Using regenerative management practices to support vineyard soil biodiversity and health

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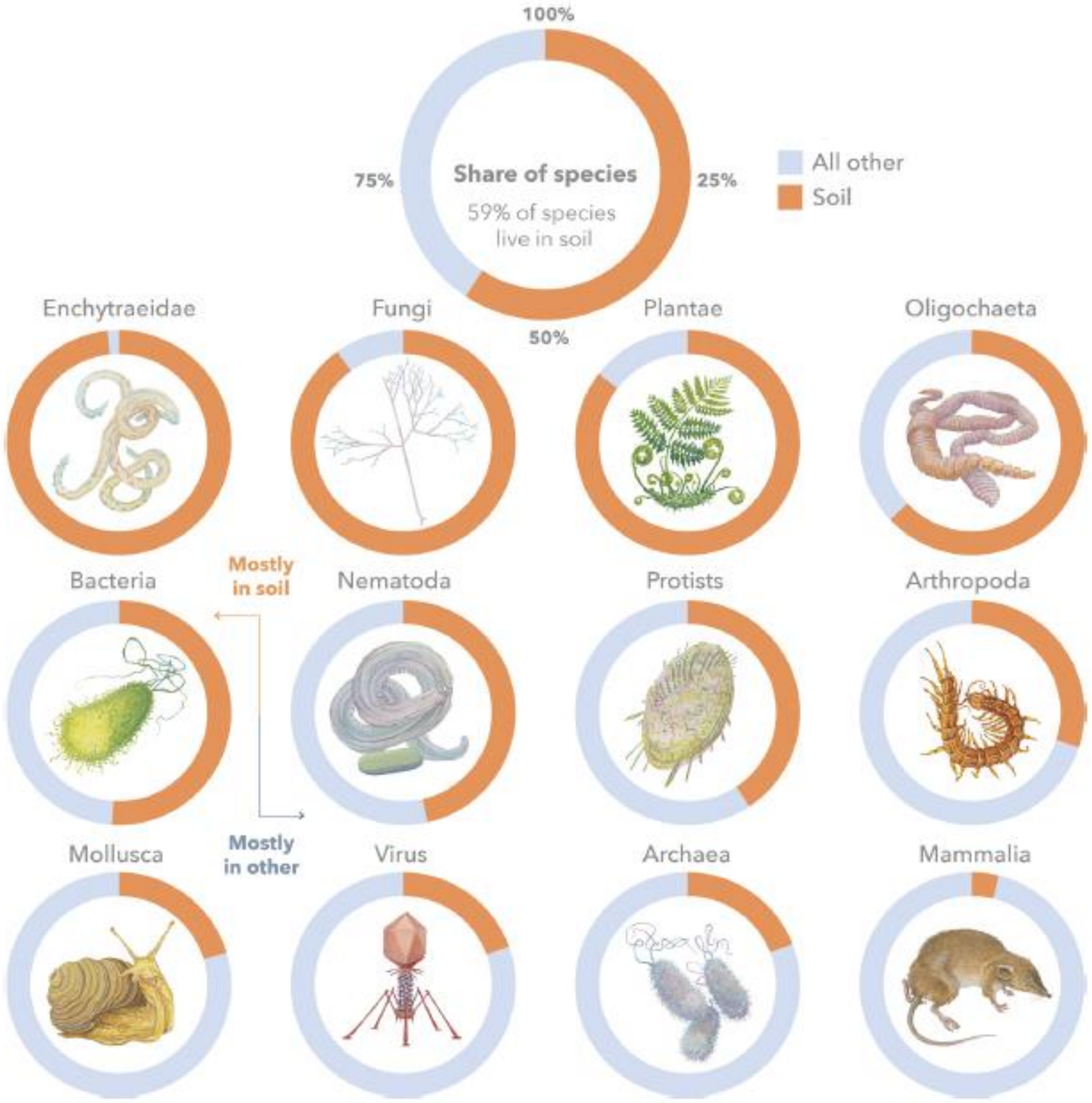
All life kingdoms are represented in soil

Credits: Jessica Chiartas

‘Soil is likely home to 59 ± 15% of the species on Earth’

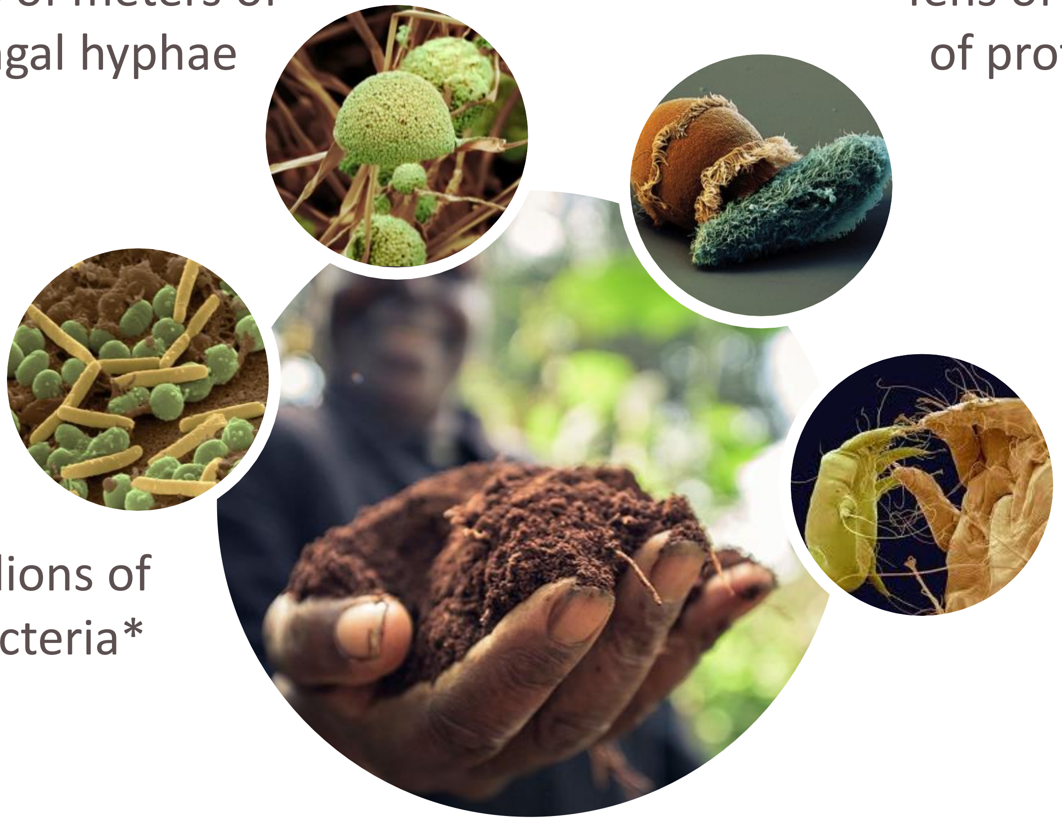


Anthony et al. (2023)

Soils are full of life

100’s of meters of
fungal hyphae

Tens of 1000’s
of protozoa



Billions of
bacteria*

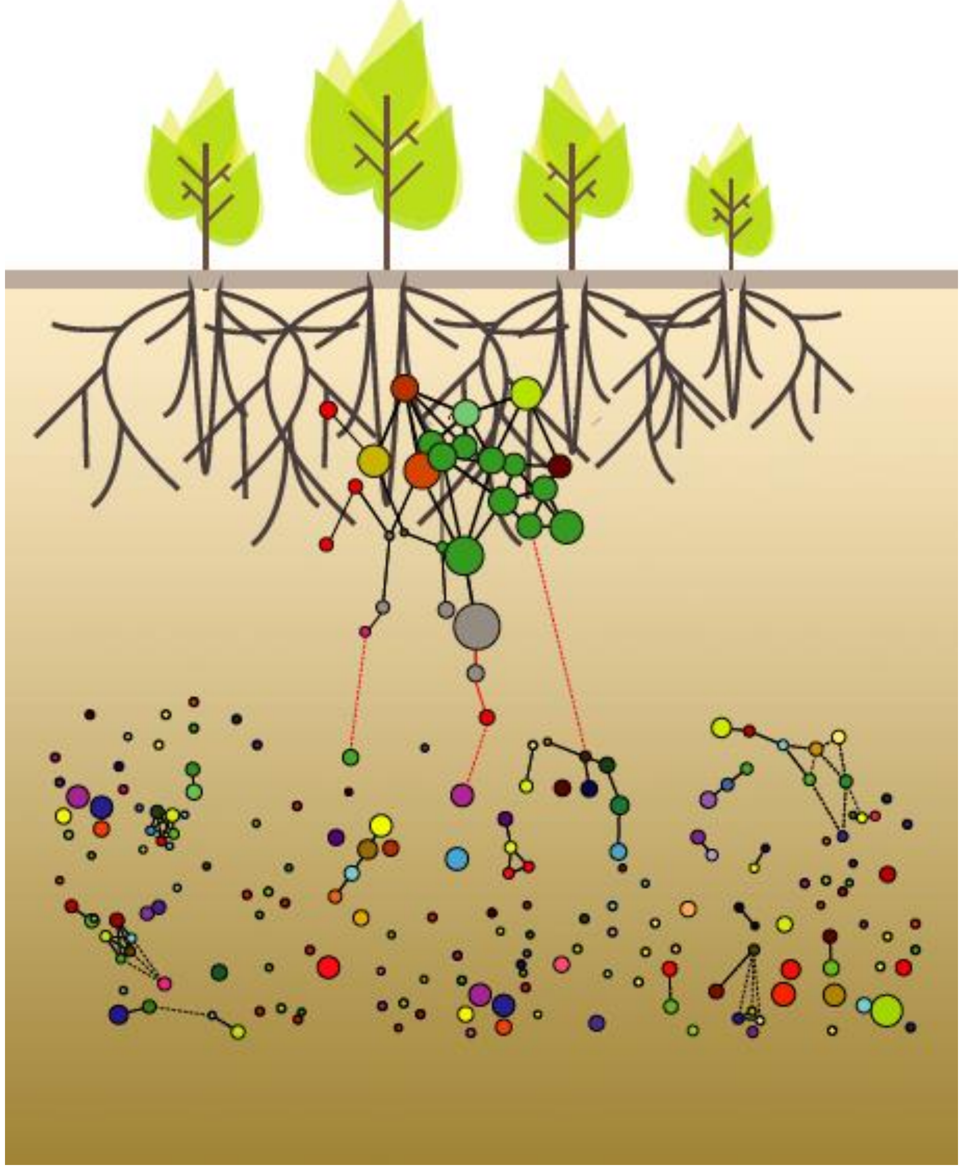
Hundreds of
arthropods

...right in the palm of your hand

Credits: Jessica Chiartas

* 1000s of unique species

Soil ecological interactions



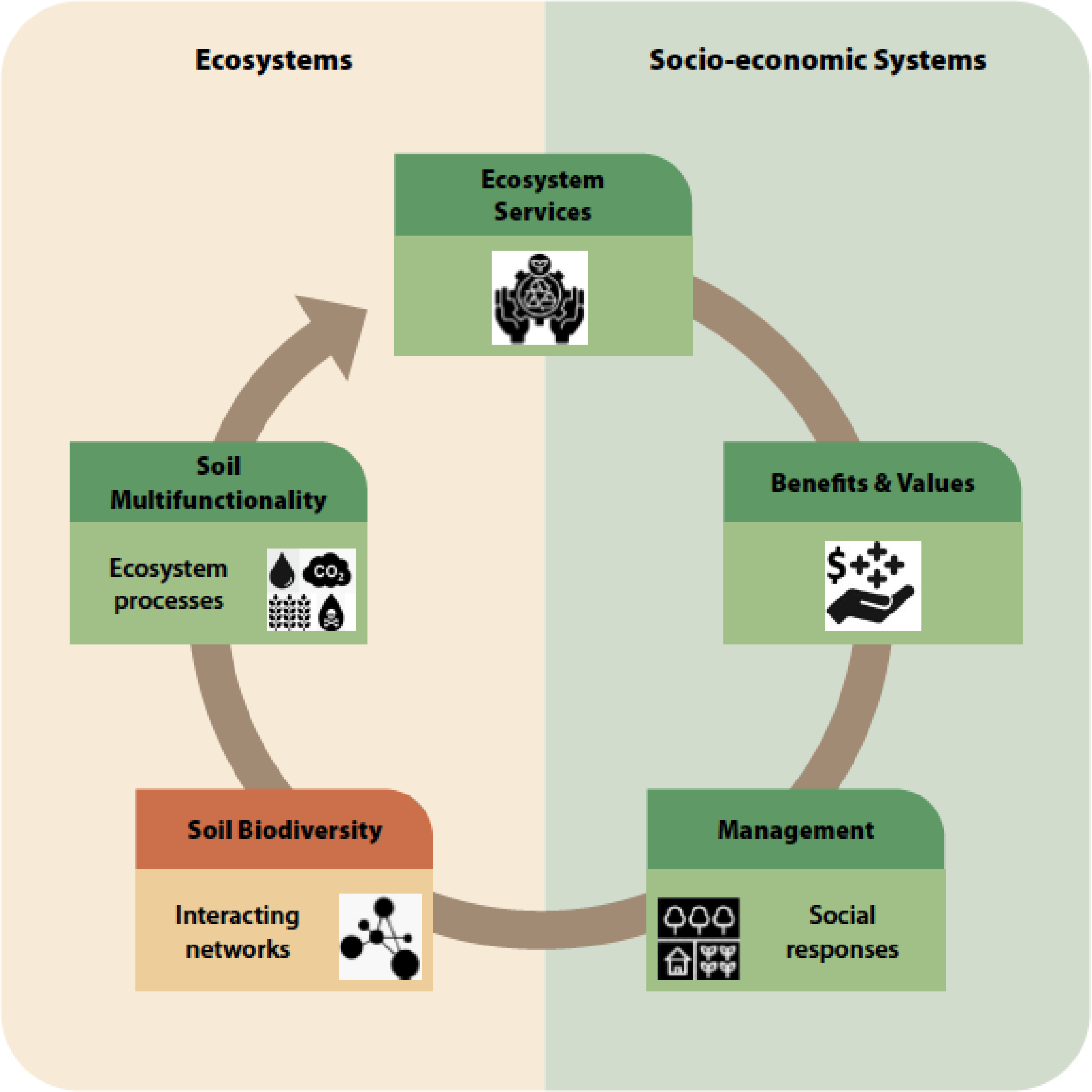
Source: De Vries and Wallenstein (2017)

Soil Health

- Nutrient cycling
- Carbon management
- Disease regulation
- Water regulation

Soil biodiversity underpins soil health and agroecosystem sustainability

Management should be targeted to biodiversity



Source: 'Soil Biodiversity in California Agriculture: Framework and Indicators for Soil Health Assessment' CDFA, 2023

Vineyard soil biodiversity

The soil microbiome drives:

- Nutrient cycling
- Disease control
- Carbon sequestration
- Wine fermentation

Little information about other types of soil biodiversity

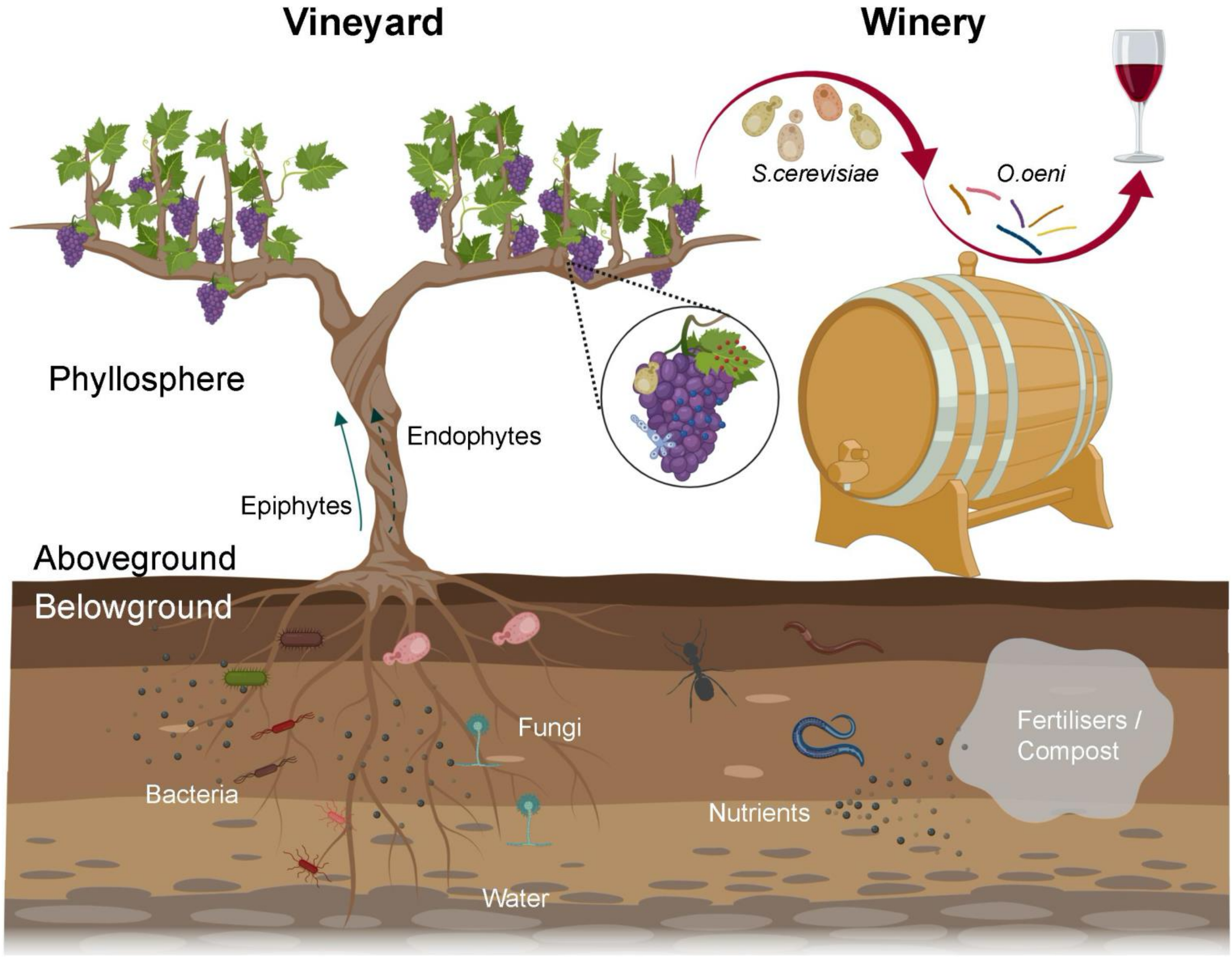


Image source: Liu et al 2019

Monitoring soil biodiversity: what should I look for?

Who is there?

Level	Indicator	Potential Methods
Abundance *(often with conversion factor)*	**Counts**: Cells, organisms, CFUs **Cellular Constituents:** Carbon, lipids, DNA, necromass, metabolites	Soil faunal counts, most probable number, direct counts (microscopy), colonization rates (mycorrhizae), phospholipid fatty acid analysis (PLFA), fatty acid methyl ester (FAME) analysis, total DNA, quantitative polymerase chain reaction (PCR) of taxonomic or functional genes, plating and CFU (colony forming units) counts, turbidity, flow cytometry, ergosterol, Microbial biomass carbon/ nitrogen/etc (MBC/N)
Identity	**Genotype Identification:** 16S/18S signature, ITS signature **Phenotype Identification:** Morphology, biochemical signature (lipids), culture-based methods	Plating and colony identification, nematode anatomy or morphology, microscopy identification (fungi, bacteria), flow cytometry, PLFA/NLFA (neutral lipid fatty acid)/FAME, quantitative PCR, FISH (fluorescence in situ hybridization)
Functional Traits	**Genetic Analysis:** Functional traits **Phenotype Analysis:** Morphology, proteome	Functional gene analysis, metagenomics, metaproteomics, metatranscriptomics, metabolomics, nematode anatomy or morphology
Interactions *(including measurements and derived data)*	Co-occurrence patterns, food web relationships	Network analysis of organism (taxonomic, functional group), co-occurrence patterns, food web modeling, process modeling, biochemical indicators (quorum sensing signals, antibiotics, signaling molecules)
Processes	Biogeochemical transformations, metabolites, growth rates	Enzyme assays, Potentially mineralizable nitrogen (PMN), Potentially mineralizable carbon (PMC), Respiration, Substrate induced respiration (SIR), Bioassays, qCO_2 (the microbial metabolic quotient, or respiration-to-biomass ratio), Biolog - Microbial Identification & Characterization, isotope analysis

What are they doing?

Source: 'Soil Biodiversity in California Agriculture: Framework and Indicators for Soil Health Assessment' CDFA, 2023

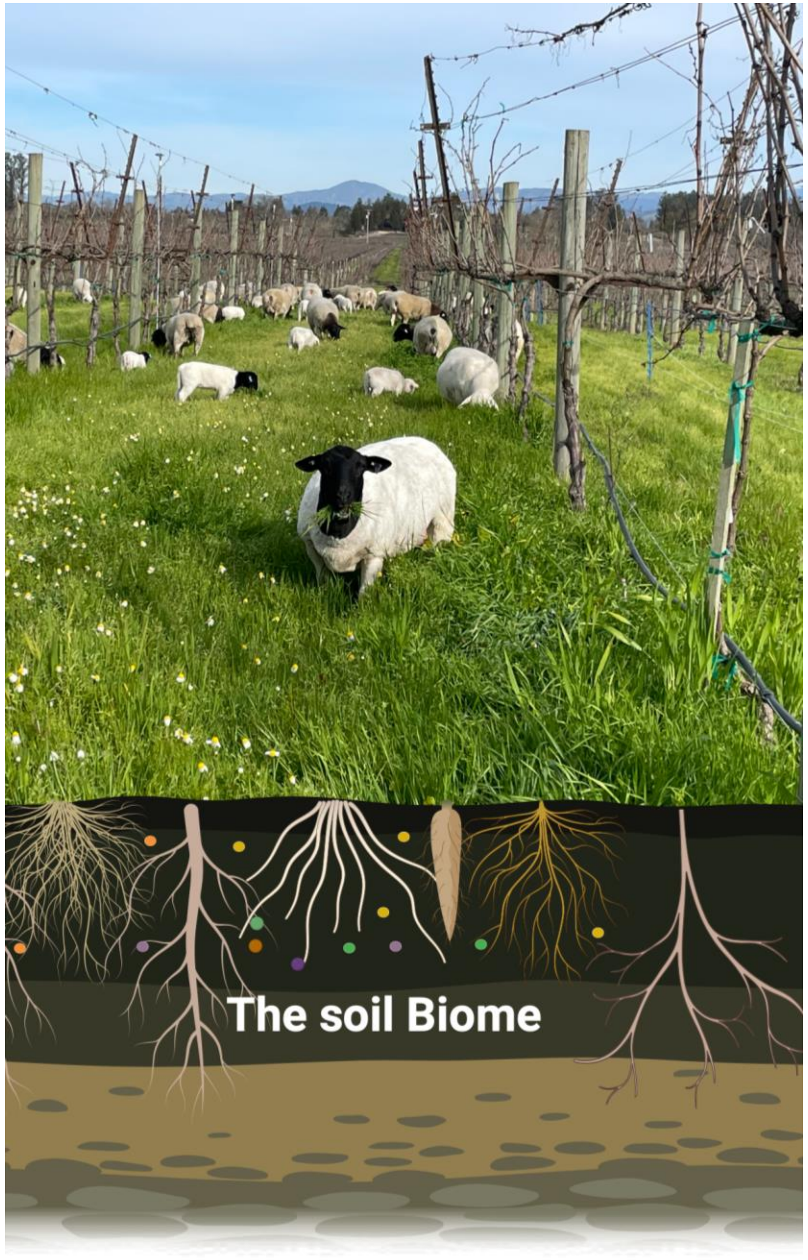
Selection of indicators depends on the goal

Source: 'Soil Biodiversity in California Agriculture: Framework and Indicators for Soil Health Assessment' CDFA, 2023

Least useful				Most Useful

[EXAMPLE CASE STUDY #3B] Assist Growers to Manage the Functions of Healthy Soils Using Information on Soil Biodiversity and Processes					
Indicator and Method	**Meaningful and Targeted**	**Relevant to the Scale and Biology of the Organisms**	**Standard or Commonly Used Method**	**Costs, Accessibility, and Interpretability**	**Suggested Indicator with Comments**
Bioindicator Category: ABUNDANCE					
Microbial Biomass: **Phospholipid Fatty Acid Analysis (PLFA)**	Quantitative biomass estimate with some information on identity Requires uncertain conversion factor.	Currently not optimal for nematodes Only relevant for microorganisms	ISO/TS 29843-2:2021(en) Soil quality — Determination of soil microbial diversity — Part 2: Method by phospholipid fatty acid analysis (PLFA) using the simple PLFA extraction method	Limited # of labs Does not require significant amounts of data processing Samples need to be analyzed quickly after collection	**PARTLY RECOMMENDED:** PLFA does provide abundance information for broad groups, including those suppressive to disease causing organisms. It does not allow for positive identification of pests and disease causing organisms or nematodes.
Nematode Biomass: **Nematode Counts**	Abundance of plant parasitic nematodes of concern	Yes, plant parasitic nematodes are good indicators for disease and pest potential	ISO 23611-4:2022(en) Soil quality — Sampling of soil invertebrates — Part 4: Sampling, extraction and identification of soil-inhabiting nematodes	Several Labs do this at reasonable cost, including CDFA diagnostic labs and commercial labs	**RECOMMENDED:** Nematode counts are the most commonly utilized current method to provide estimates of problem populations
Microbial Biomass: **DNA (total)**	Quantitative biomass estimate - information on identity only with further tests Requires uncertain conversion factor.	Depending on amount of soil extracted, is not ideal for measuring abundance of macrofauna	ISO 11063:2020(en) Soil quality — Direct extraction of soil DNA	Analysis is rapid and cheap to perform after DNA is extracted	**NOT RECOMMENDED** due to the limited information on specific abundance of pests and pathogens

Supporting soil biodiversity: what should I do?



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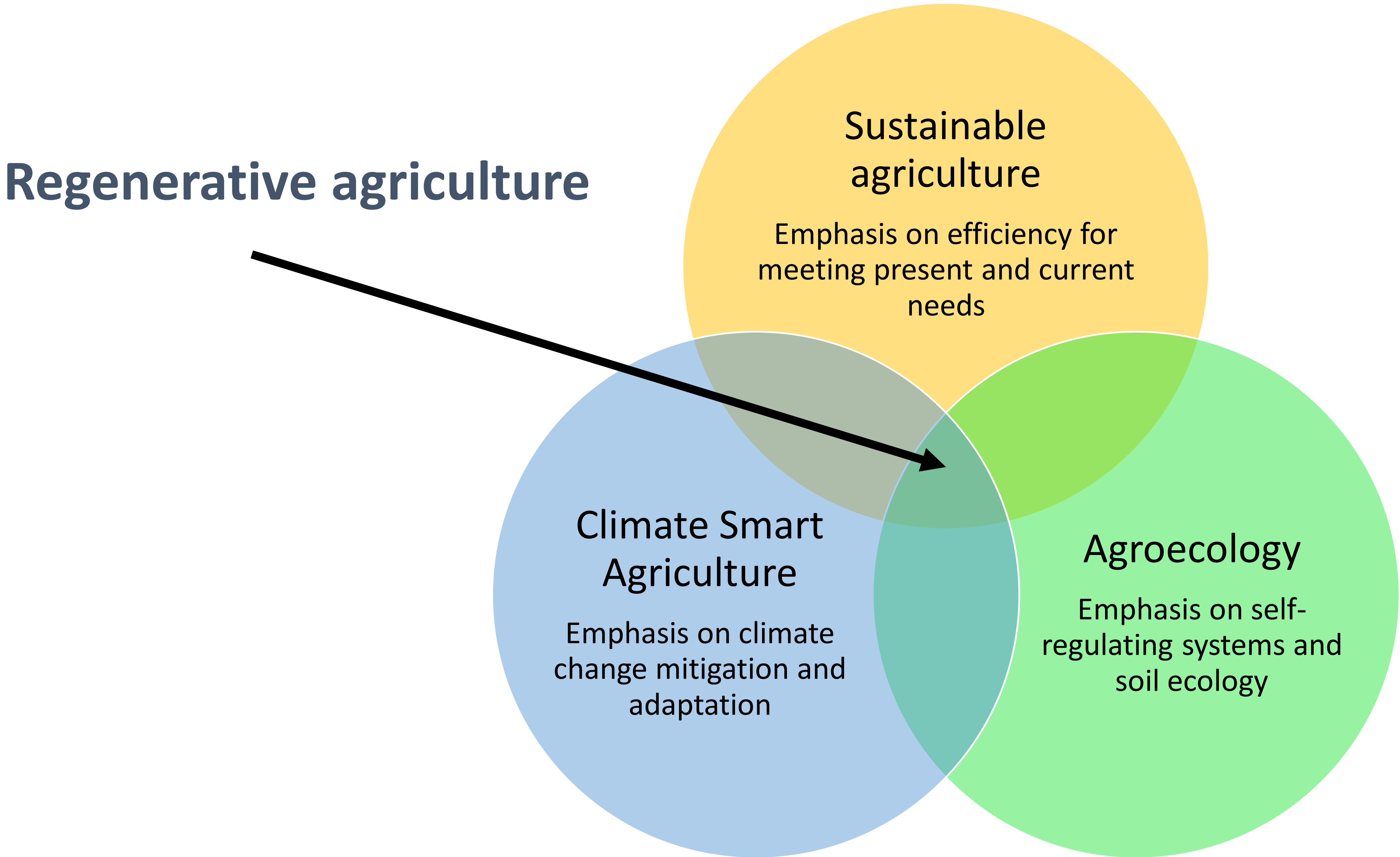
Regenerative management

'A toolkit of principles and practices to restore and preserve biodiversity and soil health by creating a functioning ecosystem that reduces external inputs while producing nourishing farm products'

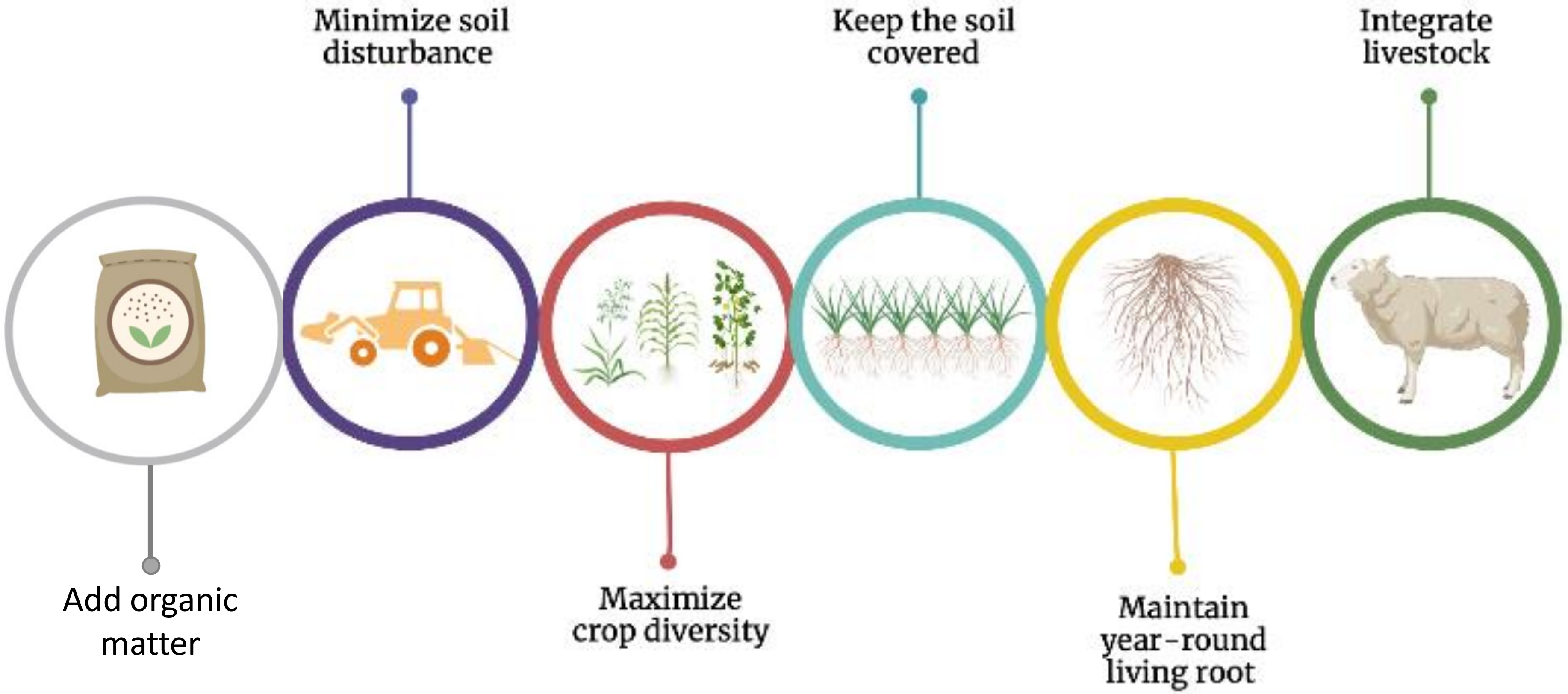
Schreefel et al 2020



Regenerative agriculture
Sustainable agriculture
Emphasis on efficiency for meeting present and current needs
Climate Smart Agriculture
Emphasis on climate change mitigation and adaptation
Agroecology
Emphasis on self-regulating systems and soil ecology

Principles of regenerative management

Everyone needs **food** (carbon or organic matter) and a **home** (soil structure)



Effects of organic fertilizers on the soil foodweb

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Katherine Watts (Cal Poly)
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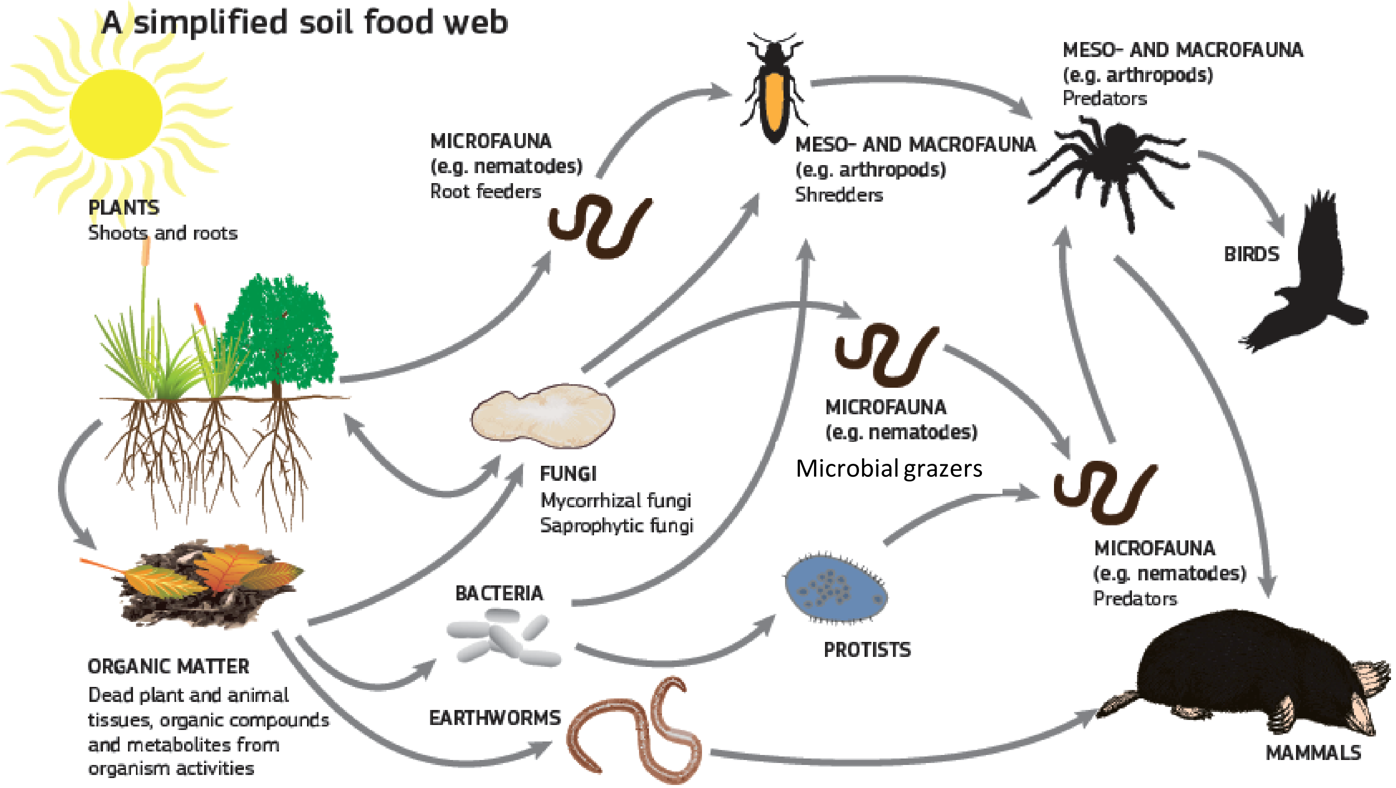
Cristina Lazcano (UCD)

Objective: assess the effects of fertilizer inputs (i.e. organic vs inorganic vs no fertilizer) on soil health using nematode food webs as proxies



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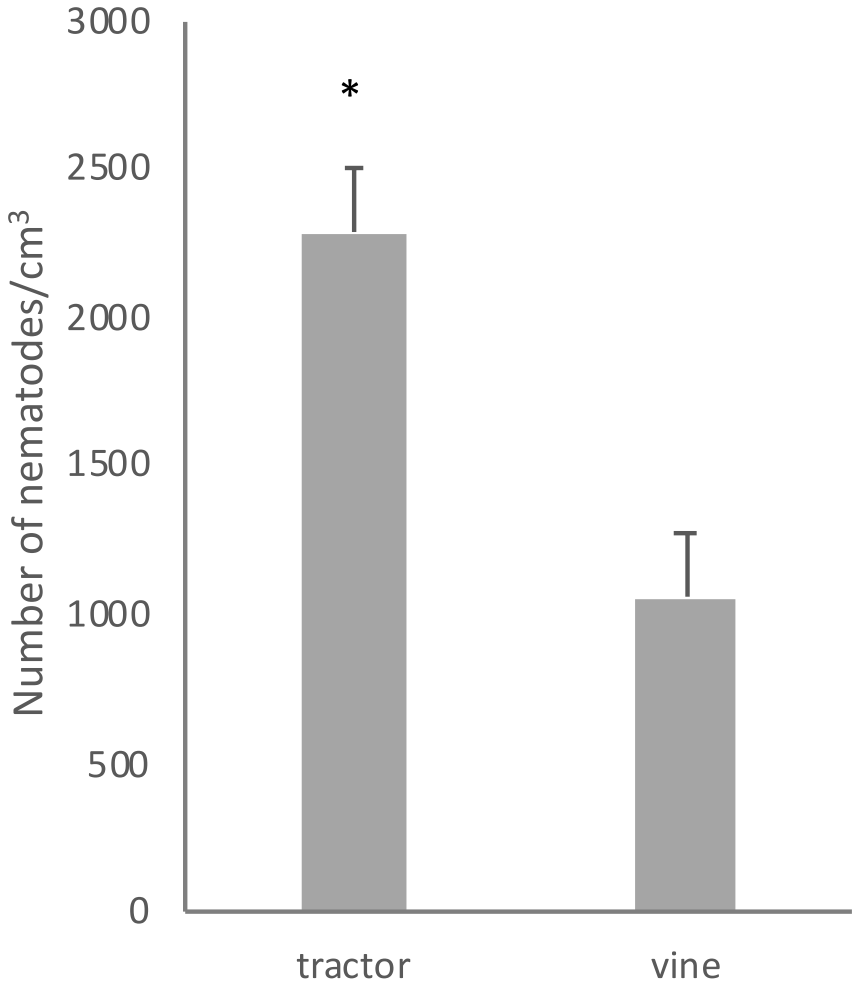
NIVEN FAMILY WINE ESTATES

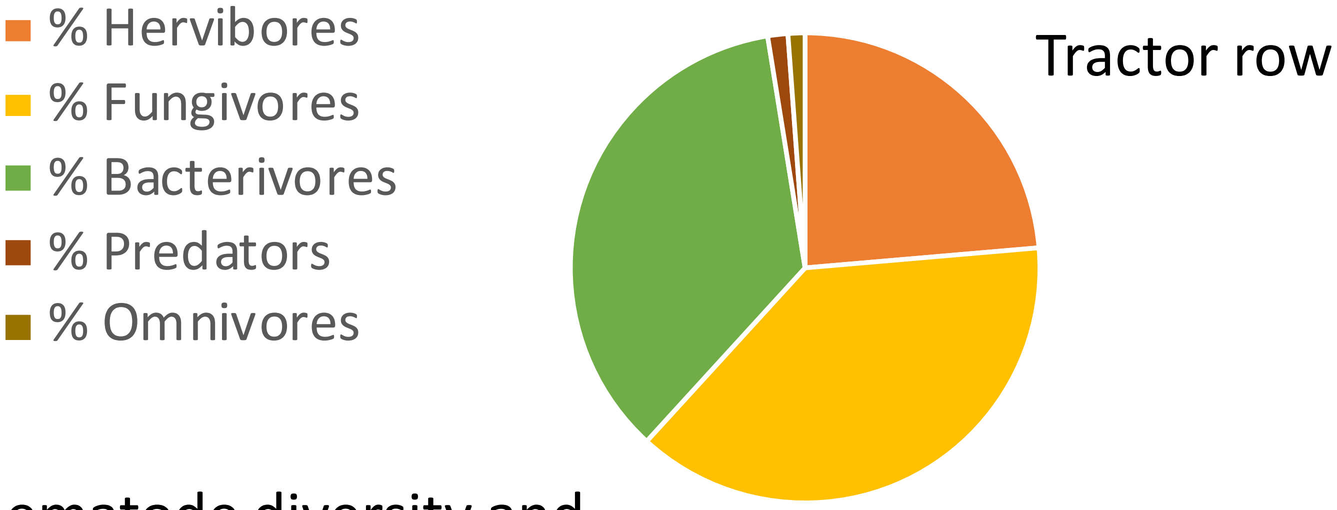
Effects of organic fertilizers on the soil foodweb

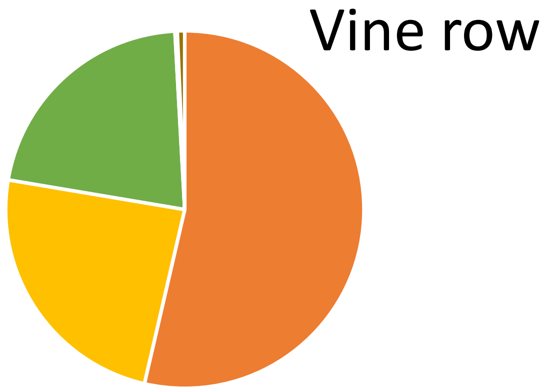
Paragon vineyard, Edna Valley. San Luis Obispo County.



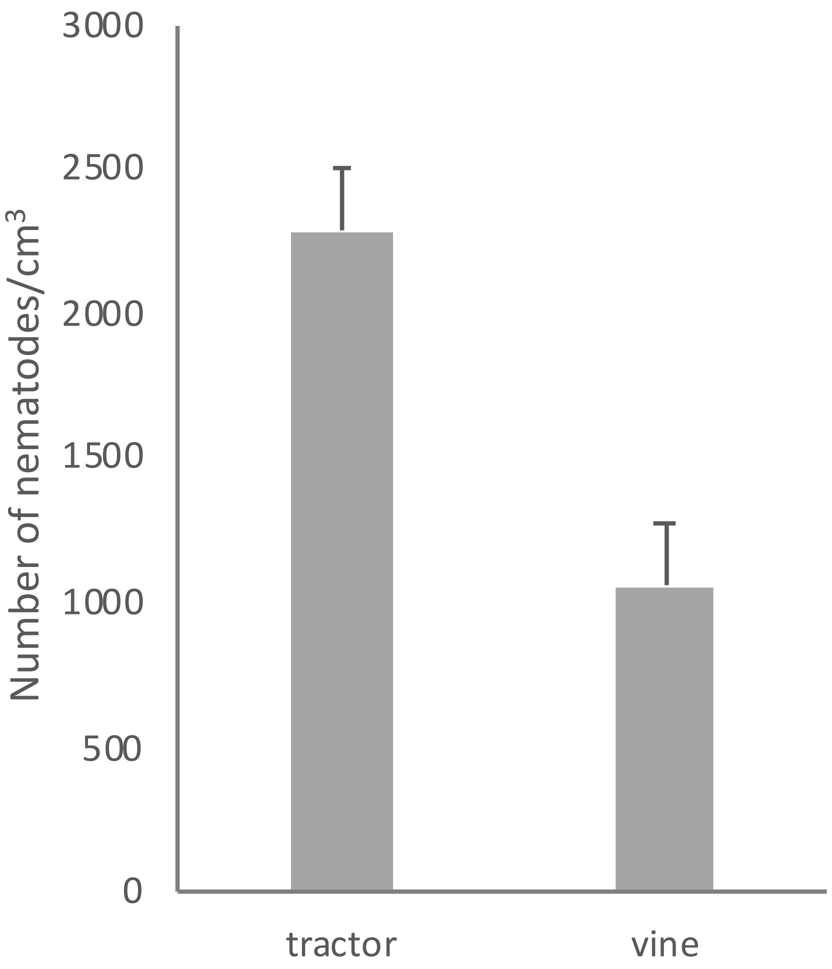
Lazcano et al. 2021

Effects of organic fertilizers on the soil foodweb





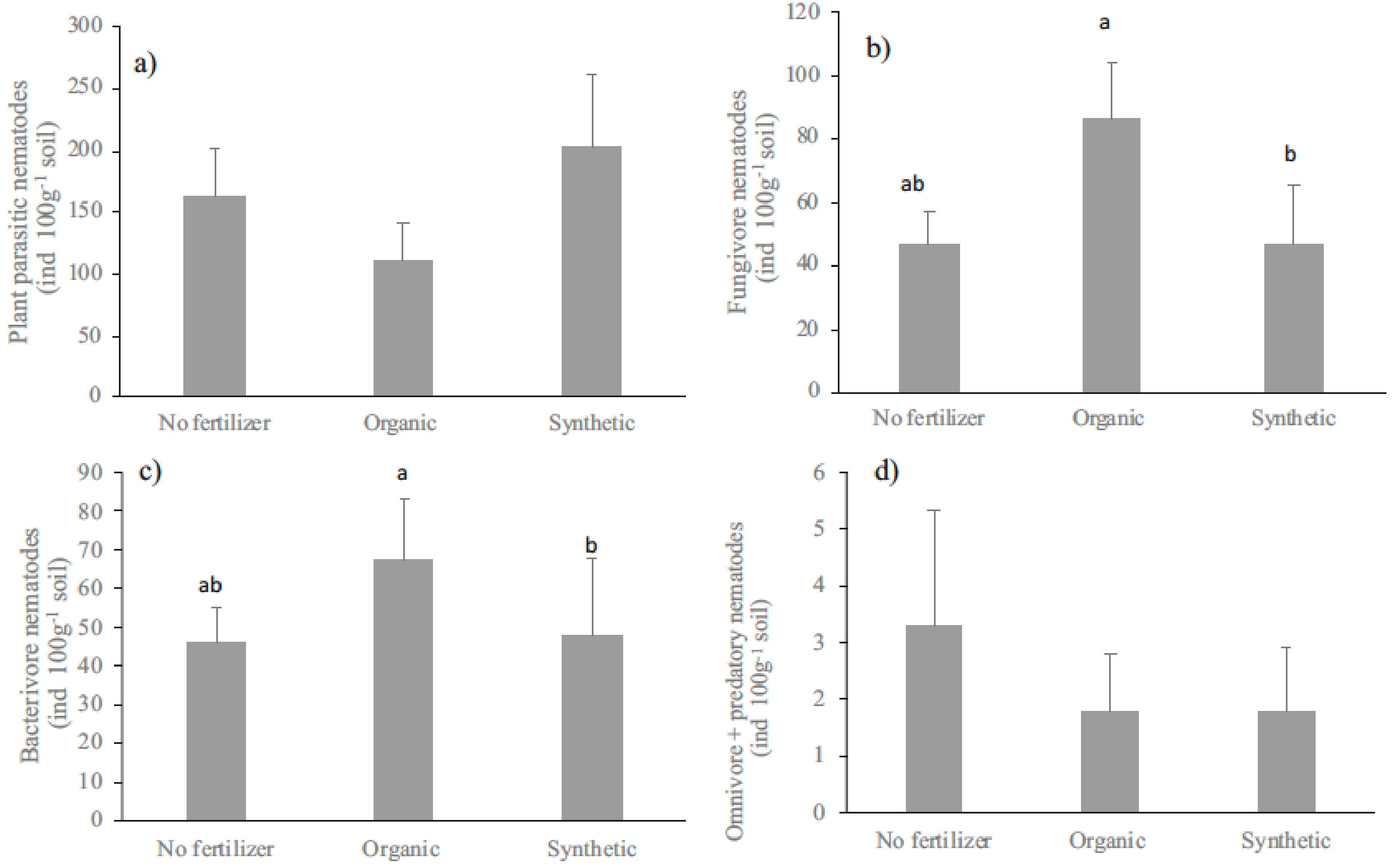
Nematode diversity and abundance in the tractor row was associated with other soil health indicators such as pH, available N and C



Lazcano et al. 2021

Effects of organic fertilizers on the soil foodweb

Organic fertilizer applied under the vine increased the abundance of fungivore and bacterivore nematodes, increasing foodweb complexity

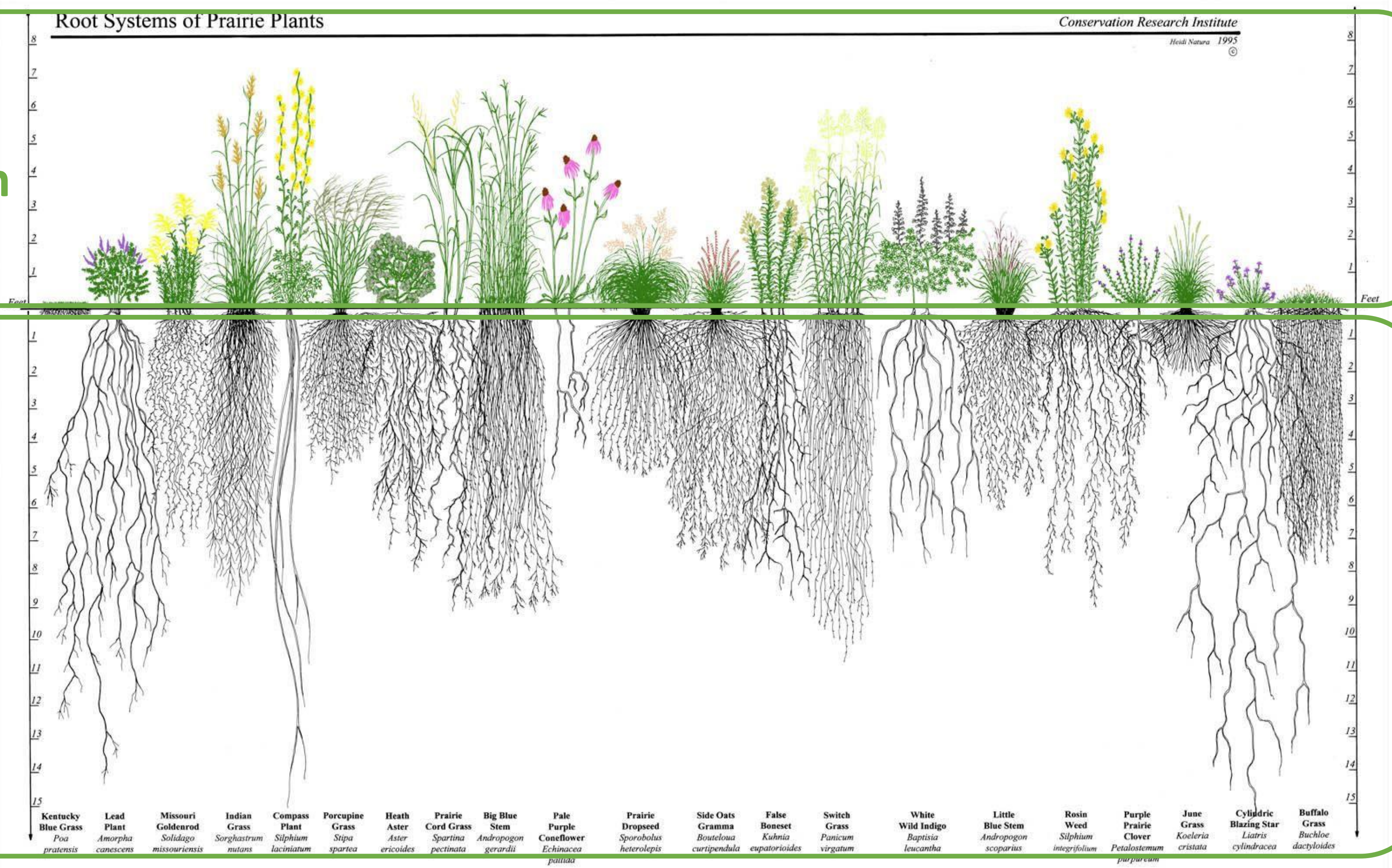


Lazcano et al. 2021

Cover crops and soil biodiversity

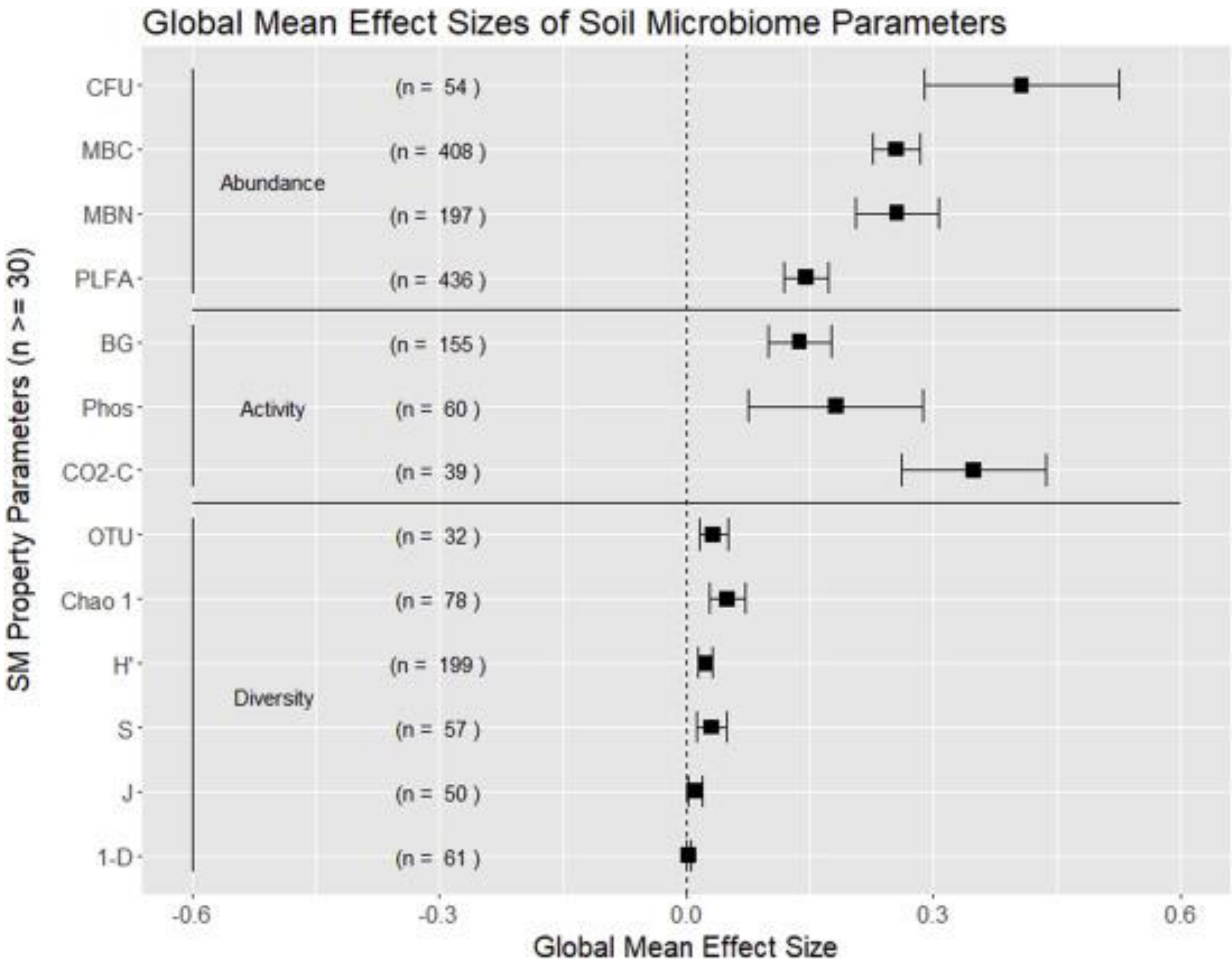
Protection from erosion

- **Organic matter inputs (food)**
- **Aggregate formation (habitat)**



Diversity of root system architecture in prairie plants from McNear Jr., D. H. (2013)

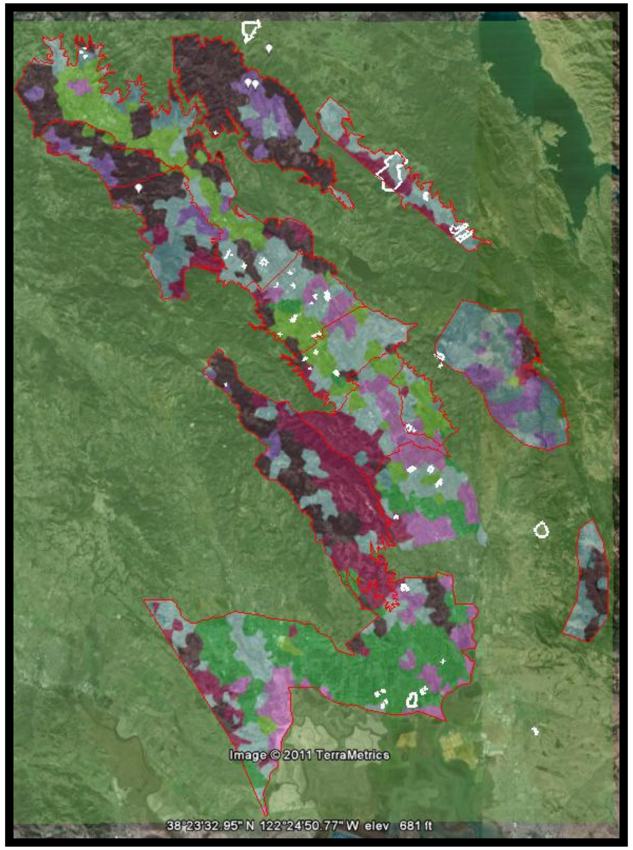
Cover crops **increase microbial abundance, activity and diversity** as shown by various indicators

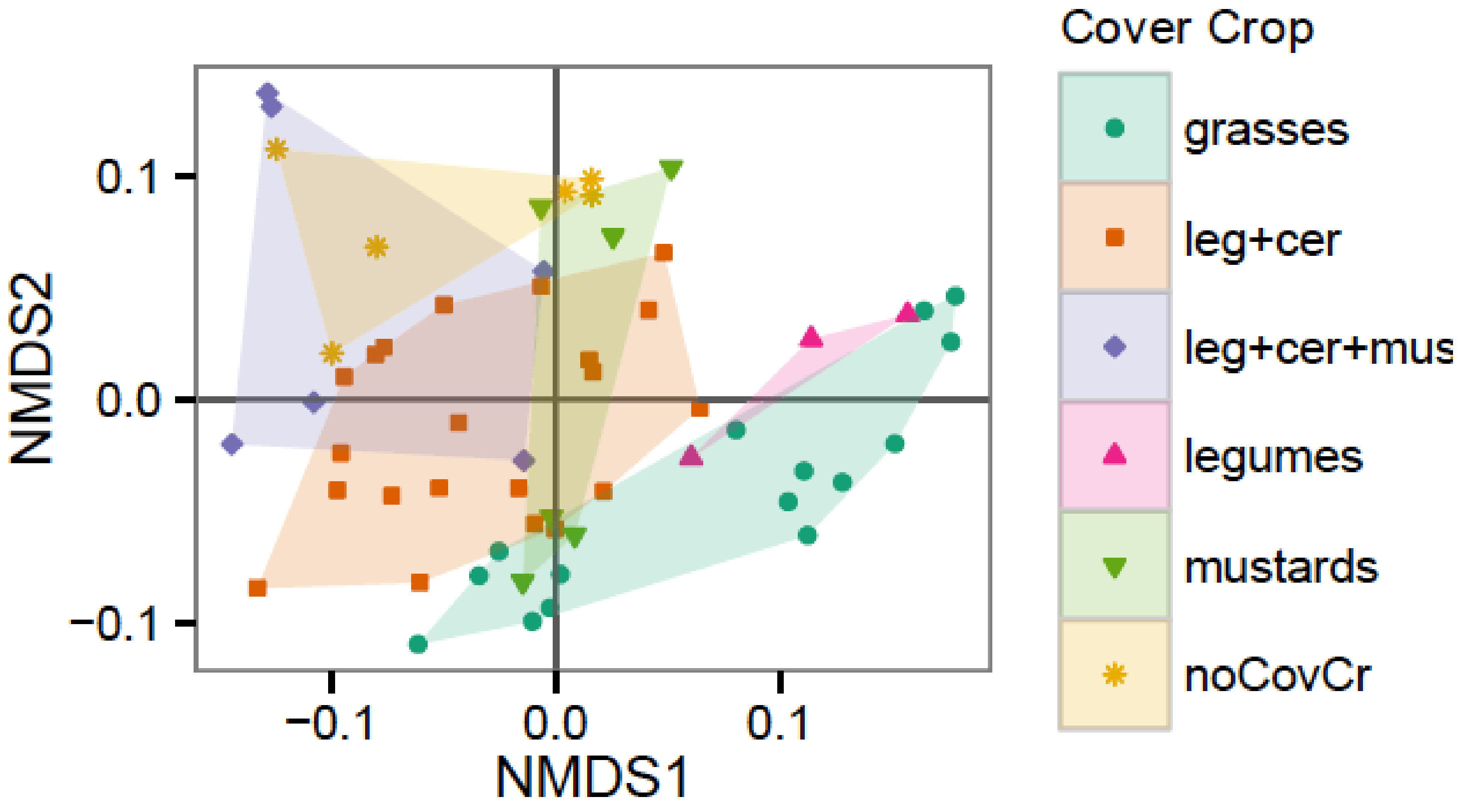


Kin et al 2020

Different cover crops change soil microbial diversity differently

Survey of 30 sites in Napa, CA





Burns et al., 2016

Cover crop management

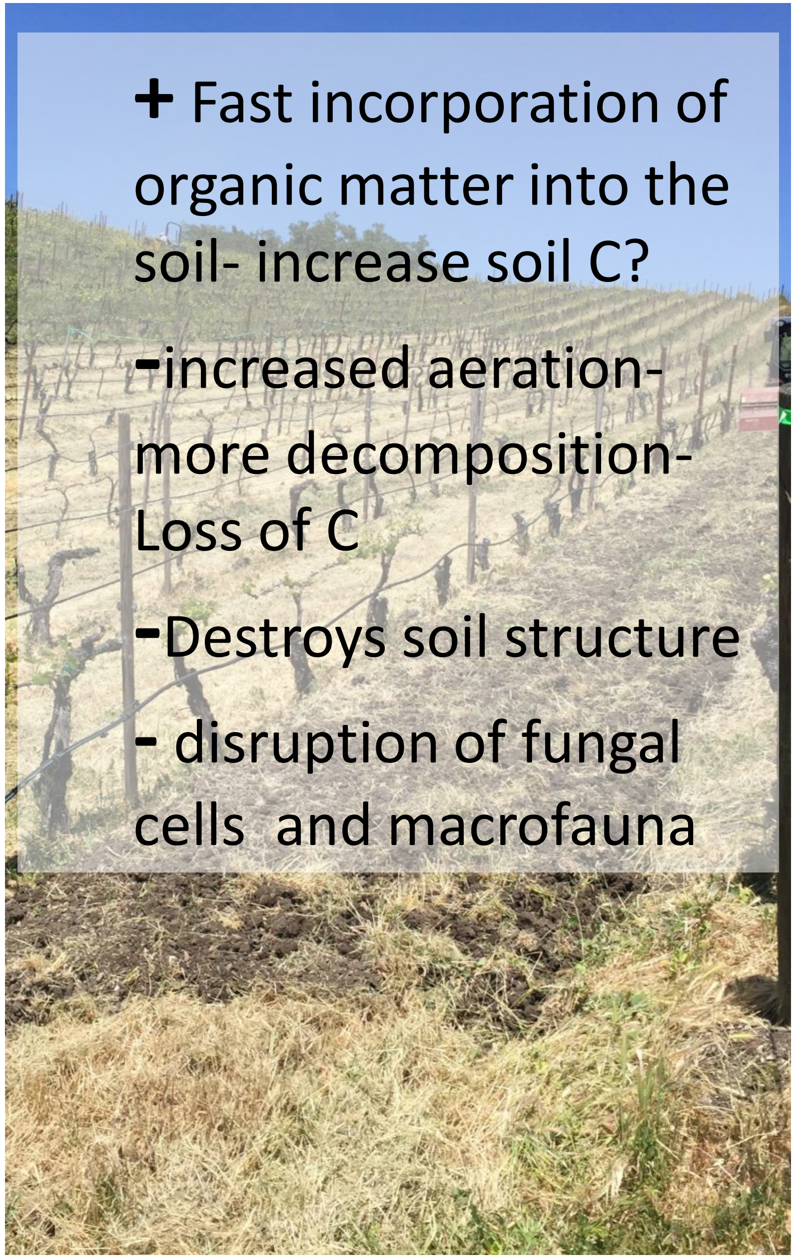
Termination

One of the most critical management decisions, since it can have profound impacts in soil physical, chemical and biological properties

What are the options?

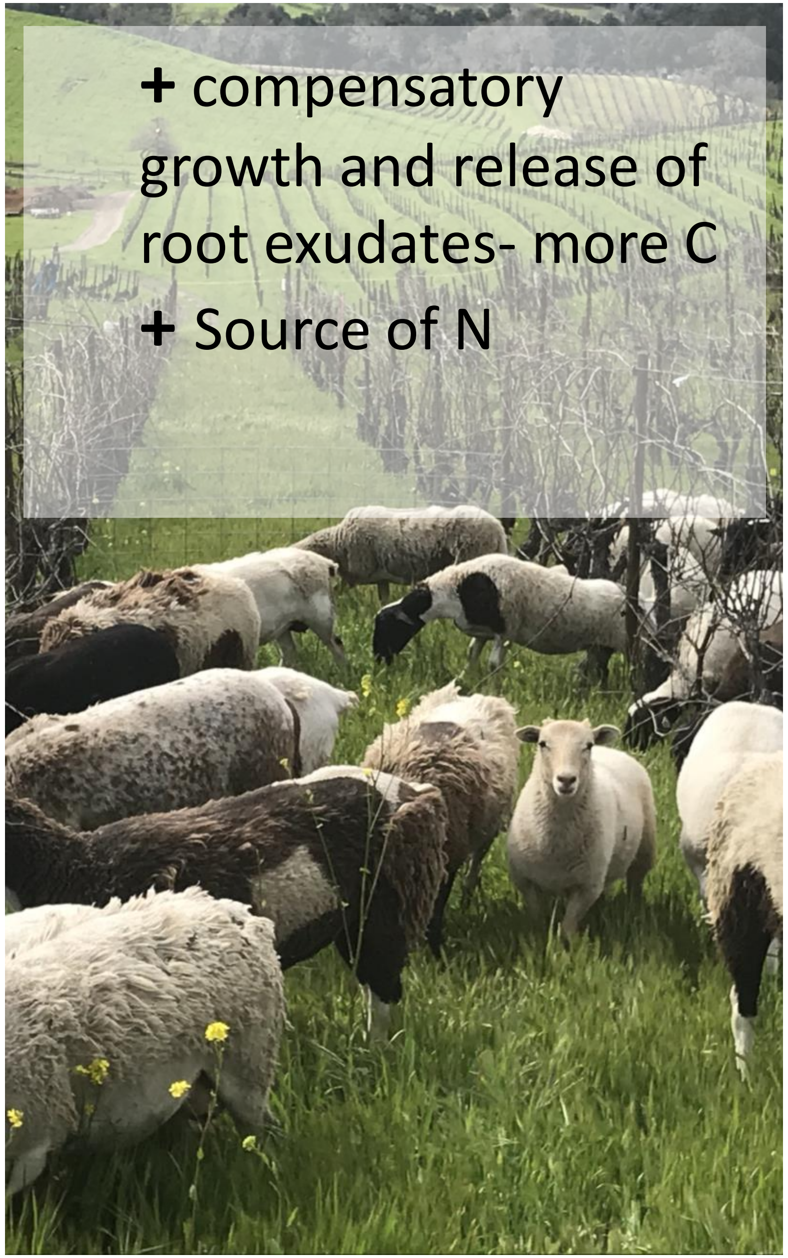
Photo: Tablas Creek vineyard, CA (USA)

Tillage

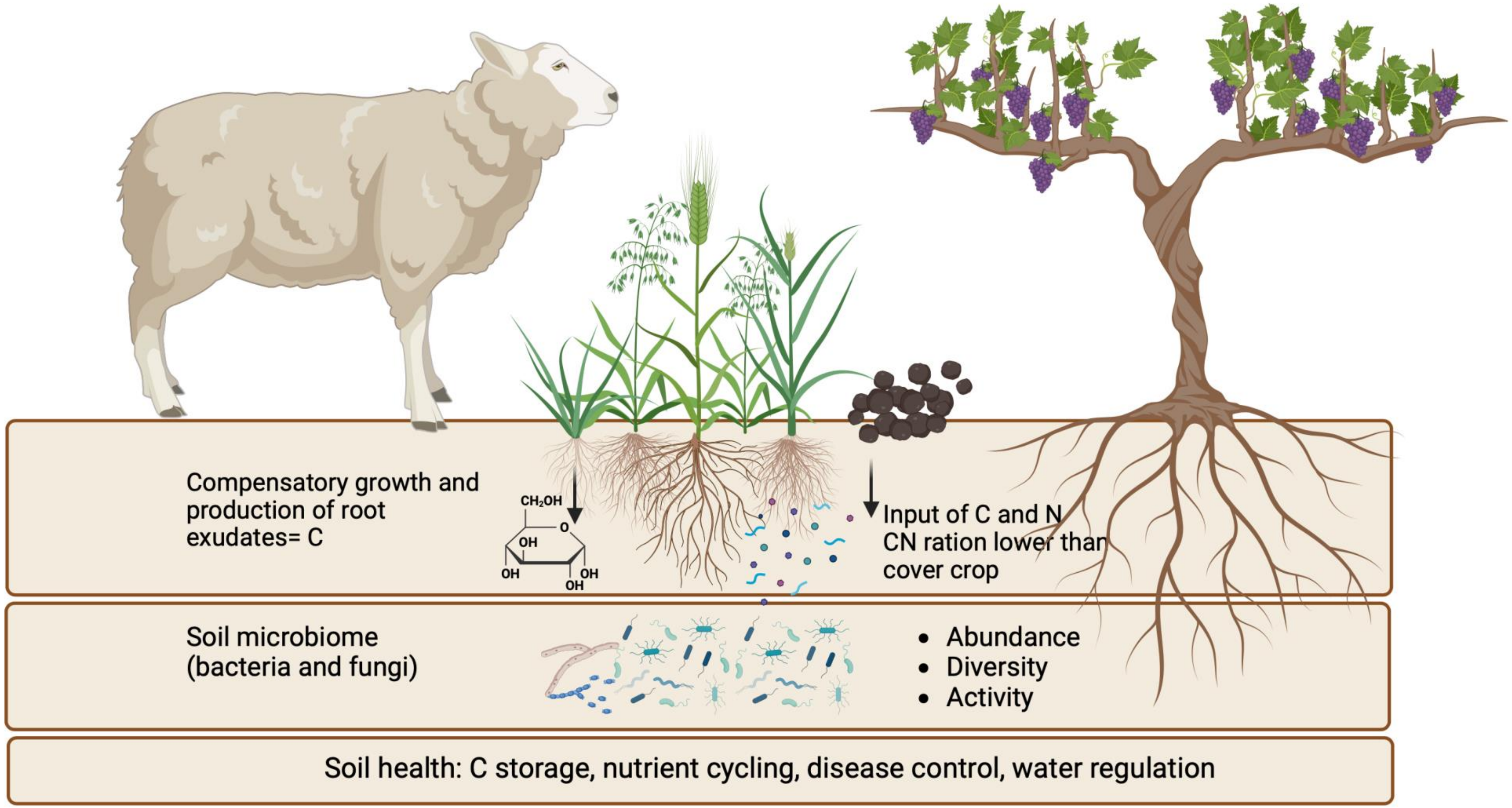


No-till

Grazing



Ecological effects of sheep grazing



Experimental design

- *Vitis vinifera* L. cv. Syrah
- 2018- 2020
- Soil: 4.5% SOM, 30% clay
- Cover crop mix
- Compost 11 t/ha
- Factorial design
  - Tillage (+/-)
  - grazing (+/-)
- 4 replicates, 16 plots

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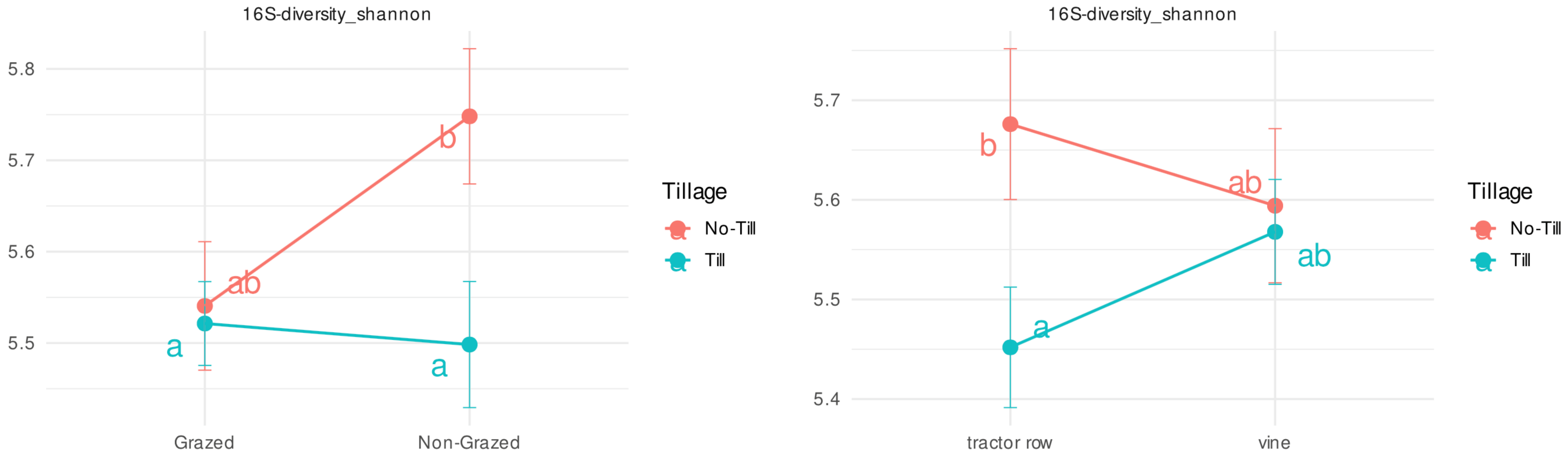
BIOME MAKERS

TABLAS CREEK VINEYARD

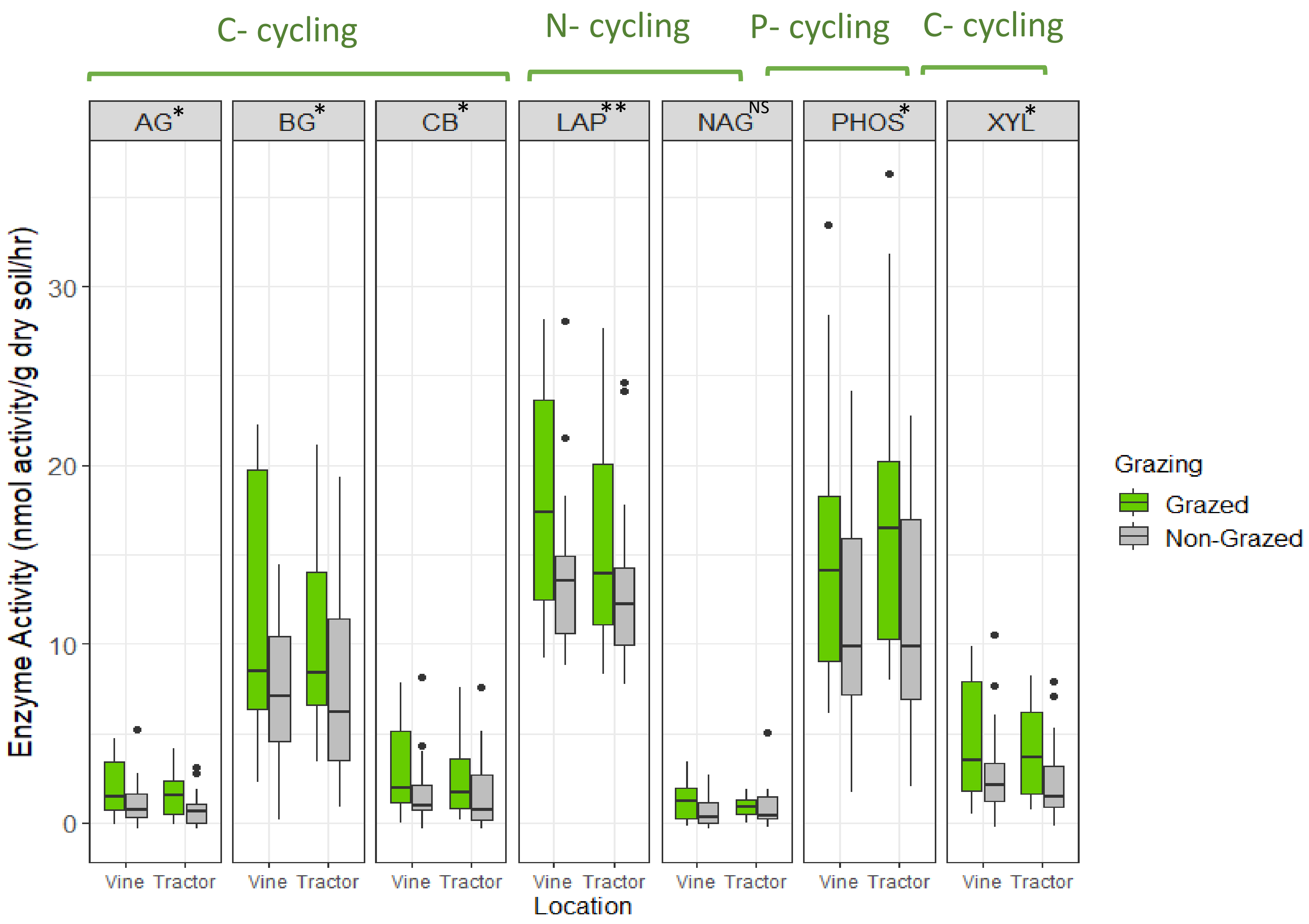
No-till increased bacterial α–diversity in non grazed plots and tractor rows



- No significant effects of tillage and grazing on fungal α–diversity

Bansal et al. In progress

Grazing increased microbial activity



Bansal et al. *In progress*

Regenerative management: challenges

Management effects differ by environment

Soil type and climate matter!

Wade et al 2022

Stacking practices: synergistic effects?

Reduced/ no-tillage

Cover crop/
vegetative cover

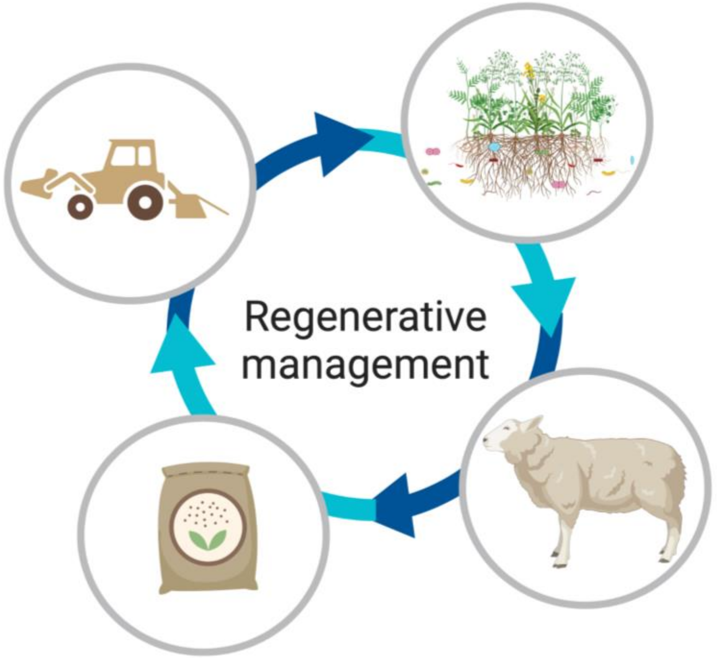
Mulching

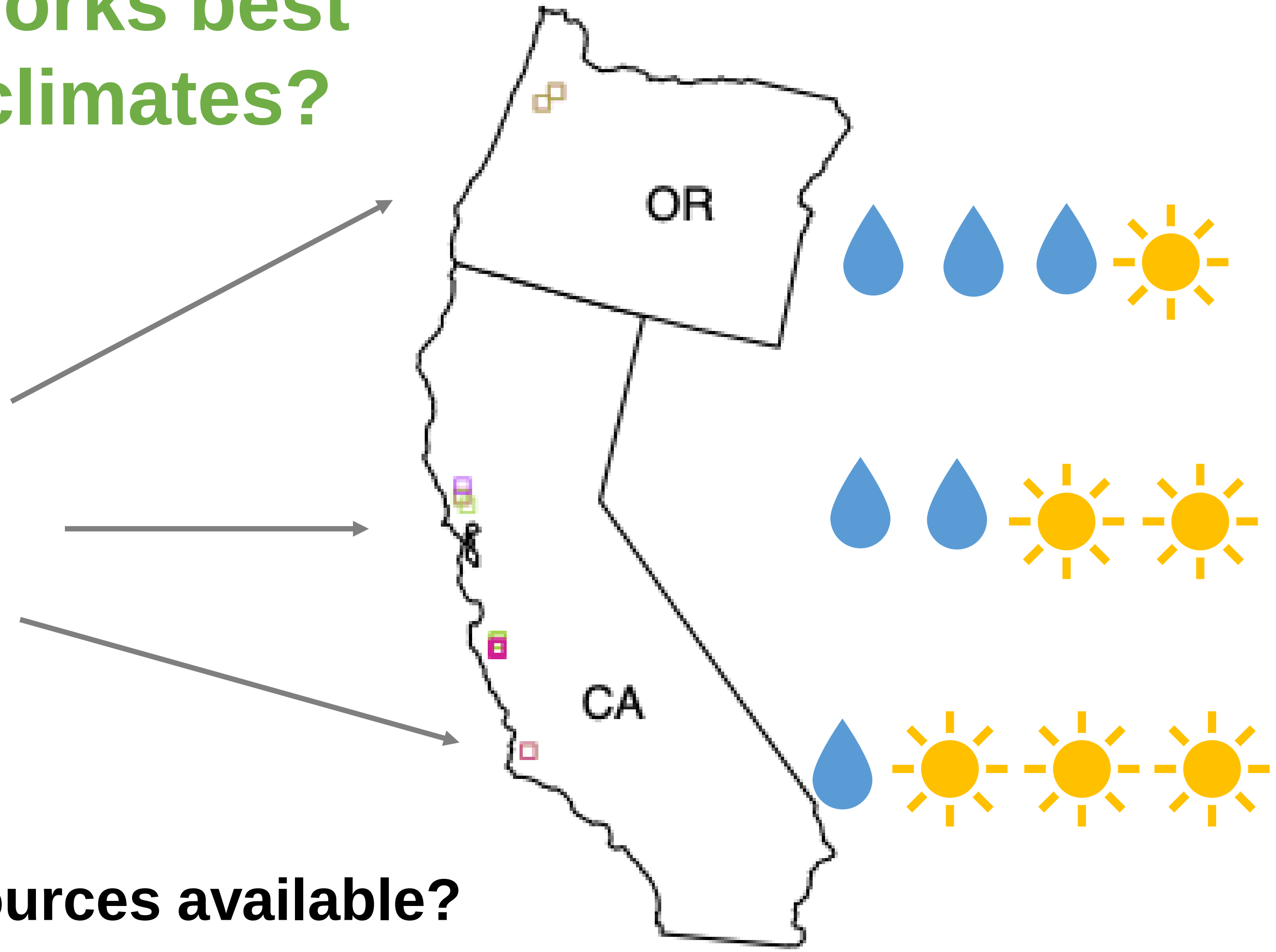
Crop Rotation

Organic amendments

Animal integration

What set of practices works best for different soils and climates?





What makes sense with the resources available?

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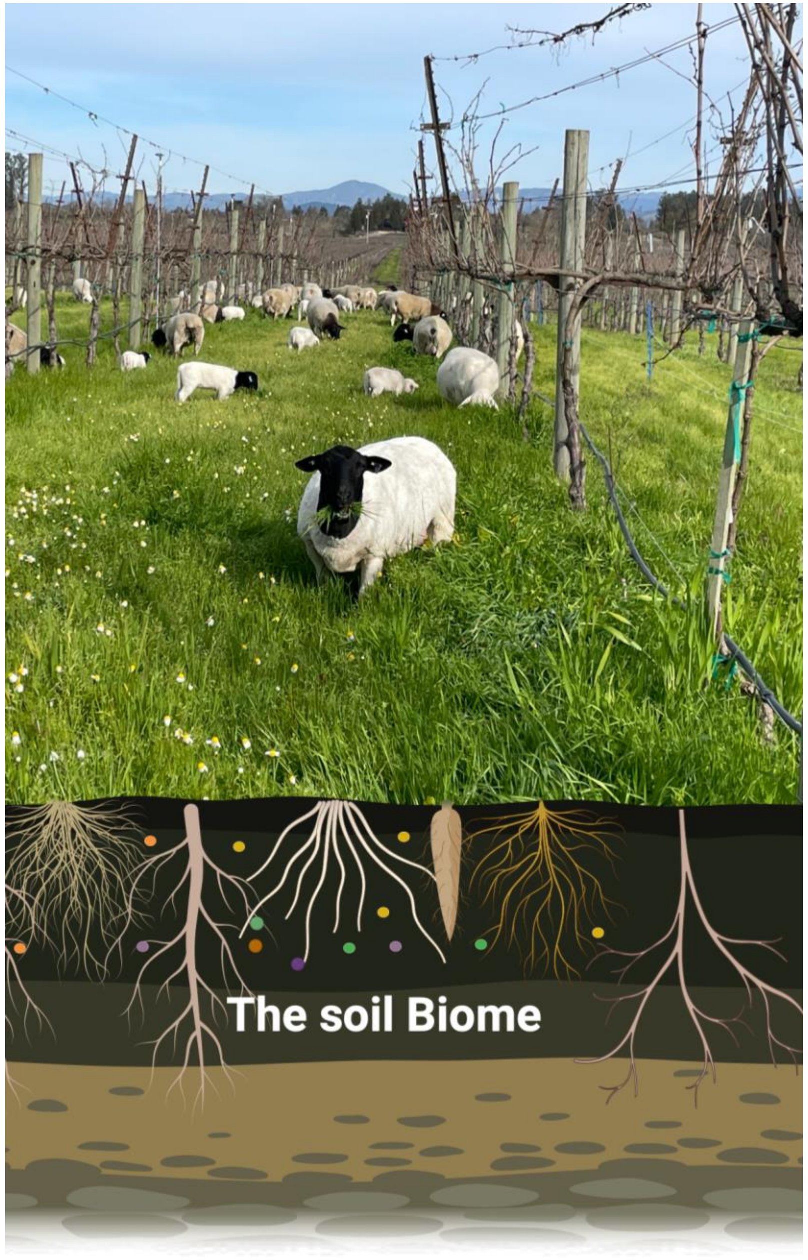
USDA United States Department of Agriculture

Jackson FAMILY WINES

United States Department of Agriculture NRCS Natural Resources Conservation Service

FFAR Foundation for Food and Agriculture Research



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Regenerative management

- Soil biodiversity supports vineyard multifunctionality
- Regenerative practices (organic amendments, no till and grazing) support biodiversity
- Unclear if stacking practices has synergistic effects
- Management effects are site-specific
- Need to monitor changes using the right indicators

Thank you!

https://lazcano.faculty.ucdavis.edu

SOIL BIODIVERSITY AND HEALTH LAB

Healthy soils for healthy food and a healthy planet