

From High Microbial Diversity to Functional Soil Health: An Early-Stage Regenerative Soil Experiments in Tropical Avocado Orchards in Santa Isabel, Puerto Rico

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Background

- High microbial diversity is often equated with soil health
- Yet functional resilience may not follow diversity
- Soil chemistry and structure may constrain function
- We tested this paradox in two adjacent soil series

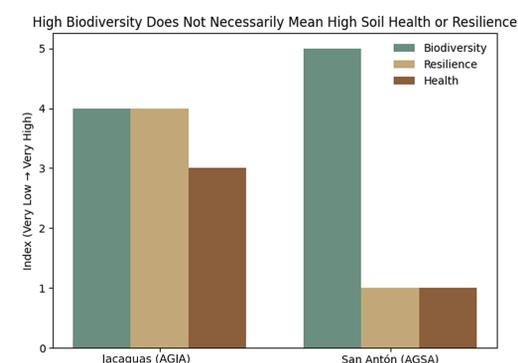


Figure 1. Comparison of microbial biodiversity, resilience, and functional soil health between two avocado orchard soils at Finca Atabey (Puerto Rico) using BeCrop® indices. Results show that very high microbial biodiversity (San Antón) does not necessarily correspond to high soil health or resilience, supporting the hypothesis that system-level chemical and physical constraints regulate the functional expression of microbial diversity.

Soil challenges in a semi-arid zone (Santa Isabel, Puerto Rico)

On the semi-arid south coast, soils can have very low permeability and clay-rich textures, and the combination of high evaporation and irrigation can intensify water stress and increase risks of soil degradation (USDA-NRCS, 2006).

Limitations of conventional agriculture

In arid and semi-arid climates, production systems that rely heavily on intensive irrigation and high external inputs can accelerate processes such as soil salinization and overall declines in soil health, raising costs and increasing vulnerability (Cuevas et al., 2019).

Why the microbiome matters for agricultural resilience

A functional rhizosphere microbiome can help crops better tolerate drought and sustain key functions (nutrition, growth, and defense), strengthening resilience at the farm level (de Vries et al., 2020).

RESEARCH HYPOTHESIS & CONCEPTUAL FRAMEWORK

Main hypothesis

High microbial diversity does not guarantee soil functionality; functional soil health emerges from the interaction between microbial potential, soil chemistry, and physical structure.

Soil chemical conditions act as enabling or constraining filters. Physical structure influences microbial organization and resilience. Management practices may shift systems from diversity-rich to functionally regenerative states.

EXPERIMENTAL DESIGN (EARLY-STAGE PROPOSAL)

Proposed Field-Based Experimental Framework

Design:

Two orchard soils (San Antón and Jacaguas)
Three management treatments per site
Monitoring over 6–12 months

Measurements (triangulation):

Microbiome (potential):
Functional metagenomics (BeCrop®)

Activity & structure (field-based):
Soil respiration (CO₂)
Infiltration rate
Aggregate stability

Chemistry (mechanistic relevance):

pH and electrical conductivity
Organic carbon
Phosphorus availability
Cation balance (Ca, Mg, K, Na, CEC)

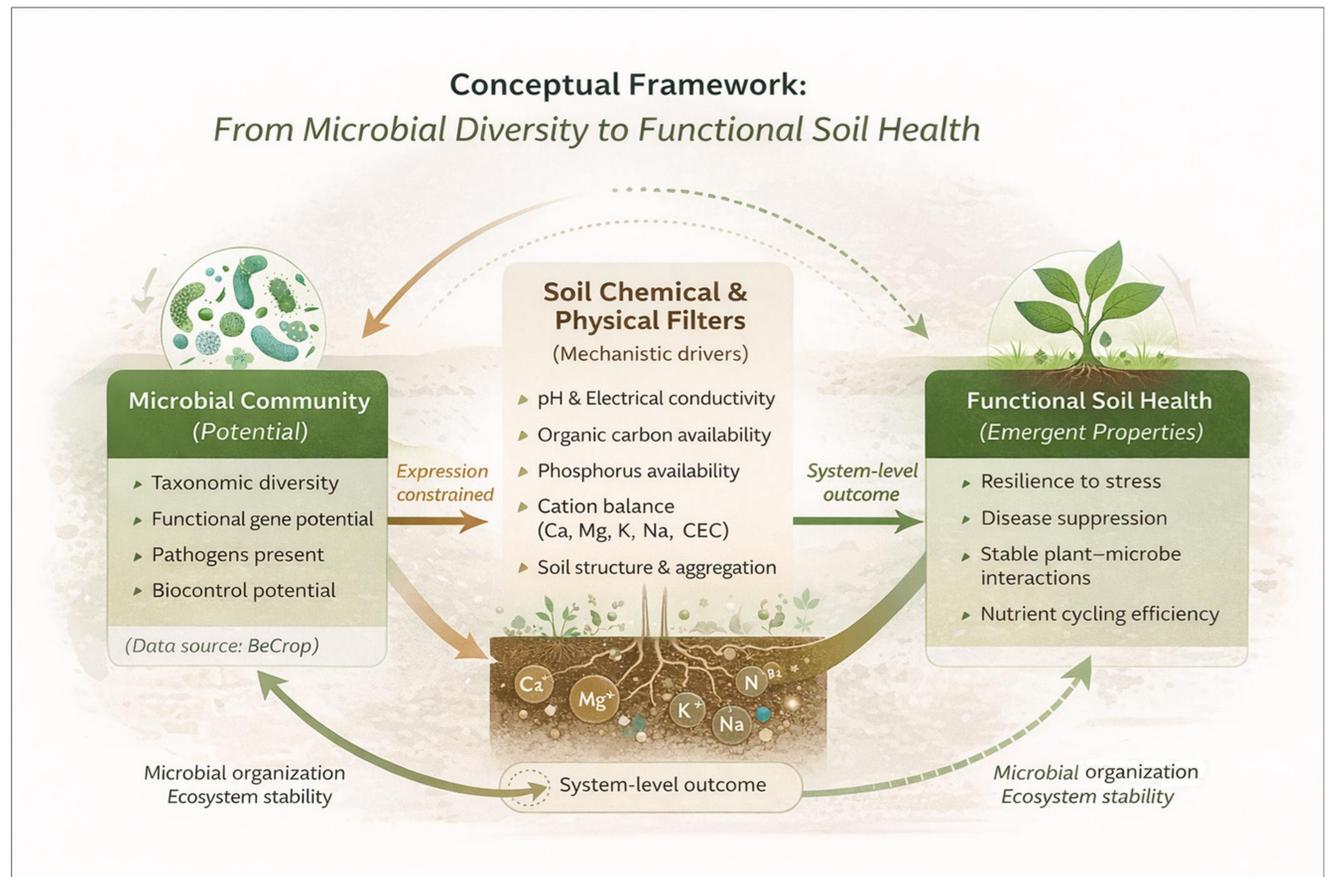


Figure 2. Conceptual framework linking microbial diversity to functional soil health. In the BeCrop® framework, microbial biodiversity reflects taxonomic richness and functional genetic potential, whereas soil health emerges from ecosystem-level organization and vulnerability to disease. This framework proposes that soil chemical and physical conditions act as enabling or constraining filters that determine whether diverse microbial communities translate into resilient, functionally regenerative soil systems. The proposed experiment integrates metagenomic profiles with targeted chemical measurements and field-based indicators to test this hypothesis under real orchard conditions.

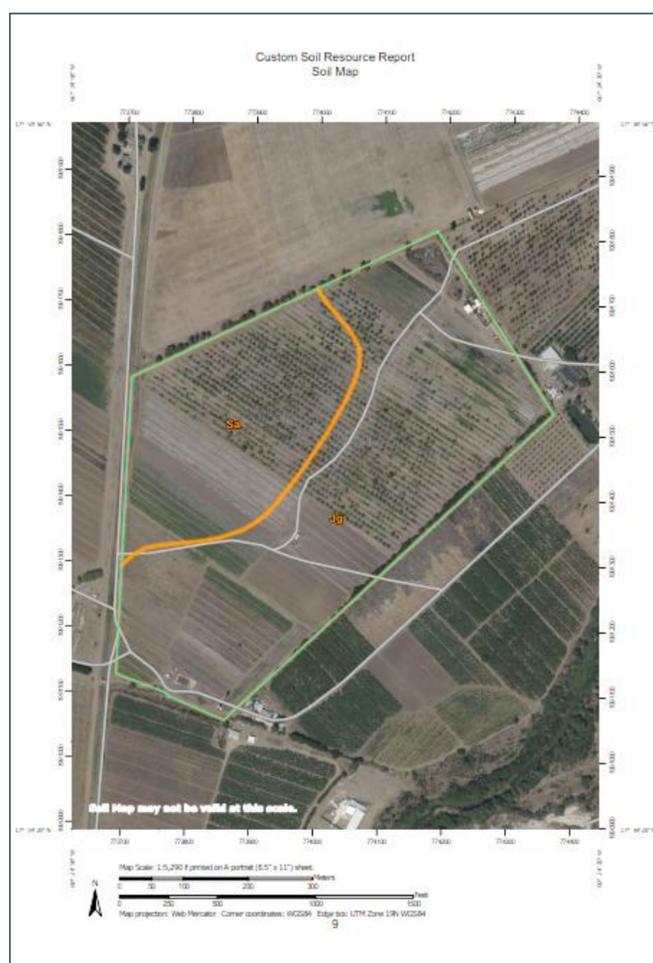


Figure 3. Map of the avocado orchard showing the delineation of the San Antón (Sa) and Jacaguas (Jg) soil units. The orange line indicates the internal boundary between both soil series within the same production field. Aerial image with georeferenced coordinates (WGS84).

WHY THIS MATTERS & COLLABORATION

- Addresses a key conceptual gap in soil microbiome research.
- Links microbial diversity to function through chemistry and physics.
- Conducted in a real, long-term agricultural system.

Opportunities for Collaboration

- Microbial activity and functional assays
- Soil chemistry–microbiome coupling
- Method development for field-relevant monitoring
- Graduate or pilot research projects

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