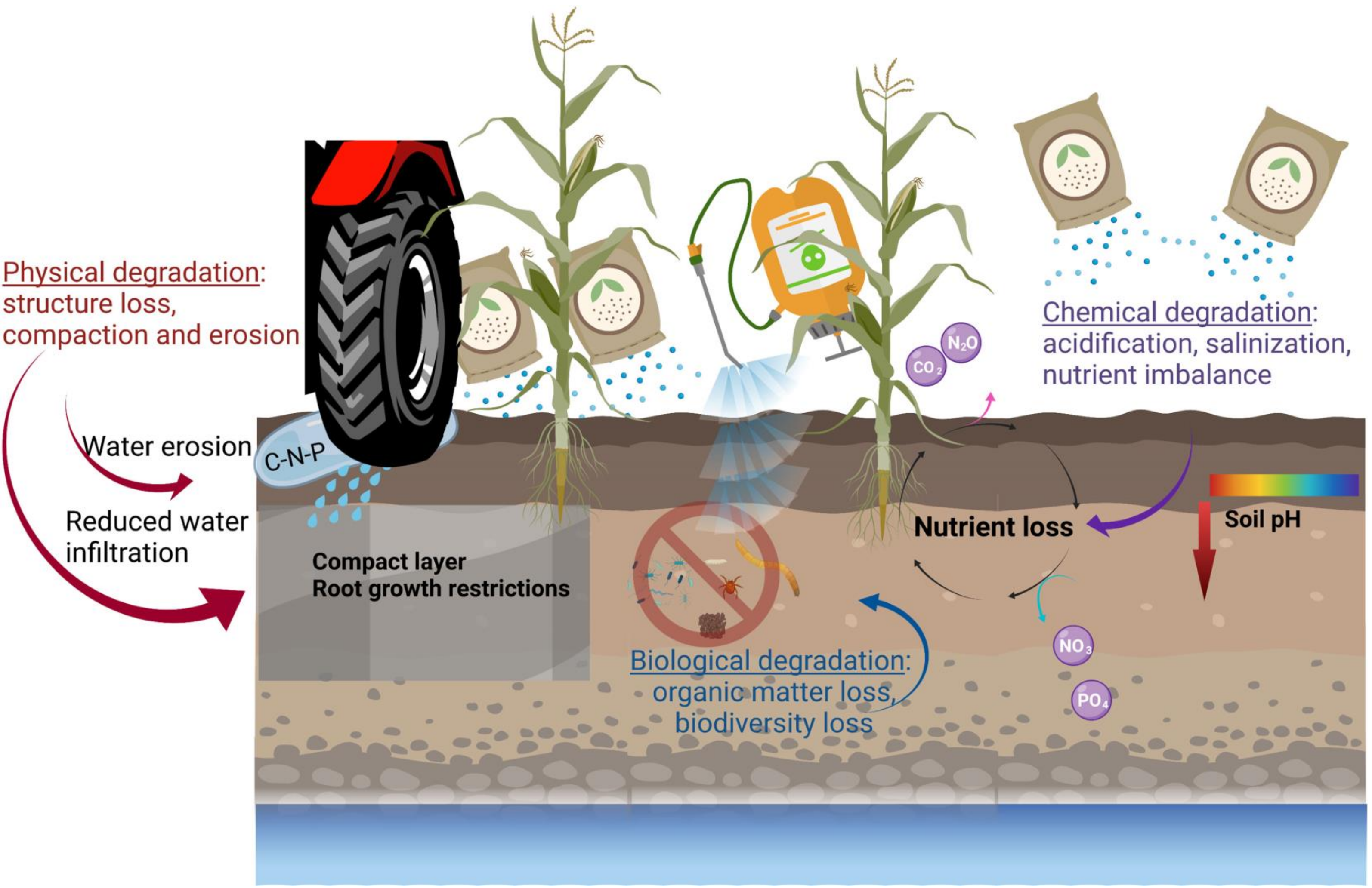
Habitats loss have led to a concerning **loss of biodiversity** Agriculture has been the primary driver of biodiversity loss in Europe, with over 60% of EU-protected habitats and species associated with agricultural land in unfavourable conservation status (EEA, 2020)

Pirsaheb, Meghdad & Moradihamadani, Negin. (2020). Sonochemical degradation of pesticides in aqueous solution: investigation on the influence of operating parameters and degradation pathway – a systematic review. RSC Advances. 10. 7396-7423. 10.1039/C9RA11025A.
EEA (2018). European Waters: Assessment of Status and Pressures 2018. European Environment Agency Report No 7/2018. Retrieved from https://www.eea.europa.eu/publications/state-of-water
EFSA (2023). The 2021 European Union Report on Pesticide Residues in Food.. Retrieved from https://efsa.onlinelibrary.wiley.com/doi/full/10.2903/j.efsa.2023.7939
EC (2022). Agri-food data portal: Agri-environmental indicator - greenhouse gas emissions. European Commission. Retrieved from https://agridata.ec.europa.eu/extensions/DashboardIndicators/FarmStructures.html
EEA (2020). State of Nature in the EU: Results from reporting under the nature directives 2013-2018. European Environment Agency Report No 10/2020. Retrieved from https://www.eea.europa.eu/publications/state-of-n

Conventional Agriculture direct treats

Long-term Perspective:

soil health degradation, driven by the depletion of **organic matter** and the loss of **soil biodiversity**, threatens the very foundation of agricultural productivity.



Over 60% of European soils are degraded, with soil erosion, compaction, and loss of organic matter being the most significant threats (JRC, 2021).

This degradation undermines the vital functioning mechanisms that support crop growth and ecosystem services.

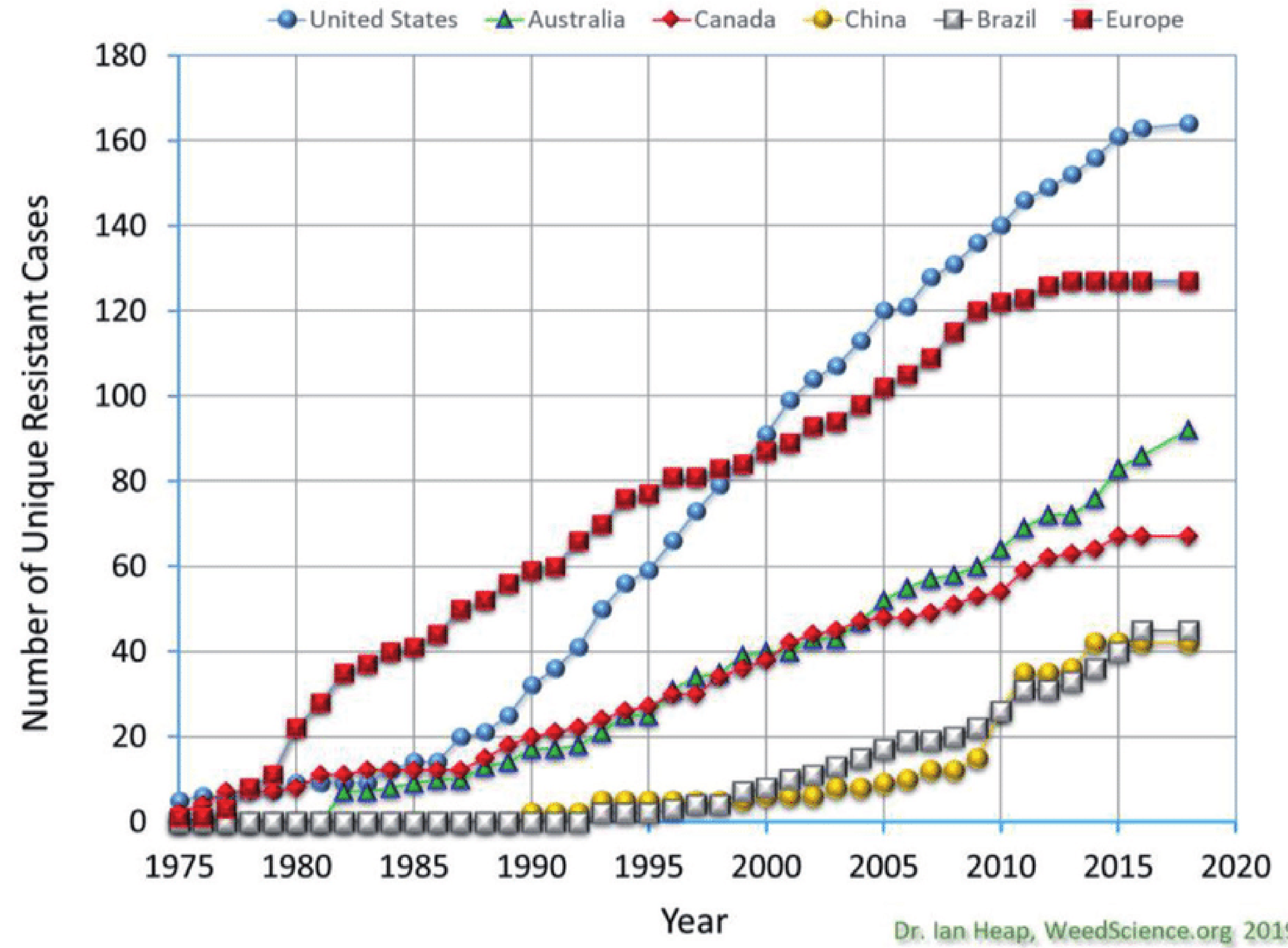
Conventional Agriculture direct treat

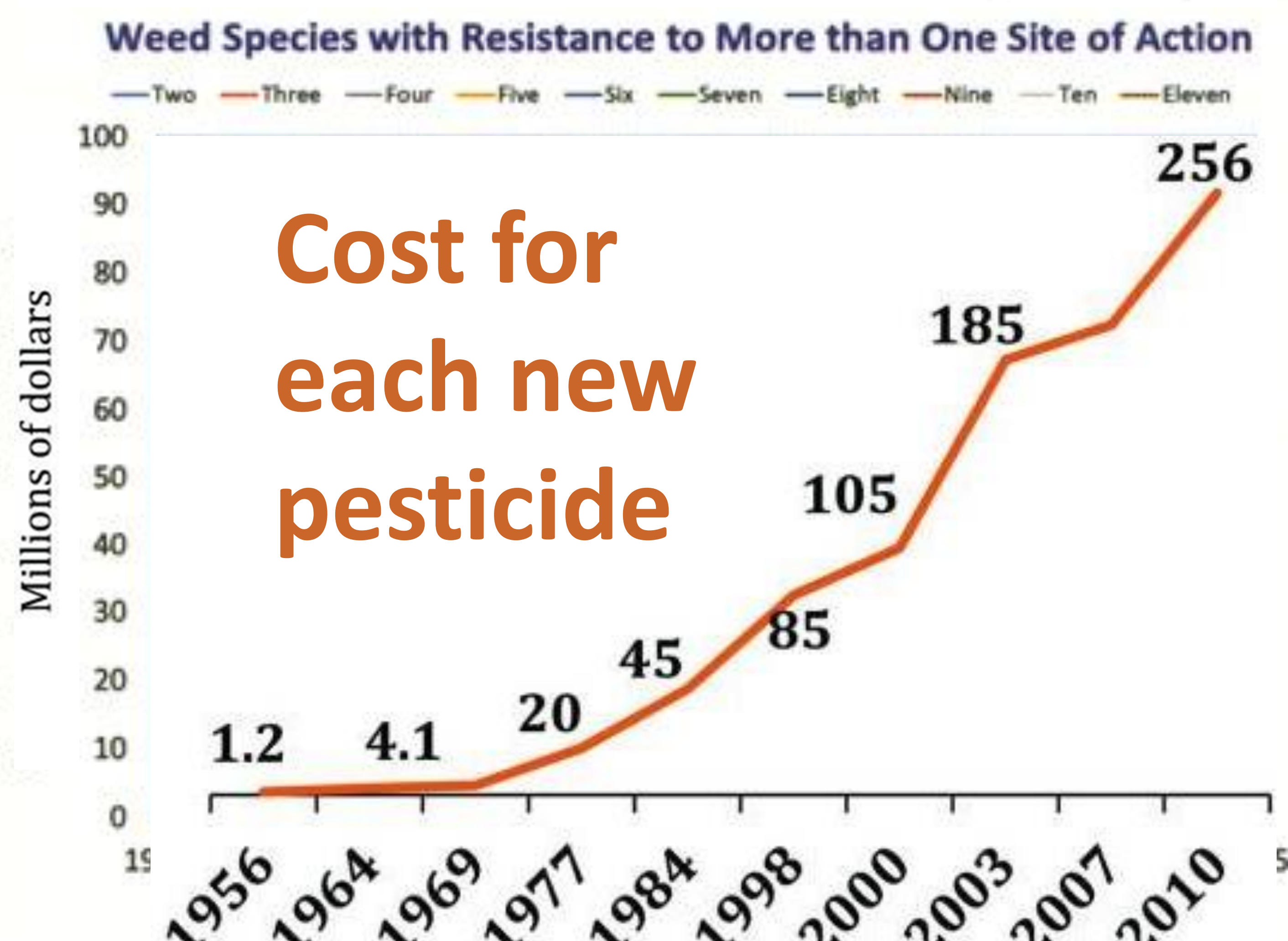
Short-term Perspective:

The overreliance on synthetic inputs and control measures has led to the emergence of **resistance** in pests and weeds.

The International Survey of Herbicide Resistant Weeds reported that, as of 2022, there were 505 unique cases of herbicide-resistant weeds globally, with over 100 cases reported in Europe (Heap, 2022).

This resistance poses a significant challenge to the efficacy of current weed management strategies.



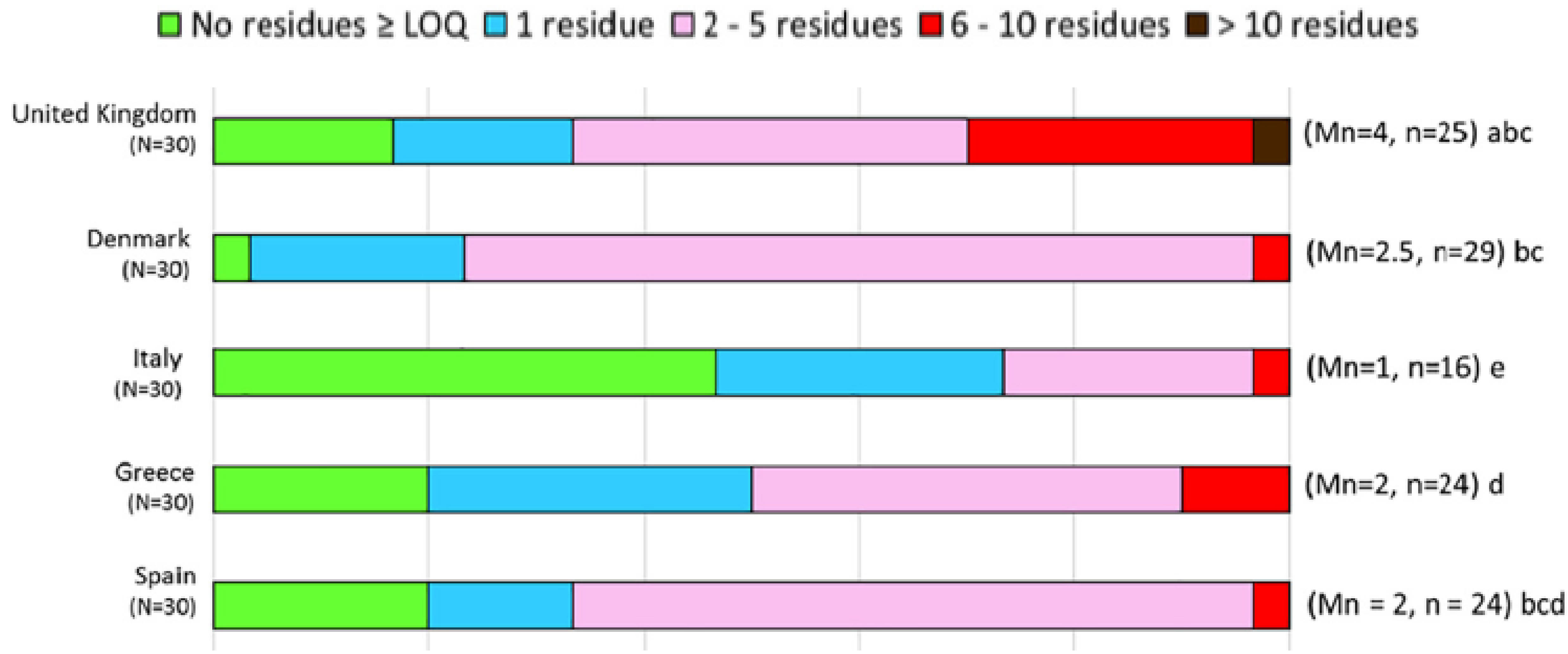


Glare, T.; Caradus, J.; Gelernter, W.; Jackson, T.; Keyhani, N.; Köhl, J.; Marrone, P.; Morin, L.; Stewart, A *Trends Biotechnol.* **2012**, *30*, 250–258.

Drivers of change: soil pollution by pesticides

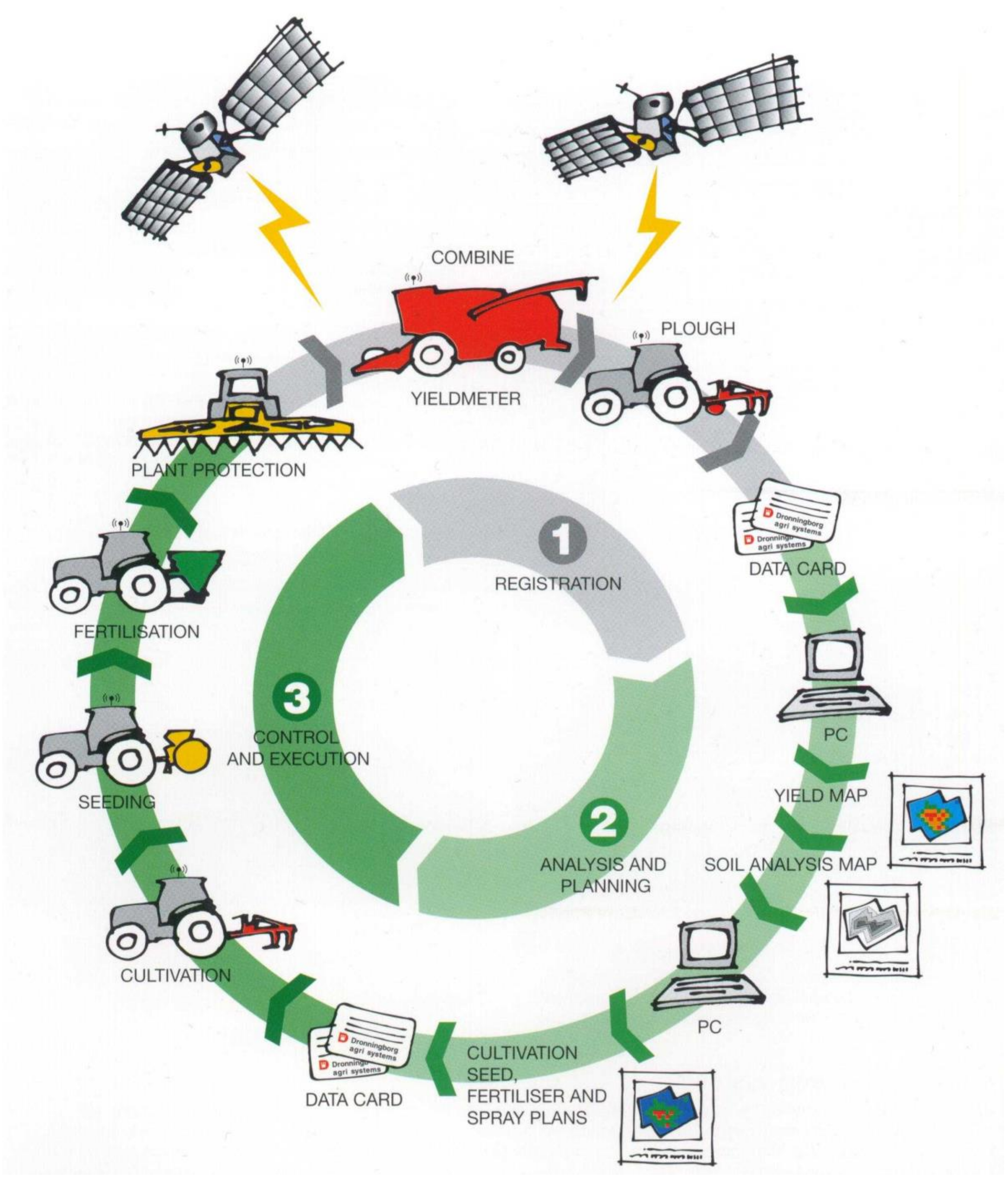
Limits of quantification:
0,01 mg/kg (LC-MS/MS multi); 0,005 mg/kg (GC-HRMS); 0,05 mg/kg (glyphosate/AMPA)

(Liquid Cromatography & Mass Spectrometry; gas chromatography-high-resolution mass spectrometry; aminomethylphosphonic acid)



Silva et al. (2019). Sci. Tot. Env. 653, 1532-1545

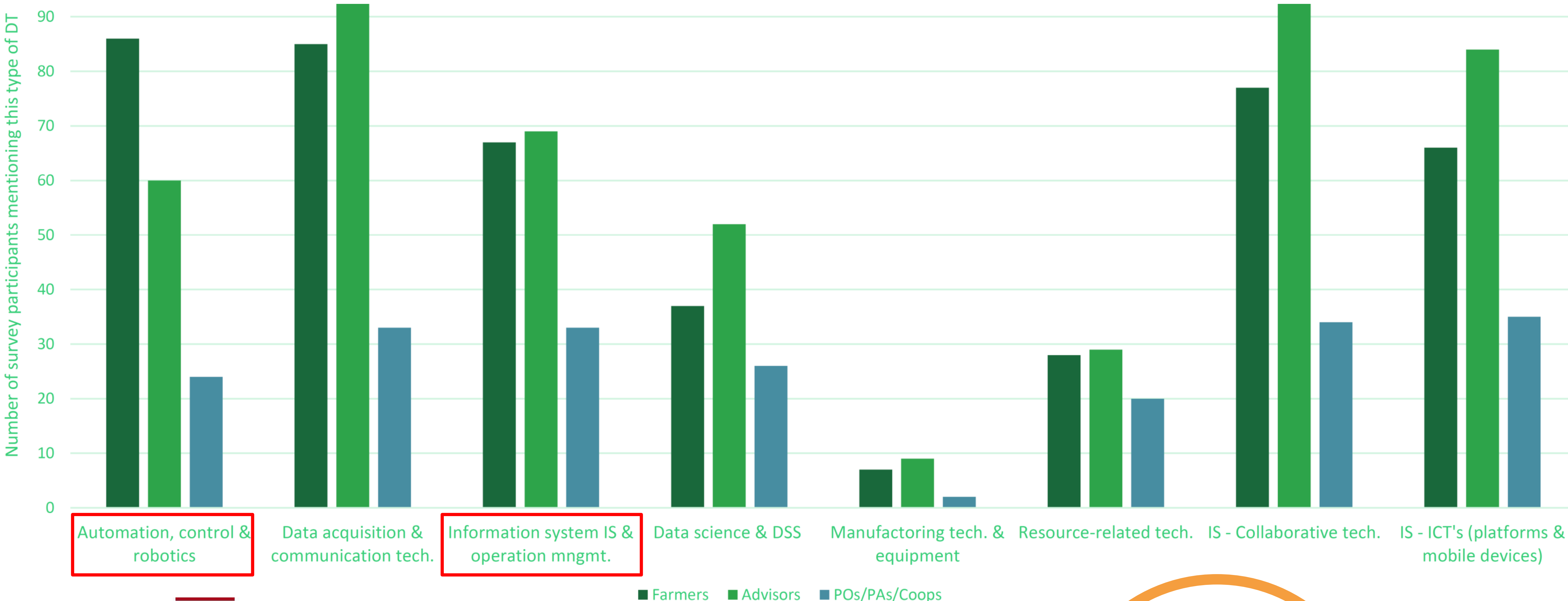
Agriculture 3.0 Can it be the solution?

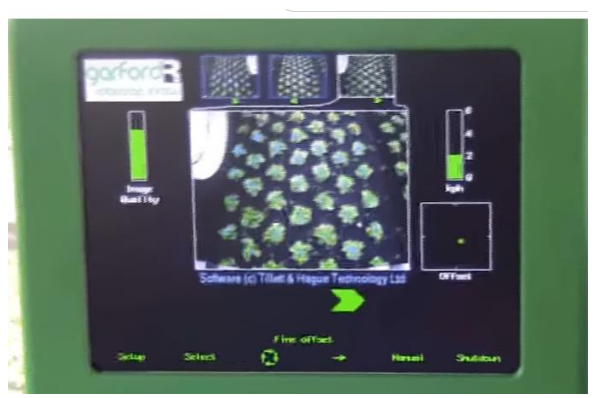


"Precision Farming improves the accuracy of the operations, managing in-field variability.
The goal is to ***optimise*** *the agronomic output while reducing the input ('more with less')"*

CEMA aisbl - European Agricultural Machinery

Digitalization 4.0, some examples?





Use robotics/automation for field operations with lower environmental impact and optimization of effectiveness, such as fungal disease or insect management.

Uv-c application to prevent powdery mildew (Oidium)

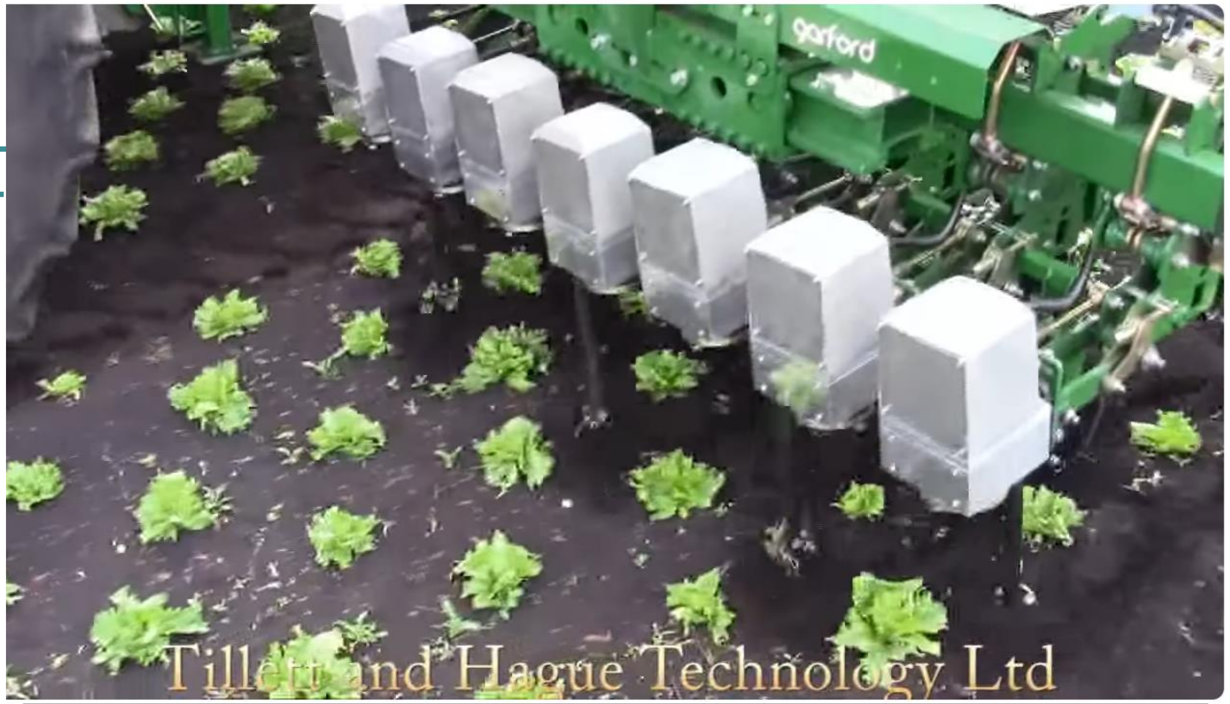
AgroRobot remove bugs throught vacuum

Did you see any diversity?

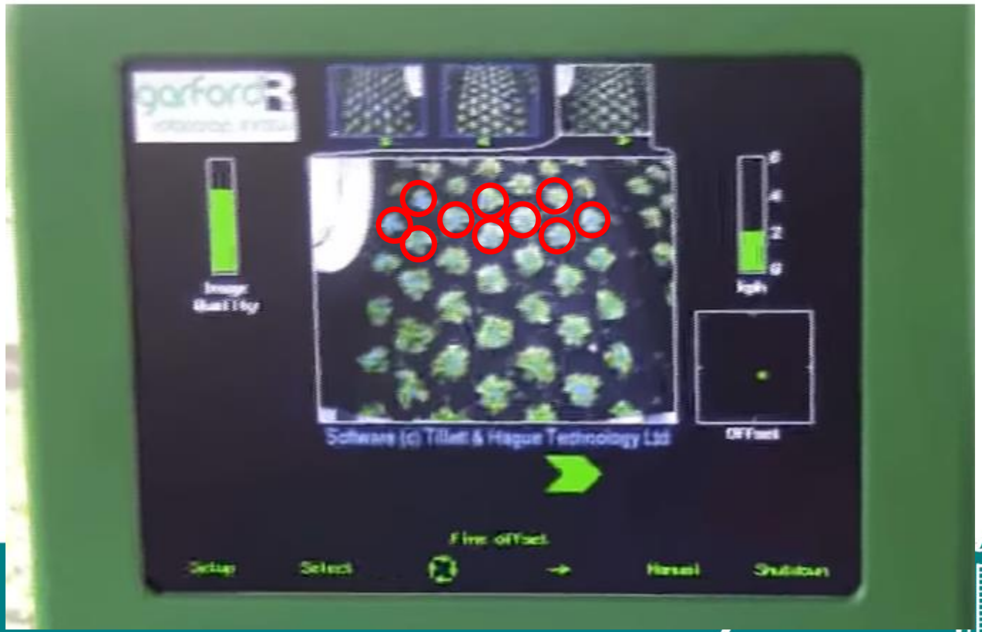
Very effective and smart application of a **substitution approach.**

Use robotics/automation for field operations with lower environmental impact and optimization of effectiveness, such weed management.

Automation of tractor:
horticulture, as vineyard;
high revenue labour intensive crop



Robocrop in row weeder recognize the crop and remove ALL the weeds



Main goal: reduce labour effort

Automation to reduce labour effort

Robocrop: avoid lot of hours of hard unspecialized work

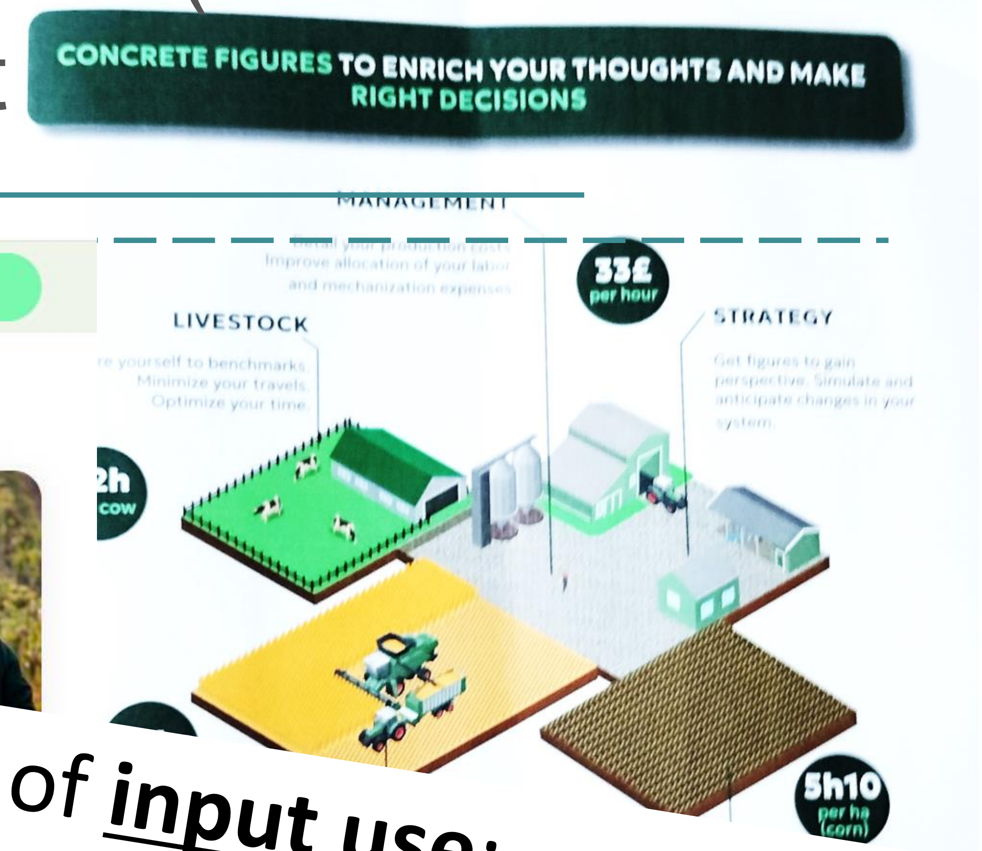
Automation of tractor:
Allow to avoid 1 driver

Take many decisions based on RTK and image processing.
No increase in complexity; quantitative change

Take a **decision**: start a process of autonomous field management based on image management.

Increase in complexity of management;
Offer the opportunity to start a qualitative change

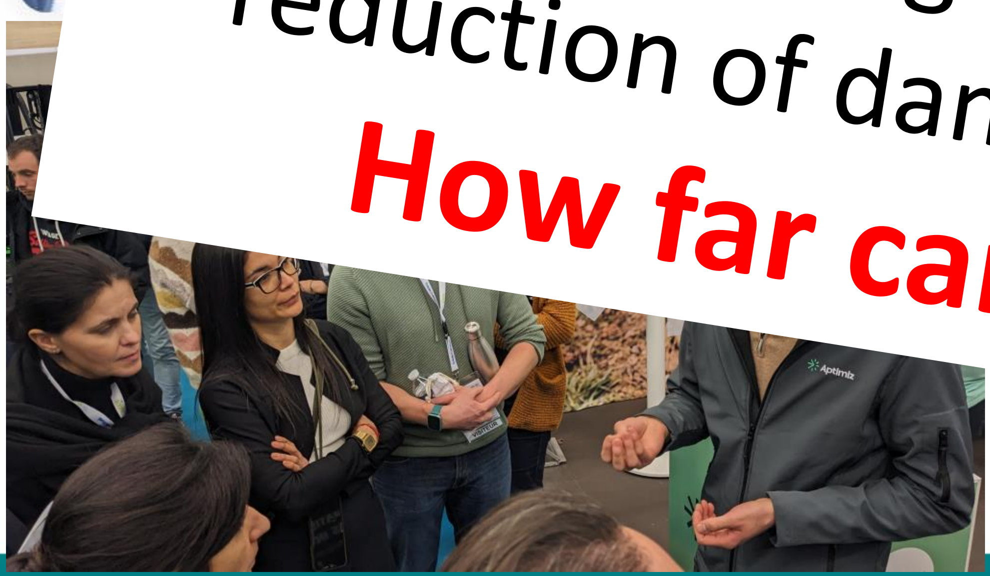
Use of sensors for any mean of production (even workers) to optimize farm management



Digitalization here is increase efficiency of **<u>input use</u>**;
or to **substitute** pesticide with physical solutions;

Methodologically it is still Agriculture 2.0 +
"reduction of damage" or "substitution approach"

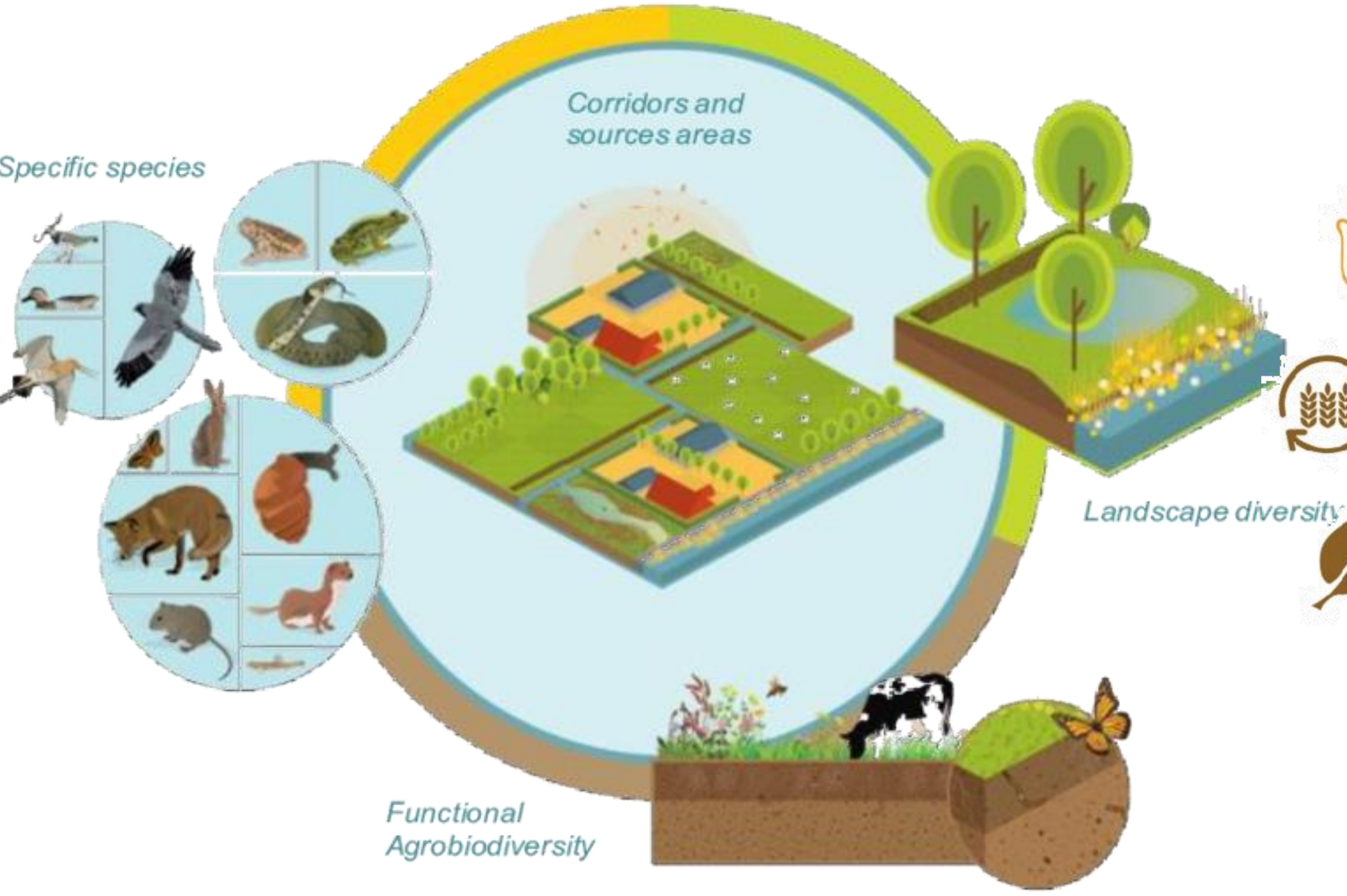
How far can inputs be optimized?

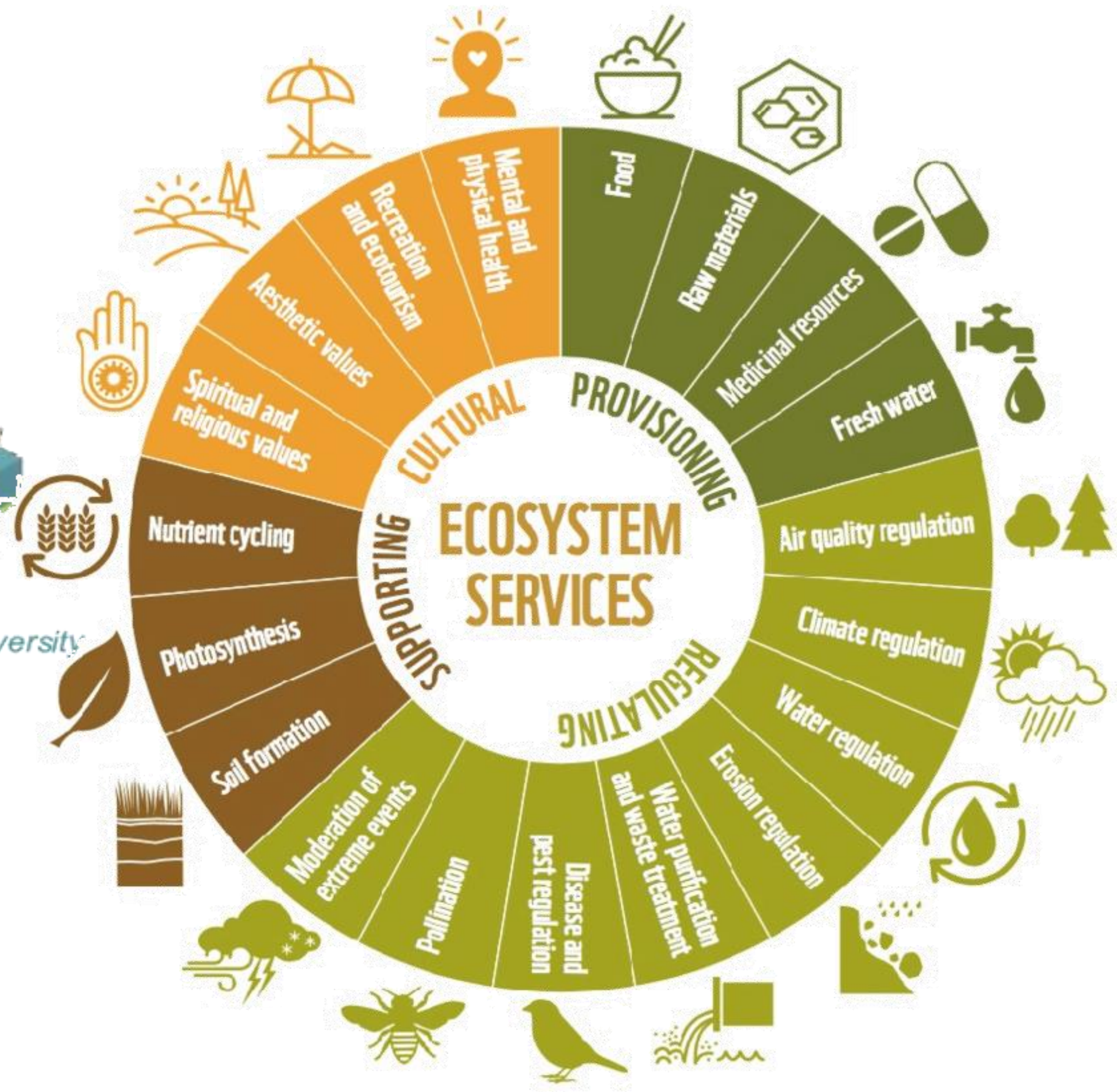


SIVAL, Angers 2024

Agroecological lens:

Agroecological lens:

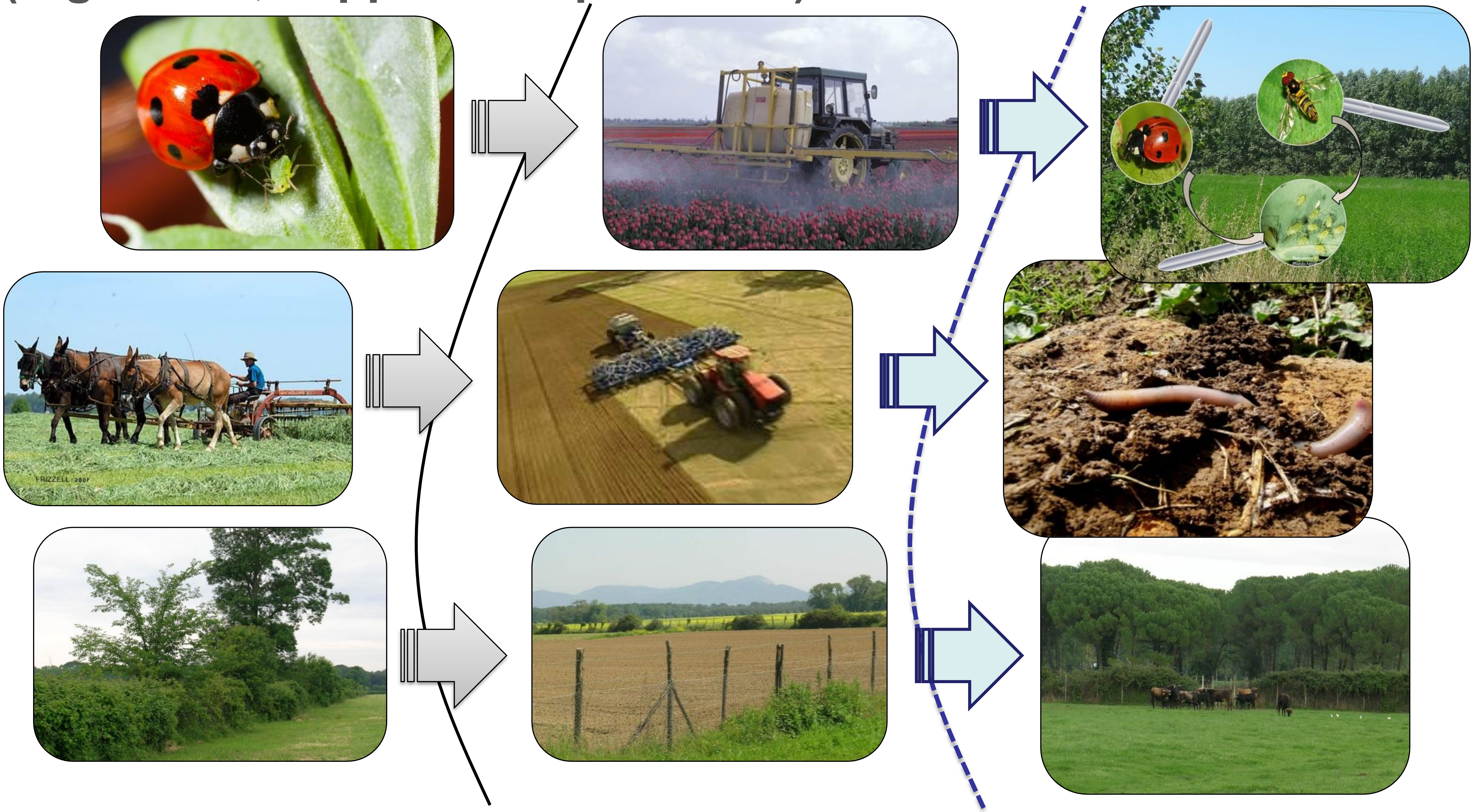




Erisman, Jan Willem & van Eekeren, Nick & De Wit, Jan & Koopmans, C.J. & Cuijpers, W.J.M. & Oerlemans, Natasja & Koks, B.J.. (2016). Agriculture and biodiversity: A better balance benefits both. AIMS Agriculture and Food. 1. 157-174. 10.3934/agrfood.2016.2.157.

WWF, 2016 (adapted from Millennium Ecosystem Assessment, 2005)

Using diversity (complexity) in the agroecosystem to obtain servic (regulation, support and provision).



Agroecologia:
Sostenibilità Economica, Sociale ed Ambientale

La sostenibilità: soddisfare le necessità produttive del presente senza compromettere la capacità future.

I sistemi agroalimentari sostenibili sono quelli che riconoscono l'importanza della conoscenza e dell'uso rispettoso delle risorse naturali e della biodiversità locale, **pianificando i sistemi con una visione a lungo termine, con l'obiettivo di mantenere il loro potenziale di fornire servizi ecosistemici per le generazioni future** in modo economicamente sostenibile e socialmente giusto (Ikerd 2008).

Sostenibilità Economica

- **Riduzione dei Costi di Input:**
  L'agroecologia promuove l'uso di pratiche agricole che **riducono la dipendenza da input esterni** costosi come fertilizzanti chimici e pesticidi. Ad esempio, l'uso di compost e altre pratiche di fertilizzazione organica può ridurre i costi e migliorare la fertilità del suolo nel lungo termine.

- **Valorizzazione dei Prodotti Locali:**
  Promuovere e valorizzare i prodotti locali non solo sostiene l'economia regionale, ma può anche ridurre i costi di trasporto e migliorare la resilienza delle comunità locali. Ad esempio, la trasformazione dei sottoprodotti agricoli in nuovi prodotti commerciabili può creare nuove opportunità di mercato.

Sostenibilità Sociale

- **Creazione di Posti di Lavoro di qualità:**
  Le pratiche agroecologiche spesso richiedono manodopera più specializzata (knowledge intensive) rispetto all'agricoltura convenzionale, creando così posti di lavoro di qualità.

- **Coinvolgimento dei diversi attori della filiera:**
  L'agroecologia incoraggia la **partecipazione** dei diversi attori coinvolti nelo sviluppo dell processo produttivo, nella gestione dei processi di transizione e di impiego delle risorse naturali e dell'agroecosistema. Questo può rafforzare il tessuto sociale e migliorare la coesione comunitaria, cercando di gestire I conflitti attraverso un approccio cooperativo e multi attoriale.

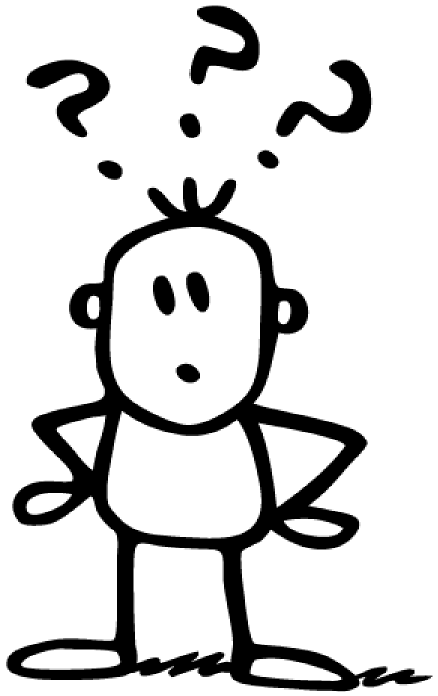
Sostenibilità Ambientale

- **Conservazione della Biodiversità:**
  L'agroecologia promuove l'utilizzo della biodiversità funzionale e l'integrazione di specie animali e vegetali, contribuendo alla conservazione della biodiversità.

- **Riduzione dell'Impatto Ambientale:**
  Le pratiche agroecologiche mirano a ridurre le esternalità negative dell'agricoltura "convenzionale" attraverso l'uso consapevole delle risorse non rinnovabili ed un utilizzo **rigenerativo** delle risorse naturali potenzialmente rinnovabili.

From Agrobiodiversity to Functional Agrobiodiversity

- **Functions** or **services**? A terminological dilemma
- In an agroecosystem perspective **functions** and **services** tend to coincide
- Which functions (services)?
  - Productivity (of crops/livestock)
  - Soil nutrient cycling (crop nutrition)
  - Biological control (of crop pests)
  - (Weed suppression)
  - Mitigation/adaptation to climate change
  - …
- Both production- and non-production-related services matter



Can biodiversity deliver agroecosystem functions (services)?

Not all biodiversity is useful in agroecosystems

Positive → *service*

Negative → *disservice*

Neutral

The useful (functional) part of biodiversity must be selected and fine-tuned to every given context (agroecosystem)

↓

Traits

Many people tend to confuse **biofunctionality** with **functional biodiversity**

Functional agrobiodiversity: categories

Agron. Sustain. Dev. (2014) 34:327–348
DOI 10.1007/s13593-013-0178-1

REVIEW ARTICLE

Functional agrobiodiversity and agroecosystem services in sustainable wheat production. A review

Ambrogio Costanzo • Paolo Bàrberi

- **Functional** ***identity (bio functionality)***

The presence of a set of homogeneous phenotypic traits related to the expression of an ecosystem service (e.g. a smothering **cover crop species**)

- **Functional** ***composition*** (i.e. complementarity)

The complementary effect of different traits, expressed by co-occurring elements, on the expression of an ecosystem service (e.g. the smothering effect of **intercropping**)

- **Functional** ***diversity s.s.***

The direct effect of heterogeneity within the crop stand on the expression of an ecosystem service (e.g. the smothering effect of **a genetically diverse crop stand**)

Costanzo & Bàrberi (2014). Agronomy for Sustainable Development 34, 327-348.

This picture depicts a problem: which one?

Picture from http://www.vegetablegardener.com/

Defining the Service

We can define the target **Agroecosystem service:**

Reduce aphids population

In the agroecosystem, who can reduce aphids population?

Picture from here

Defining the functional group

Based on the target **Agroecosystem service**, we define the **Agroecosystem Functional Group**

Natural enemies of aphids

Picture from here

Picture from here

Picture from here

How can they reduce aphids population?

Defining the functional group

Based on the way the elements included in the Agroecosystem Functional Group express the service, this group can be split in

Trait-based functional groups

Natural enemies of aphids

Parasitoids | **Predators**

And we can go deeper…

Bio-Functionality

- In synthesis

  0) What to do?

  – **Reduce aphids population:**
    The Agroecosystem service

  1.1) Who can do it?

  – **Natural enemies of aphids**
    The Agroecosystem Functional Group

  1.2) How they do it?

  – Predation → **predators**
  – Parasitism → **parasitoids**
    Trait-based Functional Groups within the Agroecosystem Functional Group

Parasitoids

Predators

From Bio-Functionality …

Now, I can say this:

The service «**reducing aphids population**»

… is expressed by the **presence of «Natural Enemies»** …

… which can be «predators» or «parasitoids»

One species of predators is enough

I defined the «Bio-Functionality»

Identification of the functional groups

… to Functional Diversity

Once defined the **Bio-functionality**, if I say that:

The service «**reducing aphids population**»

Within-group diversity

… is **better expressed** by the presence of **3 different species** of natural enemies **instead of just 1**

I'm talking of Functional Diversity

… to Functional Diversity

or even that:

The service «**reducing aphids population**»

… is **better expressed** by the **co-presence** of **predators AND parasitoids** instead than by just one of the two groups

I'm talking of Functional Diversity

Within-group diversity

Parasitoids

Predators

The big question:

how can diversity improve services?

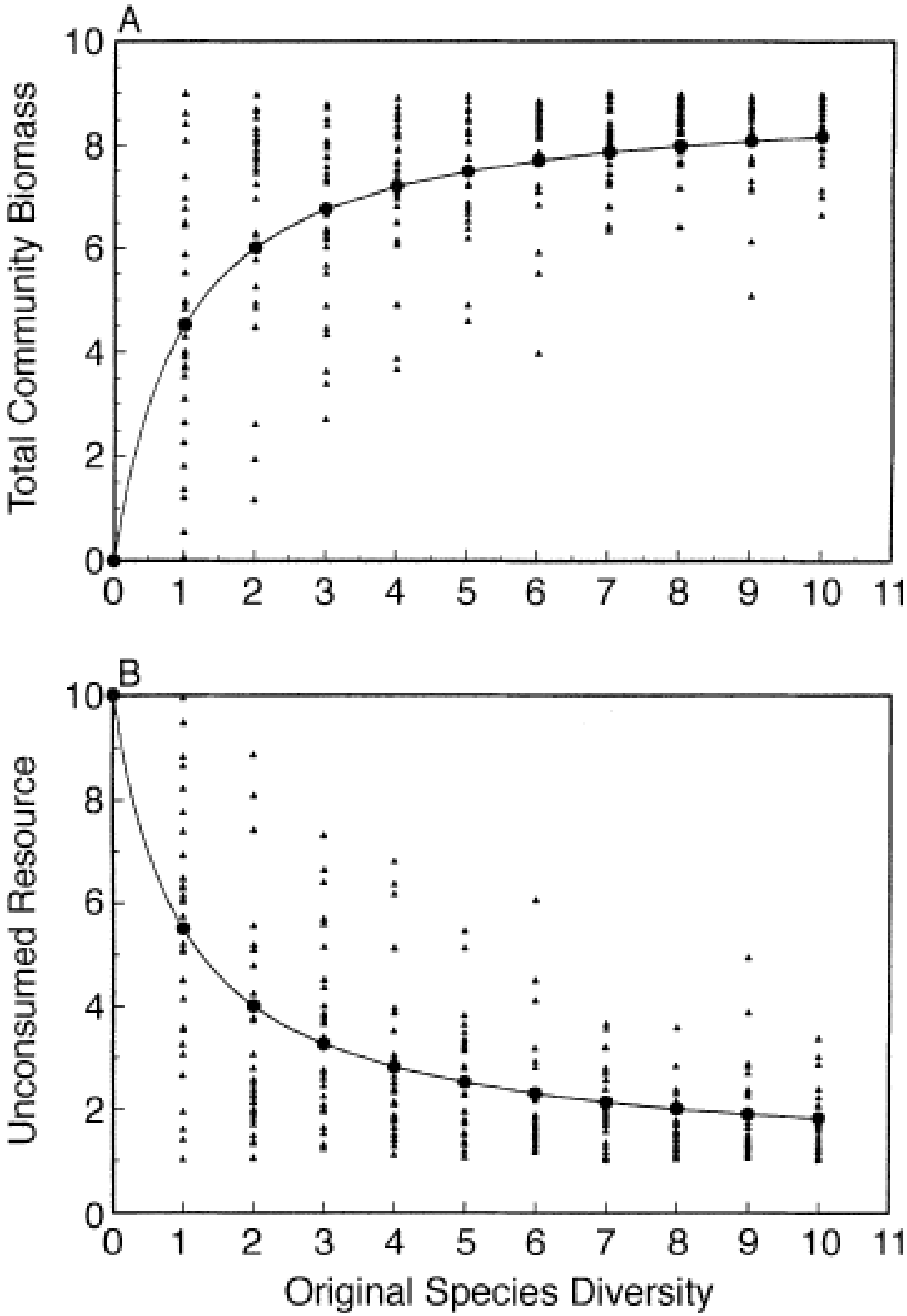
There are many possible answers.

This simulation shows that,

with higher species richness:

A. Total biomass increases

B. Resources are more efficiently consumed



Tilman (2001)

The big question:

how can diversity improve services?

Here is an experimental example

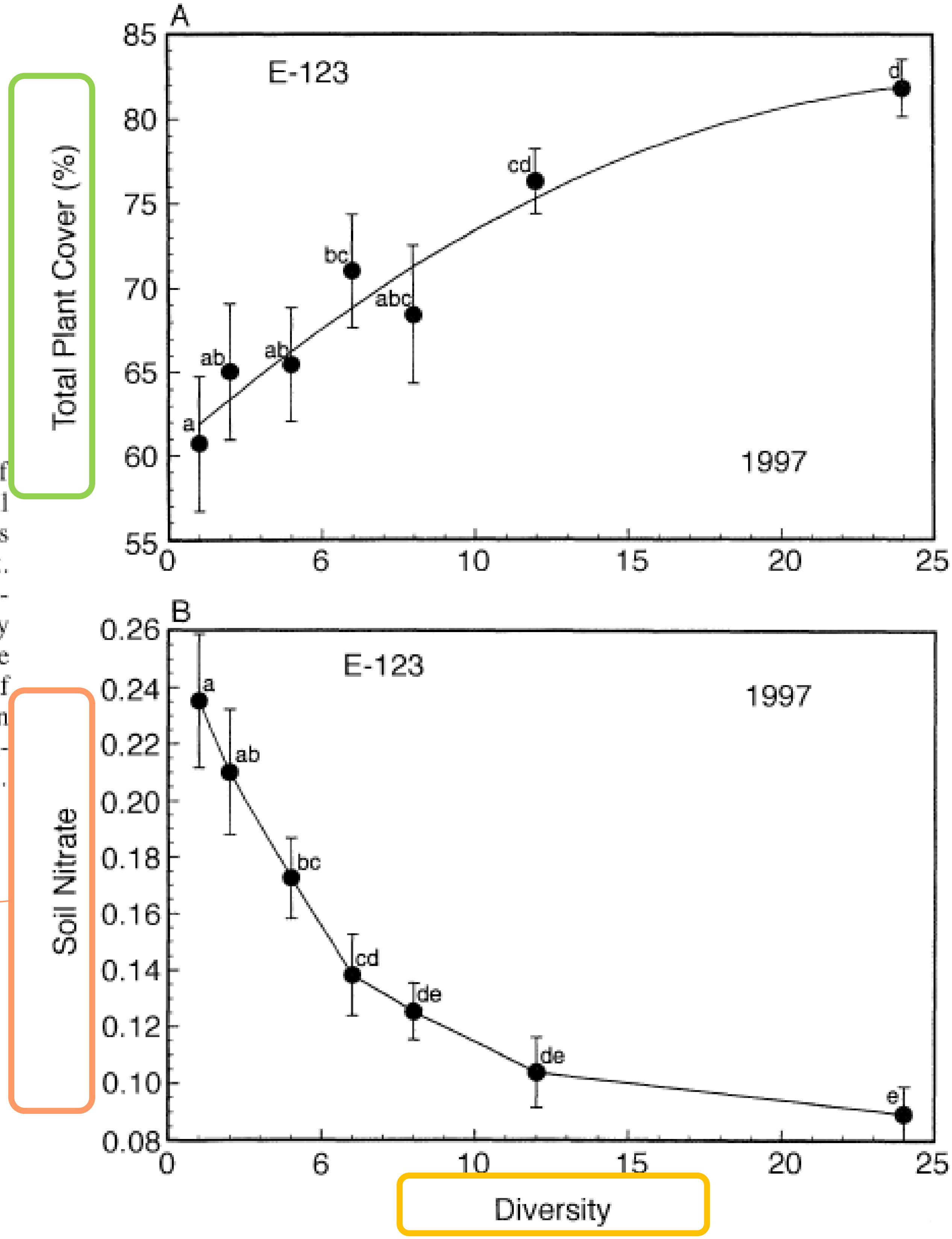


FIG. 7. (A) Total plant cover, a measure of total community plant biomass, for the small biodiversity experiment at Cedar Creek. Results are for 1997, the fourth year of the experiment. Mean responses (±1 SE) are shown, as are results of contrasts. Means that differ significantly at the $P < 0.05$ level do not share any lowercase letter. The curve shown is fitted through all of the data. (B) The dependence of soil nitrate on diversity for this same experiment, shown similarly, for soil cores from a depth of 0–20 cm.

The Resource

Tilman (2001)

The big question:

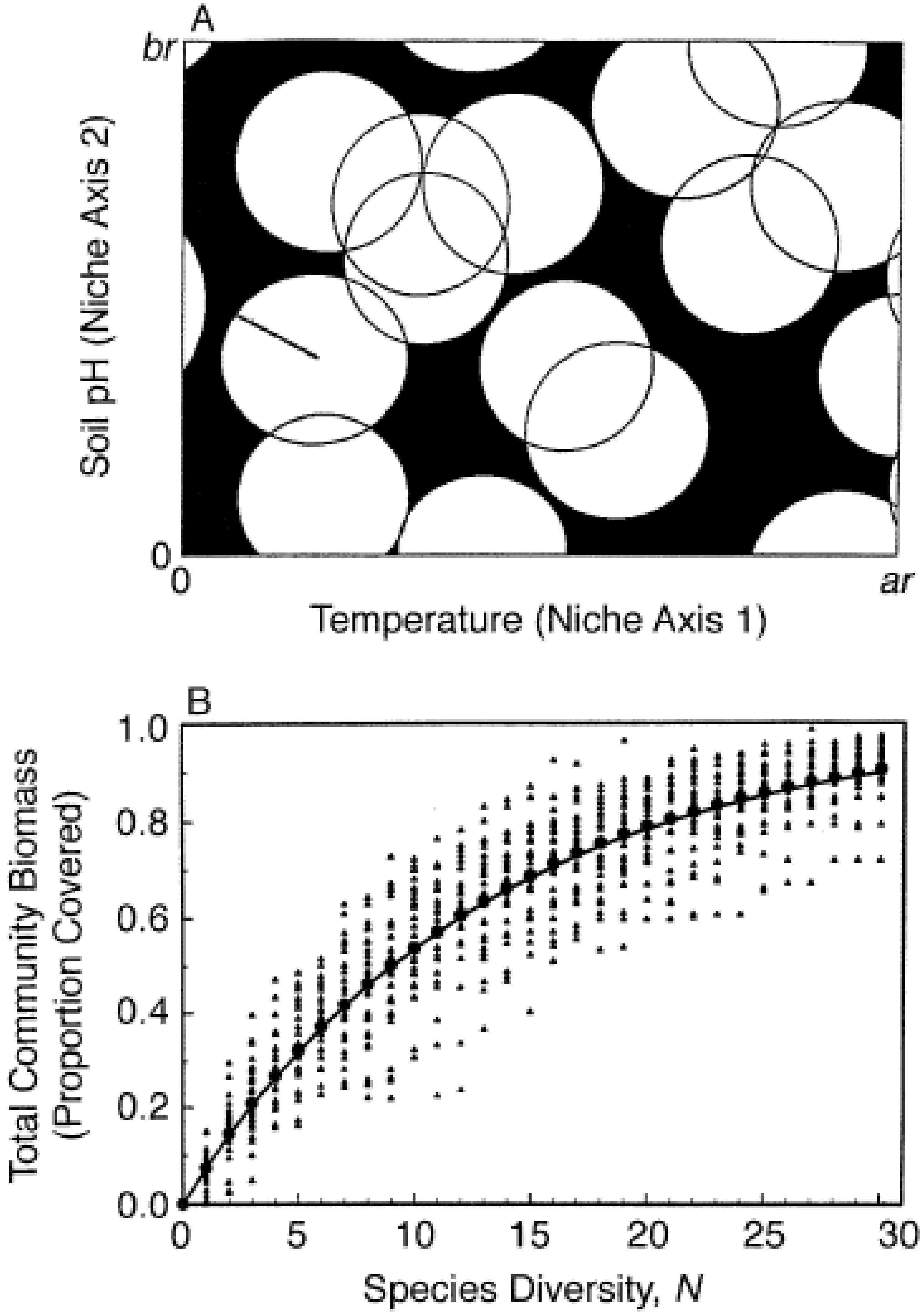
how can diversity improve services?

And here is the explanation:

Each species has its own **ecological niche** (the white circles in plot A).

Species diversity →
Niches diversity →
More efficient resource use

This is the
Niche Differentiation Hypothesis



Tilman (2001)

Ecological nichevs Habitat

Ecological niche

Definition: The ecological niche represents the role and location of a species within an ecosystem, including its interactions with other organisms and the physical environment.
Components:
Spatial: Where the species lives (habitat).
Trophica: What it eats and by whom it is eaten.
Functional: The ecological function of the species (e.g. predator, decomposer).
Example: A frog's niche may include its diet (insects), its role as prey for snakes, and its habitat (ponds).

Habitat

- **Definition: Habitat is the physical place where a species lives. It is the natural environment that provides the resources necessary for the survival of the species.**
- **Components:**
- **Abiotic: Physical factors such as light, temperature, water, and soil.**
- **Biotic: Presence of other species (predators, prey, competitors).**
- **Example: A frog's habitat could be a pond or stream at a certain latitude, height above sea level.**

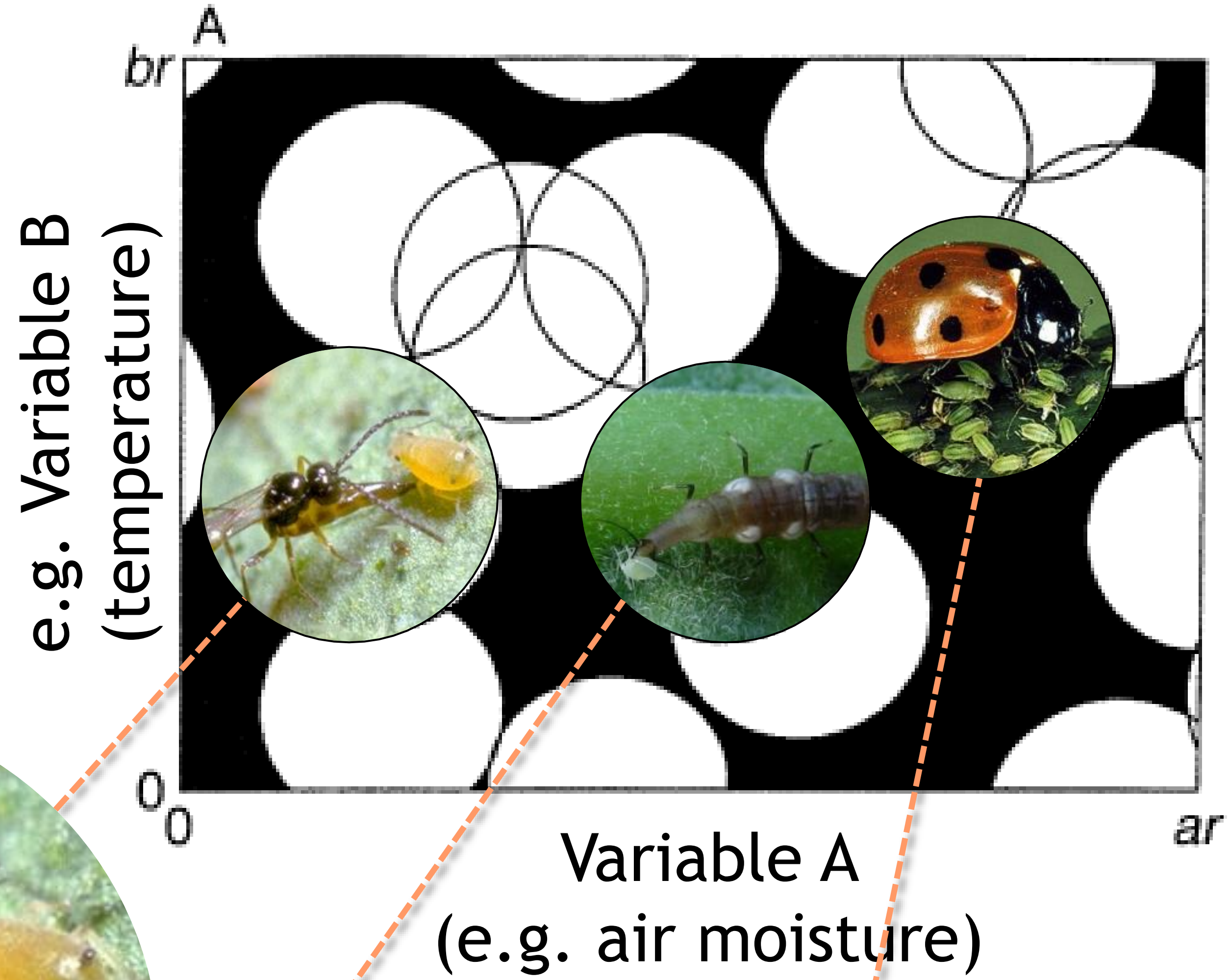
Key Differences

Ecological Niche: It concerns the role and interactions of a species. It is more specific and complex.
Habitat: This is the physical place where a species lives. It is more general and descriptive.
Possible Sources of Confusion
Overlapping Terms: Often used interchangeably, but they are not synonymous.
Niche Complexity: The ecological niche is a broader concept that includes habitat, but also interactions and the role of the species in the ecosystem.

The big question:

how can diversity improve services?

Let’s try to transfer this concepts into our example on **aphids’ natural enemies**



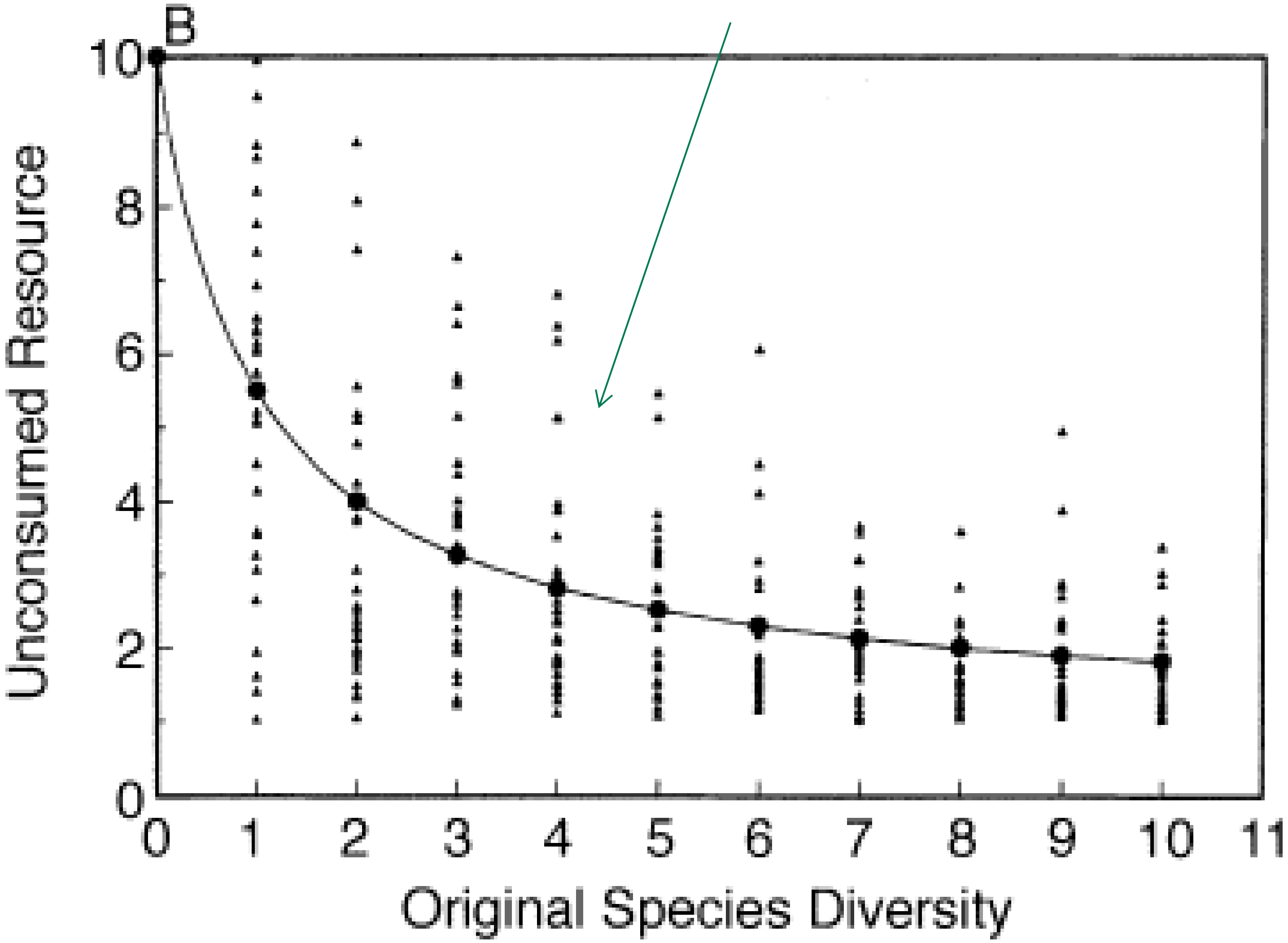
Each natural enemy will occupy its own niche, in which it will «consume» aphids

The big question:

how can diversity improve services?

The service is

«reducing aphids abundance»



For our «natural enemies»,

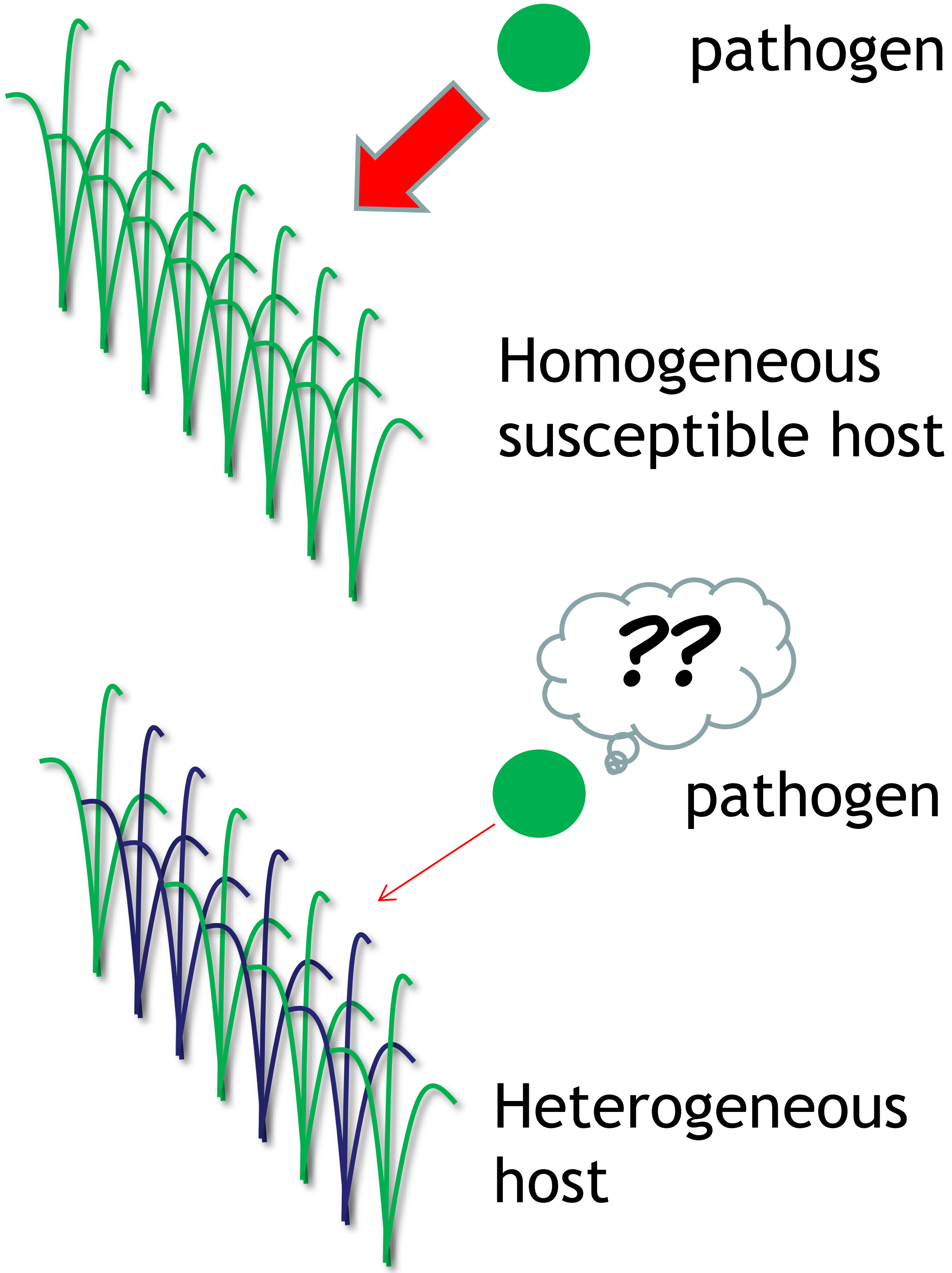
aphids are «the resource»

The big question:

how can diversity improve services?

A variant is the improved **resistance to diseases** in mixed instead of homogeneous populations.

The Host Dilution Effect



The big question:

how can diversity improve services?

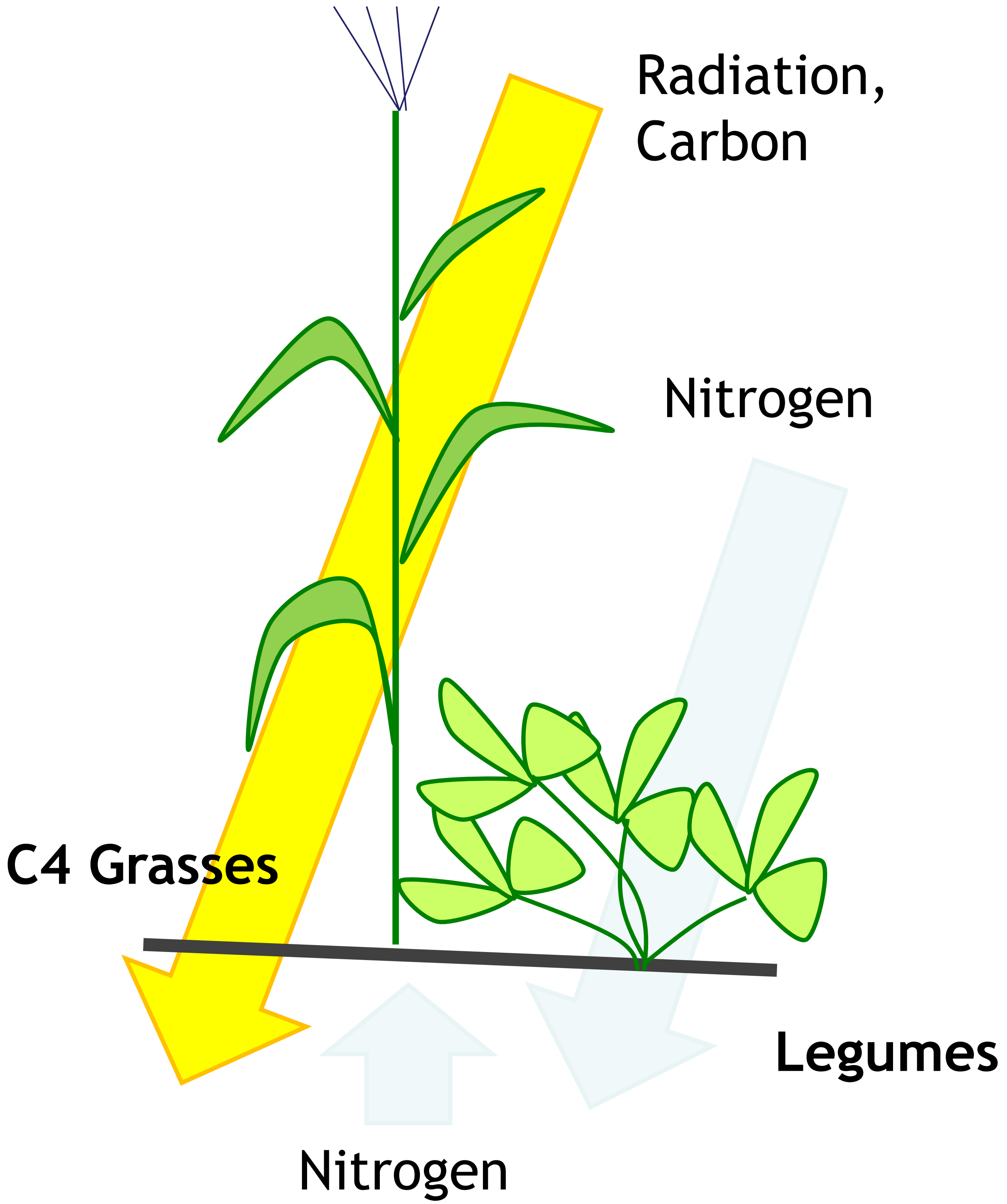
Beyond richness, why diversity in functional traits can be so important?

Niche Complementarity Effect

C4 grasses + Legumes is a classical example:

C4 grasses maximise photosynthetic efficiency but **need Nitrogen**

Legumes **fix Nitrogen**

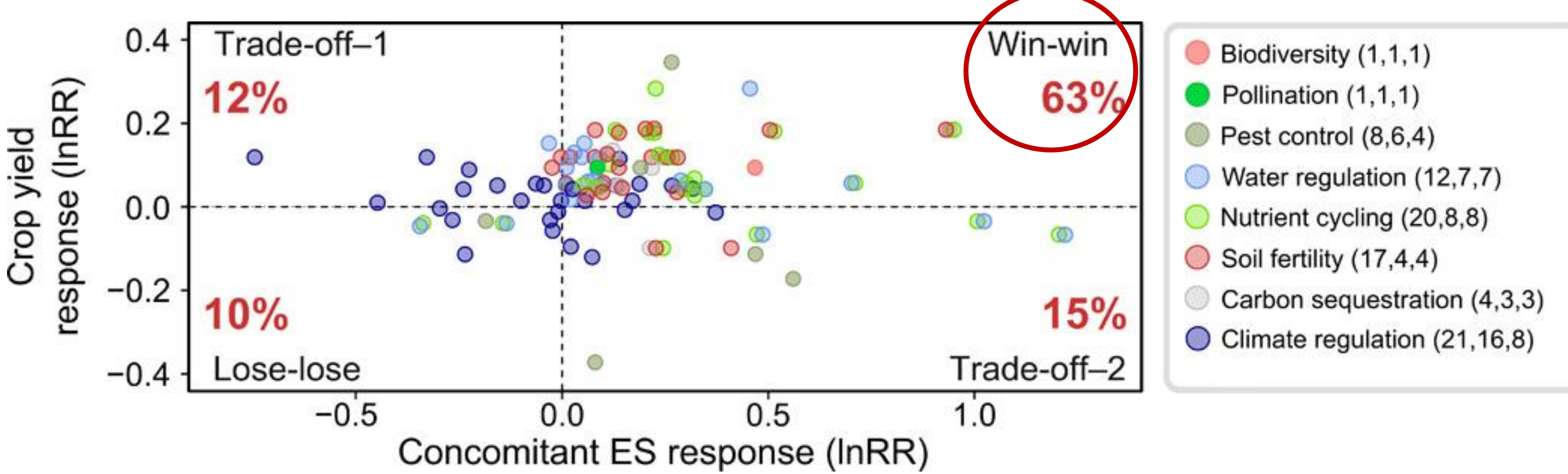


SCIENCE ADVANCES | RESEARCH ARTICLE

ECOLOGY

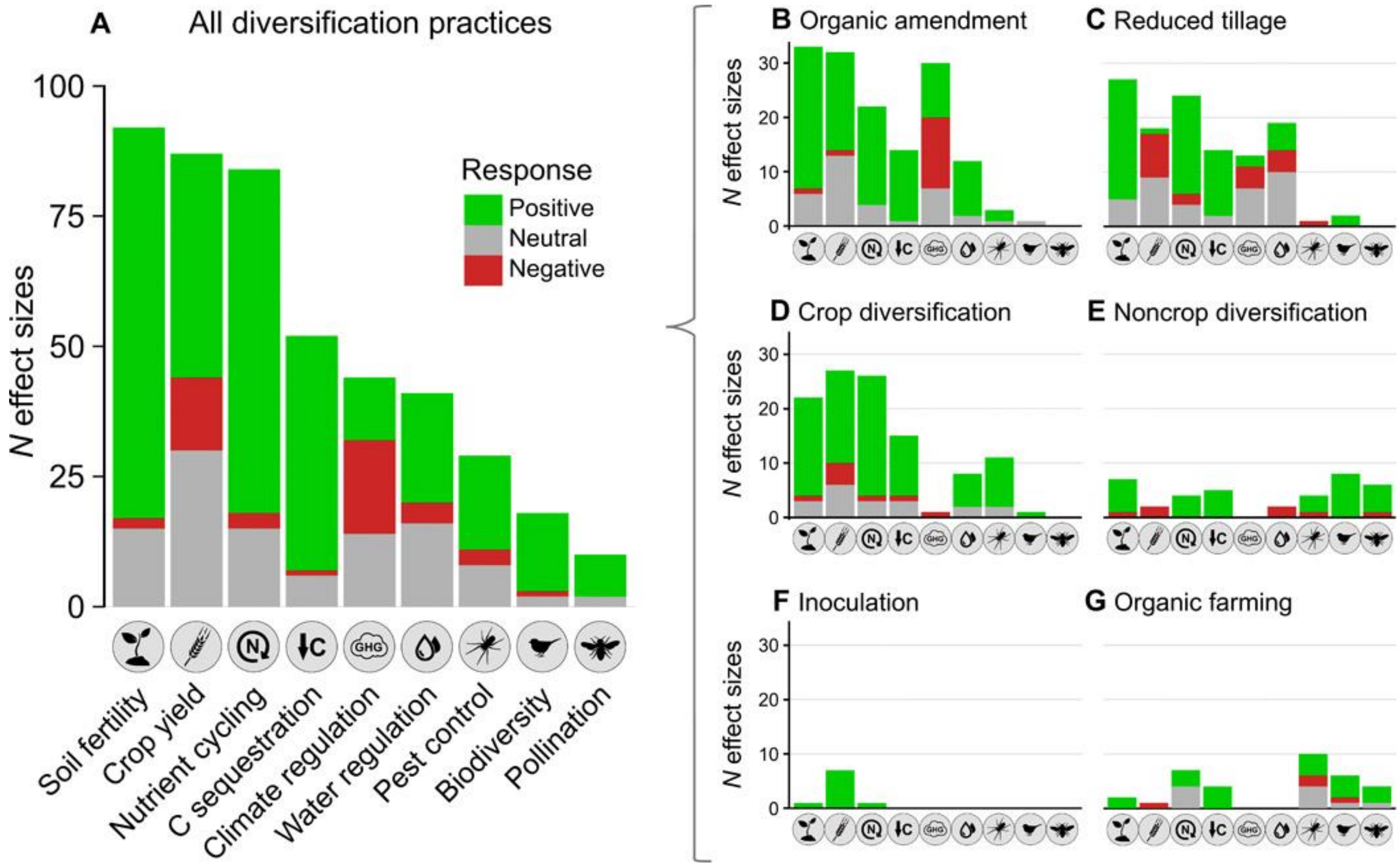
Agricultural diversification promotes multiple ecosystem services without compromising yield

Giovanni Tamburini[1,2]*, Riccardo Bommarco[1], Thomas Cherico Wanger[1,3†], Claire Kremen[4,5], Marcel G. A. van der Heijden[6,7], Matt Liebman[8], Sara Hallin[9]



Tamburini *et al.*, *Sci. Adv.* 2020; **6** : eaba1715 4 November 2020

Diversified systems and ecosystem services



Tamburini *et al.*, *Sci. Adv.* 2020; **6** : eaba1715   4 November 2020

What do we work on?

- **Genetic** agrobiodiversity
  - Crop cultivars
  - Cultivar mixtures
  - Evolutionary populations (e.g. CCP)
- **Species** agrobiodiversity
  - Crop rotations/sequences
  - Cover crops
  - Intercropping/living mulches
- **Habitat** agrobiodiversity
  - Field margins
  - Hedgerows
  - Other semi-natural habitats

Mediterranean (agroecological) systems

Tradition as a source of innovation

Diversity at the species level: in space

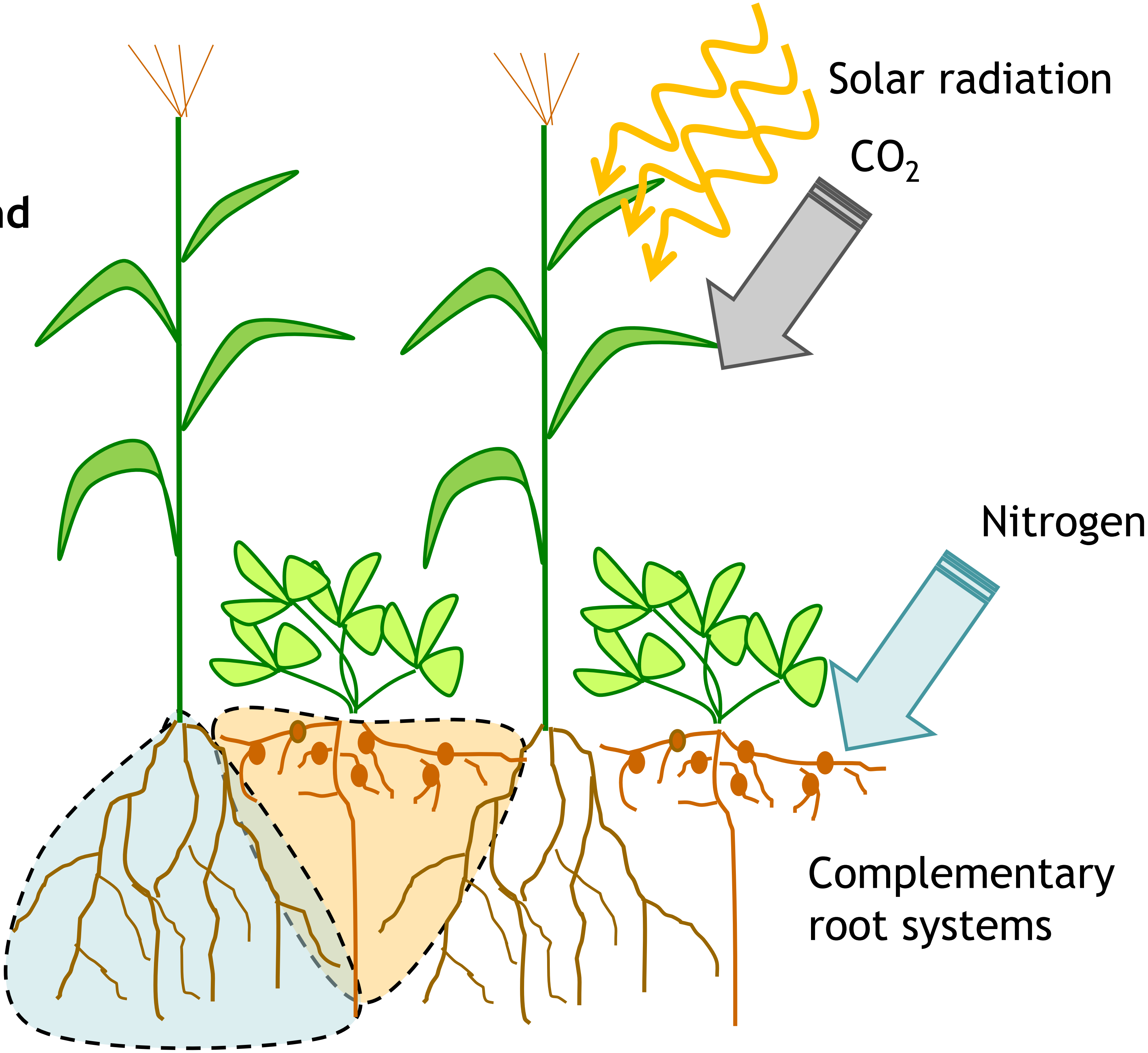
Tradition: alfa alfa (or perennial clover) intercropped with cerals

Sowing of the legume in the wheat crop to anticipate the next pasture meadow

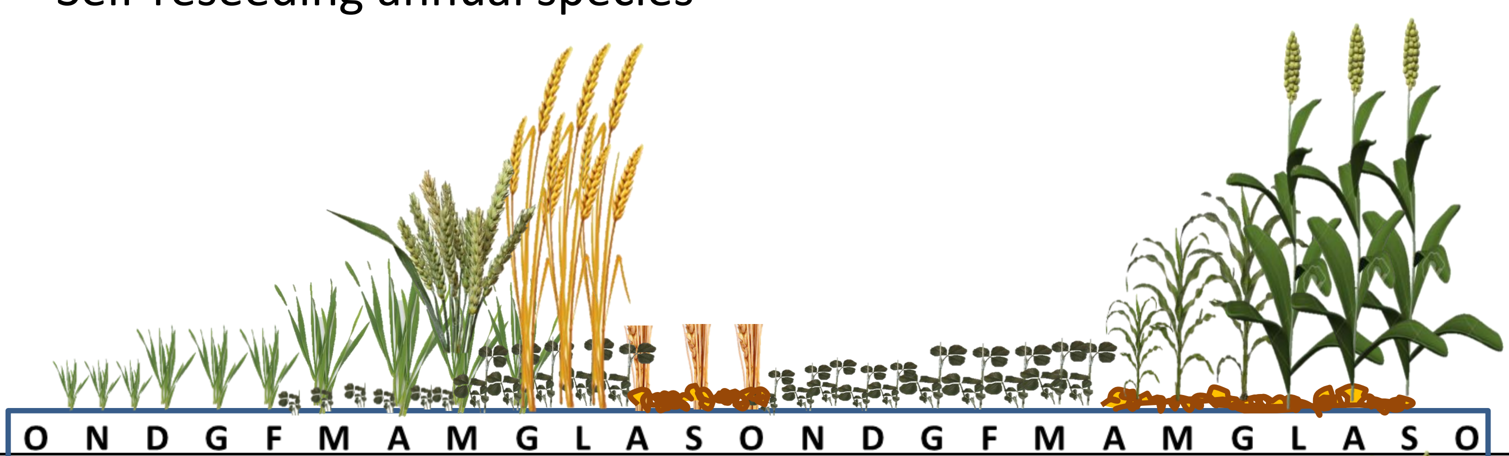
Diversity at the species level: in space

Complementarity of resource use in mixes between grasses and legumes: an efficient and productive system

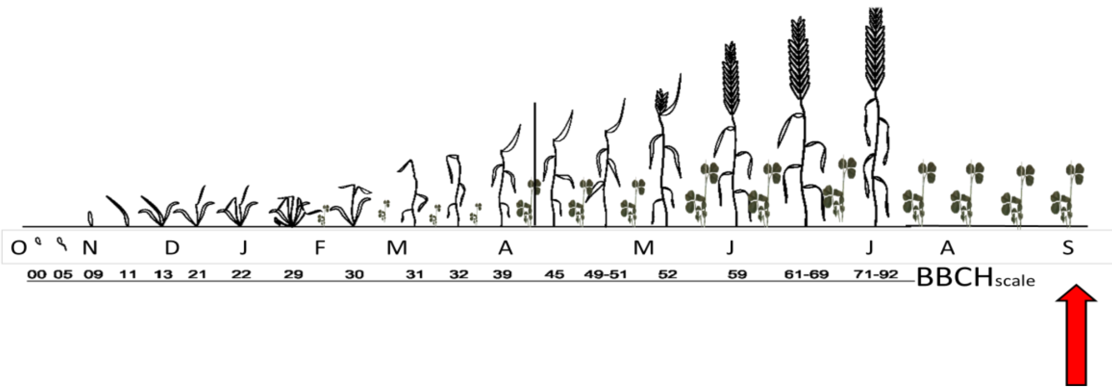
- Reduce competition between planned species
- Controlling spontaneous puncture
- Cover the ground
- Provide organic matter
- Provide nitrogen (and to the next crop)
- …



Innovation: servizi agroecologici

Cropping system (26 species tested)	General hypothesis	Services provided after wheat harvesting
Annual species 		• Dead mulch for the control of spontaneous flora or a green manure
Self-reseeding annual species 	Services: **Management of spontaneous flora Soil quality Washer quality**	• Dead mulch in summer., reborn in autumn winter (catch crop). • It can provide dead mulch or subsequent spring green manure.
Perennial species 		• Pasture meadow (original purpose), • Catch crop in winter and a dead mulch or green manure in spring

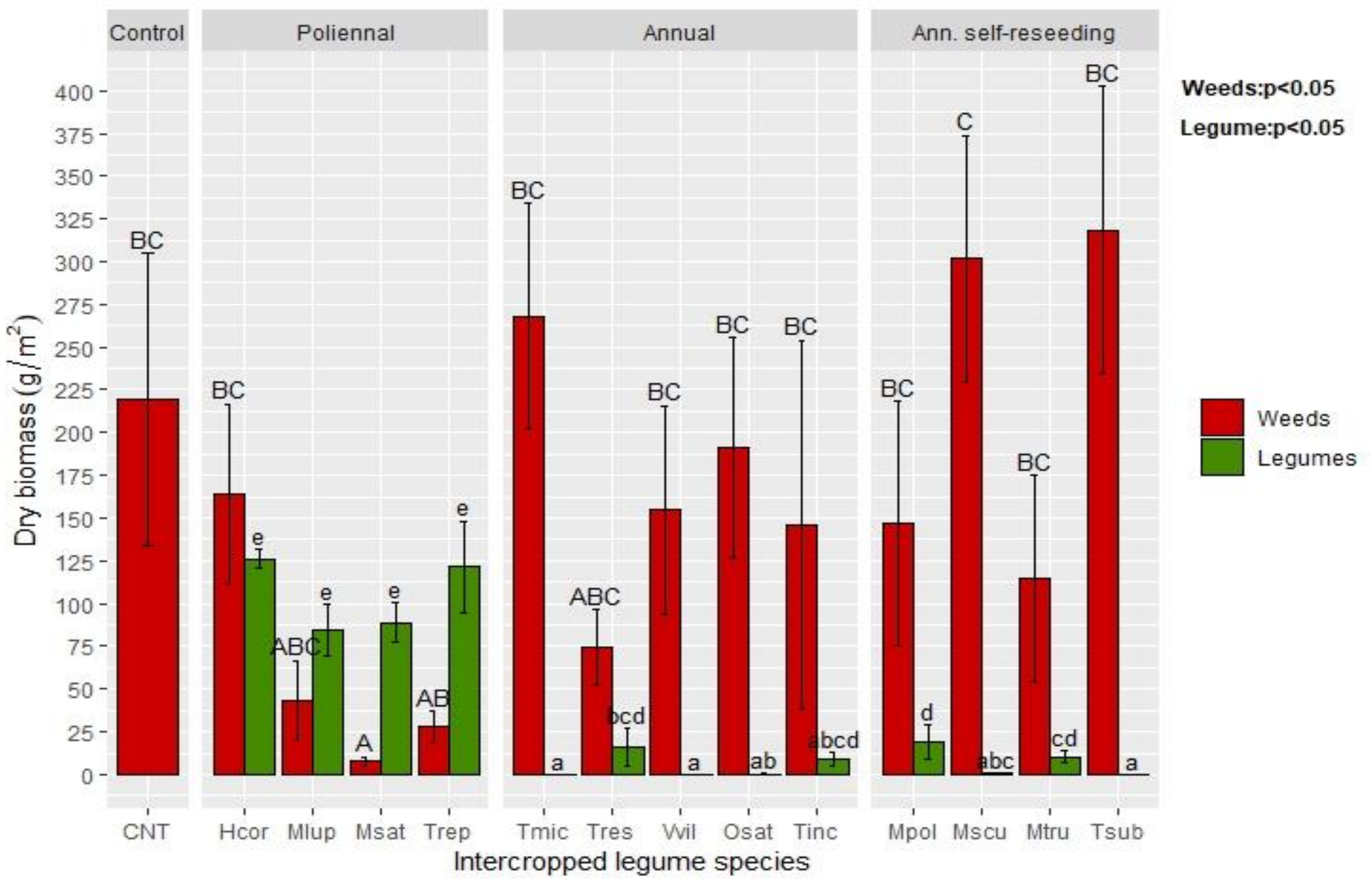
federico.leoni @santannapisa.it (PhD)



Relay intercropping of legume in wheat

Site: Ravenna

Data from sampling performed in September



Dry biomass of intercropped legumes species and weeds in September. CNT: control (wheat as sole crop)**,** **Hcor**: *Hedysarum coronarium*, **Mlup**: *Medicago lupulina*, **Trep**: *Trifolium repens*, **Msat**: *Medicago sativa*, **Tmic**: *Trifolium michelianum*, **Tres**: *Trifolium resupinatum*, **Vvil**: *Vicia villosa*, **Osat**: *Ornithopus sativus*, **Tinc**: *Trifolium incarnatum*, **Mpol**: *Medicago polimorfa*, **Mscu**: *Medicago scutellata*, **Mtru**: *Medicago truncatula*, **Tsub**: *Trifolium subterraneum*.

Control

Medicago sativa (12 September 2018)

Results

Innovation: no till in organic horticulture

- Reduces labor costs and emissions
- Increases soil quality:
- Improve the structure
- Reduces compaction (?)
- Increases organic matter (?)
- Improve the management of rainwater (?)
- Safeguarding biodiversity of soil microorganisms

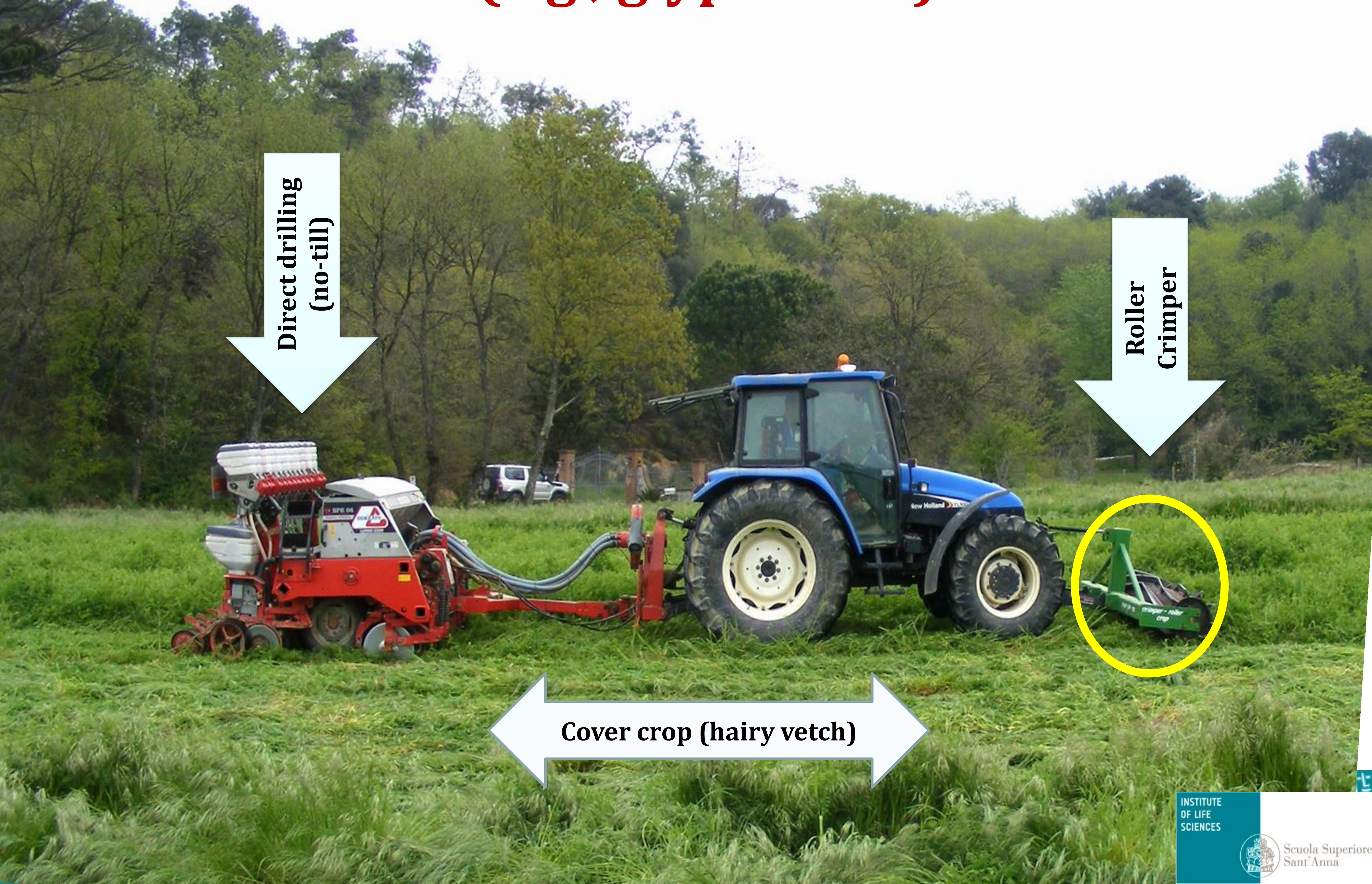
Main issues: Reduces nutrient availability

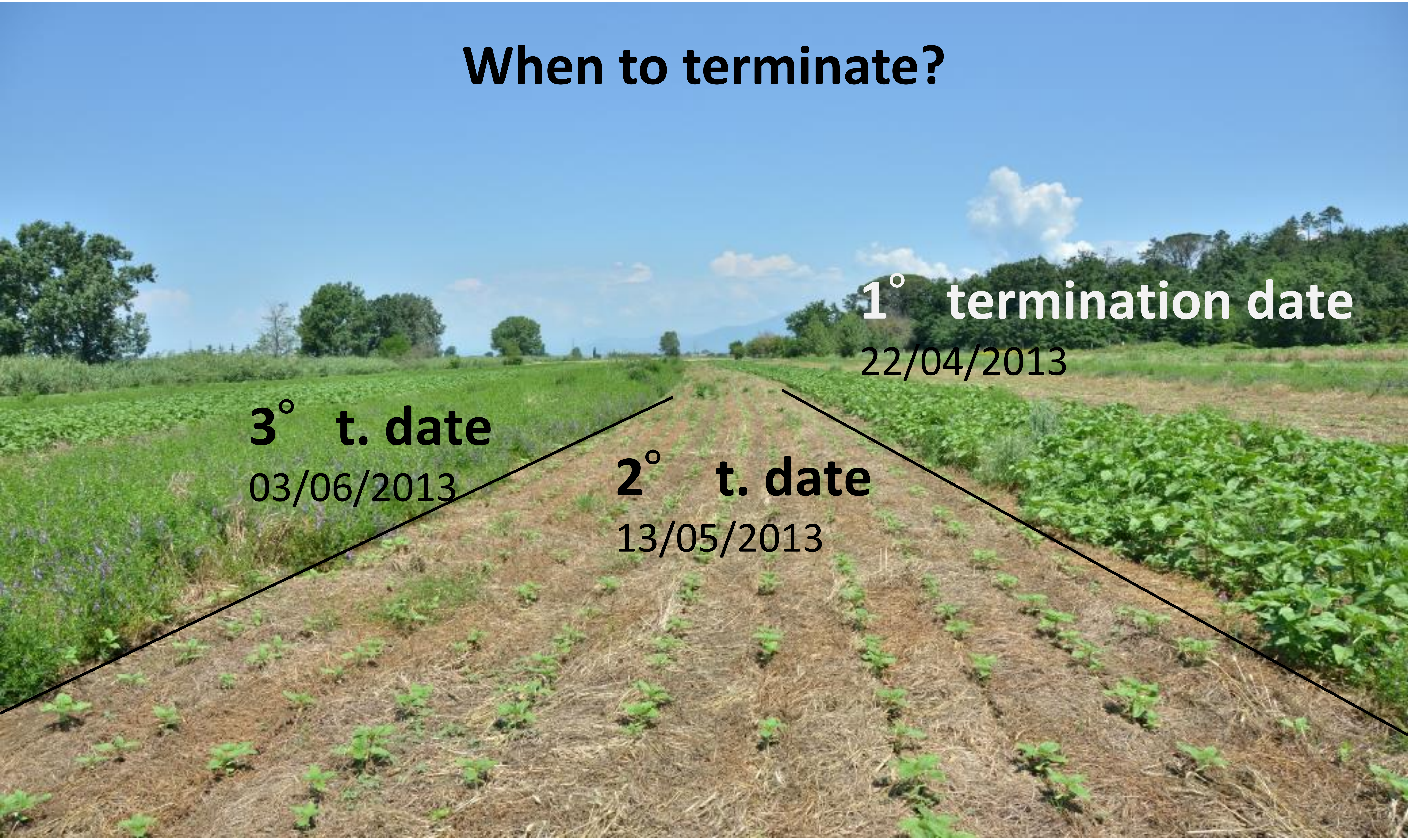
Increases the pressure of weed flora

Dead mulch :sunflower direct seeded on vicia mulch


time 1
Sunflower seeded
before vetch flowering
time 2
Sunflower seeded
at beginning of vetch flowering
time 3
Sunflower seeded
at 70% vetch flowering
7 June 2013

Agroecological alternatives to contentious inputs (e.g., glyphosate)




When to terminate?
1° termination date
22/04/2013
3° t. date
03/06/2013
2° t. date
13/05/2013

No-till system with legume (vetch) cover crop devitalised mechanically (roller crimper)

Wheat/(cover crop)/sunflower rotation

- **N supplied** by late roller-crimped cover crop: 135 kg/ha (3-yr average)
- **Sunflower yield:** 4 to 5 t/ha (no significant difference compared with 100% and 50% glyphosate)
- **Operational costs:**
  - Ploughed sunflower (no vetch): 583 €/ha
  - No-till sunflower + vetch + 100% glyphosate: 600 €/ha
  - No-till sunflower + vetch + roller-crimper: **540 €/ha**

Antichi et al. (2022). Agron. Sust. Dev. https://link.springer.com/article/10.1007/s13593-022-00815-2

Functional *composition*: an example

AIM OF RESEARCH

- To study the influence of cover crop **functional mixtures** on weed suppression in no-till organic aubergine

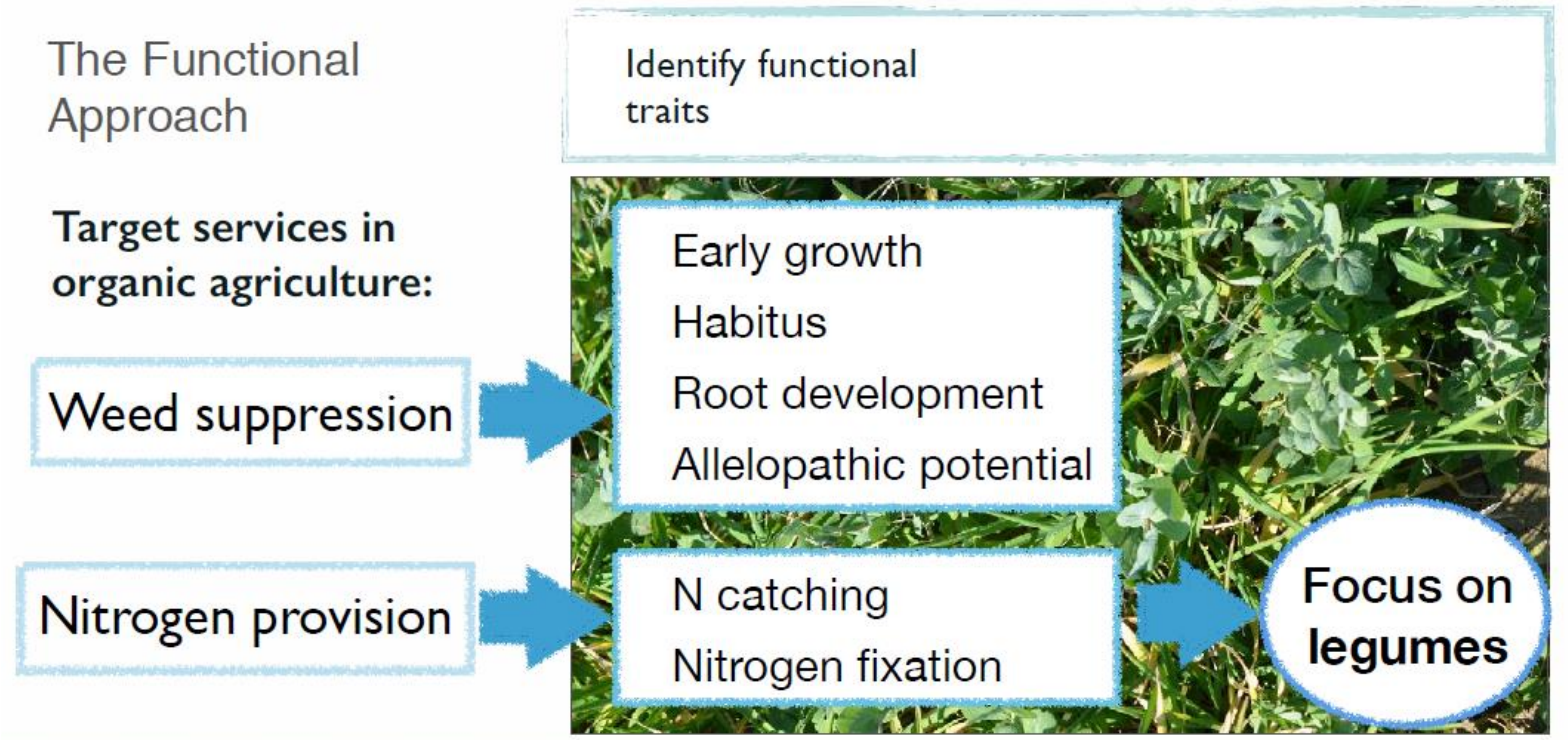
RESEARCH HYPOTHESES

- Cover crop mixtures based on a higher number of species (= *functional biodiversity*) improve weed suppression
- Weed suppression is further enhanced in cover crop mixtures based upon selected trait combinations for the target service (= *functional composition*)

Case study

Cover crop functional mixtures in a no-till organic vegetable system

Ranaldo et al., Weed Res., 2020



Case study

Cover crop functional mixtures in a no-till organic vegetable system

Design cover crop mixtures to enhance agroecosystem services

Functional Groups (FG)

Pure stands

Large Seeded Legumes
Pisum sativum L.
Vicia sativa L.

- Nitrogen fixation
- Development in height
- Vining habitus

Small Seeded Legumes
Trifolium incarnatum L.
Trifolium squarrosum L.

- Nitrogen fixation
- Early development and soil cover
- Deep root system

Poaceae
Hordeum vulgare L.
Avena sativa L.

- Nitrogen catching
- High compentitive ability
- Fascicled root sytem

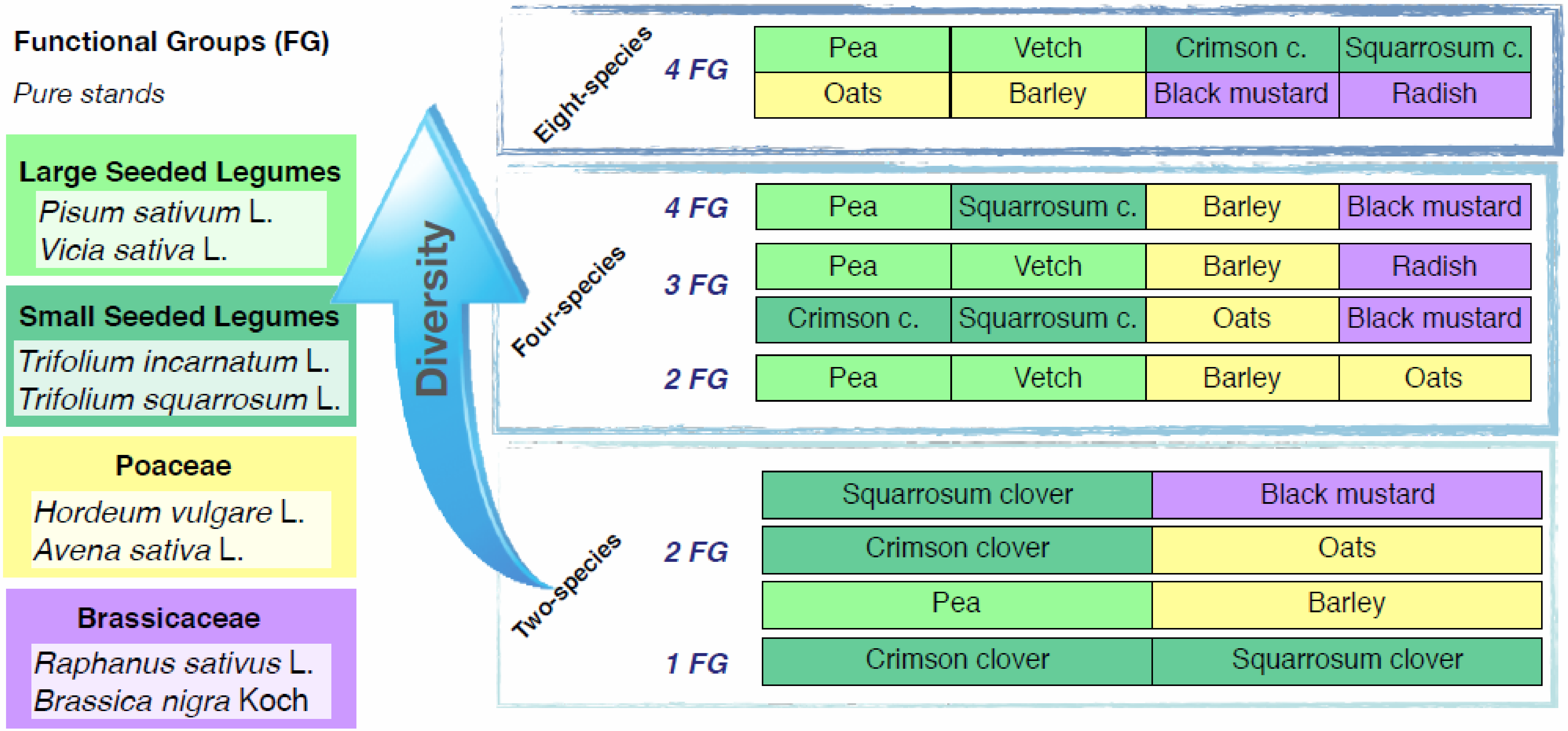
Brassicaceae
Raphanus sativus L.
Brassica nigra Koch

- Nitrogen catching
- Allelopathic potential (residues)
- Tap-root sytem

Case study

Cover crop functional mixtures in a no-till organic vegetable system

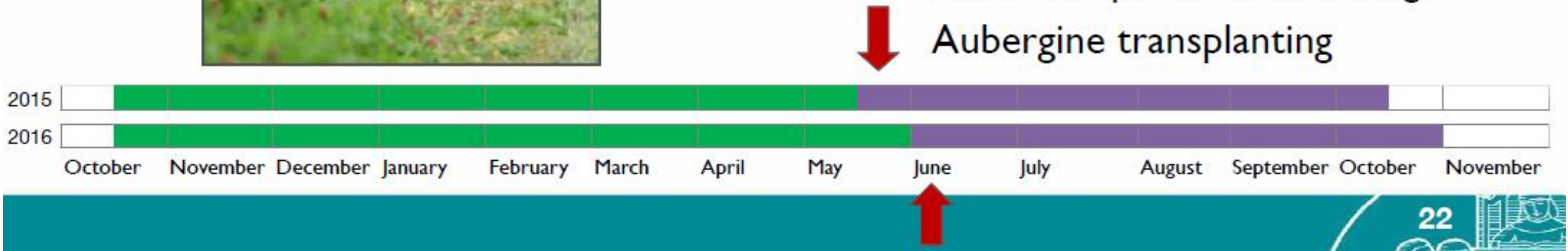
Design cover crop mixtures to enhance agroecosystem services



Case study

Cover crop functional mixtures in a no-till organic vegetable system

Cover crop termination
Roller crimper & weed flaming
Aubergine transplanting



Melanzana in agricoltura biologica e non lavorazione

Coltivazione della coltura di copertura e Devitalizzazione

marzia.ranaldo @santannapisa.it (Post Doc)

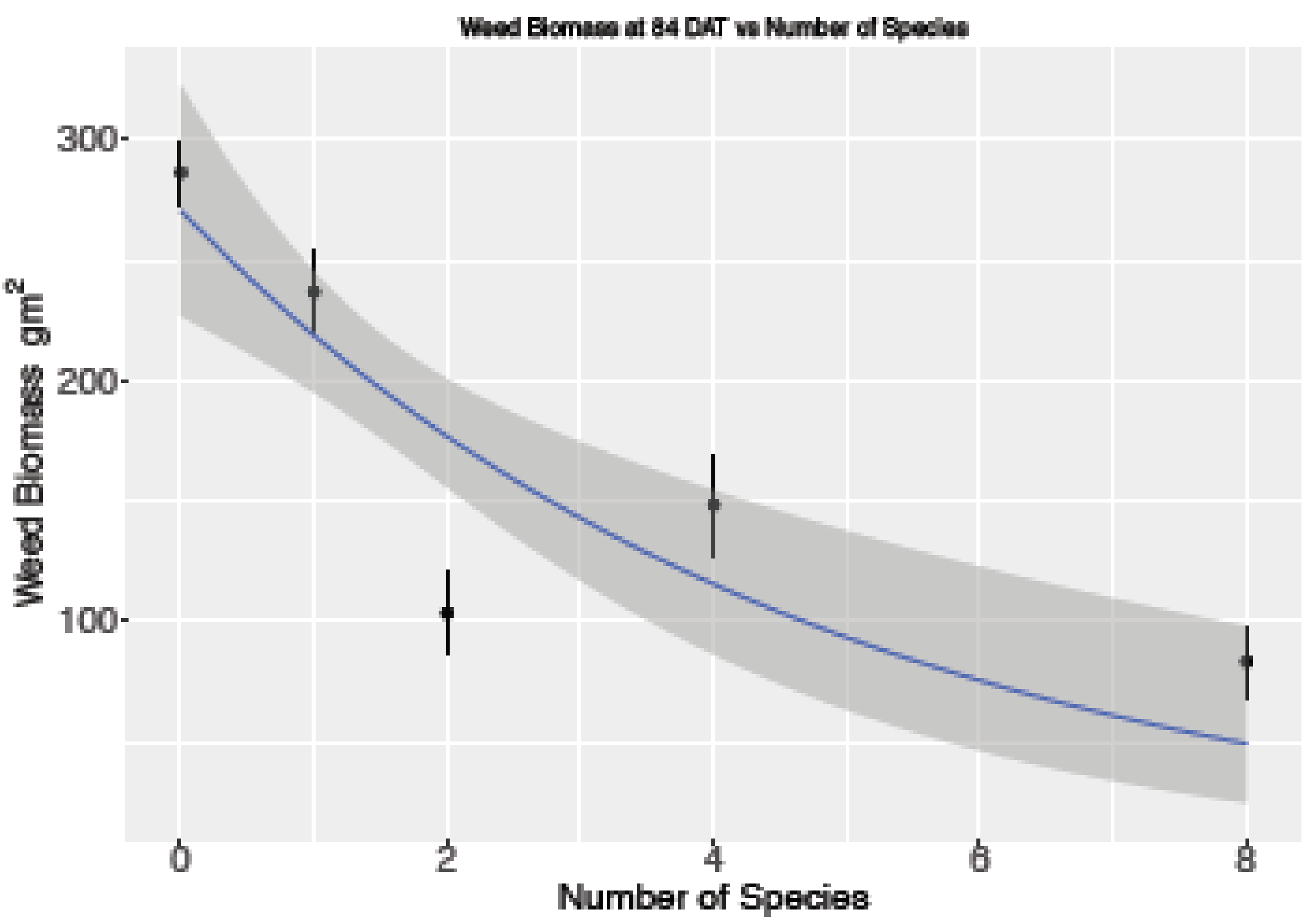
Trapianto della Melanzana

Gestione delle infestanti

Gestione delle infestanti e raccolta

La Diversità funzionale riduce la presenza di flora infestante durante lo sviluppo della coltura da reddito

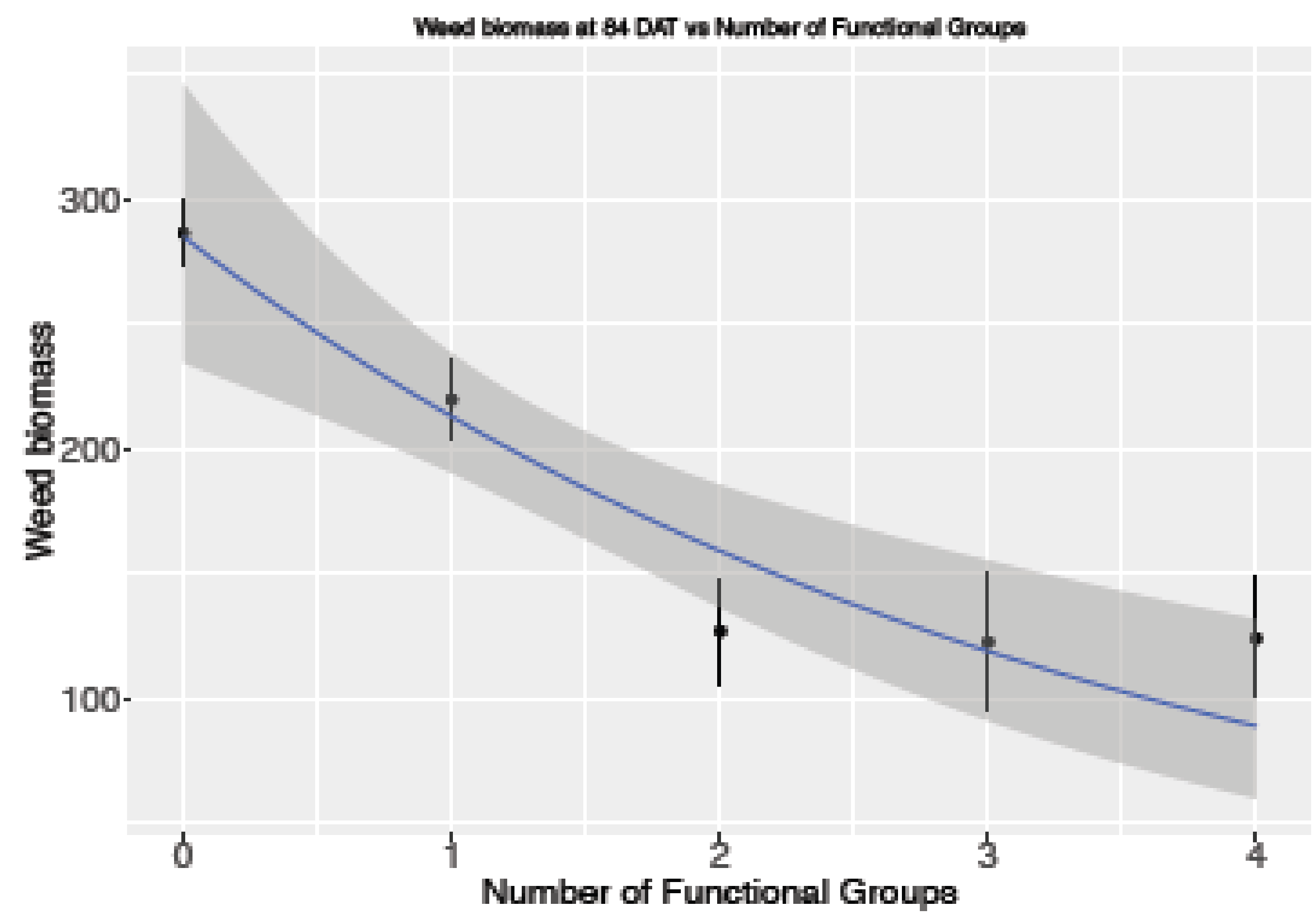
Species Diversity



y=1.672 - 0.037 log(x)

p<0.00018 ***

Functional Groups Diversity



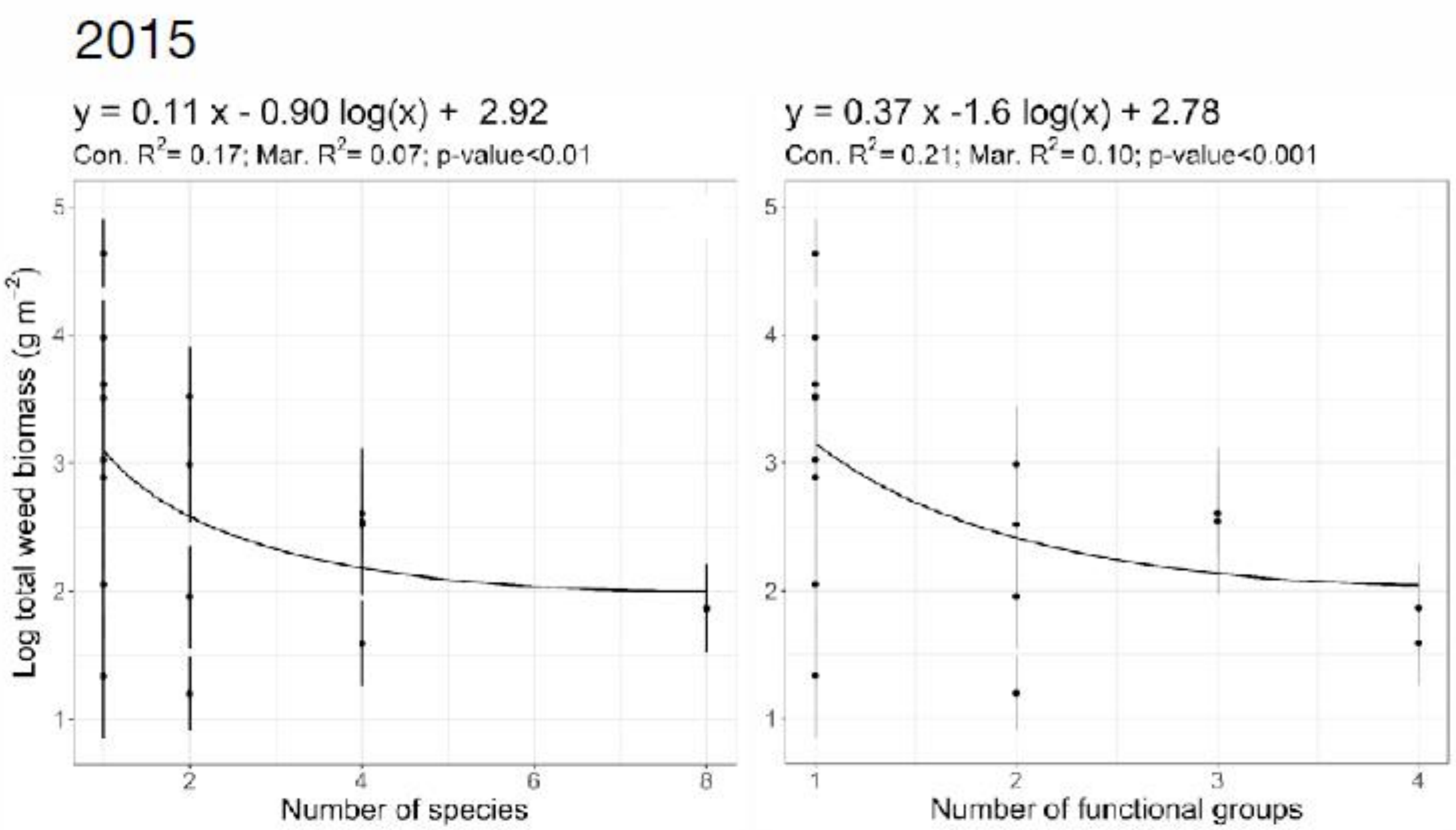
y=5.417 - 0.289 log(x)

p<3.04e-05 ***

Case study

Cover crop functional mixtures in a no-till organic vegetable system

Effect of diversity on services provisioning: **Weed suppression**

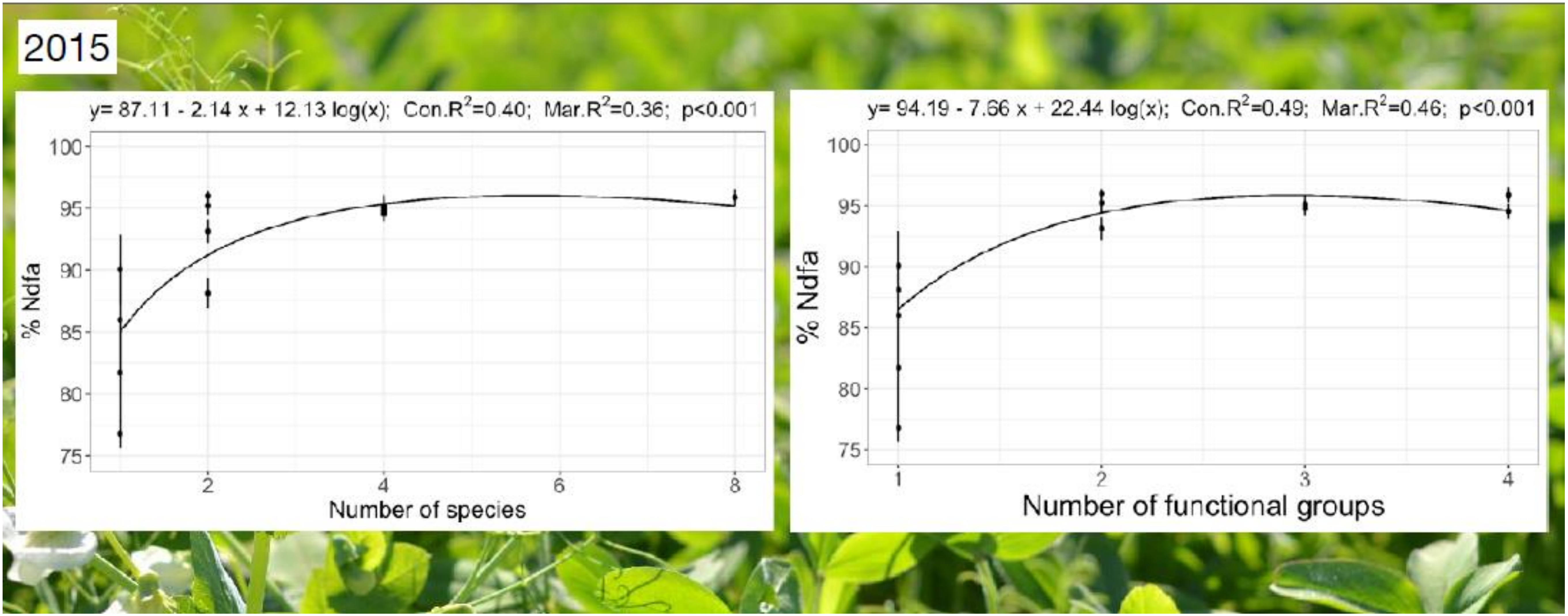


Ranaldo et al., Weed Res., 2020

Case study

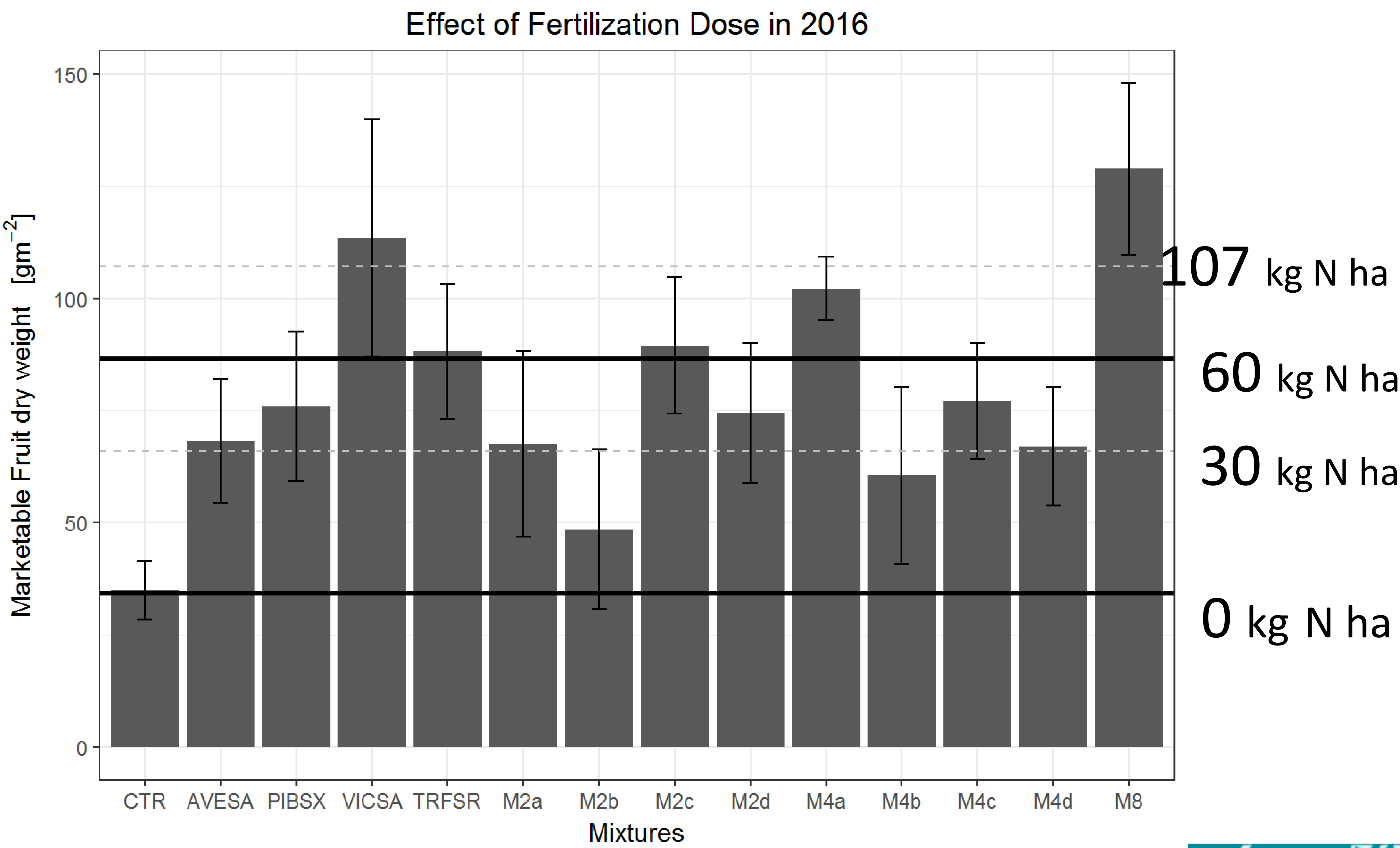
Cover crop functional mixtures in a no-till organic vegetable system

Effect of diversity on services provisioning: **Nitrogen fixation**



Ranaldo et al., Weed Res., 2020

Dose di Azoto equivalente



M2a - Squarrosum clover + Crimson Clover
M2b - Pea + Barley
M2c - Squarrosum clover + Black mustard
M2d - Crimson clover + Oat

M4a – Pea + Vetch + Barley + Oat
M4b – Pea + Vetch + Barley + Raphanus
M4c – Squarrosum clover + Crimson clover + Black mustard + Oat
M4d – Pea + Barley + Crimson clover + Balck mustard

Agroecology: a new approach for a new system

The goal is **no longer to optimize the single element** of a given system, no longer **controlling and simplifying the ecosystem** to manage what we can understand **(reductionist approach).**

The goal is **to understand its complexity**, to know the **mechanisms** and **functions** that make the agroecosystem work **and shape it to optimize and manage it**.

The characteristics, function and mechanisms of the agroecosystem **are not separable** they are interconnected and must therefore be studied in their interactions.

The study of interactions requires huge amounts of data and a huge computational effort. Agroecology is very strongly connected with technological innovation, because it requires the creation and management of a lot of knowledge.

The agroecological model is based on **intensive knowledge**, strongly dependent on the climatic, pedological, biological and social **context**. Agriculture is a human activity

Ewert, F., Baatz, R., & Finger, R. (2023). Agroecology for a sustainable agriculture and food system: from local solutions to large-scale adoption. *Annual Review of Resource Economics*, *15*, 351-381.

Come potremmo definire l'agroecologia?

Il Cesalpino 48/2019 · Agroecologia (P. Bàrberi)

Come scienza, L'agroecologia studia le interazioni ecologiche tra i diversi organismi al fine di progettare sistemi di produzione agricola che siano autoregolanti e che comportino il minor ricorso possibile a input esterni (fertilizzanti, prodotti fitosanitari).

Come pratica, L'agroecologia promuove sistemi agricoli diversificati basati sull'uso consapevole della biodiversità e dei servizi ecosistemici associati (ad esempio, il controllo biologico dei parassiti).

Come movimento, L'agroecologia sostiene l'agricoltura familiare, le filiere corte, l'uso delle risorse locali, lo scambio di conoscenze tra professionisti, cittadini e scienziati, un'equa remunerazione per gli agricoltori e la riconnessione degli agglomerati urbani e delle campagne.

The practical principles of Agroecology

- Biomass recycling, organic matter supply and optimization of biogeochemical cycles
- Low dependency on external inputs
- Conservation of limited natural resources (soil, water)
- Valorisation of unlimited natural resources (radiation)
- Conservation of genetic diversity (crops and livestock)
- Yield optimization and stability (not maximization)
- Enhancement of the positive interactions between components of the agroecosystem
  - Mixed crop-livestock systems
  - Agroforestry and agroforestry systems
  - Conservative biological control of adversity

The thirteen principles of Agroecology (AEE)

THE FIVE LEVELS OF TRANSITION TOWARDS SUSTAINABLE FOOD SYSTEMS AND THE RELATED 13 PRINCIPLES OF AGROECOLOGY SOURCE: GLIESSMAN (2007) AND report by the High Level Panel of Experts on Food Security and Nutrition (HLPE, 2019)

10 Principles (FAO)
CO-CREATION AND SHARING OF KNOWLEDGE
Agricultural innovations respond better to local challenges when they are co-created through participatory processes.

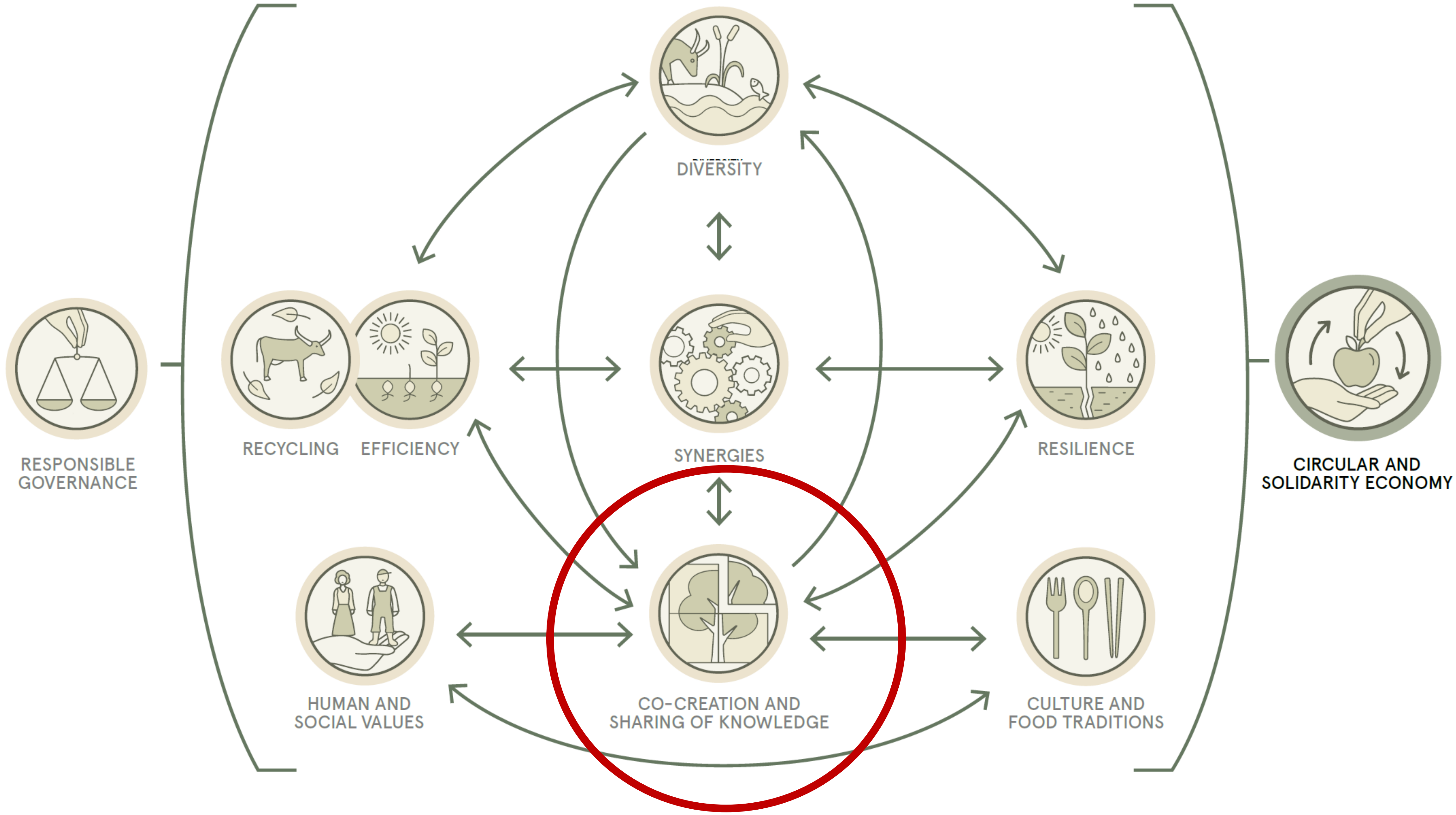


Figure 1. System components, key interactions, emergent properties and desired enabling environment in agroecology as defined by the 10 Elements of Agroecology framework (FAO, 2018).

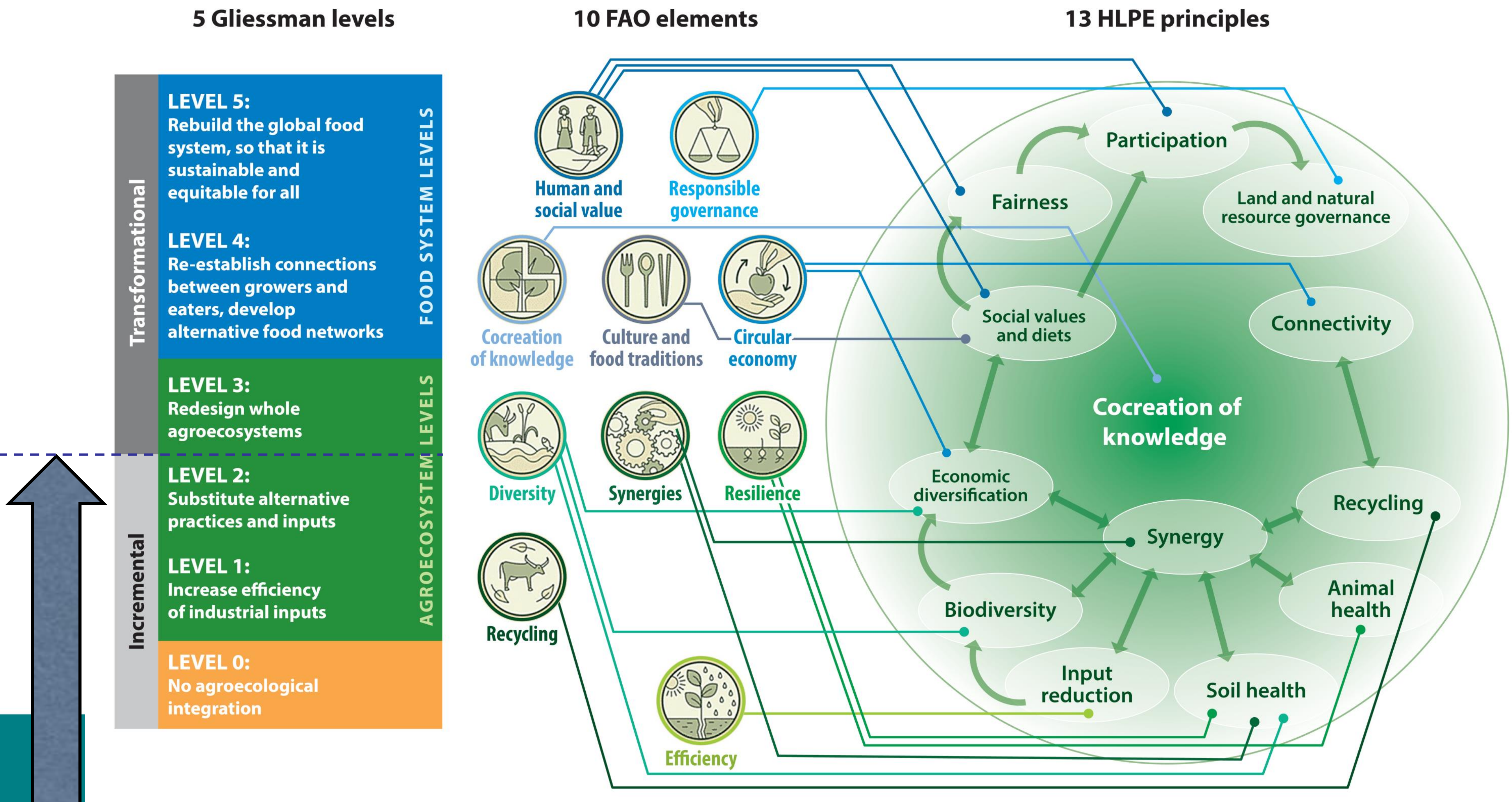
If the aim is:

-maintaining long-term productivity and food security,

-providing ecological benefits,

-and reducing negative external effects including aspects of injustice and inequality of the currently predominant conventional agricultural practices

a new approach that overcome reductionism is needed



Ewert, F., Baatz, R., & Finger, R. (2023). Agroecology for a sustainable agriculture and food system: from local solutions to large-scale adoption. *Annual Review of Resource Economics*, *15*, 351-381.

Agroecology: a new approach for a new system

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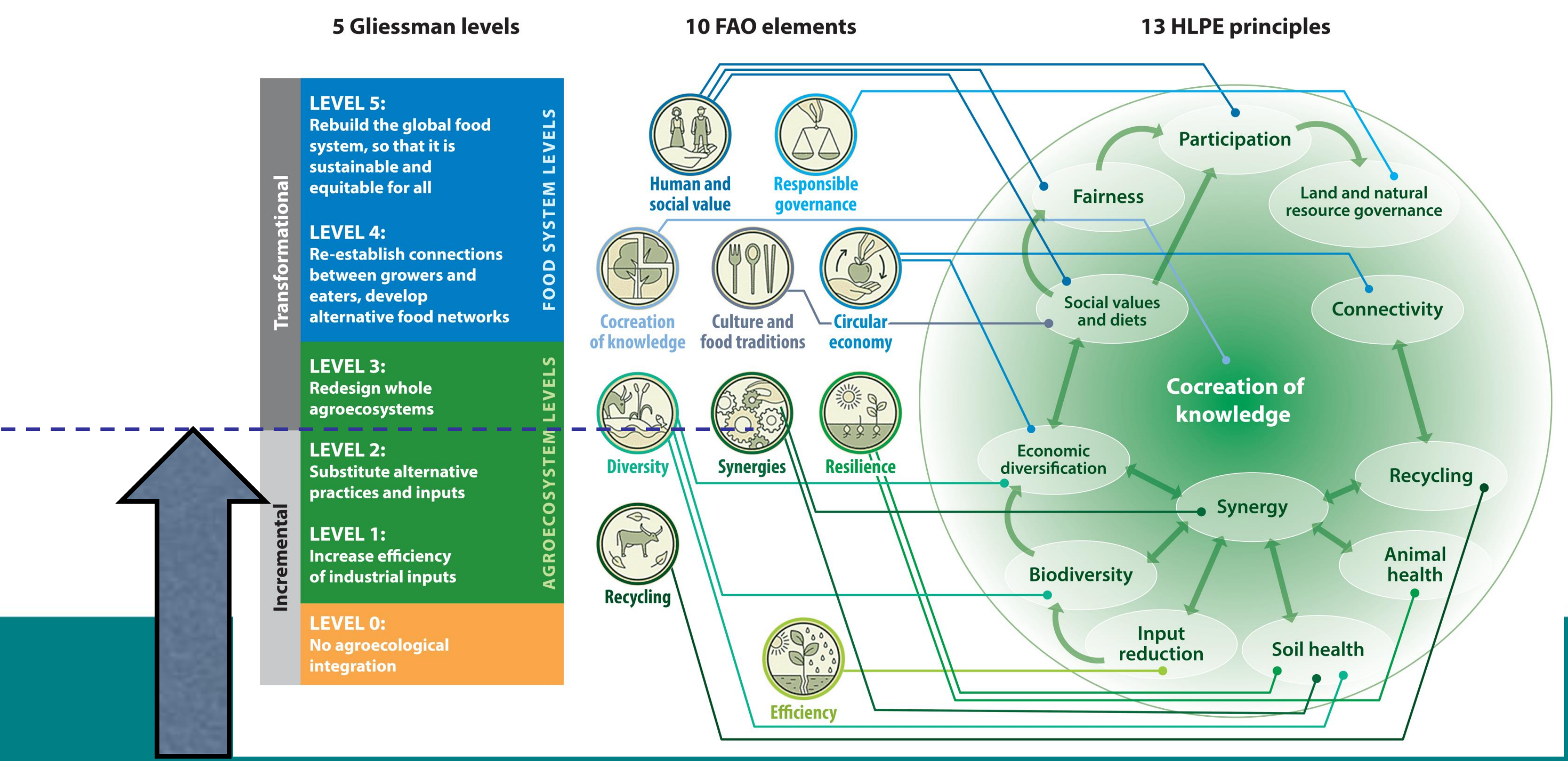
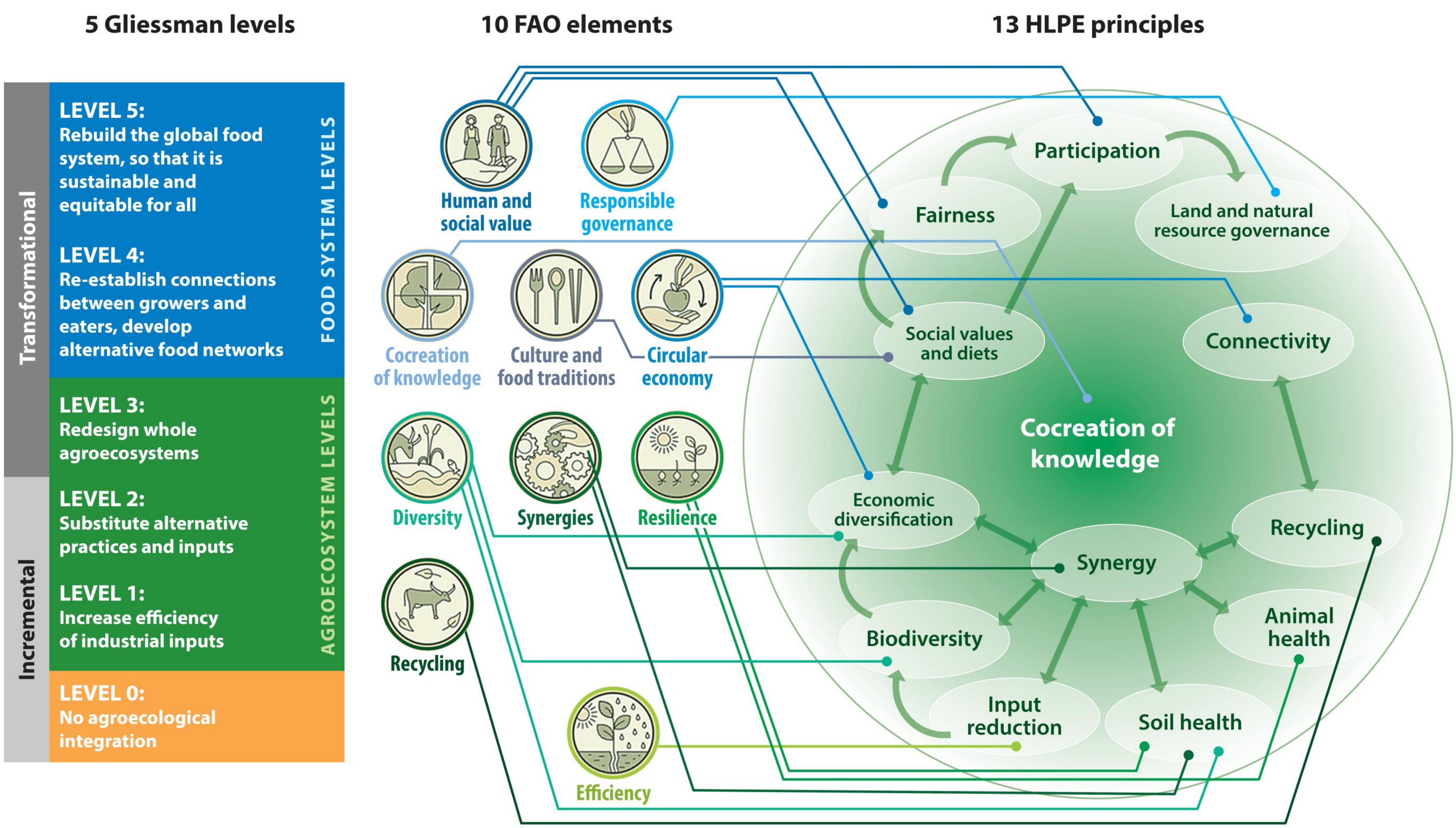
The goal is to understand the complexity, to know the mechanisms and functions that run and shape the agroecosystem to optimize and manage it.

Agroecosystem characteristics, function and mechanisms are not separable are interconnected and therefore need to be studied in their interactions.



Studying **interactions** needs huge data and huge computational effort.
The collection of high-density and high-frequency data is crucial to push the study of effective and well contextualized agroecological solutions.

Ewert, F., Baatz, R., & Finger, R. (2023). Agroecology for a sustainable agriculture and food system: from local solutions to large-scale adoption. *Annual Review of Resource Economics*, *15*, 351-381.

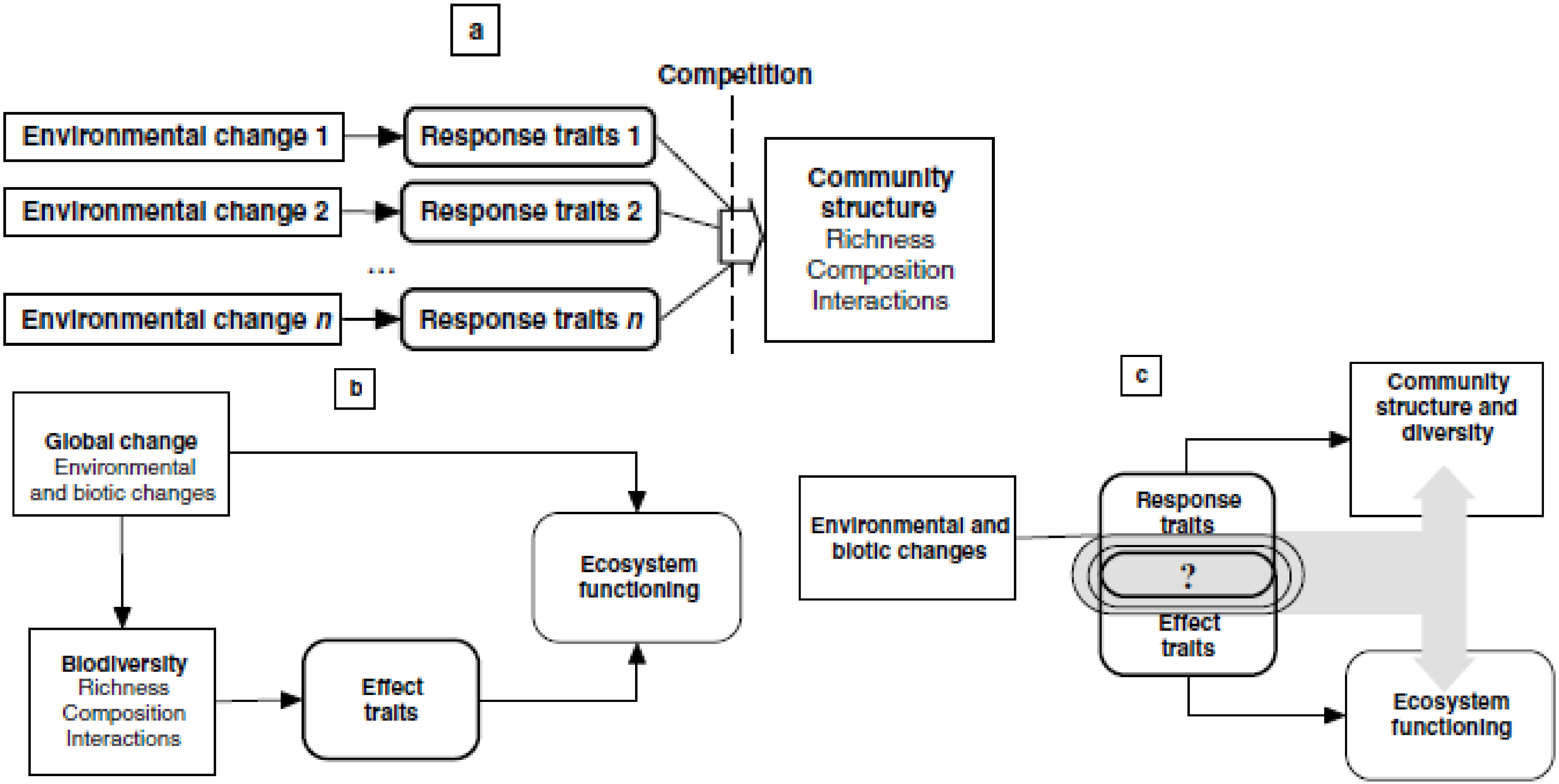

5 Gliessman levels
10 FAO elements
13 HLPE principles
Transformational
Incremental
FOOD SYSTEM LEVELS
AGROECOSYSTEM LEVELS
LEVEL 5:
Rebuild the global food system, so that it is sustainable and equitable for all
LEVEL 4:
Re-establish connections between growers and eaters, develop alternative food networks
LEVEL 3:
Redesign whole agroecosystems
LEVEL 2:
Substitute alternative practices and inputs
LEVEL 1:
Increase efficiency of industrial inputs
LEVEL 0:
No agroecological integration
Human and social value
Responsible governance
Cocreation of knowledge
Culture and food traditions
Circular economy
Diversity
Synergies
Resilience
Recycling
Efficiency
Participation
Fairness
Land and natural resource governance
Social values and diets
Connectivity
Cocreation of knowledge
Economic diversification
Recycling
Synergy
Biodiversity
Animal health
Input reduction
Soil health

Two approaches for the agroecological transition

“Trait base approach” or innovation based on the functional use of diversity

“Agroecological Multi actor-approach” that is, an approach to develop an agroecological transition process based on the participation of the various actors involved

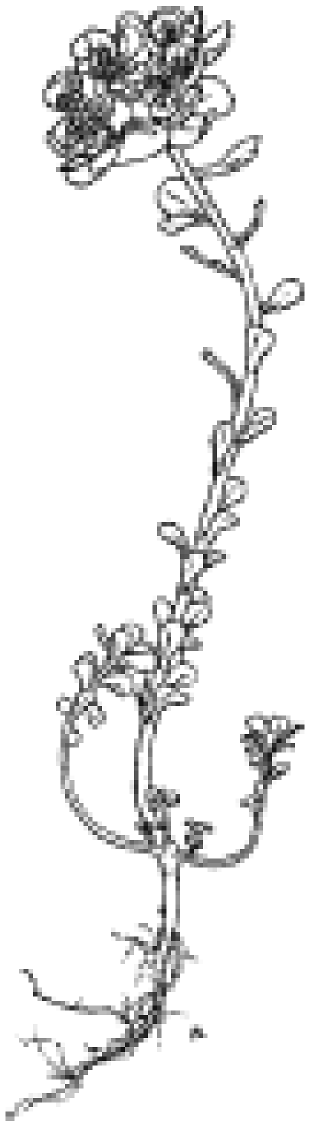
Functional agrobiodiversity: the emergence of a trait-based approach



Lavorel & Garnier (2002). Functional Ecology 16, 545-556.

Functional agrobiodiversity: the emergence of a trait-based approach

Functions	« Functional markers »
Fecundity Dispersal Recruitment	Seed mass Reproductive height Reproductive phenology
Light interception Competitive ability	Vegetative height
Resource acquisition/growth Litter decomposition	Traits of living leaves NIRS spectrum
Absorption (nutrients, water) Carbon fluxes (exsudation…) Underground competition	Root density Root diameter, length Root specific area



Life history traits
- Establishment
- Growth
- Reproduction
- Survival

Garnier & Navas (2012). Agronomy for Sustainable Development 32, 365-399.

Functional agrobiodiversity: the emergence of a trait-based approach

- In Agroecology, the objective is to select agrobiodiversity elements (at genetic, species and/or habitat level) possessing the **attributes** («effect traits») most likely providing the target AES (e.g., biological pest control).

- We have developed a **four-step approach** to streamline research and practice aimed to maximize the provision of AES.

Four-step approach to functional agrobiodiversity (i)

Table 2 Example of application of our four-step approach to the implementation of a functional agrobiodiversity study, including a participatory aspect[1]

Step	Description	Example	Participatory aspect
(i)	Definition of the context and of site-specific objectives	Improvement of soil health; diversification of cropping/ farming systems; input reduction (fertilisers, pesticides); moving towards organic crop production	Setting up local actors/ stakeholders team: participatory analysis of the agroecosystem state and co-definition of site-specific objectives (e.g. through focus groups)
		Specific Object	**Contex**

Step 1: Contex and goals

Bàrberi & Moonen, 2020

Four-step approach
to functional agrobiodiversity (ii)

Table 2 Example of application of our four-step approach to the implementation of a functional agrobiodiversity study, including a participatory aspect[1]

Step	Description	Example	Participatory aspect
(ii)	Definition of the priority agroecosystem service(s)	Improvement of soil fertility, pollution reduction, sustainable pest/disease management, water supply/quality	Co-definition of target services for each study site (e.g. through focus groups or semi-open interviews)

what

how

Step 2: priority

Bàrberi & Moonen, 2020

Four-step approach to functional agrobiodiversity (iii)

Table 2 Example of application of our four-step approach to the implementation of a functional agrobiodiversity study, including a participatory aspect[1]

Bàrberi & Moonen, 2020

Step	Description	Example	Participatory aspect
(iii)	Definition of the agroecosystem functional group(s) and of key traits/attributes associated to the delivery of priority agroecosystem service(s)	Local legume plants (e.g. as cover crops/intercrops), mulches, natural enemies of the target pests, wild plant species and habitat structures (headlands, hedgerows, woodland, multi-layer agroforestry etc.) attracting natural enemies or limiting disease spread, crop cultural practices known to affect soil fertility and pest/disease containment (genotype choice, planting, fertilisation, pest/disease/ weed management etc.)	Co-definition of local resources and practices (plants, habitat elements, management techniques etc.) potentially able to provide the target services, taking into account farmers' preferences; setting-up on-farm trials

Step 3: functional groups and triats

Four-step approach to functional agrobiodiversity (iv)

Table 2 Example of application of our four-step approach to the implementation of a functional agrobiodiversity study, including a participatory aspect[1]

Bàrberi & Moonen, 2020

Step	Description	Example	Participatory aspect
(iv)	Definition of space and time boundaries, of the best set of soil health indicators, and of measurement details	Field, farm and landscape scale, fallow and cropping phase, visual estimate and on-field measurement of soil and plant status (e.g. physical, chemical and biological soil health estimated by the spade test, SPAD-based plant chlorophyll content, visual estimate of pest/disease attack), soil and plant sampling and subsequent laboratory analyses (e.g. soil structure stability, organic carbon and NPK content,	Co-definition of soil health and crop performance indicators; co-evaluation of on-farm trials (e.g. through focus groups and targeted evaluation sheets)

Step 4: boundaries and measures

Four-step approach to functional agrobiodiversity (iv, cont.)

Table 2 Example of application of our four-step approach to the implementation of a functional agrobiodiversity study, including a participatory aspect[1]

Step	Description	Example	Participatory aspect
(iv)	Definition of space and time boundaries, of the best set of soil health indicators, and of measurement details	earthworm abundance), presence and abundance of natural enemies (sample), vegetation/mulch cover (sample), crop growth and marketable yield (sample), type and abundance of surrounding wild vegetation/habitats (sample), number, type and rates of pesticides applied etc.	Co-definition of soil health and crop performance indicators; co-evaluation of on-farm trials (e.g. through focus groups and targeted evaluation sheets)

Bàrberi, P., & Moonen, A. C. (2020). *Reconciling agricultural production with biodiversity conservation*. Burleigh Dodds Science Publishing Limited.

Four-step approach
to functional agrobiodiversity (i)

Step 1: Contex and goals

Where?

Specific objects

Step 2: Priority

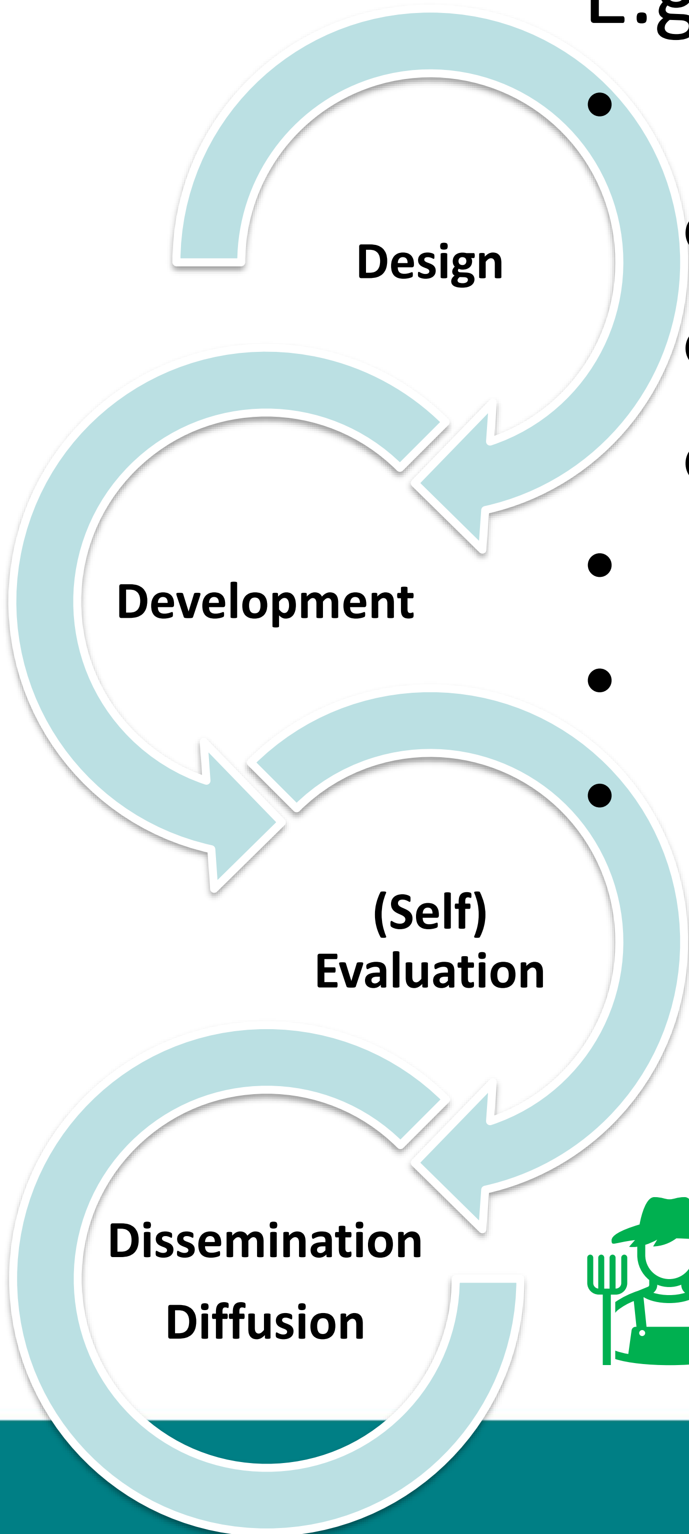
What?

Step 3: Functional groups and triats

How?

Step 4: Boundaries and measures

Multi-actor approach for an agroecological transition



Technical coach

E.g. Agronomist

- Contest aware:
  - Pedoclimatic condition
  - Socio economic dynamics
  - Collective psychology
- Facilitator (soft skills)
- **Link with market**
- **Link with technical innovative mean of production**

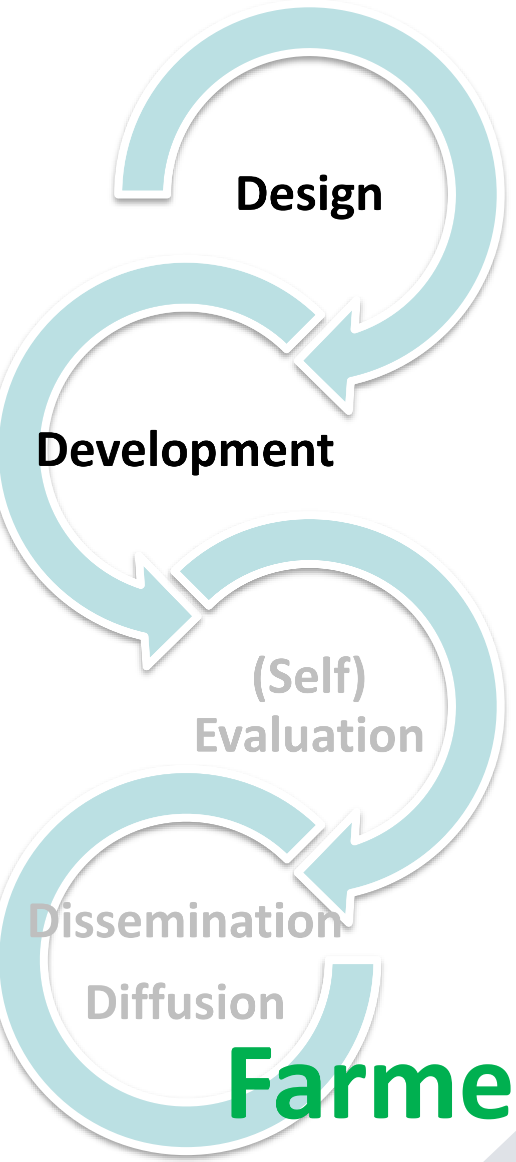
Researcher:

- Methods to test ideas
- Formalize process;
- Create and spread knowledge
- **Link with global knowledge**

Motivated Farmers (AOP)

- Will of change!
- Problems
- Ideas for solution
- **Link with local knowledge**

Design & Develop agroecological transition



Technical coach:

1. Provide an extensive depiction of local condition
2. Critical view on possible alternatives
3. Connects with nearby experience (farmers, AOP, innovative companies)

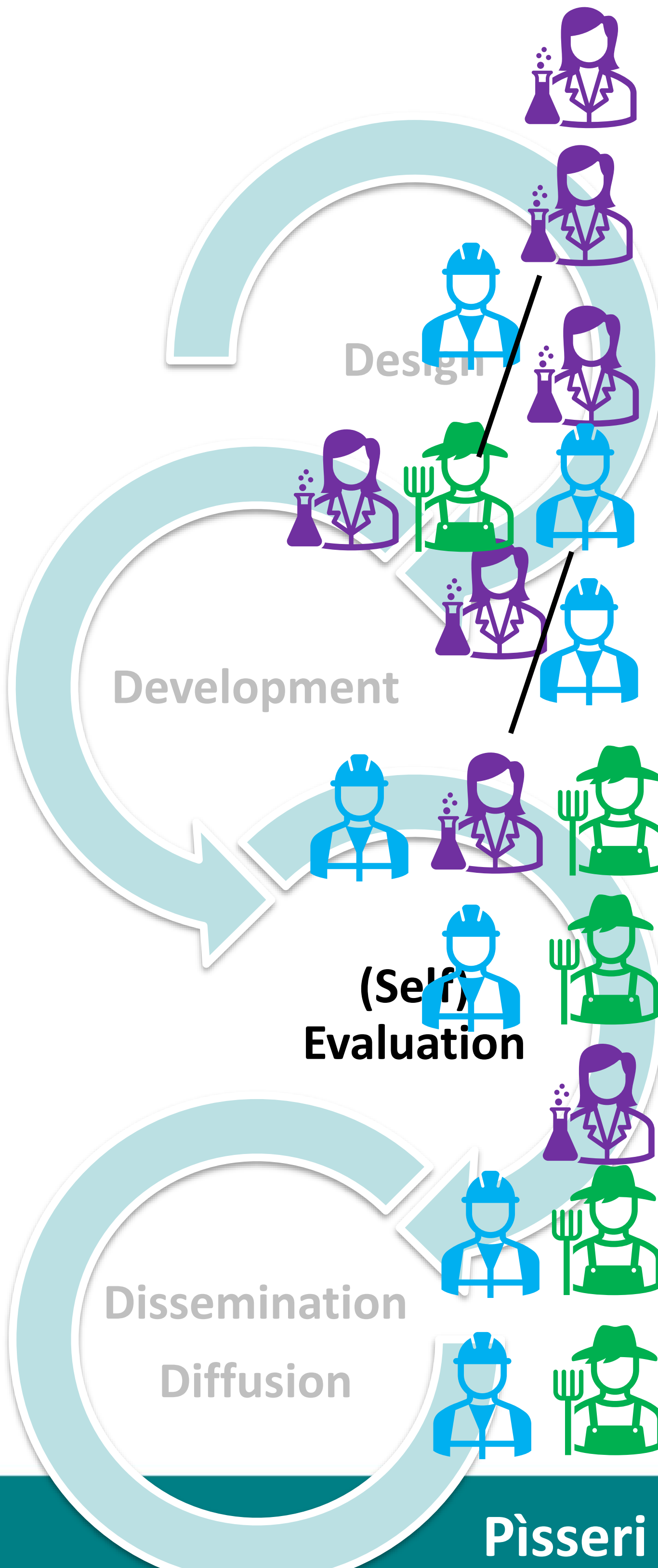
Researcher:

1. Provide protocols to test single innovation
2. Put on the table “unthinkable” solutions
3. Connects with faraway experience

Farmers: provide starting point

1. Conventional agriculture critical points
2. Agroecological solution not working as desired
3. Decide what do and how to do it

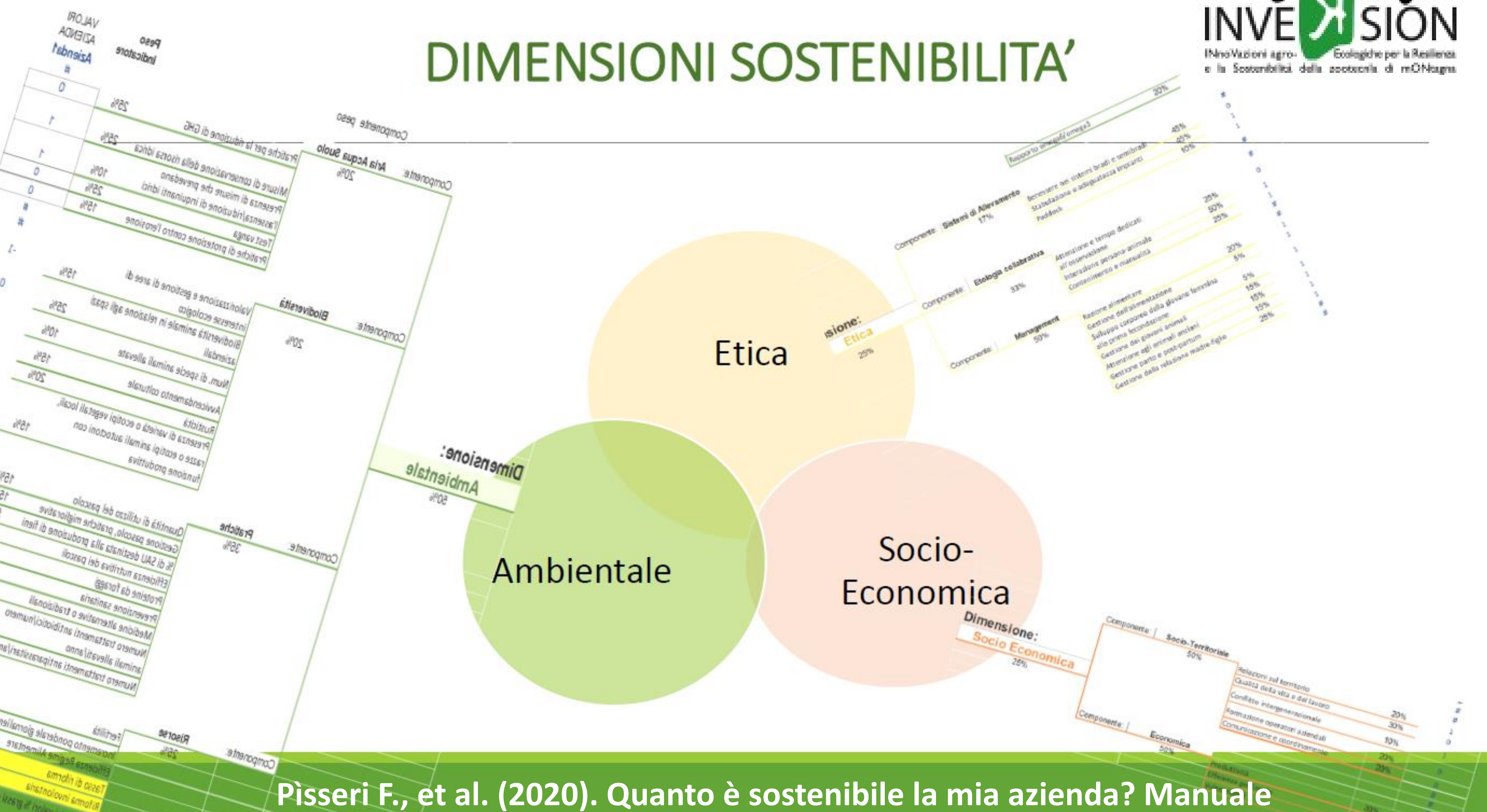
(Self) Evaluation: farm as a whole



- Selection of indicators
- Realisation of system structure
- Development of new indicators
- Formulation and adaptation of indicators
- Coordination of participatory process
- Co-definition of indicators
- Thresholds and weights
- Instrument creation
- Application and validation
- Exploitation

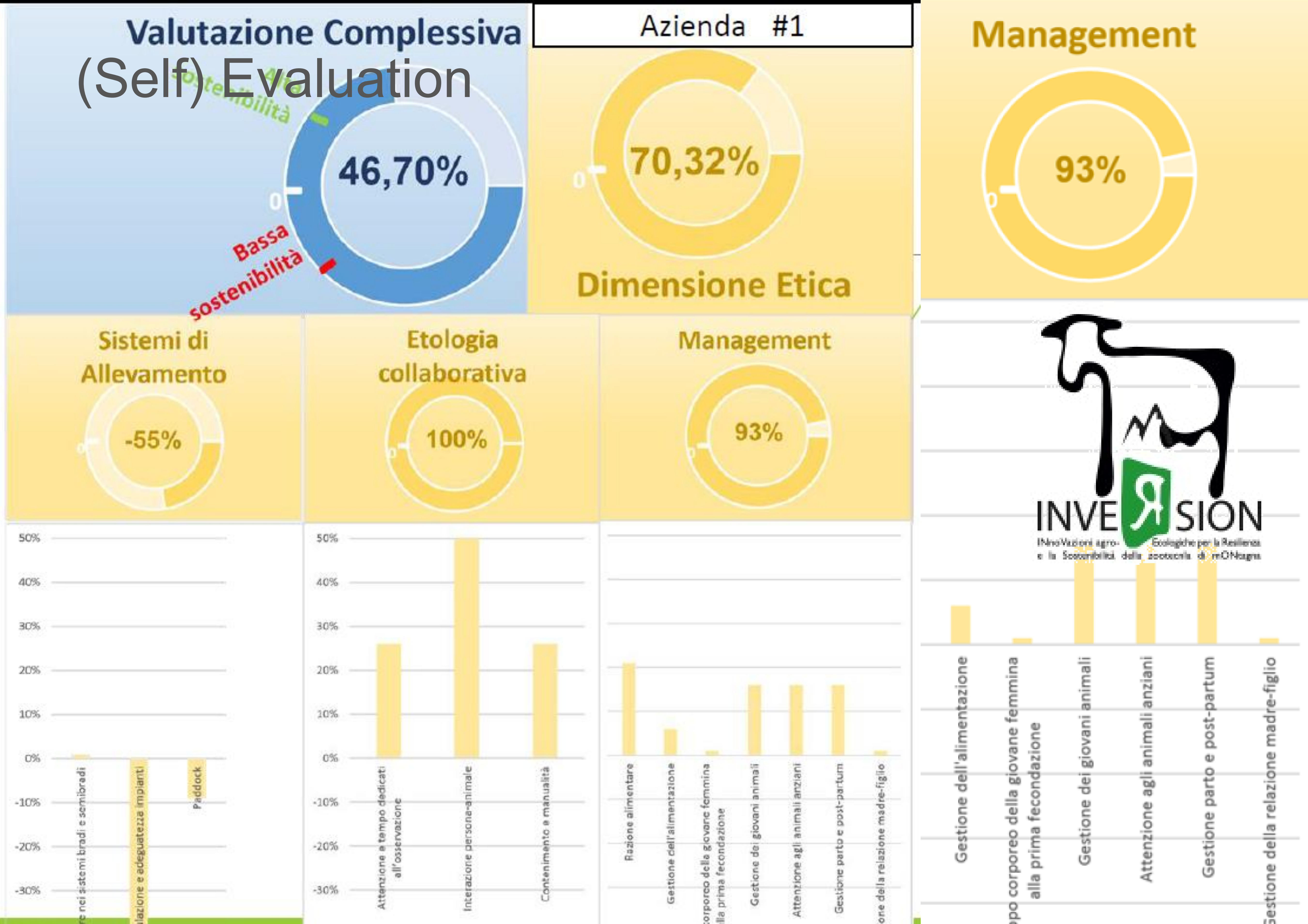
Pìsseri F., et al. (2020). Quanto è sostenibile la mia azienda? Manuale DEXi-INVERSION, per la valutazione della sostenibilità delle aziende zootecniche, 82 p., http://www.progettoinversion.it/materiali-progetto/, ISBN 978-88-901624-3-5.

(Self) Evaluation: farm as a whole



Pìsseri F., et al. (2020). Quanto è sostenibile la mia azienda? Manuale DEXi-INVERSION, per la valutazione della sostenibilità delle aziende zootecniche, 82 p., http://www.progettoinversion.it/materiali-progetto/, ISBN 978-88-901624-3-5.

(Self) Evaluation



Pìsseri F., et al. (2020). Quanto è sostenibile la mia azienda? Manuale DEXi-INVERSION, per la valutazione della sostenibilità delle aziende zootecniche, 82 p., http://www.progettoinversion.it/materiali-progetto/, ISBN 978-88-901624-3-5.

Dissemination - Diffusion

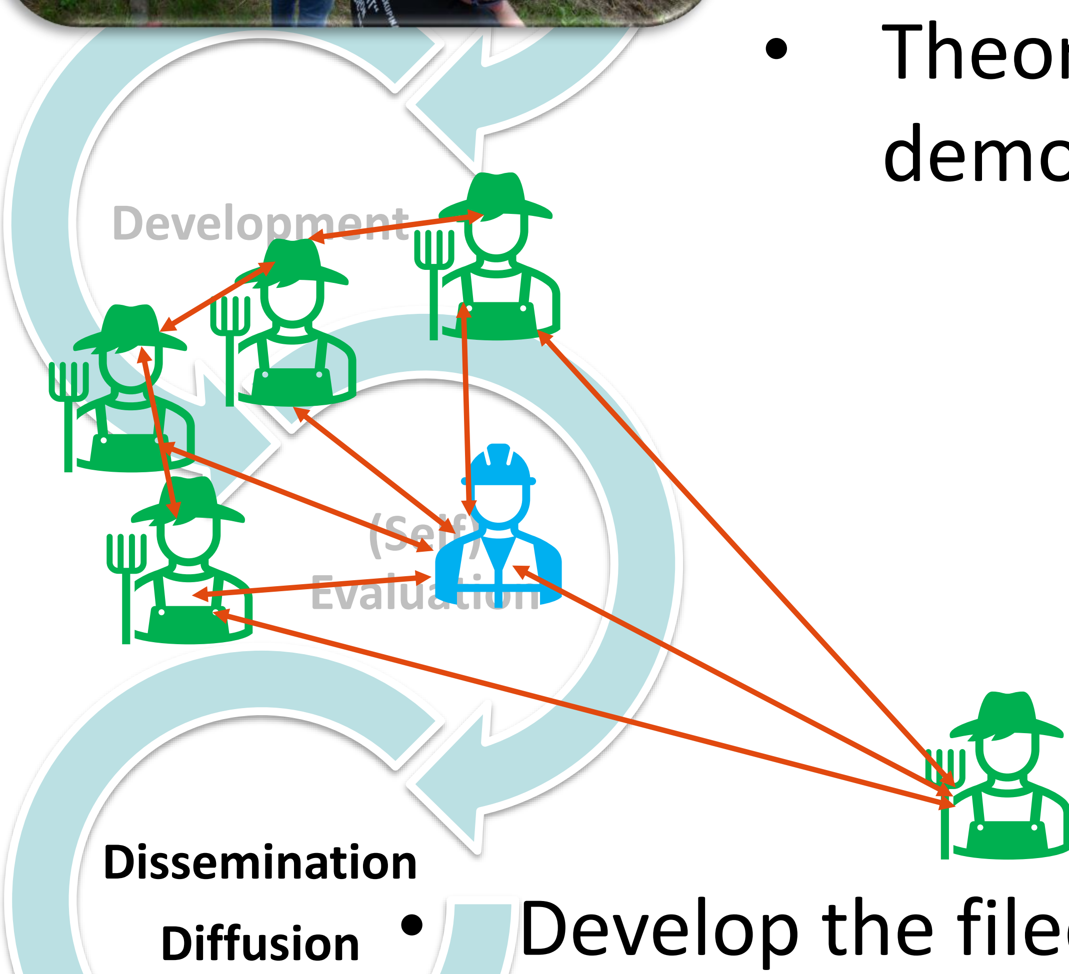
Farmer Hub (living lab)
and demo event

Science:

- Elaborate data, solid methods, adapt methods
- Verifies & critical revies innovation tested
- Theoretical background for the innovation and demo events

Technical coach:

- Arrange the filed trials
- Helps collecting data
- Prepare material to popularize the innovatio
- Arrange the demonstrative event



Farmer:

- Develop the filed trials at with farm scale
- Tells his direct experience (peer to peer)
- Evaluate critically the key point and bottl
- Host the demonstrative event

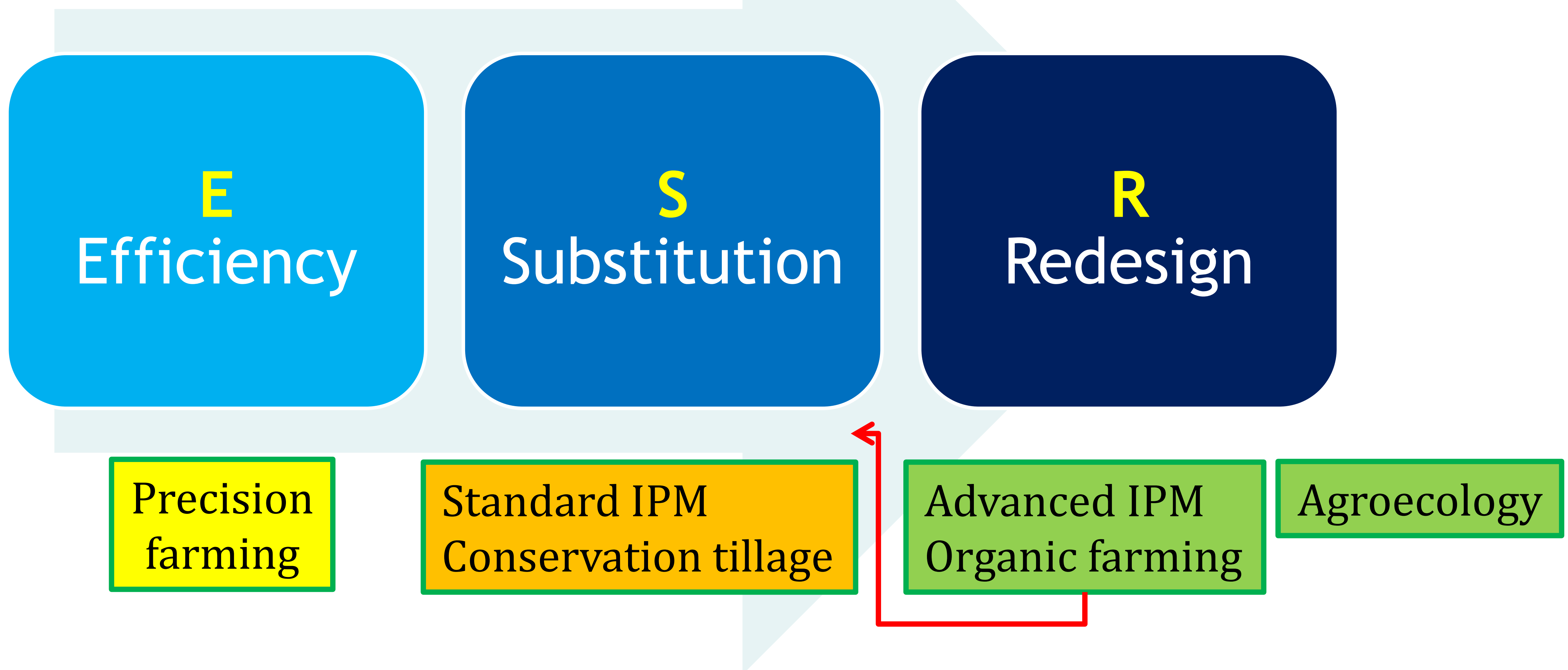
Conclusions:

Project approach not enough

- Needs to create mixed **wider** teams
- Involve **actively further** key actors (e.g. public institution and AOP)
- **Lasting in time** experience for spreading best transition process and practice
- Working on innovation, with **iterative approach (time needed)**
- Providing **continuous** assistance
- Creating new knowledge
- **Actively sharing** practical and theorical innovation
- Contributing to **continuously** re-new and adapt innovation theory and methods

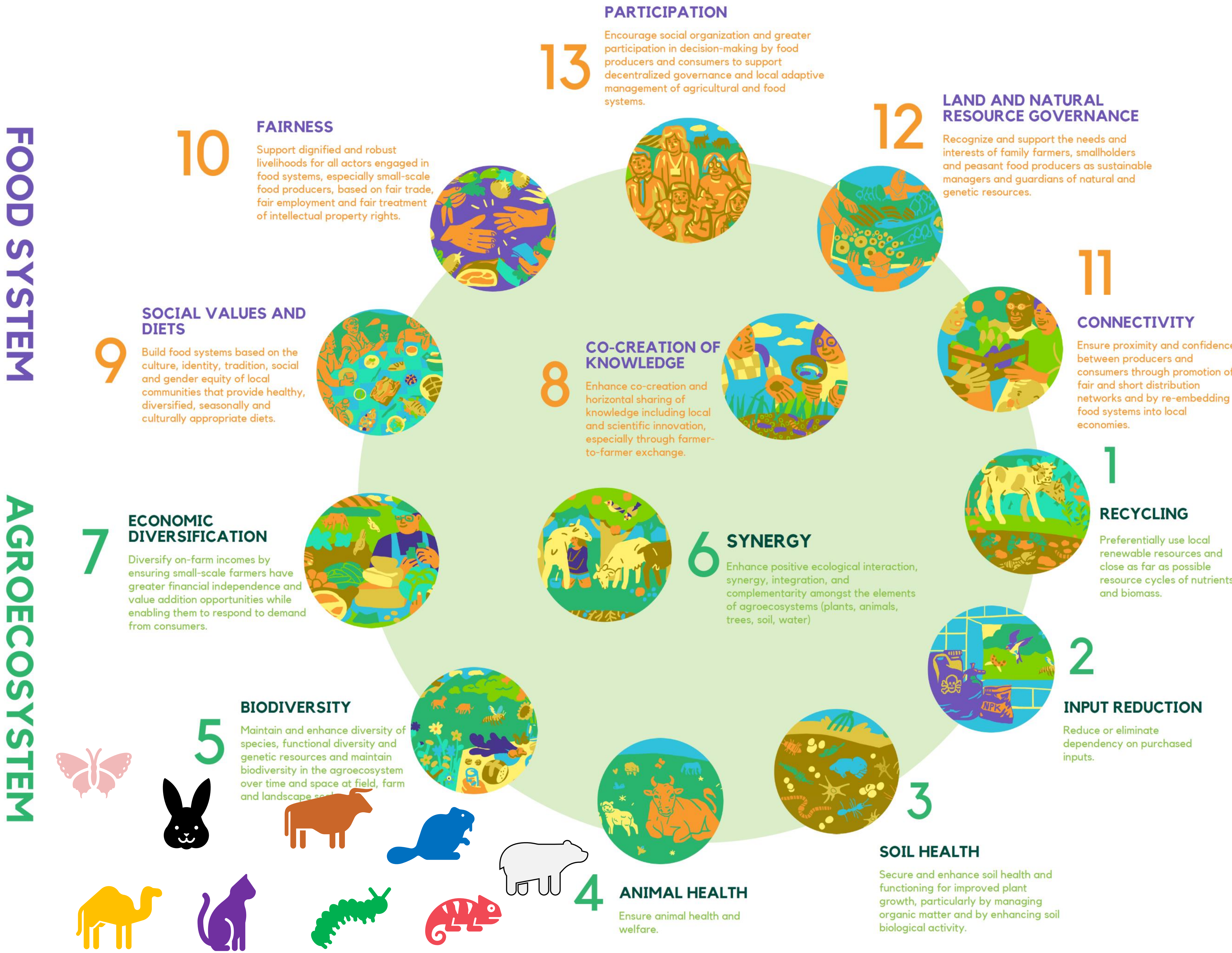
The ESR transitioning approach towards truly sustainable agricultural and food systems

- System approach
- Strong input reduction
- Agrobiodiversity
- Social aspects



Food system **transformation**

Hill & McRae (1995). J. Sust. Agr. 7, 81-87, adapted in Bàrberi (2021).


FOOD SYSTEM
AGROECOSYSTEM
13
PARTICIPATION
Encourage social organization and greater participation in decision-making by food producers and consumers to support decentralized governance and local adaptive management of agricultural and food systems.
12
LAND AND NATURAL RESOURCE GOVERNANCE
Recognize and support the needs and interests of family farmers, smallholders and peasant food producers as sustainable managers and guardians of natural and genetic resources.
10
FAIRNESS
Support dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers, based on fair trade, fair employment and fair treatment of intellectual property rights.
11
CONNECTIVITY
Ensure proximity and confidence between producers and consumers through promotion of fair and short distribution networks and by re-embedding food systems into local economies.
9
SOCIAL VALUES AND DIETS
Build food systems based on the culture, identity, tradition, social and gender equity of local communities that provide healthy, diversified, seasonally and culturally appropriate diets.
8
CO-CREATION OF KNOWLEDGE
Enhance co-creation and horizontal sharing of knowledge including local and scientific innovation, especially through farmer-to-farmer exchange.
1
RECYCLING
Preferentially use local renewable resources and close as far as possible resource cycles of nutrients and biomass.
7
ECONOMIC DIVERSIFICATION
Diversify on-farm incomes by ensuring small-scale farmers have greater financial independence and value addition opportunities while enabling them to respond to demand from consumers.
6
SYNERGY
Enhance positive ecological interaction, synergy, integration, and complementarity amongst the elements of agroecosystems (plants, animals, trees, soil, water)
2
INPUT REDUCTION
Reduce or eliminate dependency on purchased inputs.
5
BIODIVERSITY
Maintain and enhance diversity of species, functional diversity and genetic resources and maintain biodiversity in the agroecosystem over time and space at field, farm and landscape
3
SOIL HEALTH
Secure and enhance soil health and functioning for improved plant growth, particularly by managing organic matter and by enhancing soil biological activity.
4
ANIMAL HEALTH
Ensure animal health and welfare.

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