Soil Microbial Communities and Enzymatic Activities in Tropical Soils of Puerto Rico

D. Sotomayor-Ramírez[1], V. Acosta-Martínez[2], Y. Espinoza[3], Jose Amador[4]

[1] University of Puerto Rico – Mayagüez, College of Agricultural Sciences, Mayagüez, Puerto Rico;

[2] USDA-ARS, Cropping Systems Research Laboratory, Lubbock, TX ;

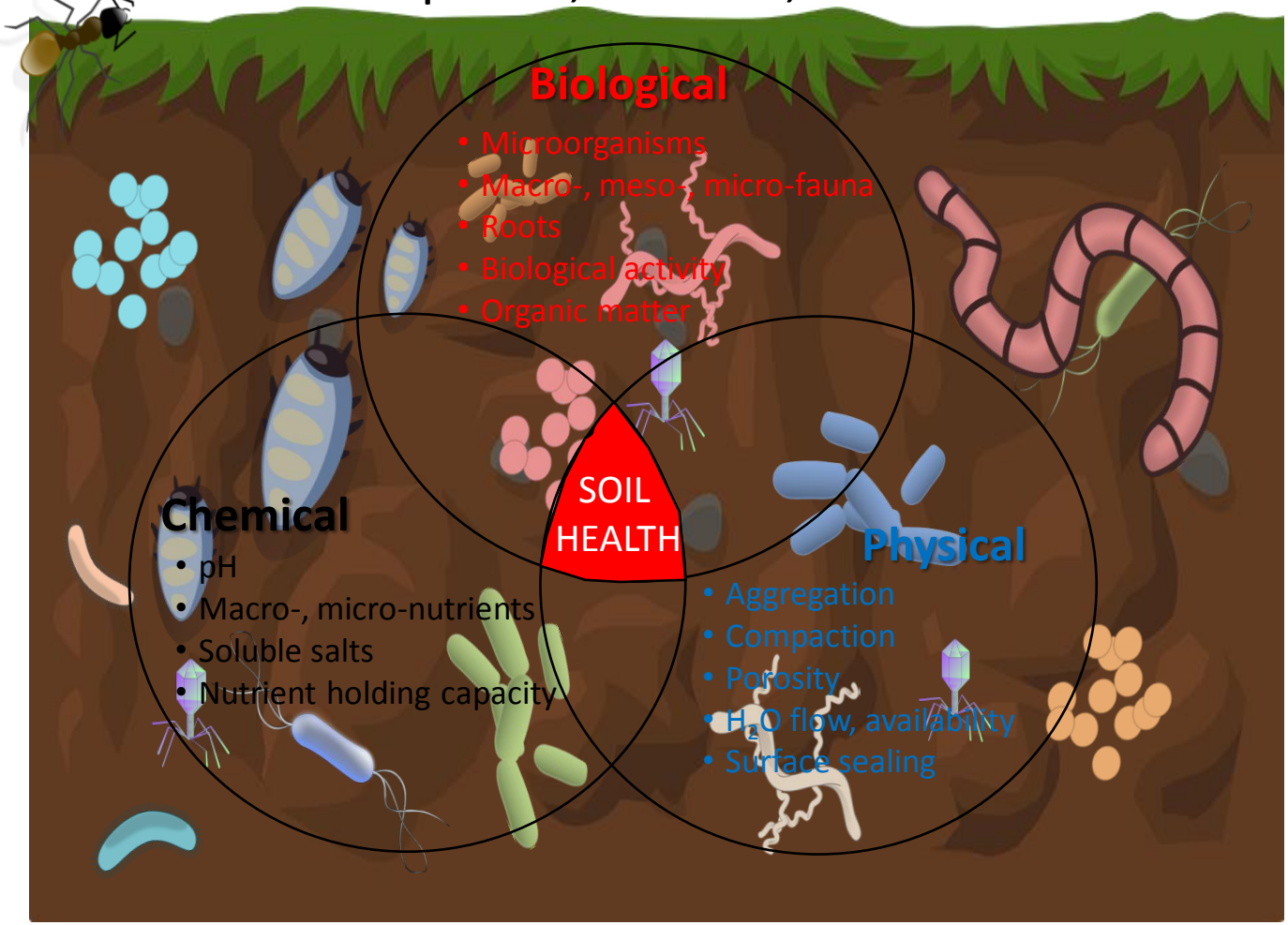
[3] Instituto Nacional de Investigaciones Agrícolas (INIA), Centro de Investigaciones Agropecuarias (CENIAP), Maracay, Venezuela;

[4] Laboratory of Soil Ecology and Microbiology, University of Rhode Island

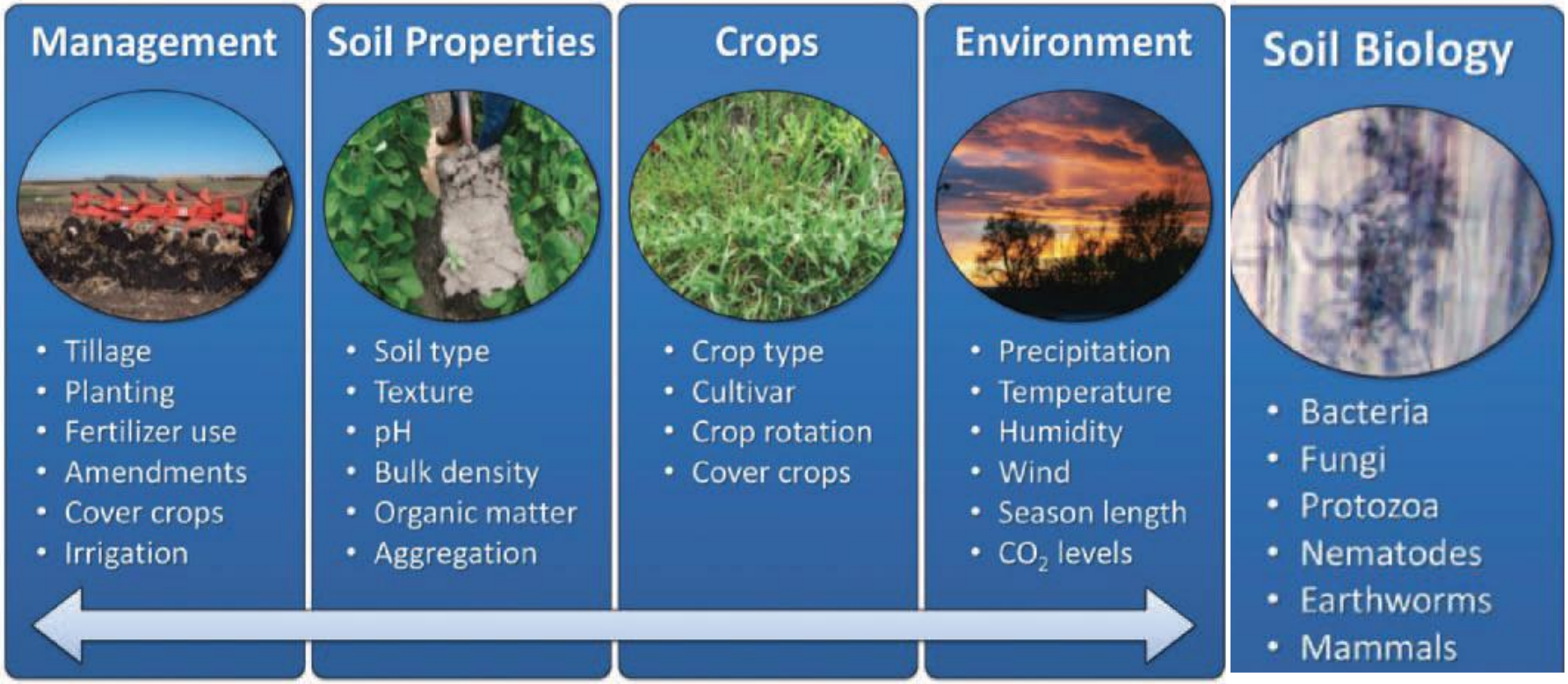
Contact information: david.sotomayor@upr.edu; 787-832-4040 x5819

Soil quality

The capacity of a soil to function
as a vital, living ecosystem
that sustains plants, animals, and humans



Understanding the impact of management on soil health & functions will require…



- **Long-term data needed for assessments**
- **Identifying the most useful metrics**
- **Biology most complex, least understood**

Information obtained:

Characteristics of the microbial community influencing soil health:

Tools/ Assessment:

HOW MANY?

Size

MBC &N
Total FAs
DNA

COMPOSITION

Fungal Populations (Sapro,AMF)

Bacterial Populations (G+, G-,actino)

PLFA, FAMEs

Structure

Microspirida
Blastocladlomycota
Chytridiomycota
Zygomycota
Glomeromycota
Ascomycota
Basidiomycota

Proteobacteria
Verrucomicrobia
Bacteroidetes
Firmicutes
Chloroflexi
Acidobacteria
Spirochates

High-throughpu
Sequencing

Diversity

FUNCTION

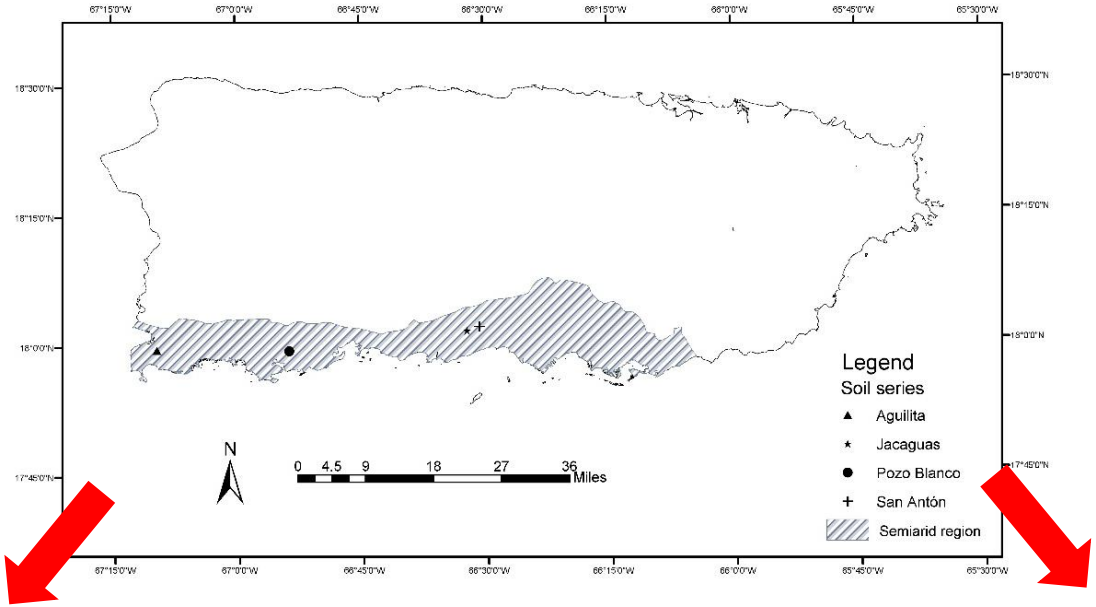
Biogeochemical Potential
&
Organic Matter Dynamics

Enz. Acts
Soil Respiratio
C mineralizati
RNA, Gene Exp
qPCR

Summary of some of our papers dealing with soil health/soil quality

1. Sotomayor-Ramírez et al. 2004. J. Agric. Univ. P.R.
2. Sotomayor-Ramirez et al. 2006. Australian Journal of Soil Research. 44: 687-693
3. Acosta-Martínez et al. 2007. Applied Soil Ecology. 35: 35-45 *
4. Acosta-Martínez et al. 2008. Applied Soil Ecology. 38: 249-260 *
5. Sotomayor-Ramírez et al. 2008. Proceedings Carib. Food Crops Soc. 44: 333-345.
6. Sotomayor-Ramírez et al. 2009. Biol. Fert. Soils. 45: 487-497 *
7. Sotomayor-Ramírez et al. 2010. J. Agric. Univ. P.R. 94: 1-23 *
8. Sotomayor-Ramírez et al. 2010. J. Agric. Univ. P.R. 94: 25-39
9. Amador et al. 2013. Tropical Ecology. 54: 365-374 *

STUDY 1: Microbial communities and enzyme activities under different management and land use in semiarid soils



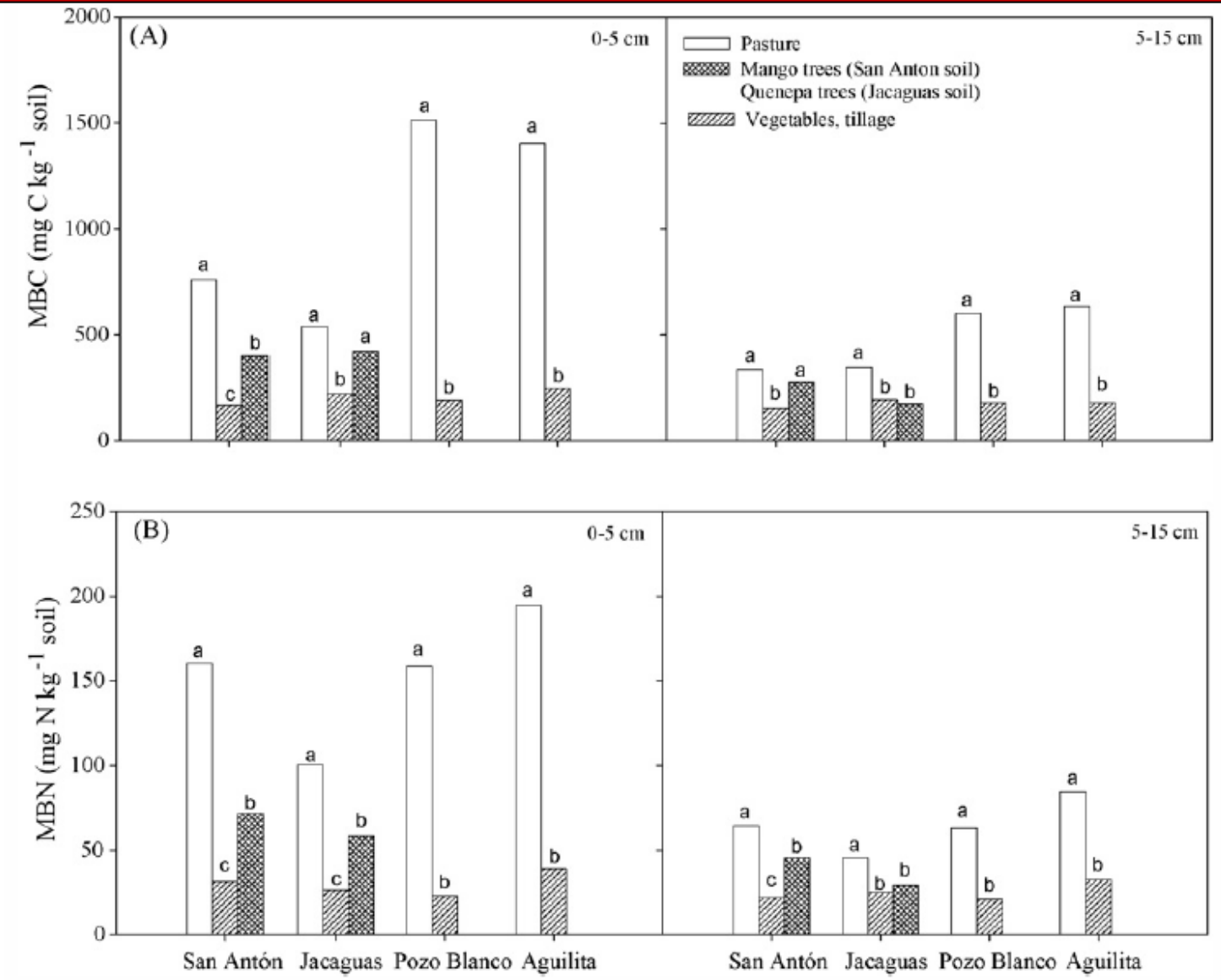
Four soils/sites

- San Antón (Cumulic Haplustolls)
- Jacaguas (Fluventic Haplustolls)
- Pozo Blanco (Aridic Calciustolls)
- Aguilita (Aridic Calciustolls)

Three management systems

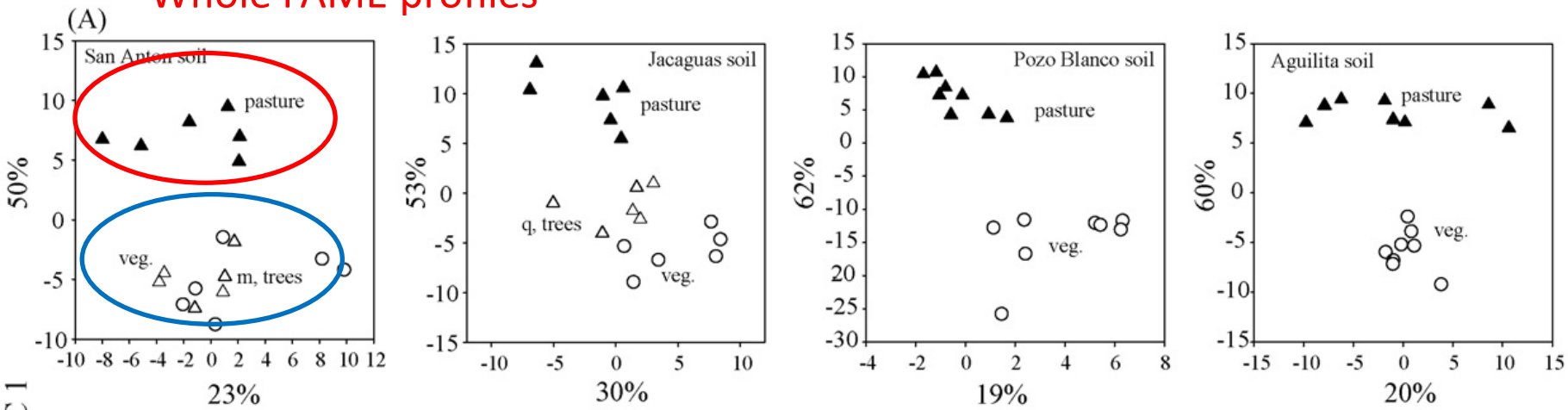
- Pasture,
- Fruit trees (Quenepas, Mango)
- Vegetables (tomato, pepper, watermelon)

Soil microbial biomass C & N

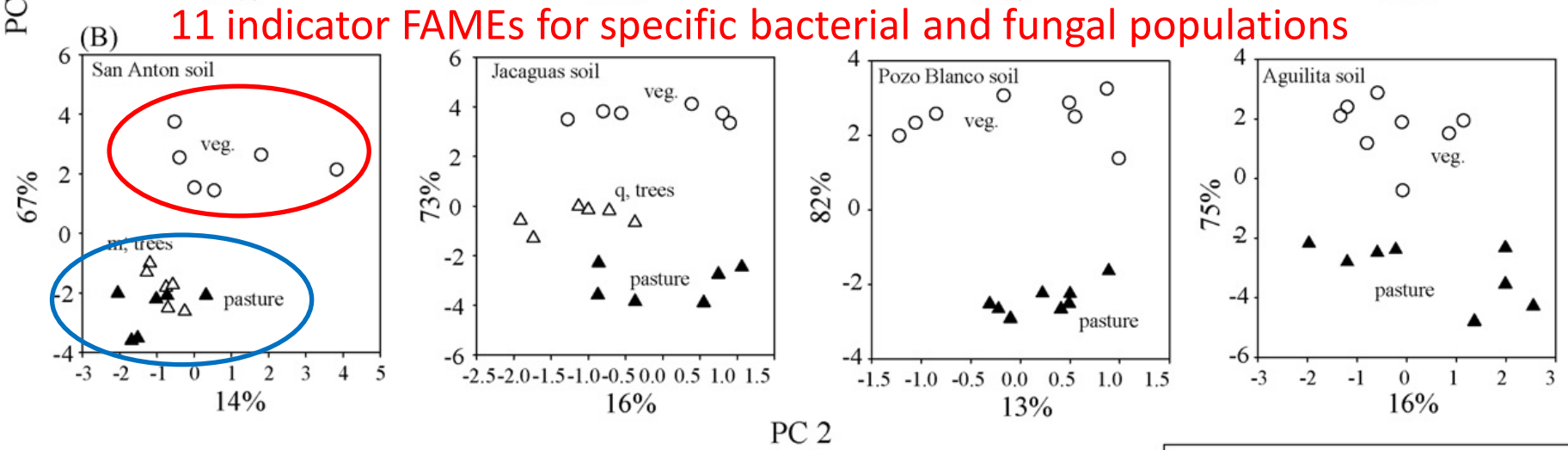


Microbial community structure

Whole FAME profiles

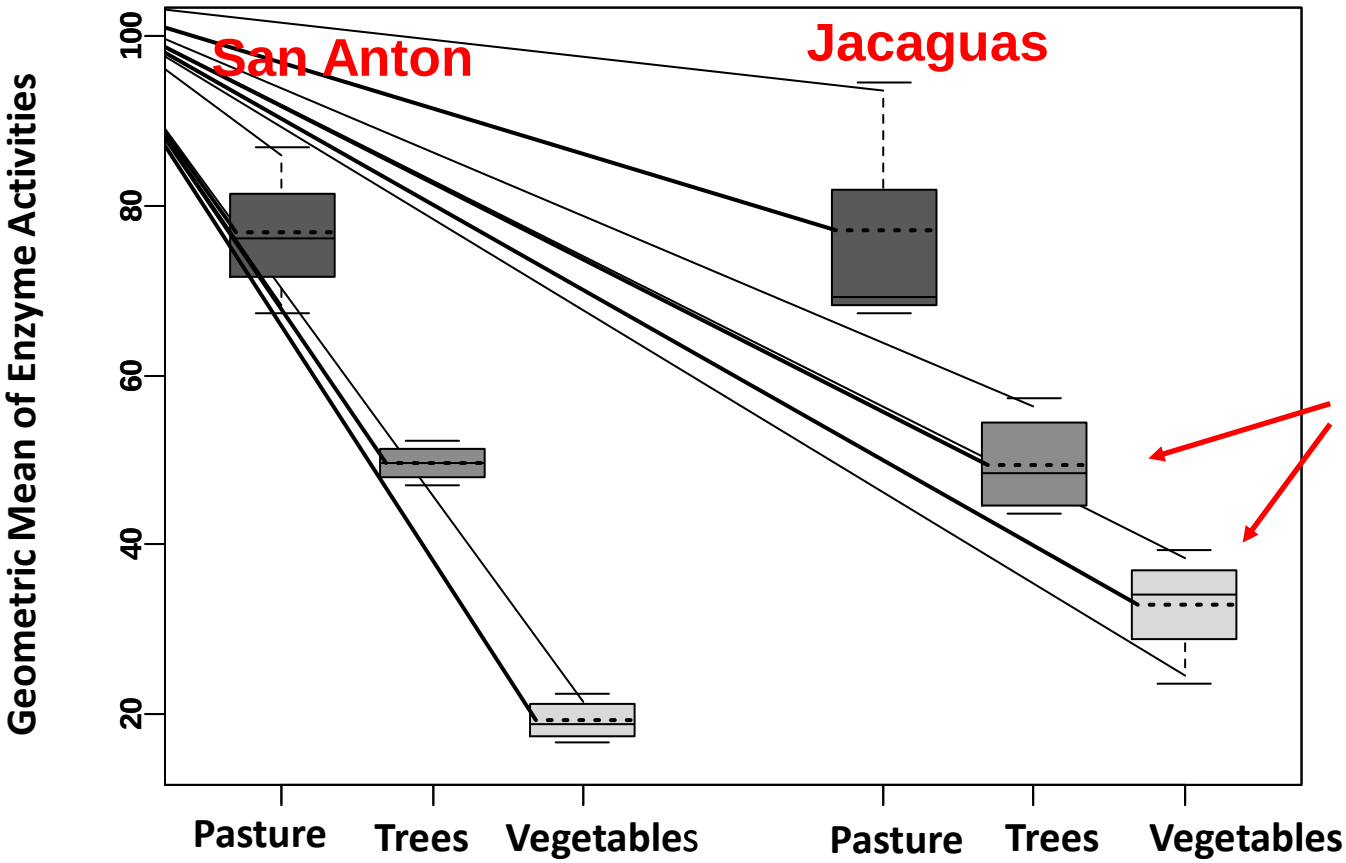


11 indicator FAMEs for specific bacterial and fungal populations



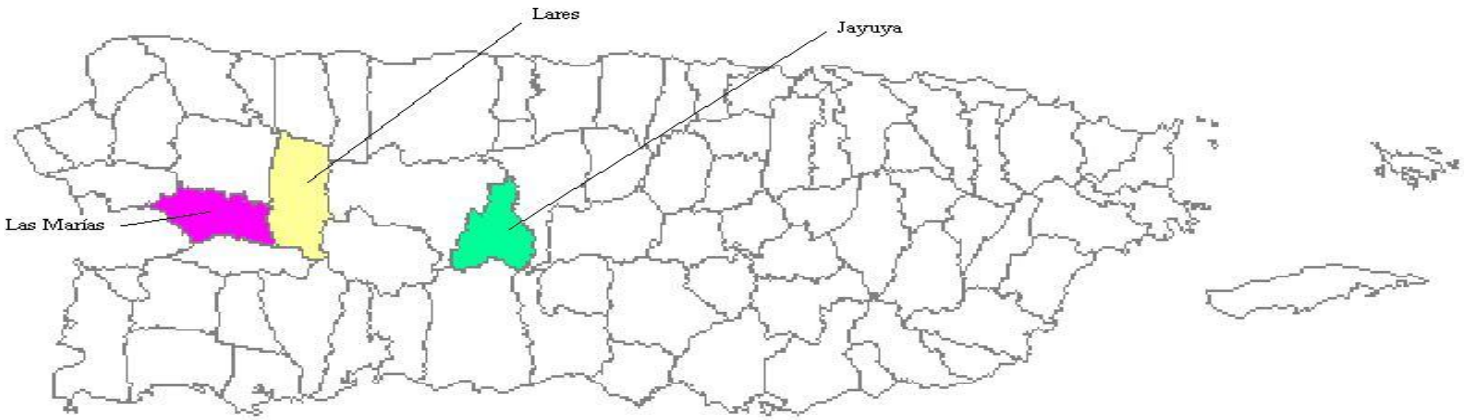
- ▲ Pasture
- △ Mangoes (m) trees (San Anton soil) or Quenepas (q) trees (Jacaguas soil)
- ○ Vegetables

Enzyme activities: (β-glucosaminidase, β-glucosidase, phosphatase, arylsulfatase)



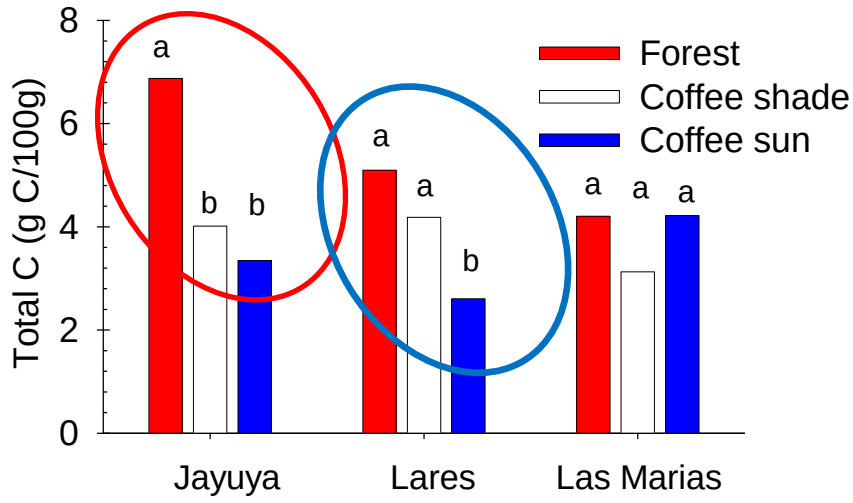
Biogeochemical potential almost double under fruit trees than vegetables while SOC was not significantly different (15.9 and 12.1 g kg^{-1})

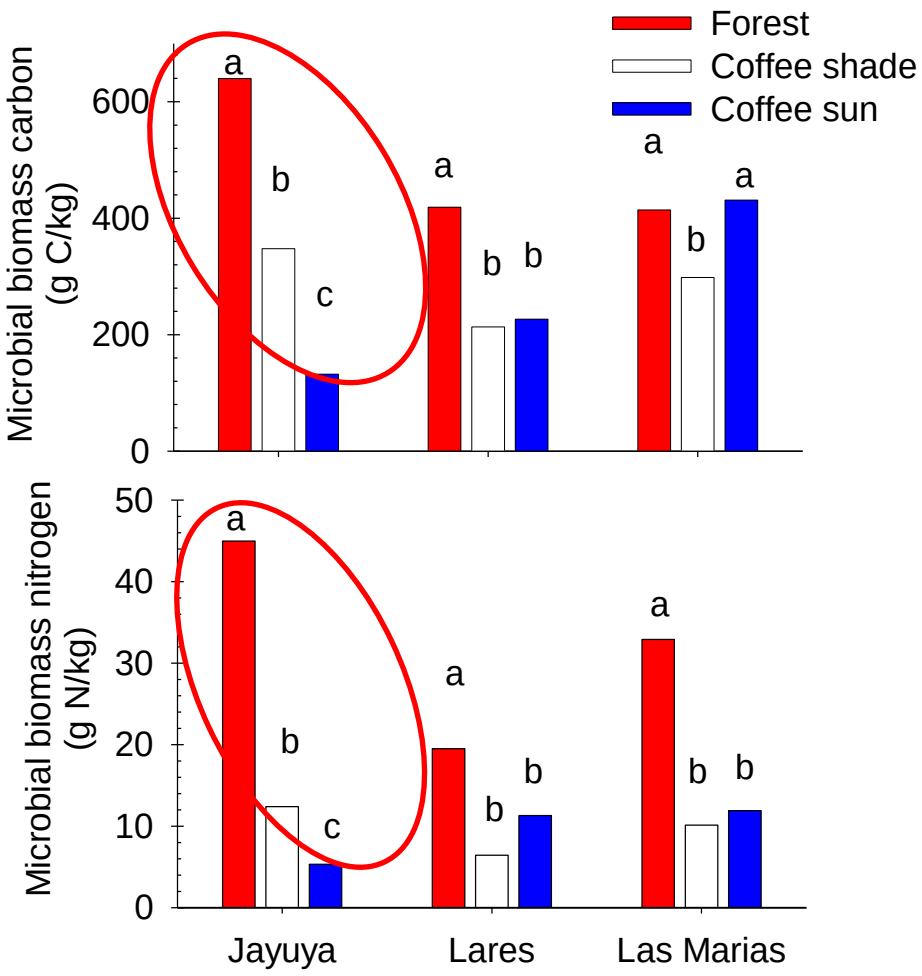
STUDY 2: Soil biological diversity (microbes & earthworms) in coffee (*Coffea arabica* L.) agroecosystems



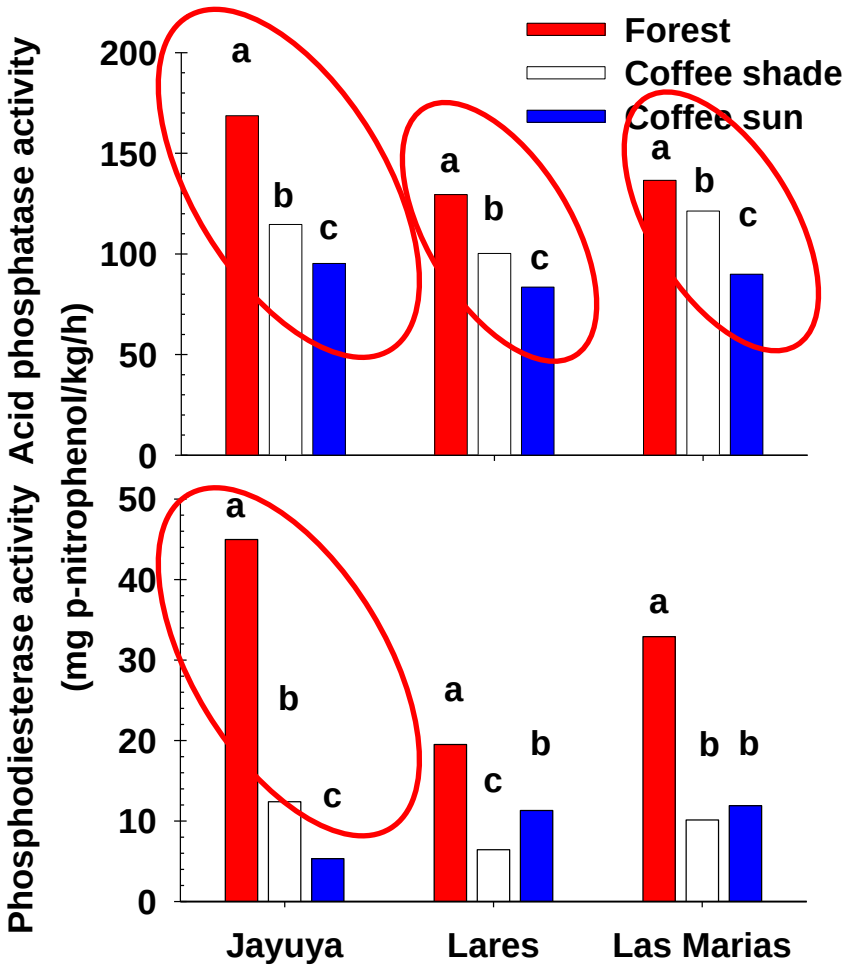
Site	Series	Taxonomic subgroup	Height above sea level (m)
Jayuya	Los Guineos	Humic Hapludox	789
Lares	Alonso	Oxic Dystrudepts	604
Las Marías	Humatas	Typic Haplohumults	286

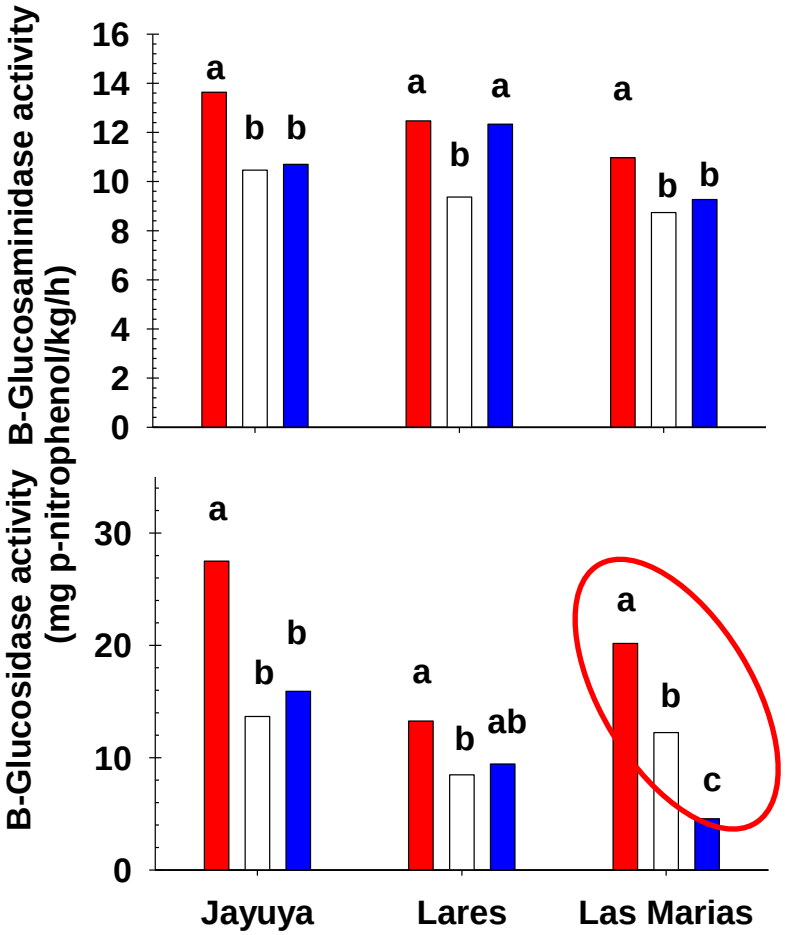
Total C and microbial biomass C and N

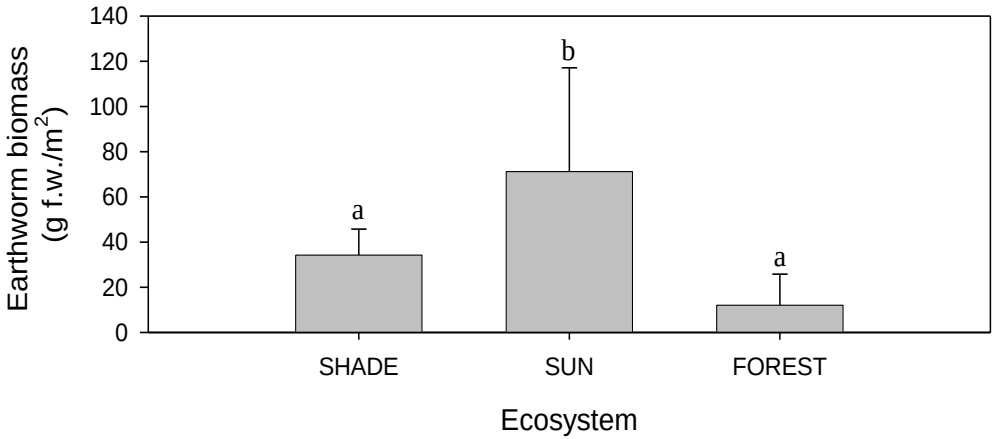


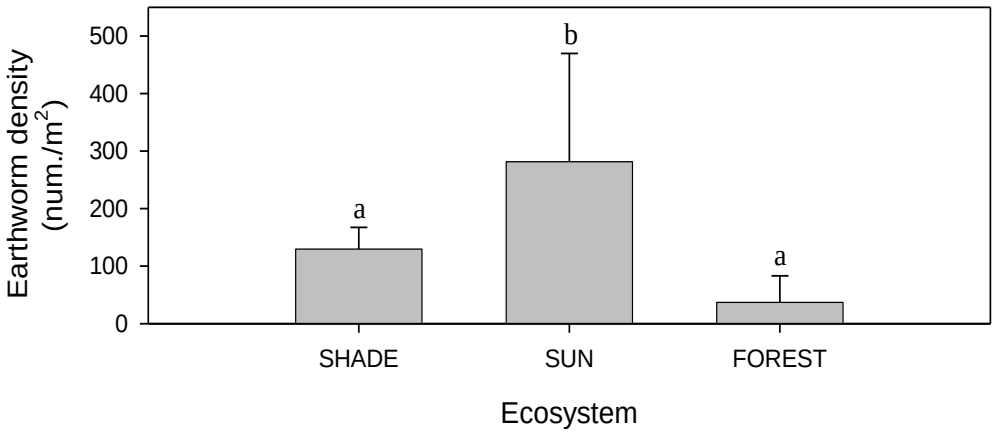


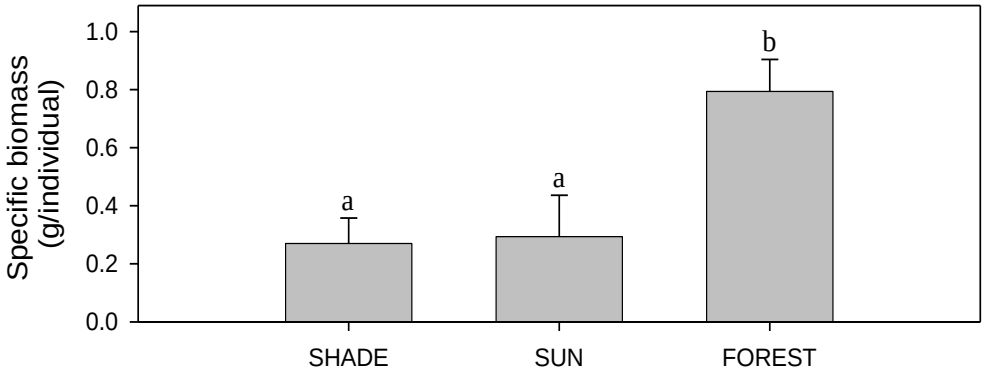
Enzyme activities



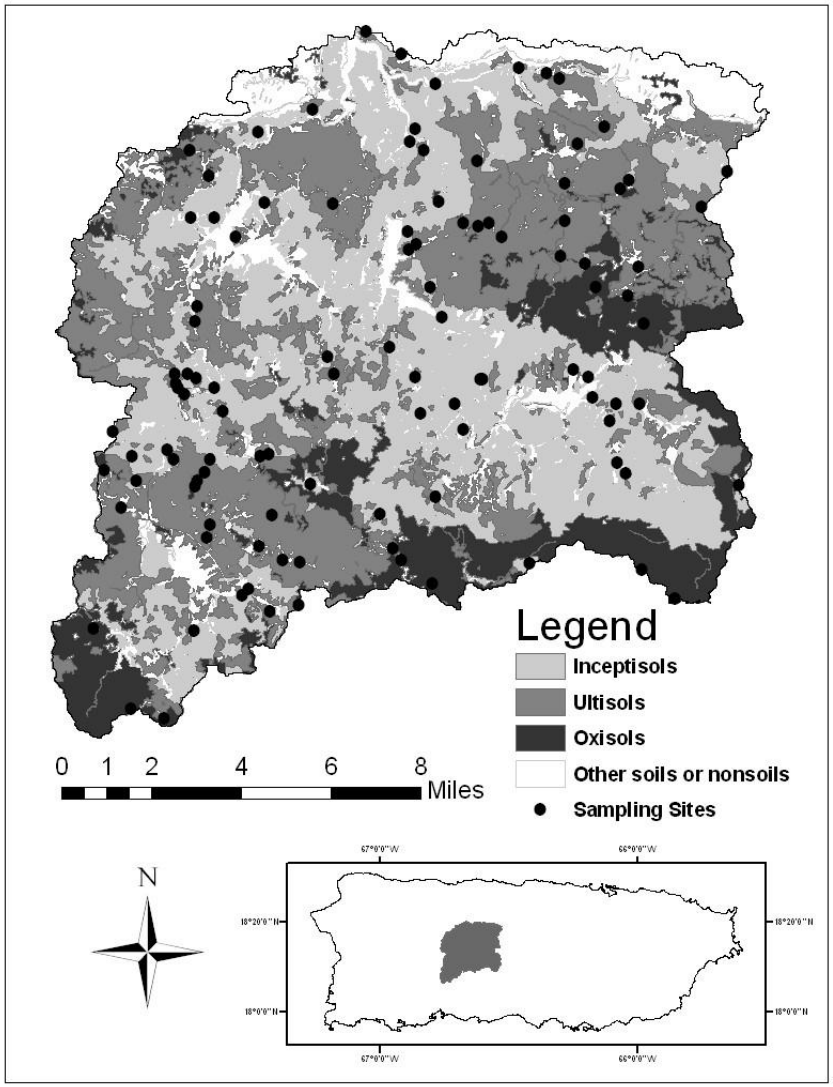


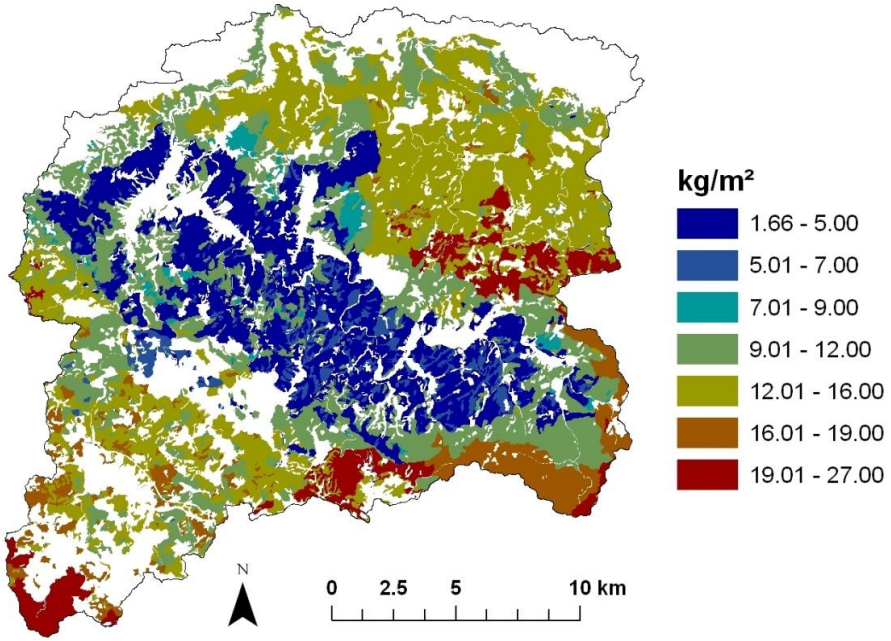

Earthworm biomass
(g f.w./m2)
140
120
100
80
60
40
20
0
a
b
a
SHADE
SUN
FOREST
Ecosystem


Earthworm density
(num./m2)
500
400
300
200
100
0
a
b
a
SHADE
SUN
FOREST
Ecosystem

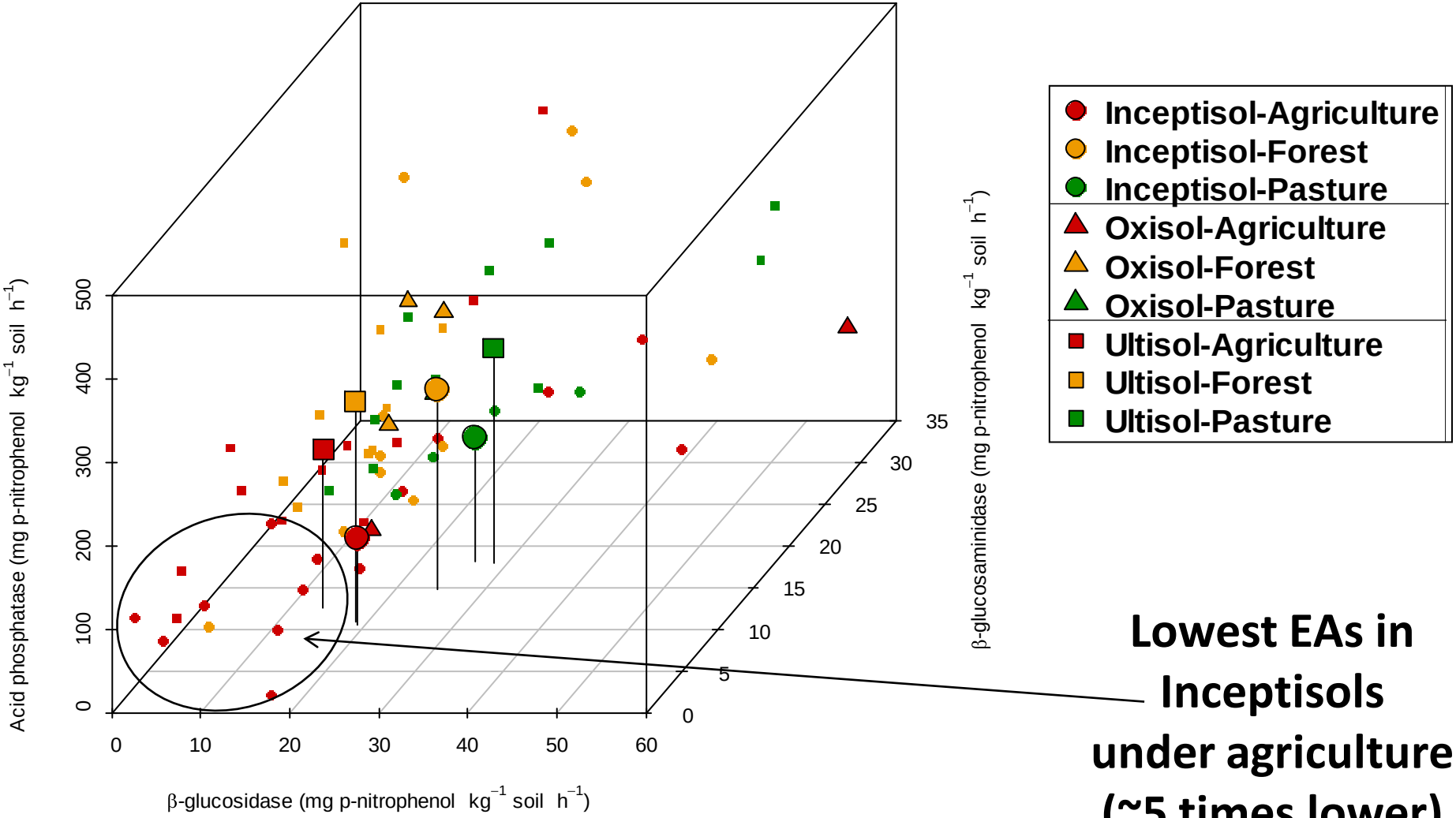

Specific biomass
(g/individual)
1.0
0.8
0.6
0.4
0.2
0.0
a
a
b
SHADE
SUN
FOREST

STUDY 3: Enzyme activities in the Río Grande de Arecibo watershed (north-central, PR)





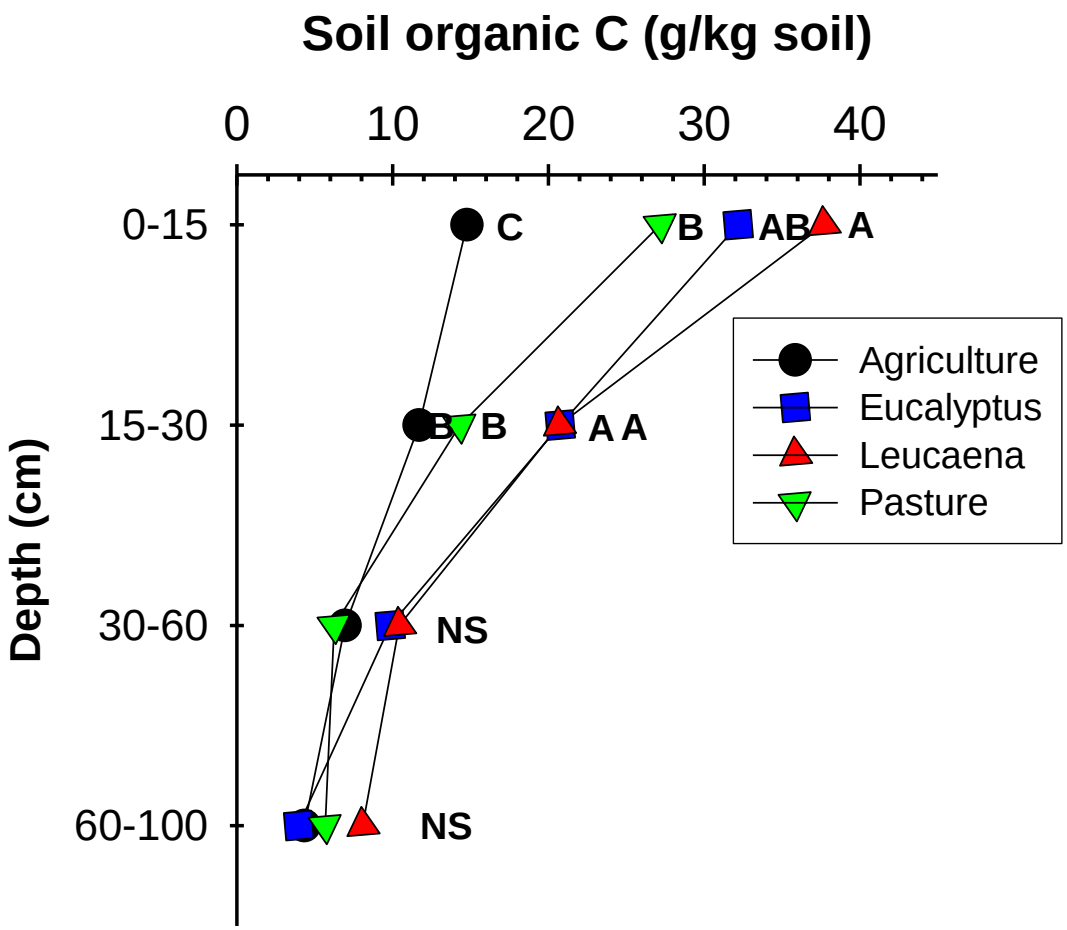
Enzyme activities



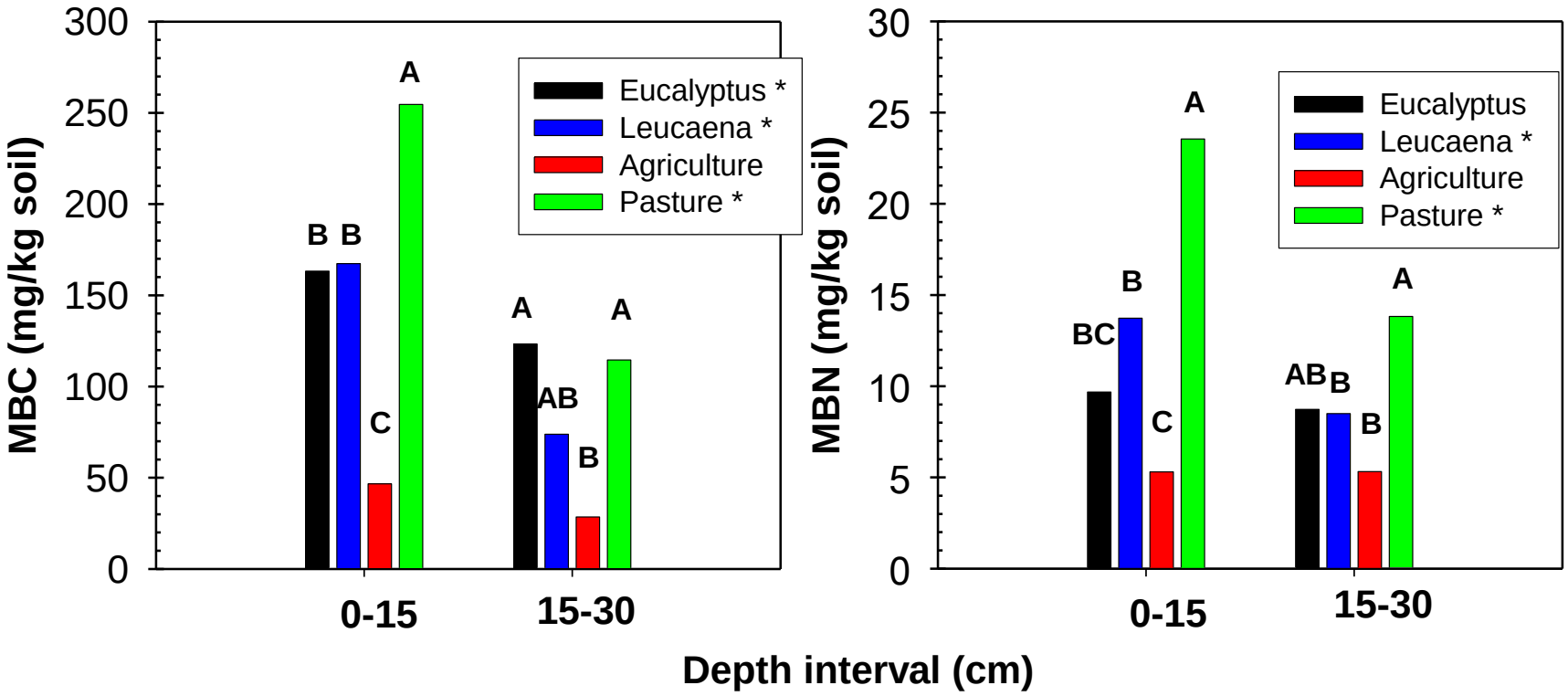
Lowest EAs in Inceptisols under agriculture (~5 times lower)

STUDY 4: Soil C, microbial biomass C &N, and enzyme activities of C & N cycling following 26-yr conversion from sugarcane (*Sacharum officinarum*) to forest (*Eucaliptus robusta* or *Leucaena leucocephala*) or pasture (mixture of tropical grasses) in Vertisols of south-west Puerto Rico

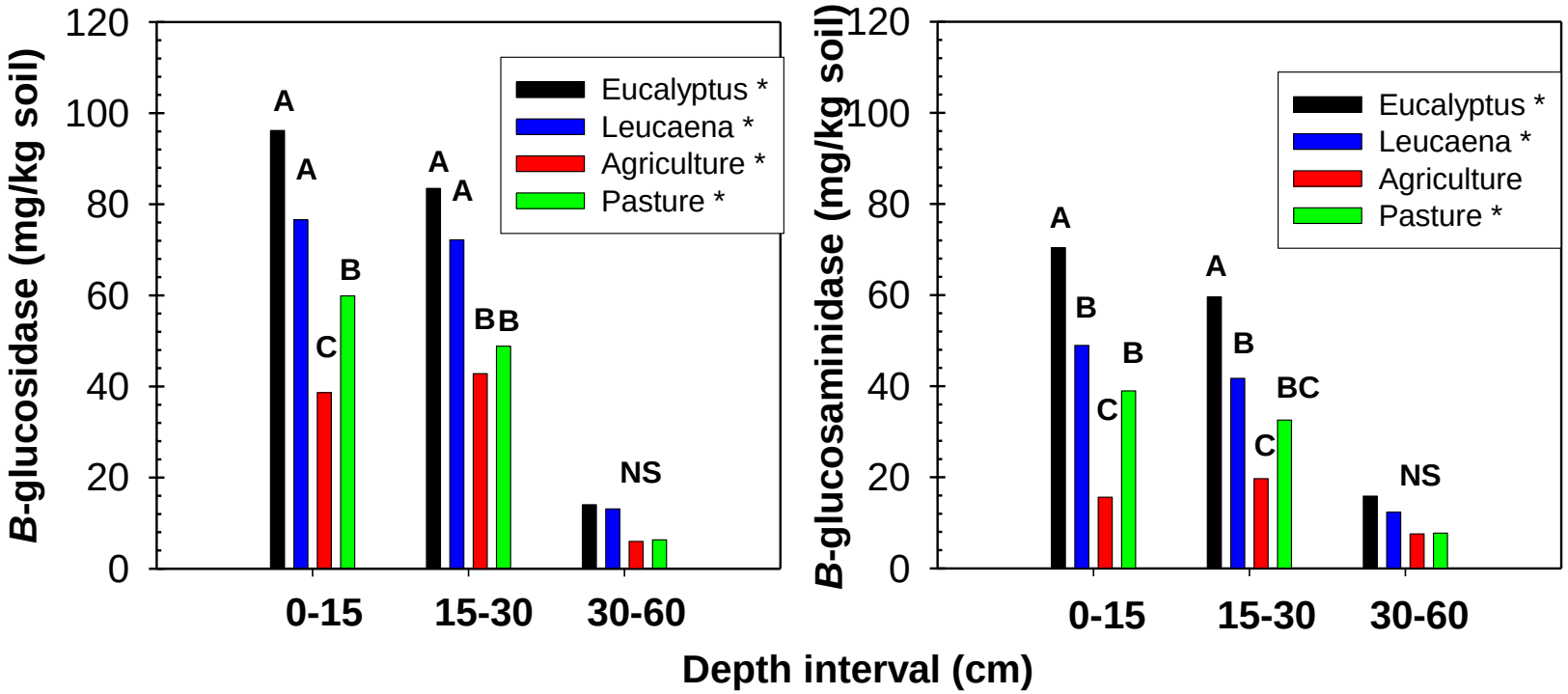
Profile soil organic C



Microbial biomass C and N



Enzyme activities



Concluding remarks

Semiarid soils w/ three management systems

- Had 30 to 50% less C under intensive tillage for vegetable production, with clear changes in the microbial community structure
- Litter-fall size return, litter quality, continuous tillage

Shade coffee

- Did not always provide a benefit to the soil community structure and enzyme activities

RGA watershed

- Three enzyme activities indicated that agricultural practices decreases (5 times lower) the biogeochemical cycling potential of Inceptisols; which tend have coarser texture in this region, but management can restore levels

Vertisols under trees, pasture and agriculture

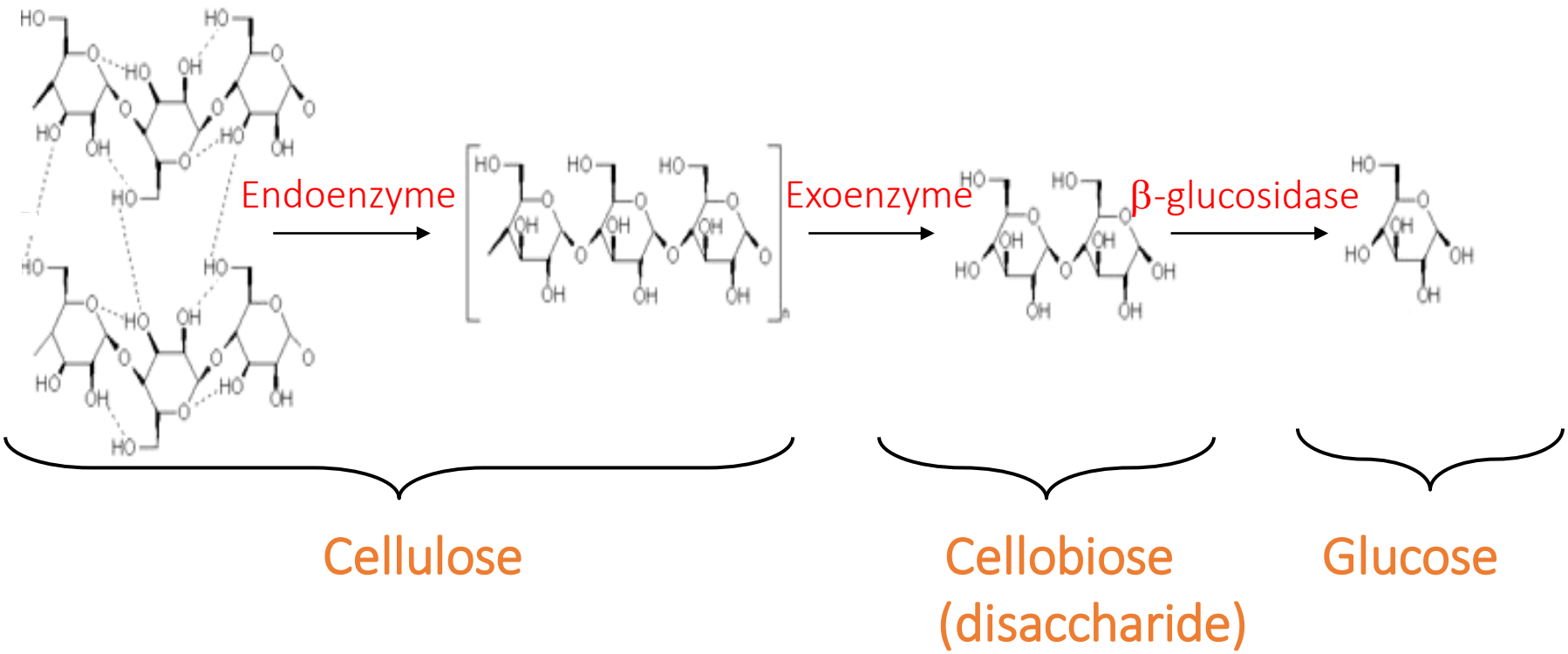
- Soil under agriculture had lowest soil quality indicators (SOC, enzyme activities, age of organic C, mineralizable C/MBC, MBC/SOC

Concluding remarks

- Agricultural intensification ←→ Sustainability
- Data ←→ Policy
- Long term, unbiased, objective,

C cycling: Cellulases

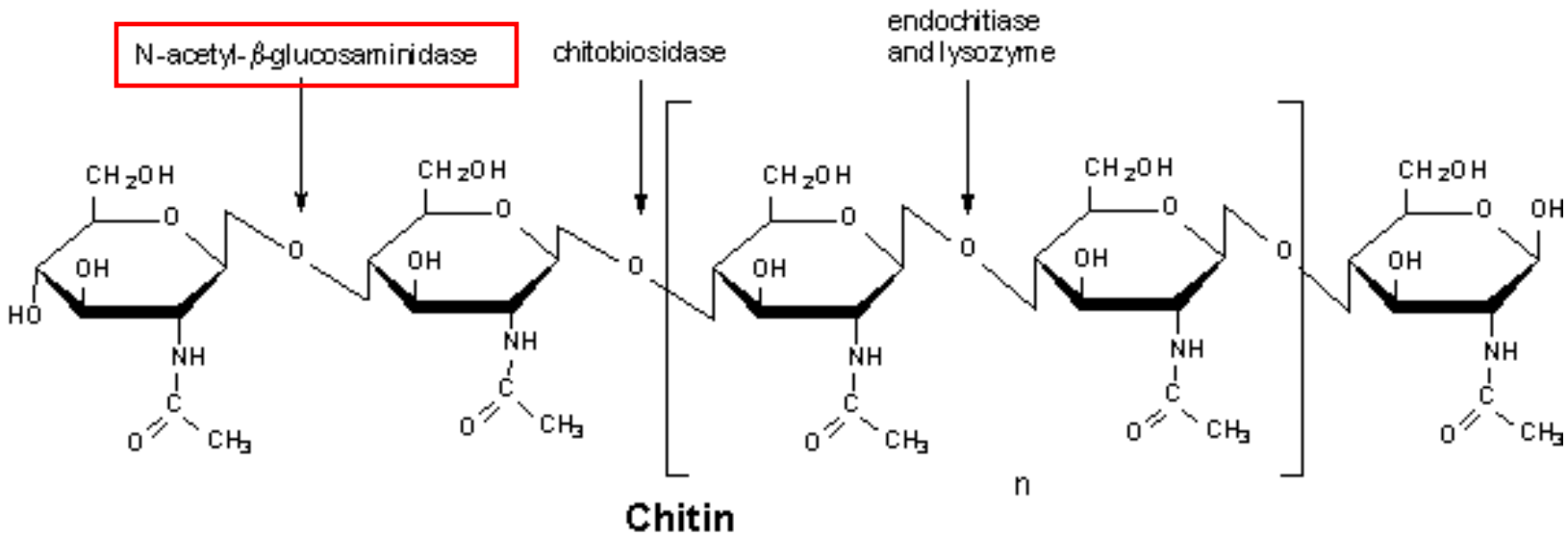
Cellulose degradation is an important process in soil C cycling catalyzed by a series of enzymes



C & N Cycling: β-Glucosaminidase

- Chitin degradation, releasing amino sugars
- Amino sugars are a major source of mineralizable N in soil

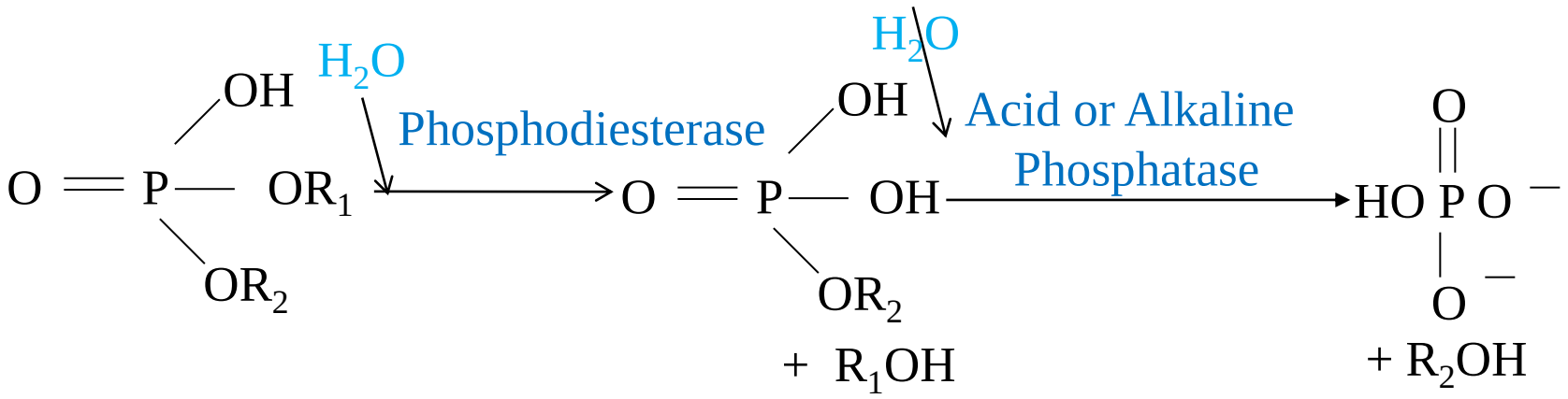
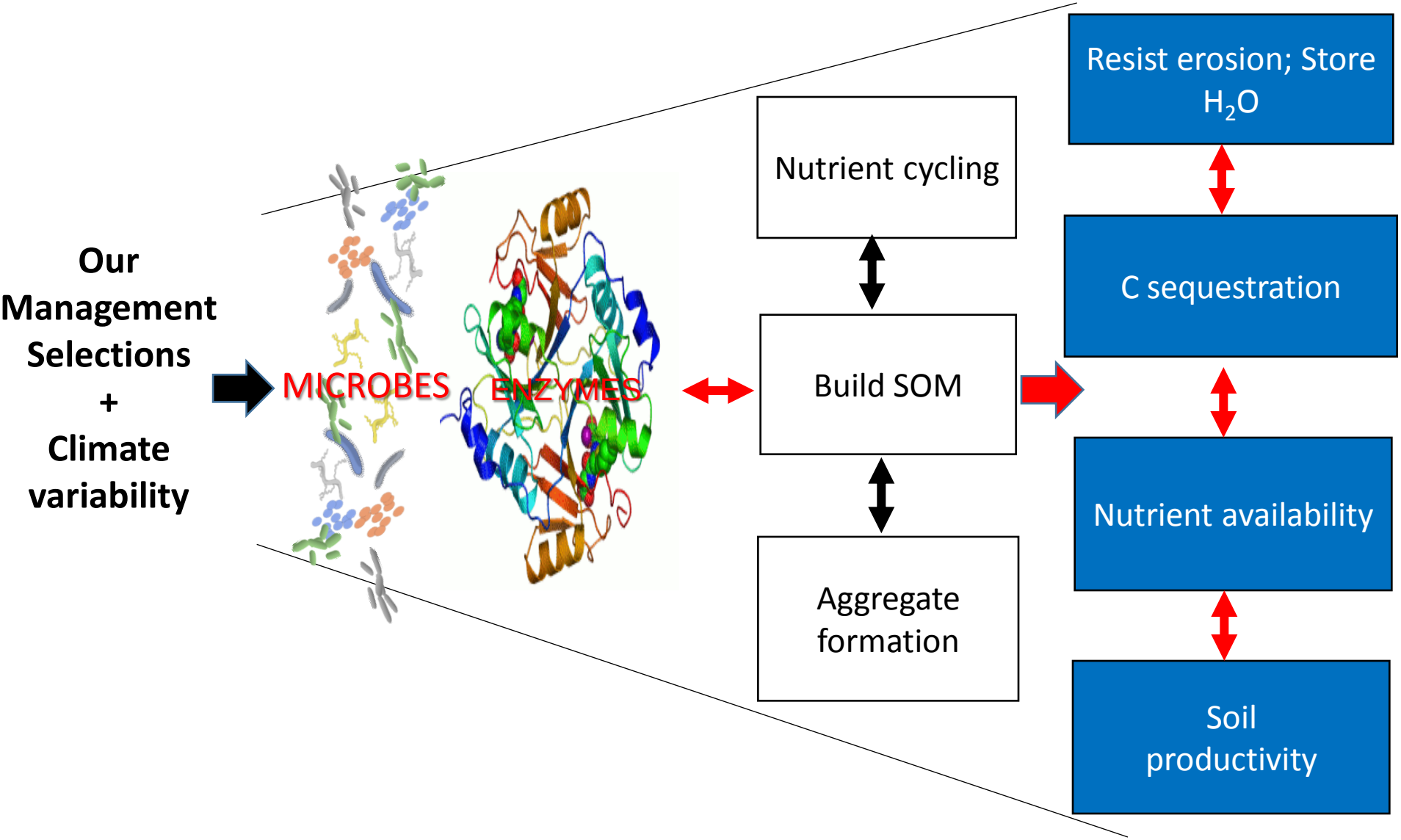
Chitase Specificity



Polymer of β-(1-4)-N-Acetyl-D-glucosamine units

http://www.sigmaaldrich.com/etc/medialib/life-science/biochemicals/migrationbiochemicals1/Chitinase_chitin.Par.0001.Image.600.gif

P Cycling: Phosphatases



Systems with enhanced soil health & functions