# Operationalizing the **soil health metaphor** to create sustainable food systems

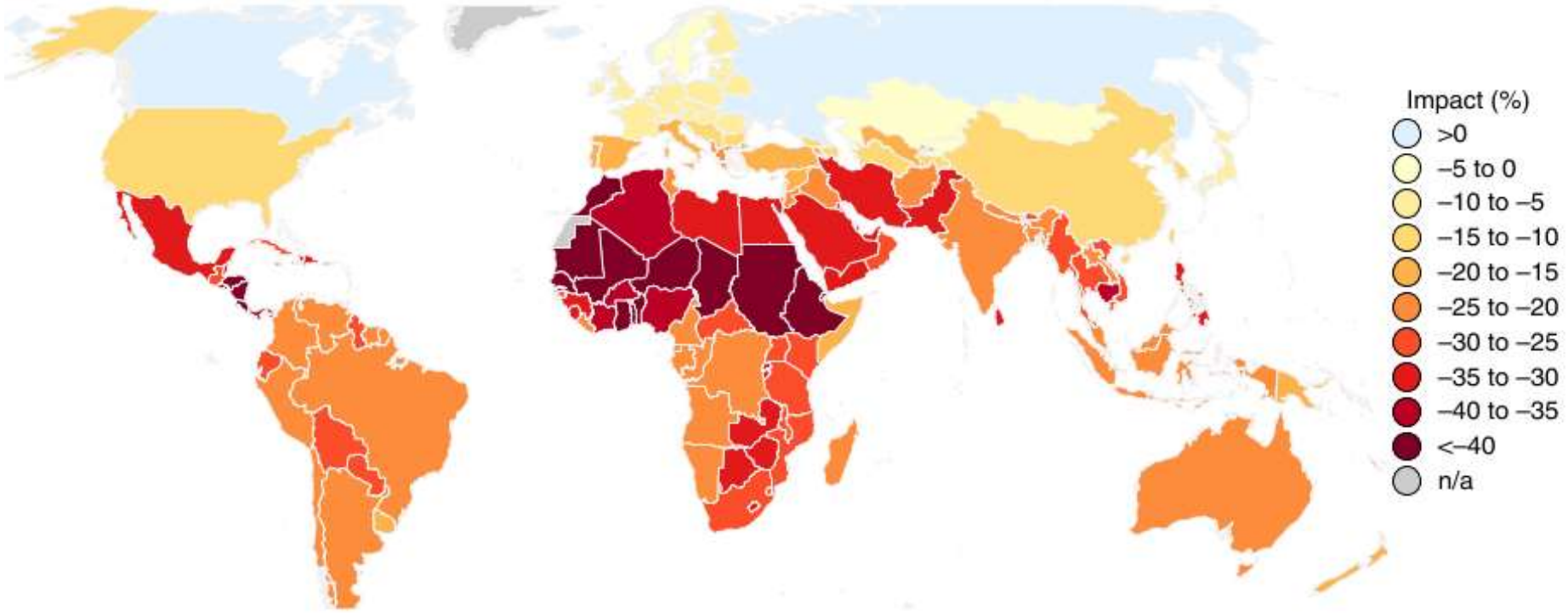
## with a focus on smallholder farming in the Global South



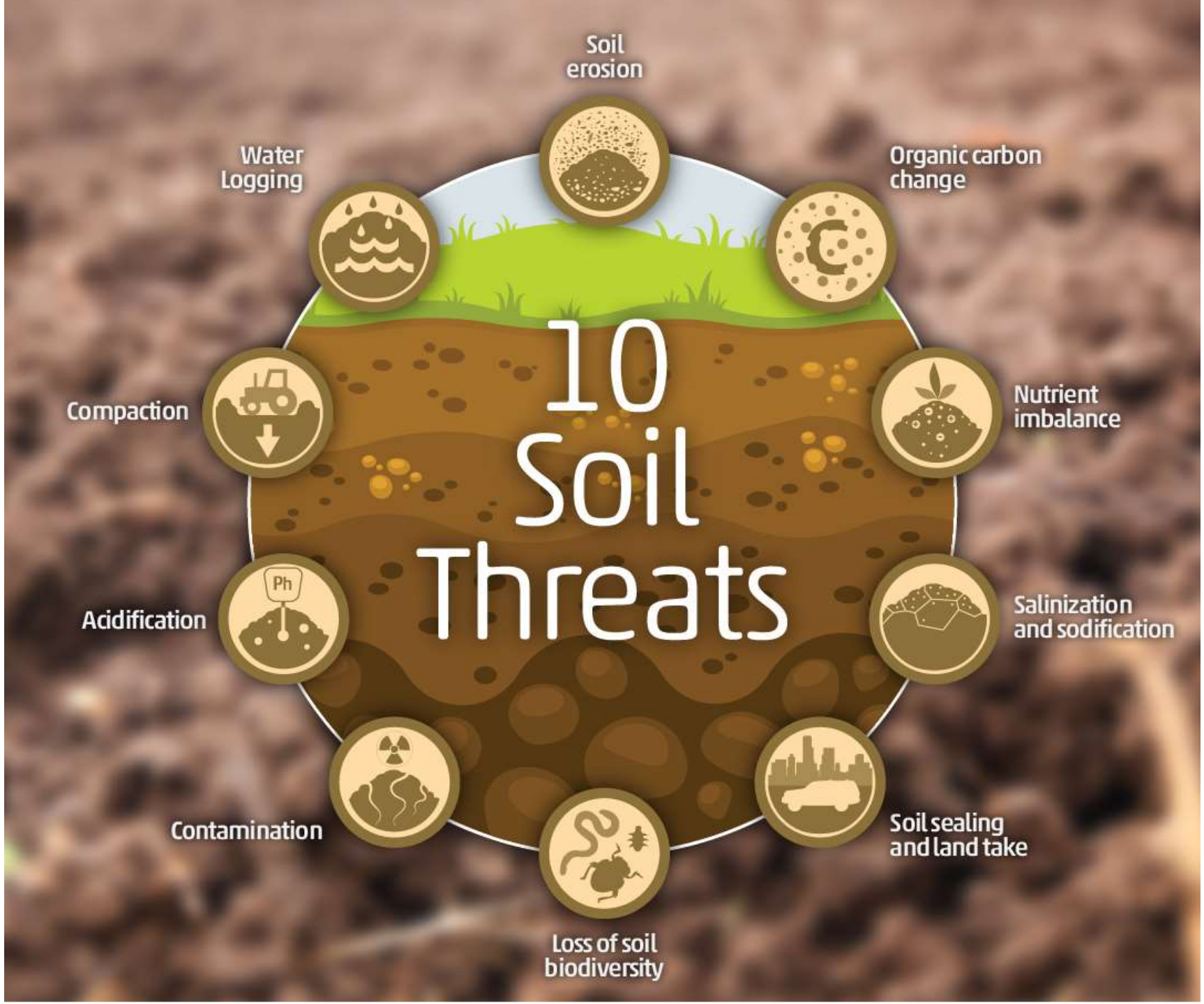

Mirjam Pulleman, CIAT and Wageningen University

Ortiz Bobea et al., 2021

# Antropogenic climate change has slowed global agricultural productivity growth




- ACC has reduced global agricultural TFP since 1961. TFP measures aggregate output per unit of aggregate input.
- The reduction is substantially more severe (26–34%) in warmer regions such as Africa and LAC.
- Global agriculture has also become more vulnerable to ongoing climate change




GLOBAL SOIL PARTNERSHIP

Food and Agriculture Organization of the United Nations

# Soil degradation & climate change are interlinked

- Threaten food security and ecosystems and the services they provide
- Smallholder farmers in the Global South are disproportionally affected

# Common drivers

- Increasing population pressure and land scarcity
- Farming on marginal lands/steep hillsides
- Low or inadequate use of mineral and organic inputs (nutrient mining)

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- High rainfall intensity, and limited soil cover
- Rapid OM decomposition, strongly weathered soils with low buffering capacity and nutrient retention

Low yields, low profitability, increasing production costs

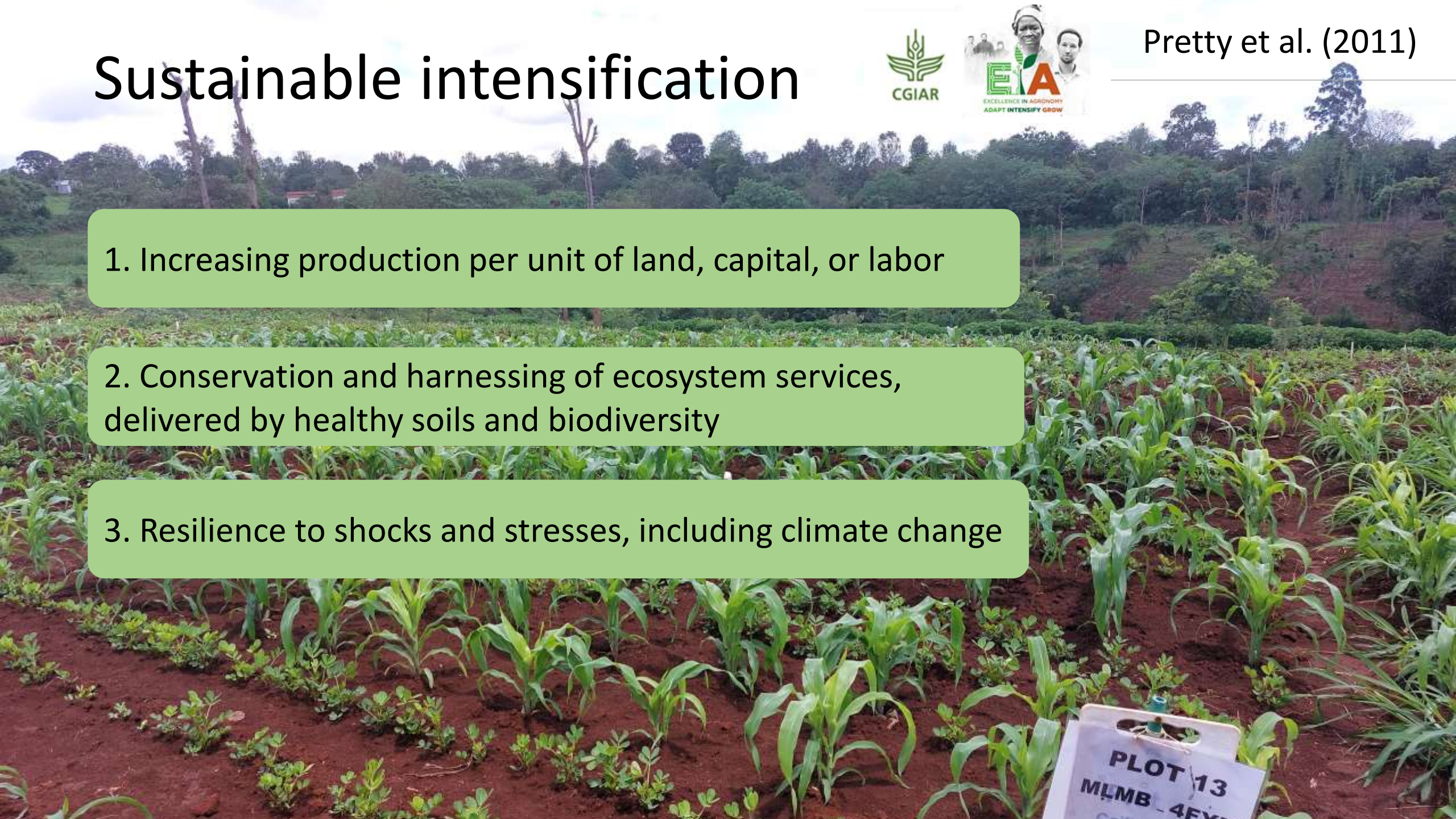
# Sustainable intensification

Pretty et al. (2011)

1. Increasing production per unit of land, capital, or labor

2. Conservation and harnessing of ecosystem services, delivered by healthy soils and biodiversity

3. Resilience to shocks and stresses, including climate change




CGIAR INITIATIVE ON Excellence in Agronomy

# Excellence in Agronomy

## for sustainable intensification and climate adaptation

https://eia.cgiar.org/

A CGIAR Initiative a CGIAR Initiative launched in 2020 with the aim to support millions of farming households, through partners, to achieve Agronomic Gain in prioritised farming systems by 2030 through:

- Increase in productivity and quality per unit of input
- resource use efficiency (nutrients, water, labour)
- Soil health & climate adaptation

AfricaRice Bioversity International CIAT CIMMYT CIP World Agroforestry Centre ICARDA ICRISAT IFPRI IITA IRRI IWMI

# Agronomic Gain, according to 4 KPIs:

Yield, Yield Quality and Profitability

Climate Adaptation, Yield Stability and Reduced Risk

Resource Use Efficiency (nutrients, water, labour)

Soil Health

# Regenerative Agriculture

Embraced by agri-food industry as a concept, or target, to support food system transformation that addresses multiple global challenges, including Net Zero



Potential for impact at scale, provided that assumed relations between principles, practices and outcomes are backed up by scientific evidence across contexts

Pulleman, Rahn, Valle (2023). https://hdl.handle.net/10568/131997

# Soil health ????

1. What is soil *health*?

2. How do we measure it?

3. How do we restore/enhance it?

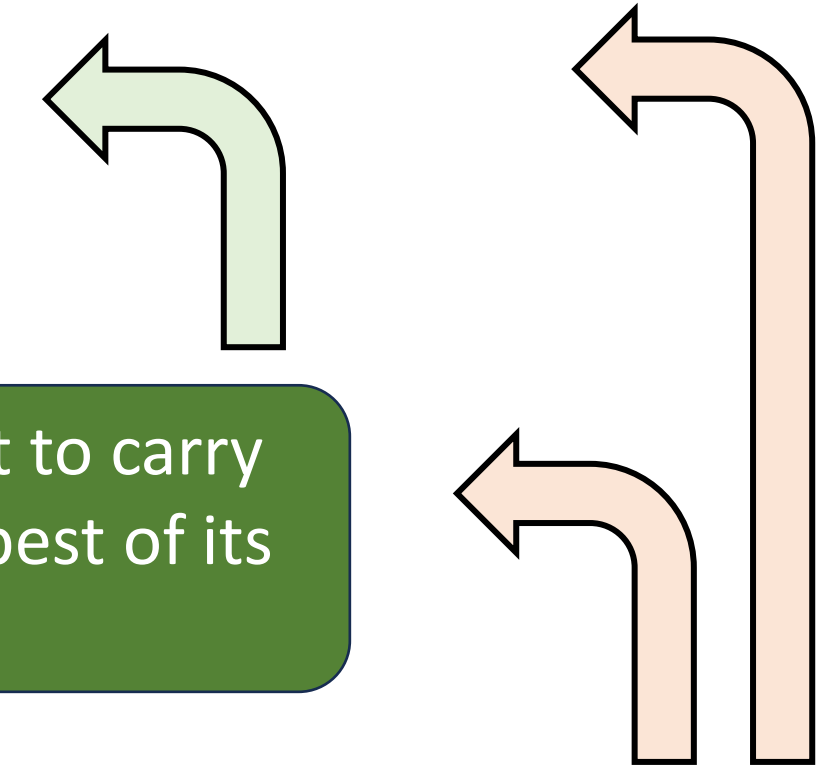
4. What role for biofertilizers & biostimulants?

1. What is soil *health*?

**Human Health**: A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO)

Patrick du Jardin - Opening address

**Plant health**: The capacity of the plant to carry out its physiological functions, to the best of its genetic potential (Agrios, 2005)



**Soil health**: the capacity of the *living* soil to perform its ecological (& social) functions, within land use and ecosystem boundaries (based on Doran and Zeiss, 2000, Janzen 2021)

# “SOIL HEALTH is a powerful metaphor”

(Janzen, 2021)

“While Soil Health has captured strong interest of industry and decision makers as a key impact area and KPI, the academic community struggles to rationalize its use as a quantifiable or measurable concept” (Powlson, 2021)

Giller, Pulleman, Sassen (2023). https://doi.org/10.18174/630630

Soil properties & processes:

Ecological functions:

Benefits:

Land use and management

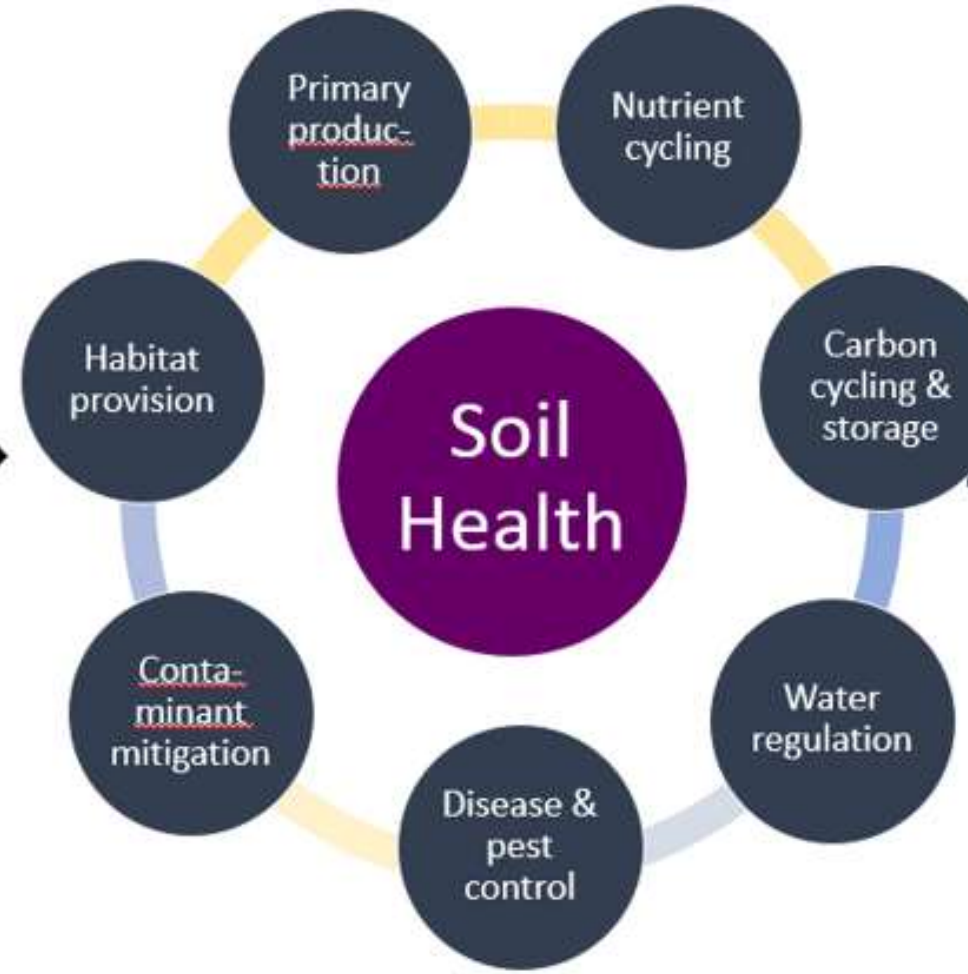
+

Ecosystem boundaries (incl. pedoclimatic conditions)

Biological

Chemical

Physical




- Food and income security
- Food safety
- Provision of clean water
- Reduce GHG emissions
- C removal
- Safeguarding biodiversity

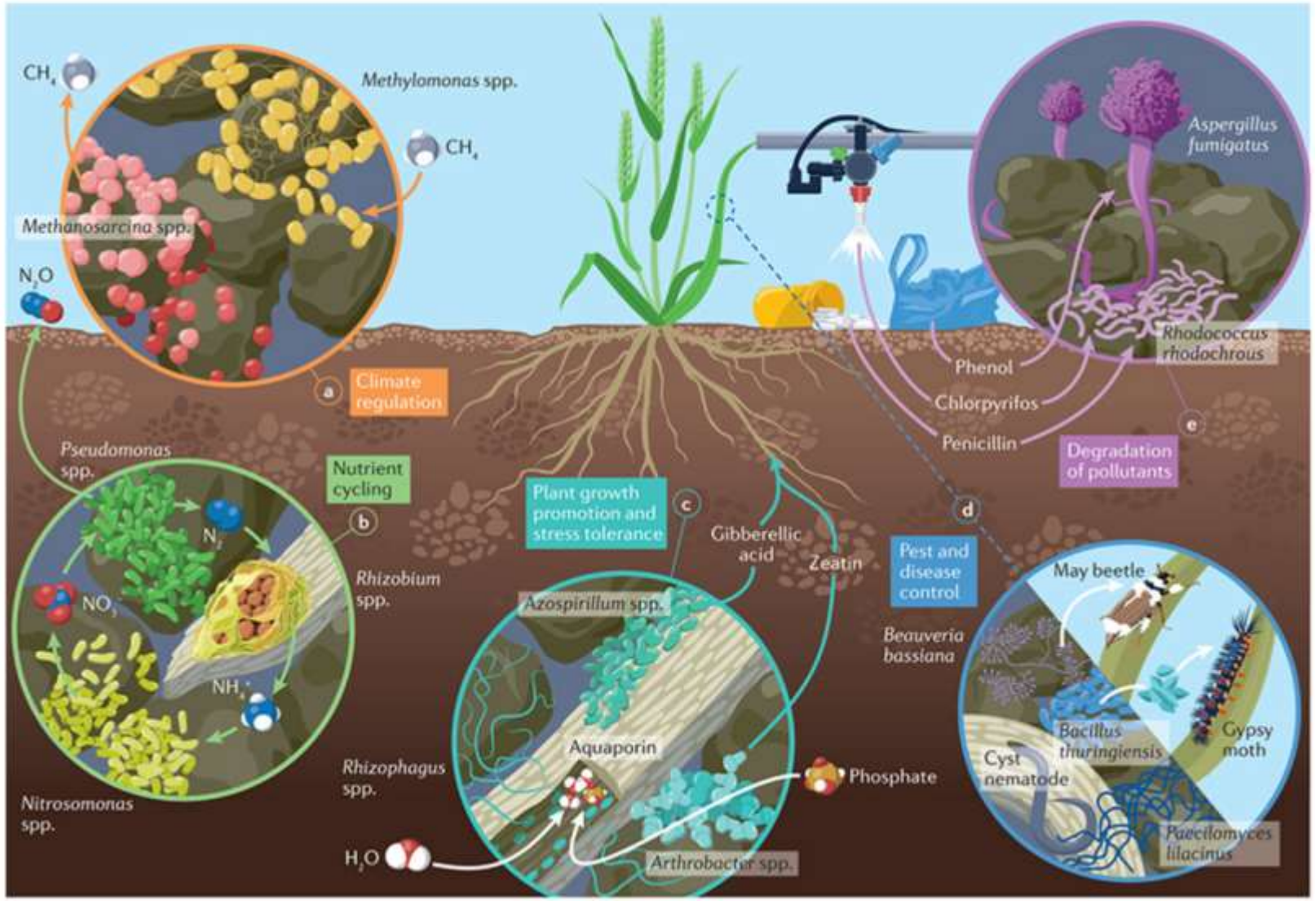
…

**Soil health** is the capacity of soil to perform its ecological (& social) functions

# The soil microbiome

Hartmann & Six (2022)

- Drives key functions in agroecosystems, determining soil fertility, crop productivity and stress tolerance.
- Intricately linked with soil structure (aggregation, pore connectivity).
- Agricultural management alters the soil structure, changing soil processes at the microscale.
- Large-scale consequences, such as soil erosion, soil fertility and GHG emissions.



# Soil ecosystem engineers as key stone species

...soil structure formation

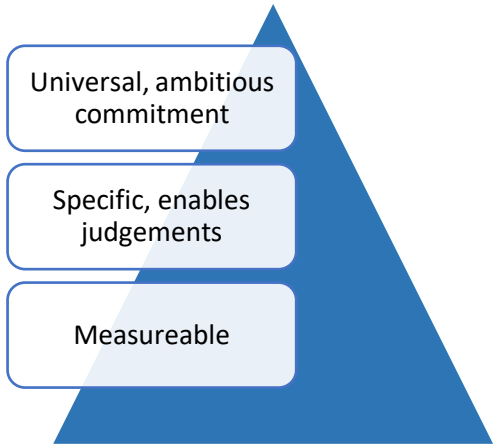
...create and modify habitats

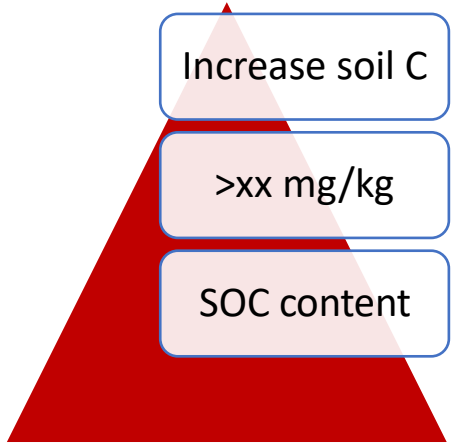
...modify availability of resources

Giller, Pulleman, Sassen (2023). https://doi.org/10.18174/630630

## 2. How do we measure it?

- Indicators: Measurable proxies (soil properties, or organisms) that represent one or more ecological processes or functions
- Pertinent (in terms of soil functions), sensitive (in response to management), robust, practical
- Chemical, physical ánd biological aspects

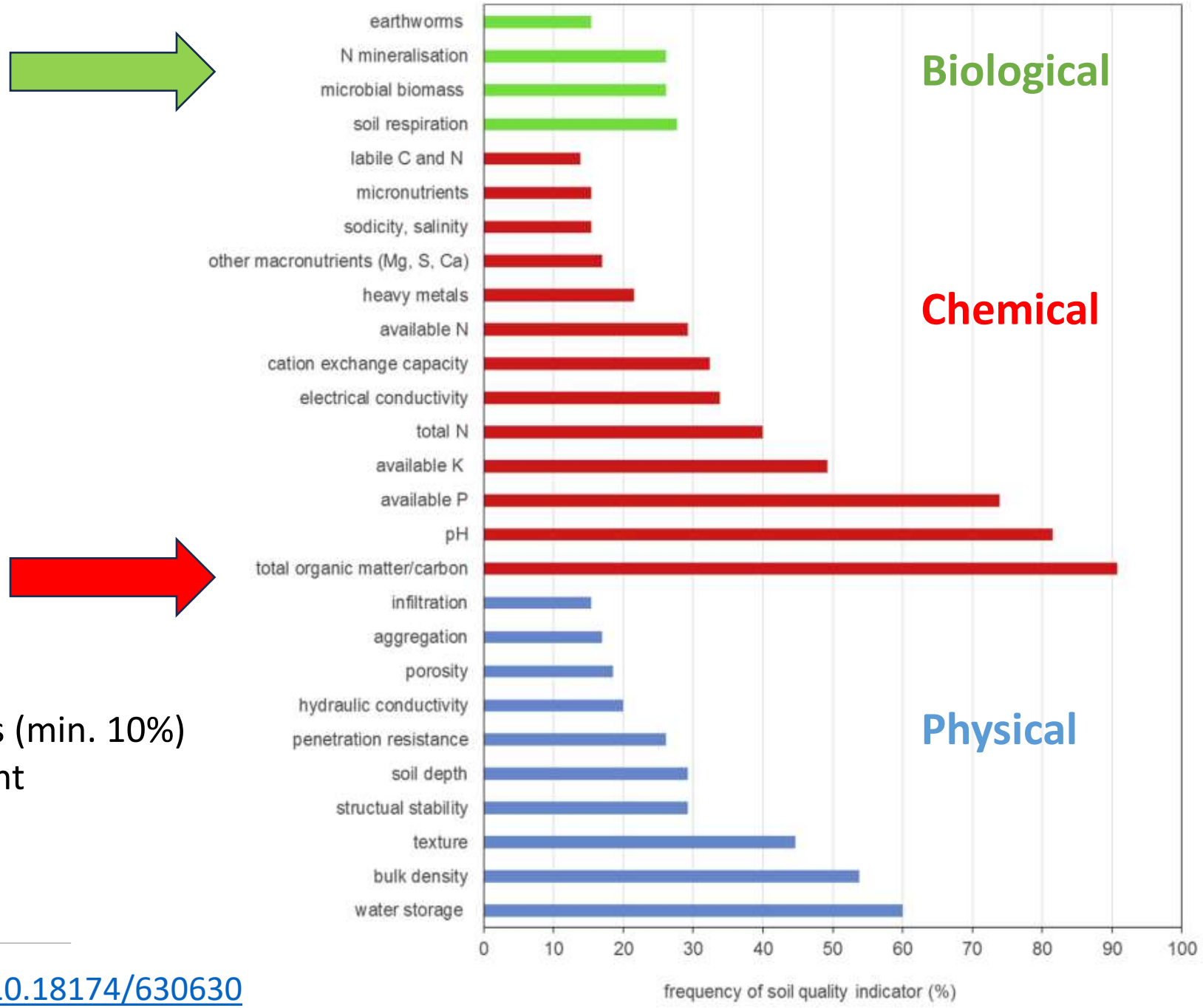
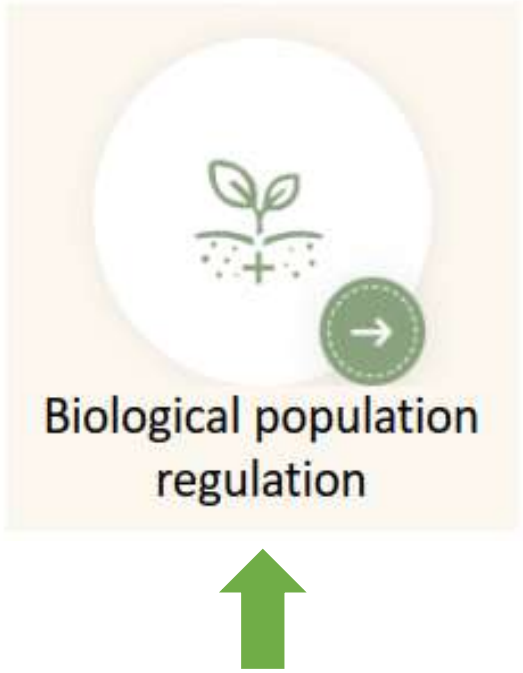


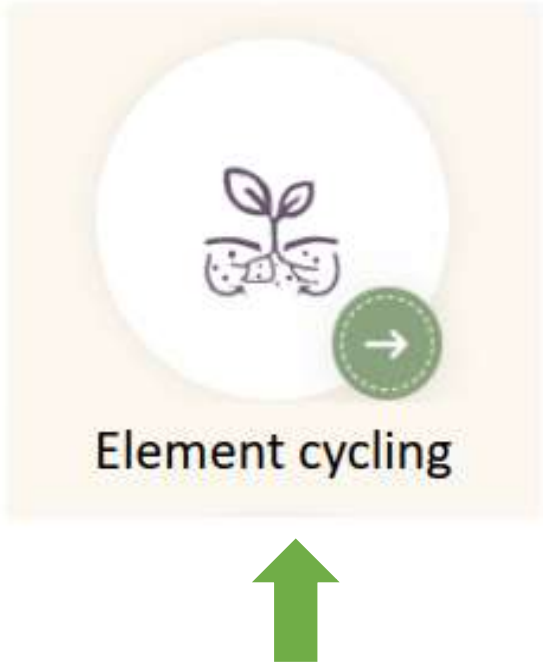

Fig. Frequency of different indicators (min. 10%) in all reviewed soil quality assessment approaches (n = 65).

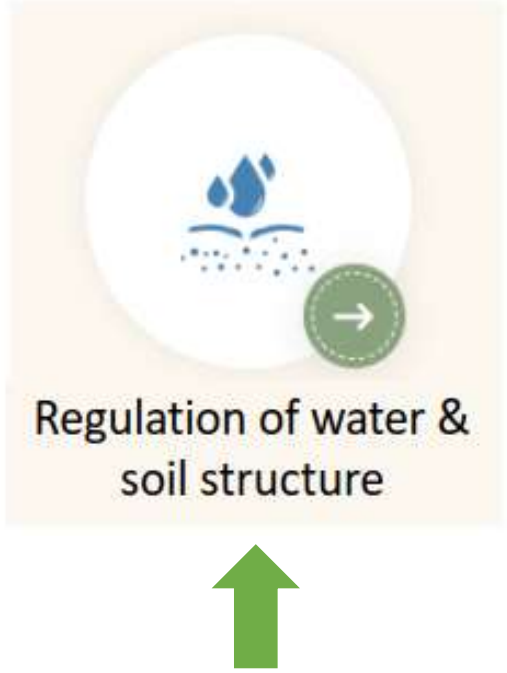
Bunneman et al. (2018). https://doi.org/10.18174/630630

Koorneef, Pulleman, Comans, De Goede (in prep.)

# Total soil organic matter/carbon as integrated soil health indicator?

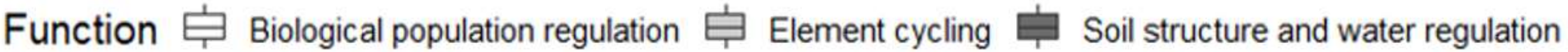



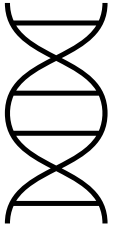
Koorneef, Pulleman, Comans, De Goede (in prep.)

# Total soil organic carbon (TOC) as integrated soil health indicator?

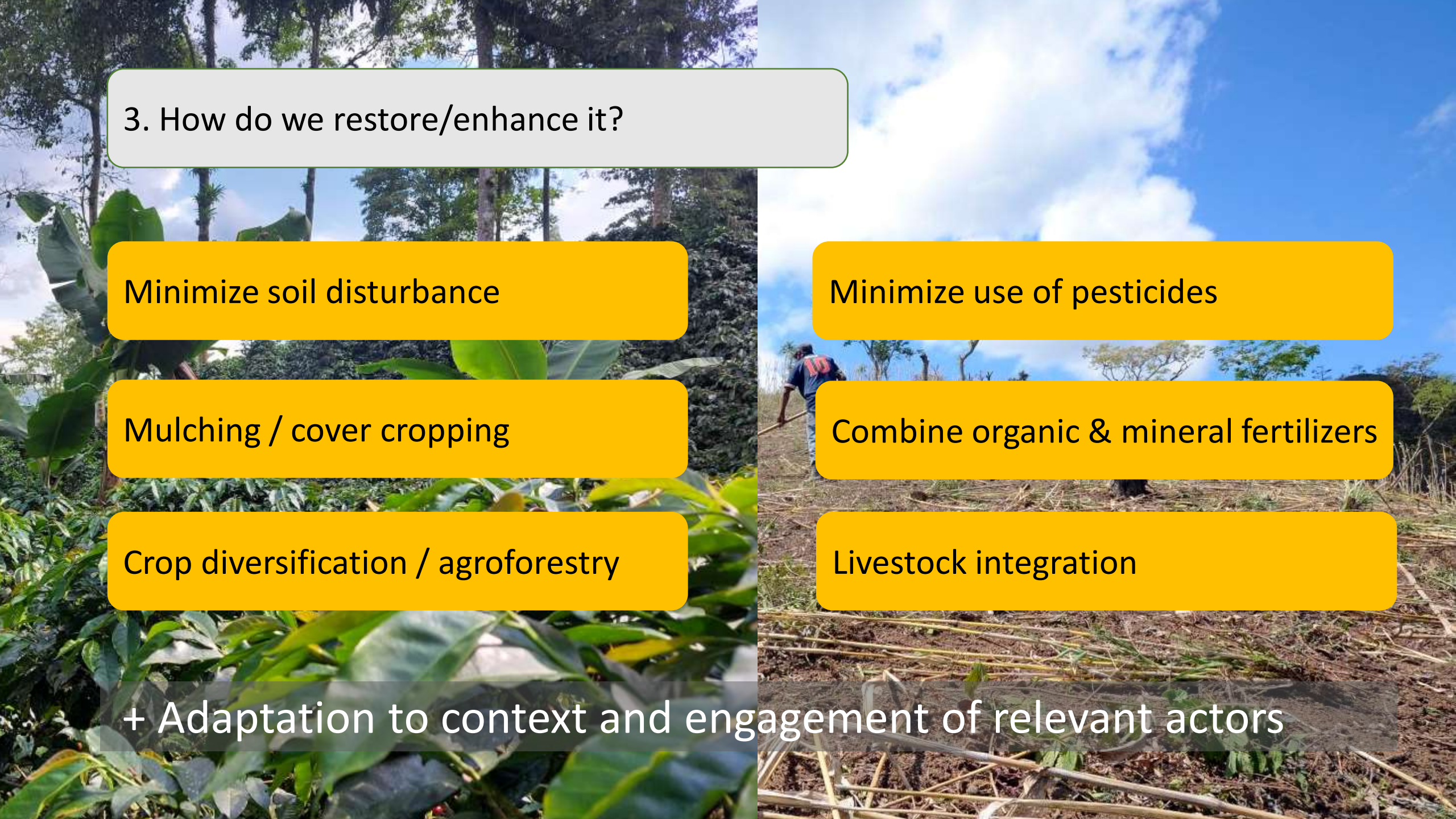


## 2. How do we measure it?

- ✓<u>Multiple</u> soil indicators chemical, physical, biological
- ✓Measure both processes and actors that are indicative of physical and chemical habitat condition, energetic reservoirs, and community structure (e.g. food web structure)
- ✓Ecosystem engineers/keystone species are of great interest due to their sensitivity to management and strong relevance for (multiple) soil functions.
- ✓Prioritize indicators and select methods/protocols, according to context and end users



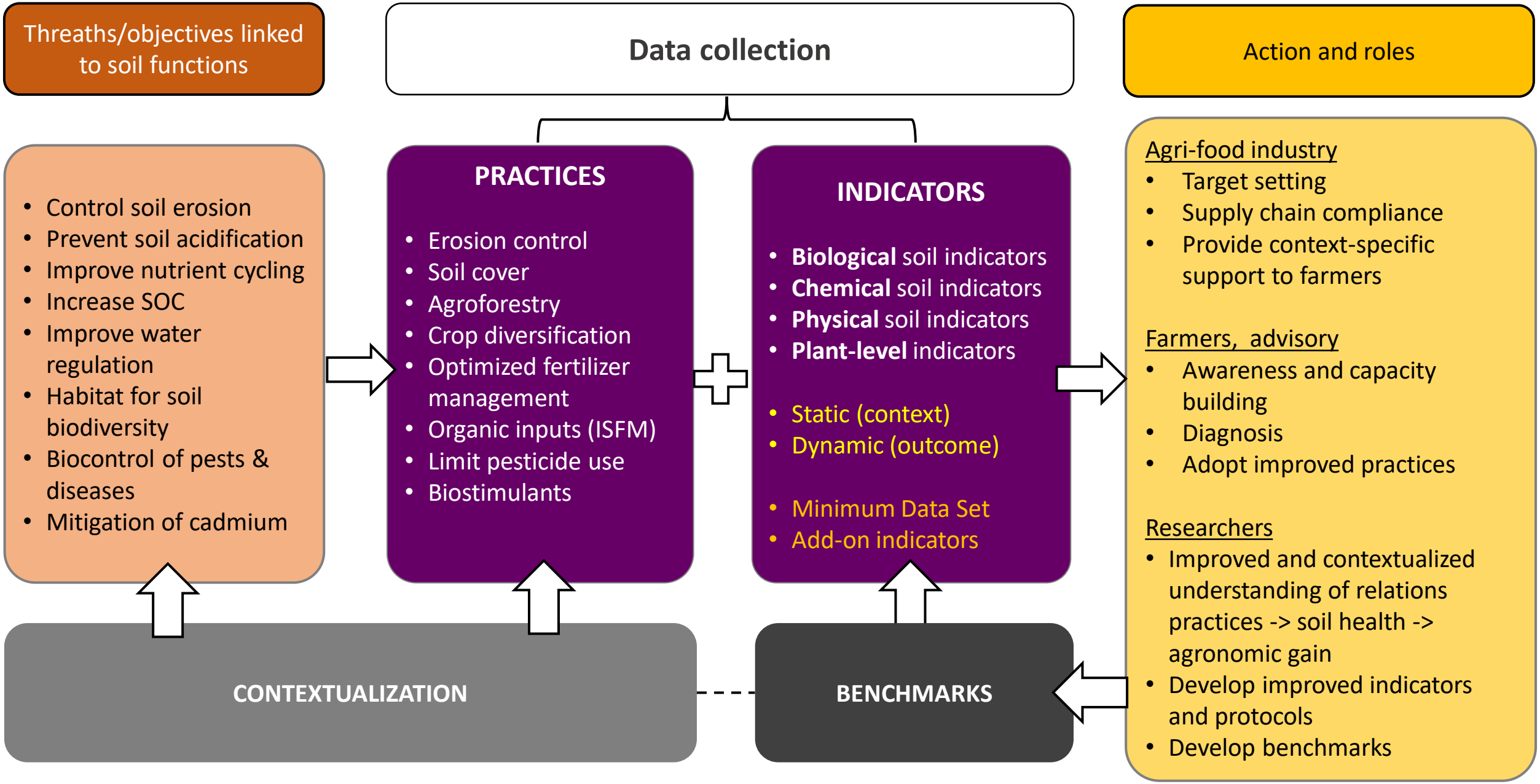
Applicability at scale is still limited by (i) costs and equipment, and (iii) lack of robust protocols, interpretations and benchmarks. This is an area of active research



## 3. How do we restore/enhance it?

- Minimize soil disturbance
- Mulching / cover cropping
- Crop diversification / agroforestry
- Minimize use of pesticides
- Combine organic & mineral fertilizers
- Livestock integration

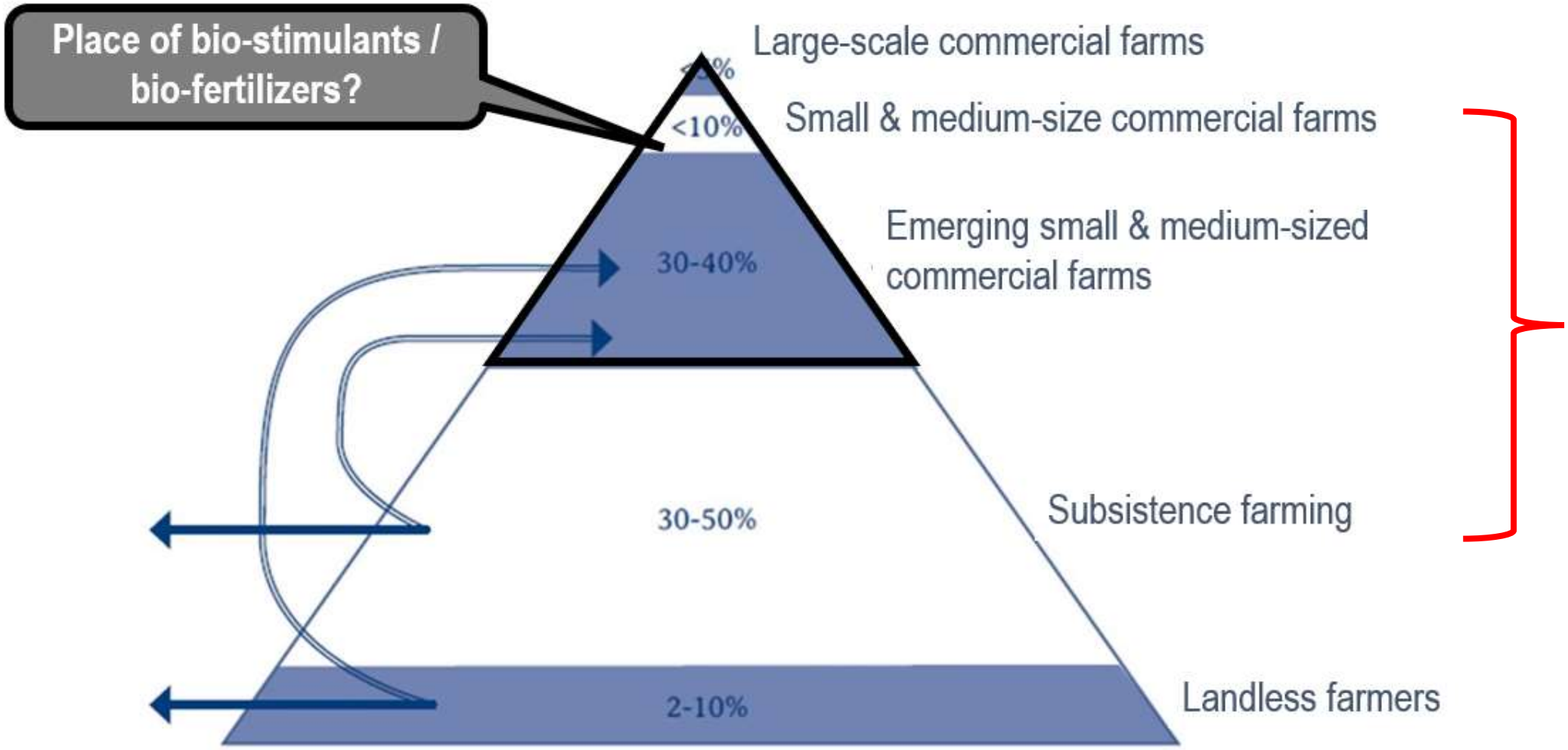
+ Adaptation to context and engagement of relevant actors




Giller, Pulleman, Sassen, 2023. https://doi.org/10.18174/630630

Courtesy: B. Vanlauwe, based on DFID, 2015

# 4. What role for biofertilizers & biostimulants?



# EM – Microorganismos de la montaña

**Reproduction** of microorganisms (solid MM)

**Activation** of microorganisms (liquid MM)

Producción Y Uso De Abonos Orgánicos

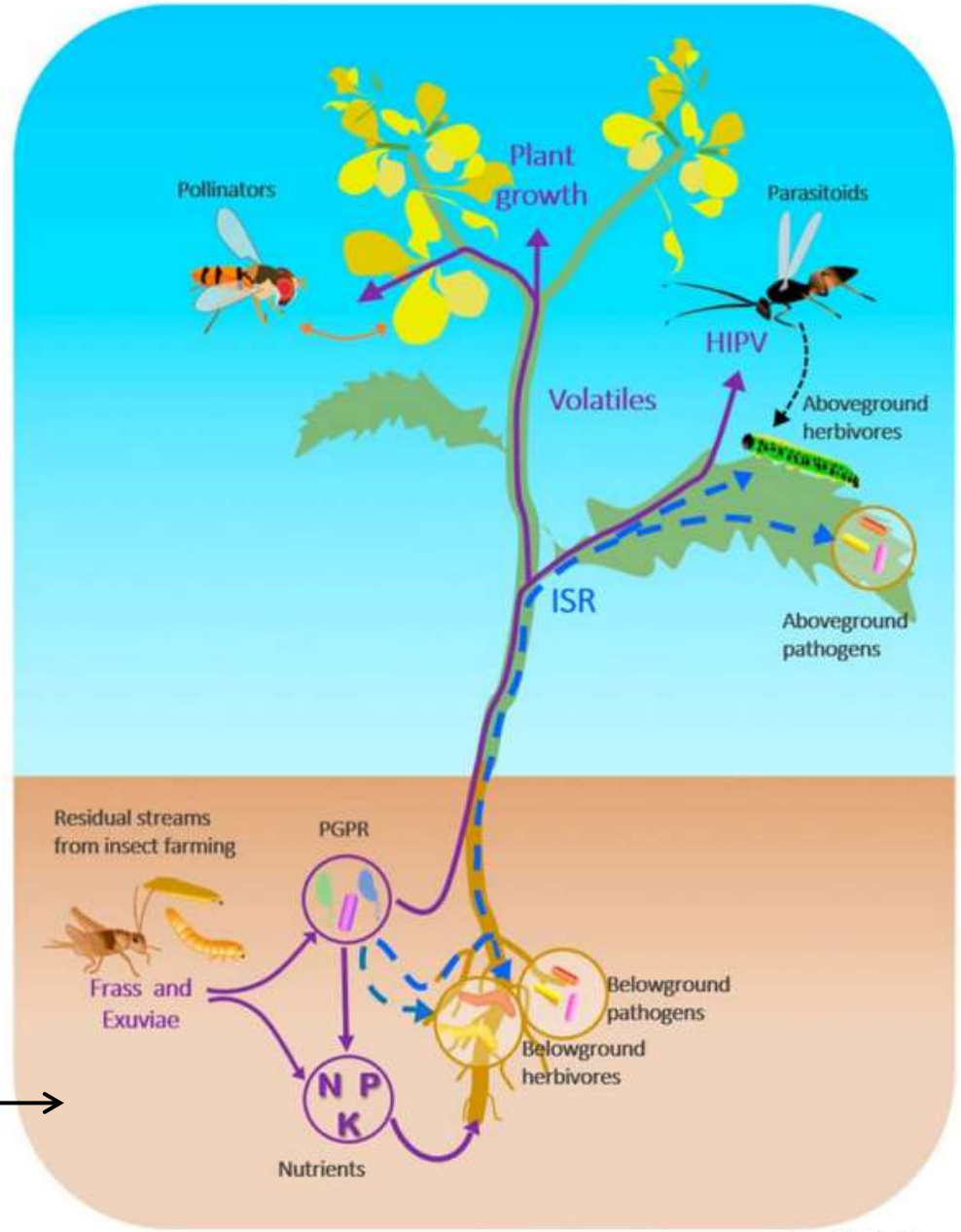
José Alejandro Aguilar P.,S.J.

# Bokashi

Barragán-Fonseca et al, 2022; Nurfikari et al 2023

# Black soldier flies






Amendments with insect residues have a good prospect of increasing natural biocontrol via **stimulation of microbial antagonists of plant-pathogenic fungi**. Insect-derived products may also affect plant growth through **herbivore-induced plant volatiles**; **induced systemic resistance**; or **plant growth-promoting rhizobacteria.**

# Take home

- Restoring / enhancing soil health is key for sustainable intensification and regenerative agriculture in the Global South, while reducing vulnerability of smallholder farmers to climate change.
- A flexible framework is proposed that can be used to target, monitor and adapt soil health interventions with relevant stakeholders
- Development of biological soil health indicators and assessment methods requires more research – given the key role of soil biology for soil health/functions
- High fertilizer costs, attention for soil health have led to the promotion of “smallholder-friendly” “biofertilizers” especially in Latin America, but scientific evidence and mechanistic understanding is lacking.
- Robust, hypothesis based, experimental research is needed to develop targeted, proven methods, alongside feasibility studies and development of business models

# Acknowledgements

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Clima-LoCa

Fostering climate-relevant and low cadmium innovations to enhance the resilience and inclusiveness of the growing cocoa sectors in Colombia, Ecuador and Peru

DeSIRA PARTNERSHIPS FOR INNOVATION

EXCELLENCE IN AGRONOMY ADAPT INTENSIFY GROW

Ground Zero: Let's get real on regeneration!