GREEN INFRASTRUCTURE'S IMPACT:
URBAN RAINWATER GARDEN INFLUENCES ON SEMI-ARID SOIL HEALTH

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(Presented by Vanessa Buzzard)

School of Natural Resources and the Environment

WRRC 104(b) 11/20/2024

OUTLINE

- Background
- Research Objectives
- Methods
- Spatial and Temporal Drivers of Indicators
- Conclusion
- Big Picture

ADDRESSING CLIMATIC AND ANTHROPOGENIC

- Background
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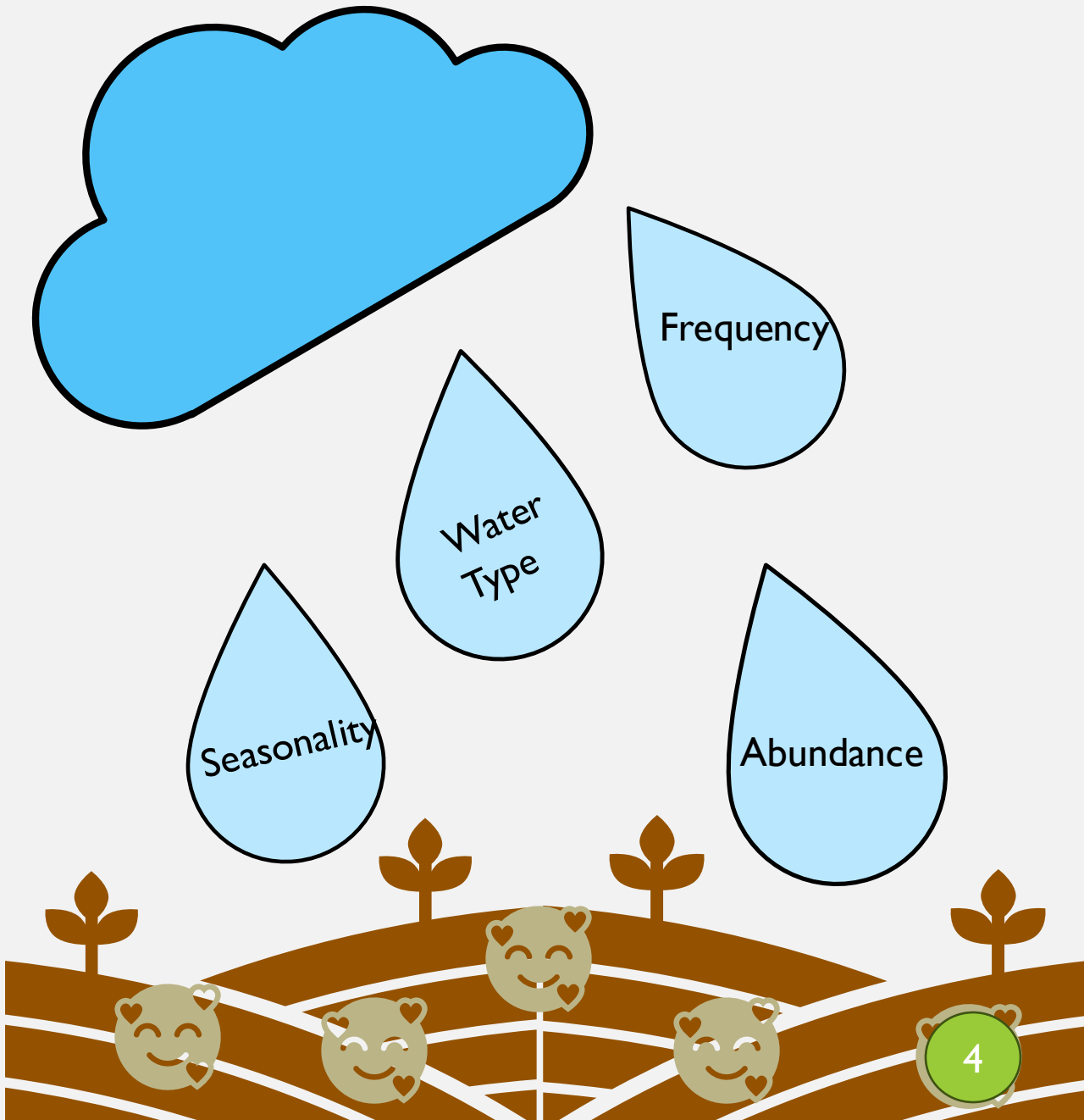
RAINWATER GARDENS

"Depressed area in the landscape that collects rainwater from a roof, driveway, or street and allows it to soak into the ground"

EPA

(*Soak up the Rain: Rain Gardens*, 2015)

Google Images from Powerpoint



GI BENEFITS

Clear Air and Water

Flood Protection

Stormwater Redirection

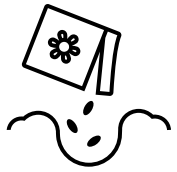
Enhanced Soil Health

***Buzzard et al., 2021**

SOIL HEALTH DEFINED

“Defined as the continued capacity of soil function as a vital living ecosystem that sustains plants, animals, and humans.”

NRCS/USDA



(*What Is Soil Health?*, n.d.)

HEALTHY SOIL FUNCTION

Regulating water

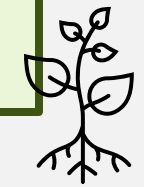
plant and animal life

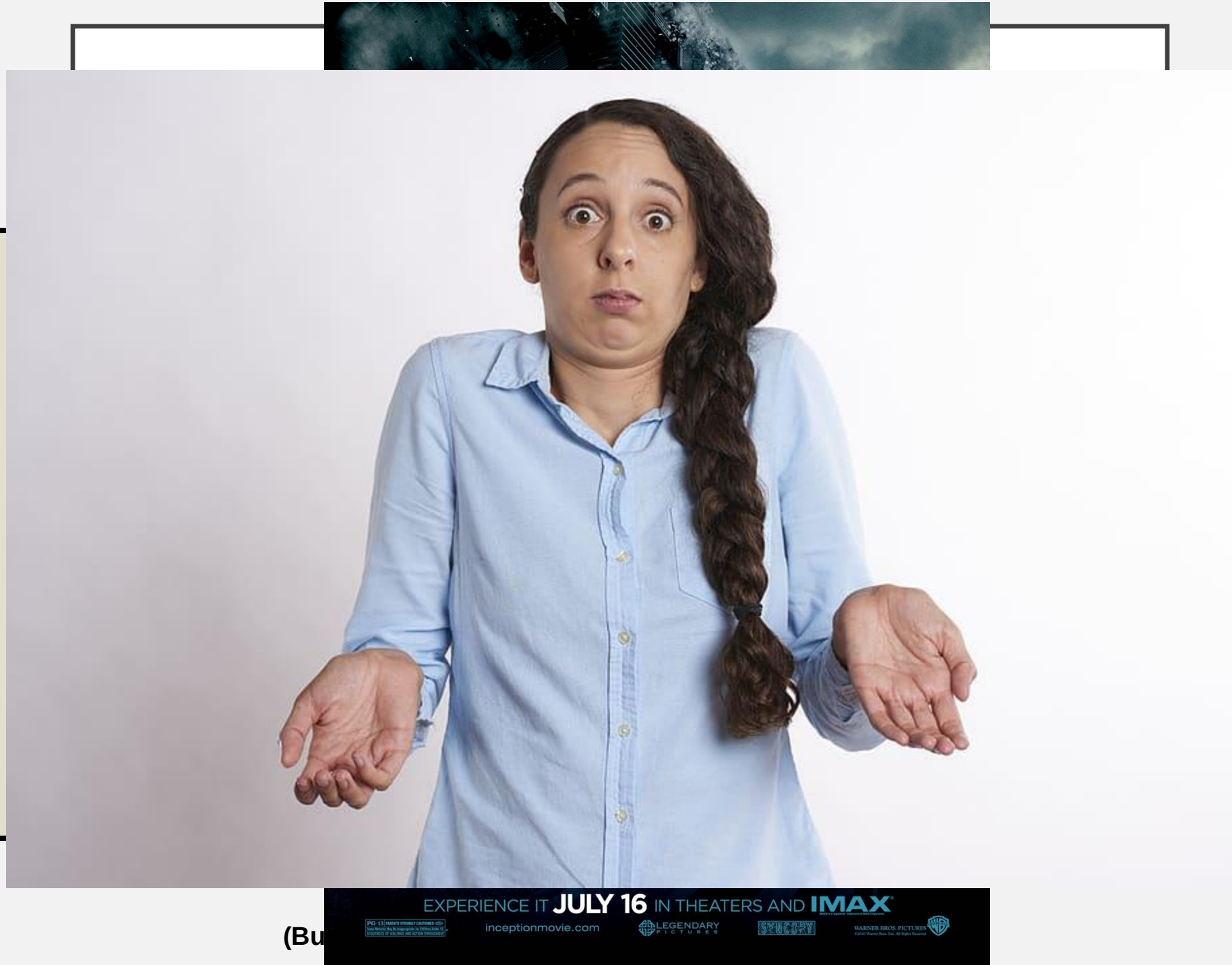
Filtering and buffering potential pollutants

Cycling and storing nutrients

Physical stability in environment

NRCS/USDA

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ADDRESSING THE PLOT HOLES AKA GAPS!

ELSEVIER

Soil Biology and Biochemistry
Volume 153, February 2021, 108111

Perspectives Paper

How microbes can, and cannot, be used to assess soil health

Noah Fierer [a], Stephen A. Wood [b c], Clifton P. Bueno de Mesquita [a]

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https://doi.org/10.1016/j.soilbio.2020.108111 Get rights and conte

Highlights

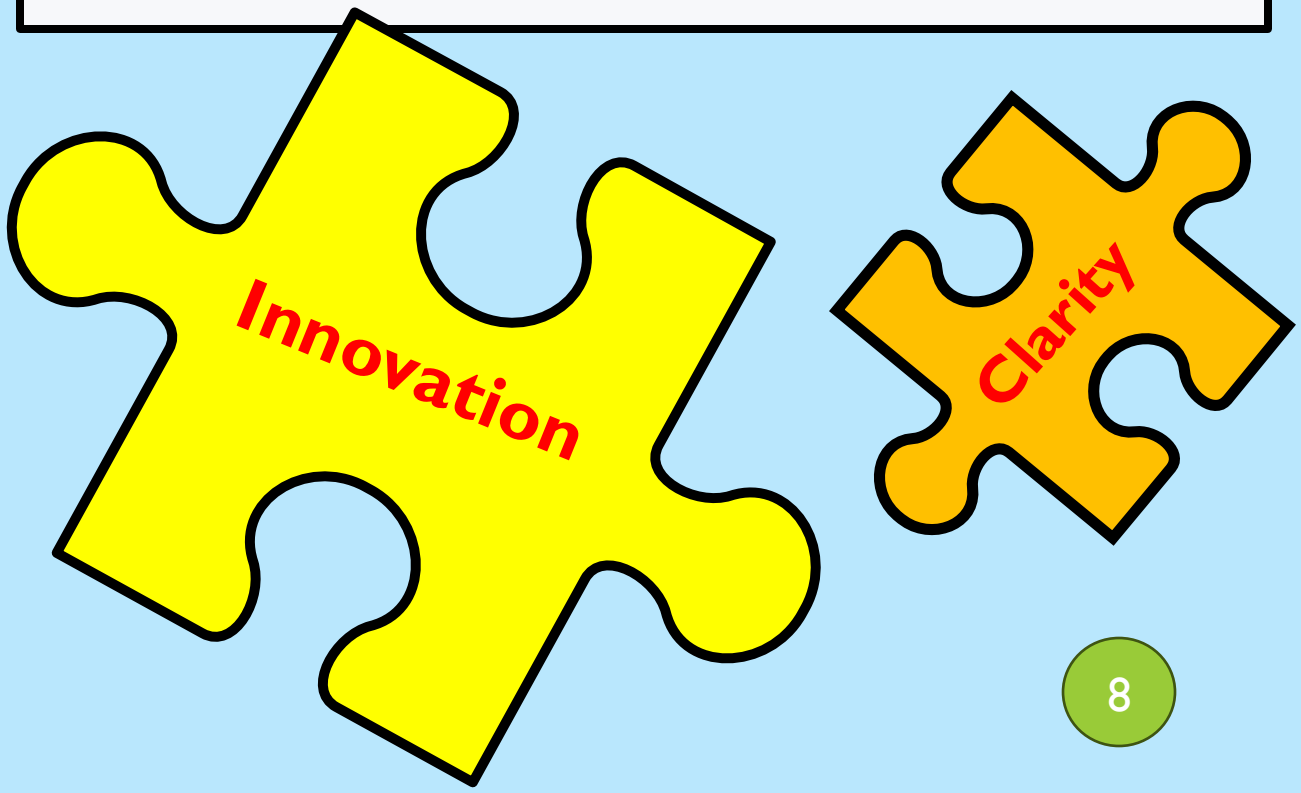
- We need to better integrate soil microbes into soil health assessments.
- Pre-existing metrics of soil health often lack clear interpretability.
- There are promising strategies to more effectively use microbes to infer soil health.

Making soil health science practical: guiding research for agronomic and environmental benefits

Stephen A. Wood, Joseph C. Blankinship

Environmental Science, Research

Research output: Contribution to journal › Short survey › peer-review



ELSEVIER

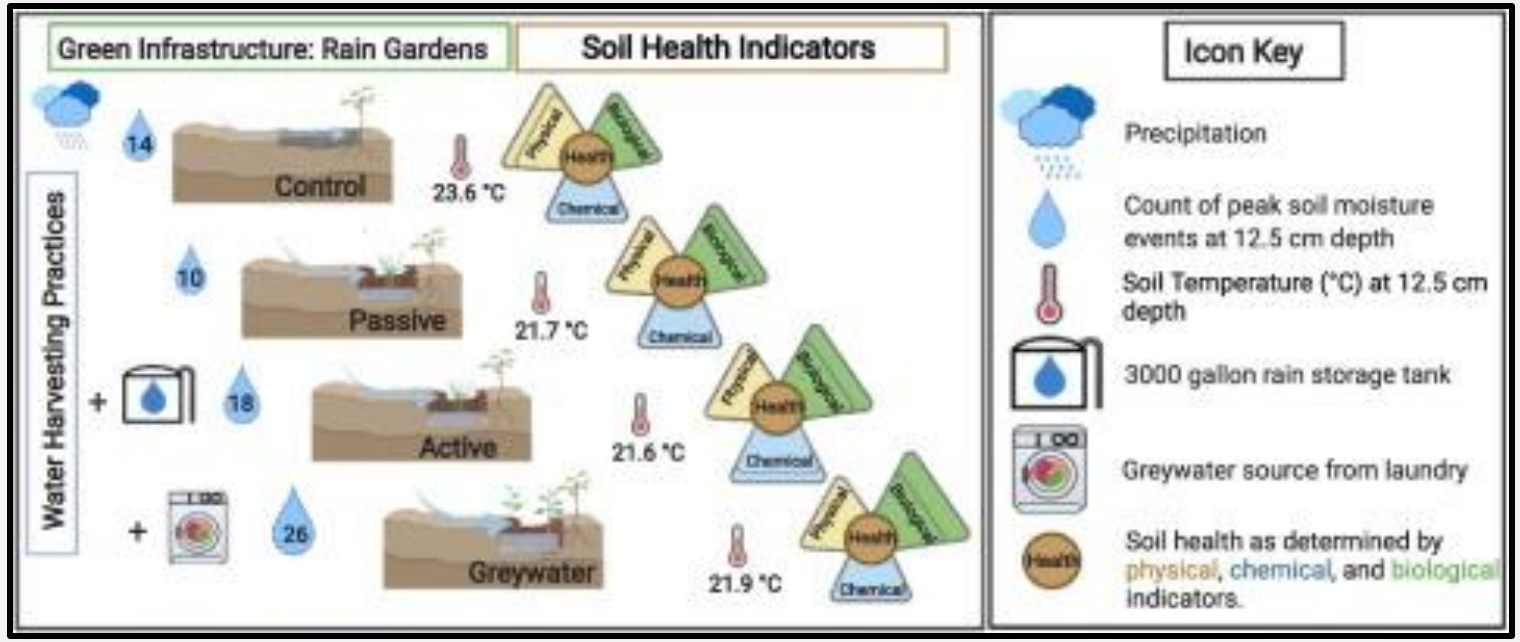
Science of The Total Environment

Volume 801, 20 December 2021, 149644

Green infrastructure influences soil health: Biological divergence one year after installation

Vanessa Buzzard [a], Juliana Gil-Loaiza [a], Nathalia Graf Grachet [b], Hannah Talkington [a], Connor Youngerman [a], Malak M. Tfaily [b], Laura K. Meredith [a c]

Management



Open Access Article

Environmental and Vegetative Controls on Soil CO_2 Efflux in Three Semiarid Ecosystems

by Matthew C. Roby [1,2], Russell L. Scott [2,*], Greg A. Barron-Gafford [3,4], Erik P. Hamerlynck [5] and David J. P. Moore [1]

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* Author to whom correspondence should be addressed.

Soil Syst. **2019**, *3*(1), 6; https://doi.org/10.3390/soilsystems3010006

Seasonal: North American Monsoon

Seasonal precipitation influenced biological soil characteristics due to increases in water availability!

‹ ENVIRONMENTAL SCIENCE

Sensitivity of soil hydrogen uptake to natural and managed moisture dynamics in a semiarid urban ecosystem

Research article | Soil Science | Biosphere Interactions | Biogeochemistry

Vanessa Buzzard [1], Dana Thorne [1], Juliana Gil-Loaiza [1], Alejandro Cueva [2], Laura K. Meredith [1,3]

Published March 17, 2022

GOAL

*Park, University, and Residential

Highlight the relationships between soil health indicators as well as external water inputs across three landscape!

- Background
- Research Objectives
- Methods
- Part One: Relational Indicator Analyses
- Part Two: Spatial and Temporal Drivers of Soil Health Indicators
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Soil Function-Indicator Matrix:

"When a direct relationship exists between the function and indicator, increasing reliability and ease of use of the associated assessment method is shown with increasing stars"

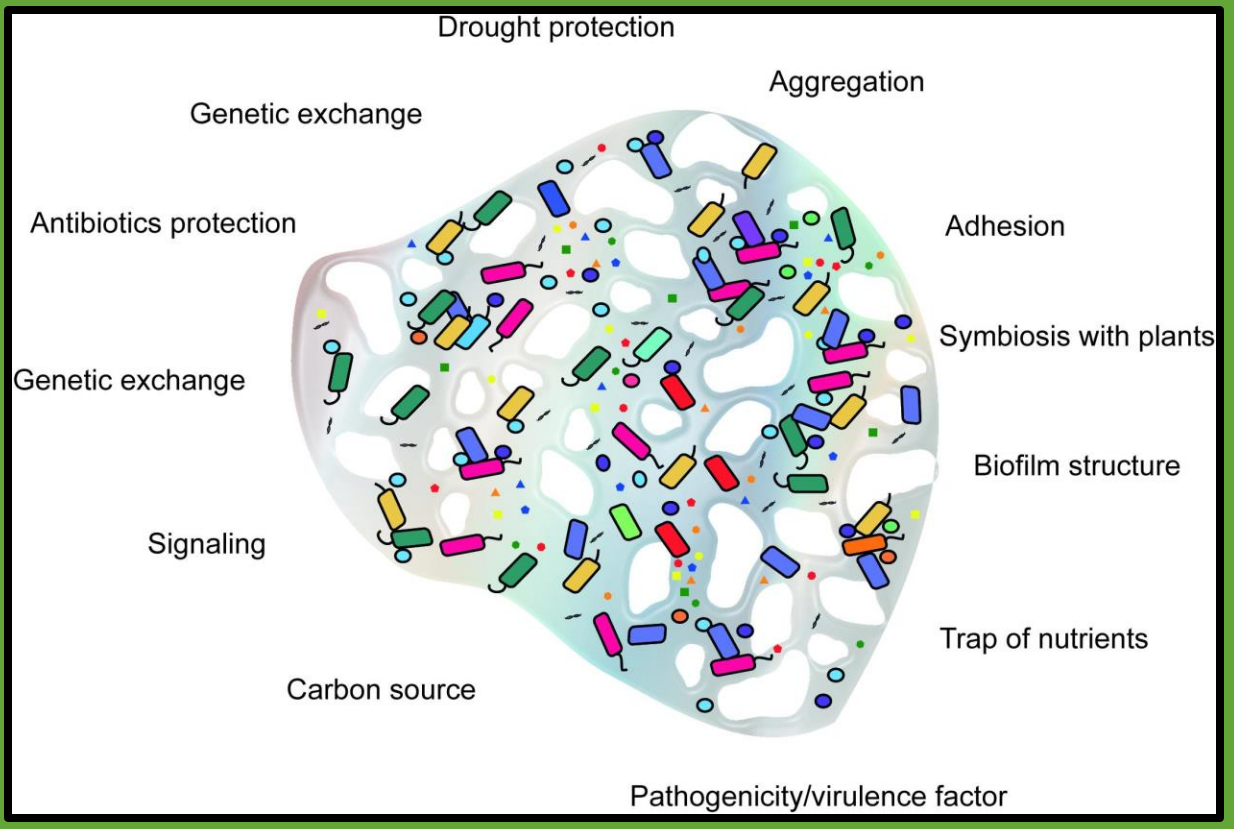
USDA, NRCS, 2015

Soil Quality Indicator	Soil Function: Sustain biological diversity, activity, and productivity "D"	Regulate and partition water and solute flow "W"	Filter, buffer, degrade, detoxify organic and inorganic materials "F"	Store and cycle nutrients and carbon "N"	Physical stability and support for plants and structures associated with human habitation "S"
Aggregate Stability [a,c,f]	★★	★★	—	★★	★★½
Available Water Capacity [a,g]	★★★	★★½	—	★★	—
Bulk Density [a,h]	★★½	★★★	—	★	★★★
Earthworms [b,d]	★★★	—	★★★	★★★	★★★
Infiltration [b,e,i]	—	★★	★	—	—
Particulate Organic Matter [a,c]	★★★	★★★	★★★	★★★	★★★
Potentially Mineralizable Nitrogen [a,c]	★★★	—	—	★★★	—
Reactive Carbon [a]	★★	★	★★★	★★	★★
Slaking [b,e,i,j]	★	★★½	—	—	—
Soil Crusts [b,d]	—	★★½	—	—	—
Soil Electrical Conductivity [b]	—	★★★	—	—	—
Soil Enzymes [a]	★★★	—	—	★★★	—
Soil Nitrate [b]	★	★	—	—	—
Soil pH [b,d]	★★	★★★	★★★	★★★	—
Soil Respiration [a,b,c]	★★★	—	★	★★★	★★
Soil Structure and Macropores [b,d]	★½	★½	★	★	★★
Total Organic Carbon [a]	★★★	★★★	★★★	★★★	★★★

[a] laboratory/office method
[b] field method
[c] time consuming
[d] simple visual observation
[e] variability requires large sample number
[f] perhaps the most informative physical indicator
[g] important for drought prone areas
[h] important for weight to volume conversions, small sampling errors result in significant interpretation problems
[i] effective educational method
[j] qualitative

New Indicator Alert

EXTRACELLULAR POLYMERIC SUBSTANCES (EPS)



Costa et al., 2018, & Flemming & Wingender, 2010

Biofilm excreted by plants, and soil microbes in response to environmental stressors:

Drought
Temperature
pH
Salinity

Support Function:

Soil Aggregation
Retention of water
Nutrient acquisition
Enzyme activates
Carbon reserve

New Indicator Alert

CARBON STABILIZATION AND DECOMPOSITION RATES

"Tea Bag Experiment"

Influences:

Plants

Climate

Temperature

Water availability

Land management practices or use.

Currie et al., 2010, Keuskamp et al., 2013, & Seelen et al., 2019

Higher rates suggest faster matter and nutrient cycling due biological activity

Assess how soil organic matter decomposes and support carbon mineralization and storage overtime

SOIL EXTRACELLULAR ENZYMES (EEAS)

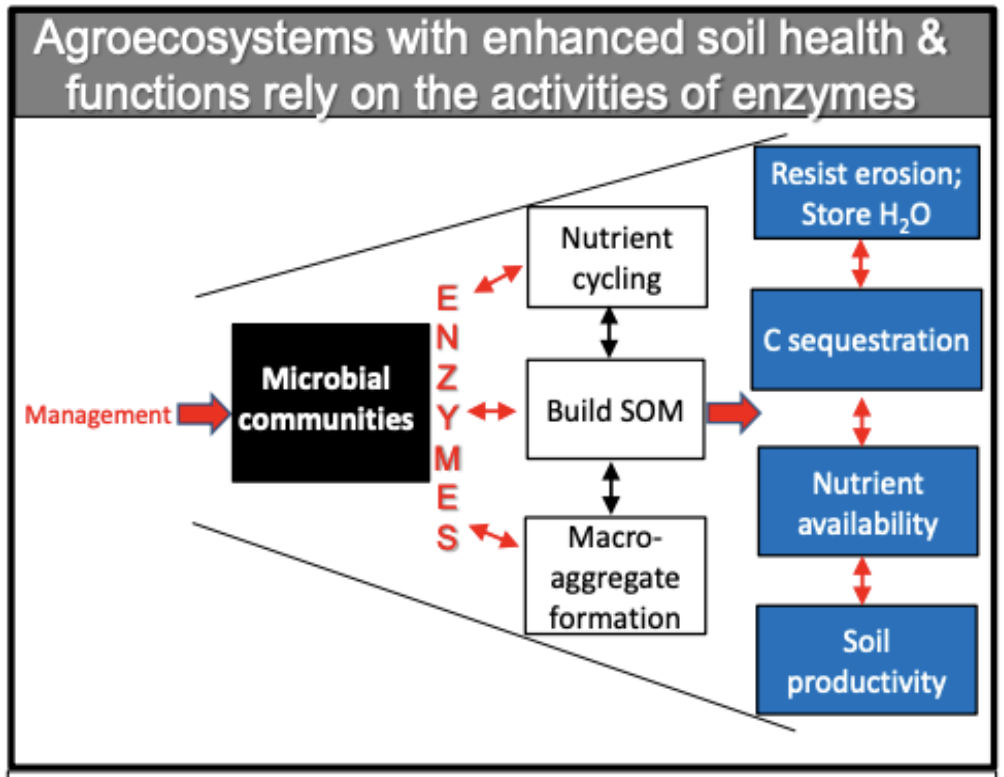


Figure 1. Microbial indicators of soil health are important drivers in a healthy soil leading to improved functions such as soil stability and resistance to erosion. Diagram courtesy of Veronica Acosta-Martínez.

Soil quality physical indicator information sheet series. (n.d.).

Enzymes excreted or released outside cells, (microbes, plant, and animal) they catalyze the the breakdown of organic compounds or matter needed for nutrient cycling (C, N, & P) and soil productivity.

Influences:

Soil management
Seasonal shift
Temperature
Soil moisture (drought ↓ activity)
pH
Soil texture
Plant roots exudates rich in substrates

(USDA Natural Resources Conservation Service, 2010)

QUESTIONS

Do soil indicators change or vary in response to:

1. Regional precipitation
   (Pre and post monsoon)
2. GI water treatments
   (Passive and Control)
3. Site

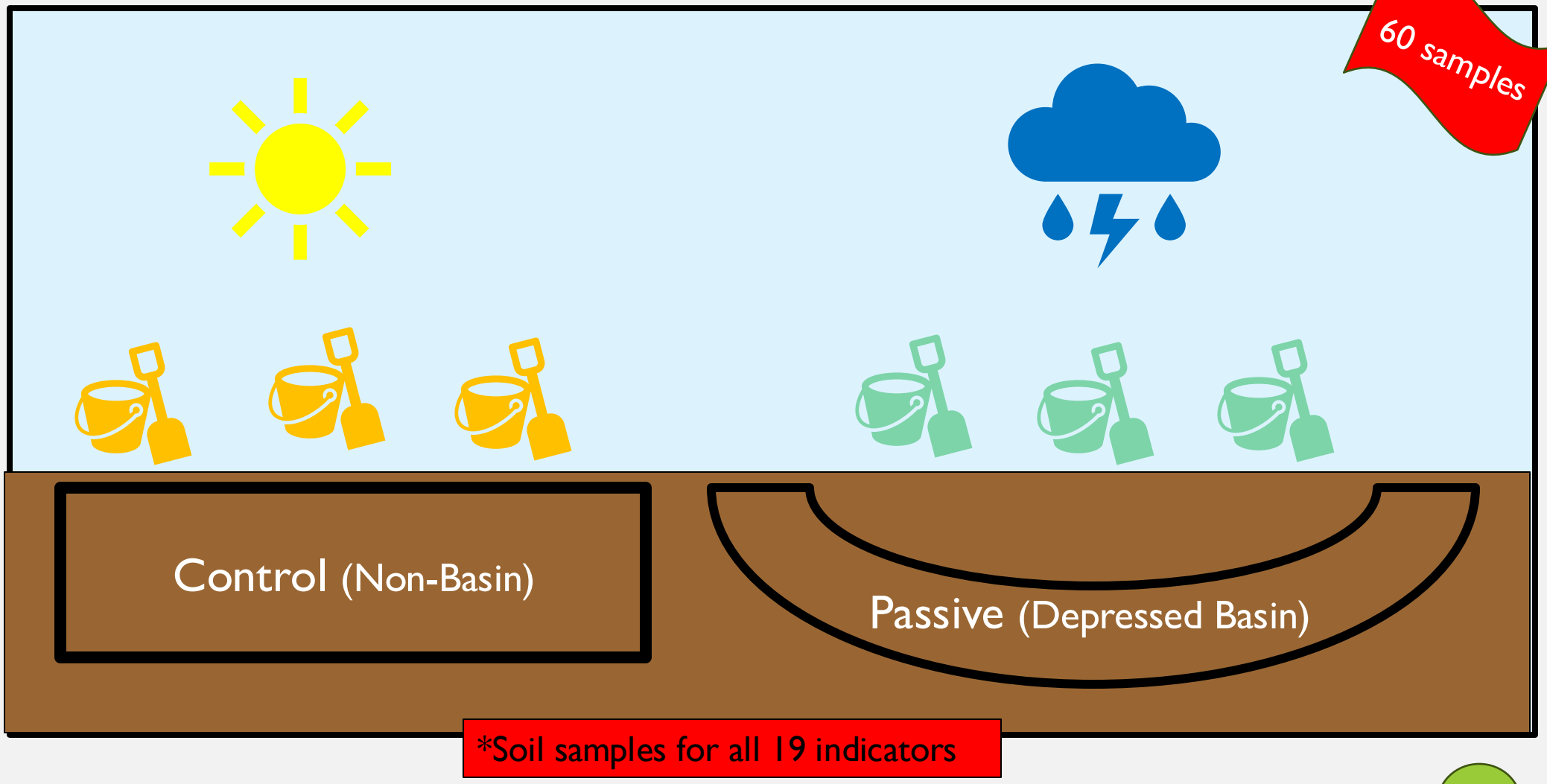
HYPOTHESIS

We hypothesize that variations in physical, biological, and chemical, indicators will be impacted by changes across sites, seasonal regimes, and treatment.

(Buzzard et al., 2021, and Buzzard et al., 2022)

Created with BioRender.com

SAMPLING DESIGN 2023



Sample Sites

- Old Main
- Gould Simpson
- Atmospheric
- Gunny Park
- Residence

ALL SAMPLED INDICATORS

Physical (4)

- Bulk Density (BD)
- Gravimetric Water Content (GWC)
- Water Holding Capacity (WHC)

*Soil Texture (Inherent Soil Characteristic)

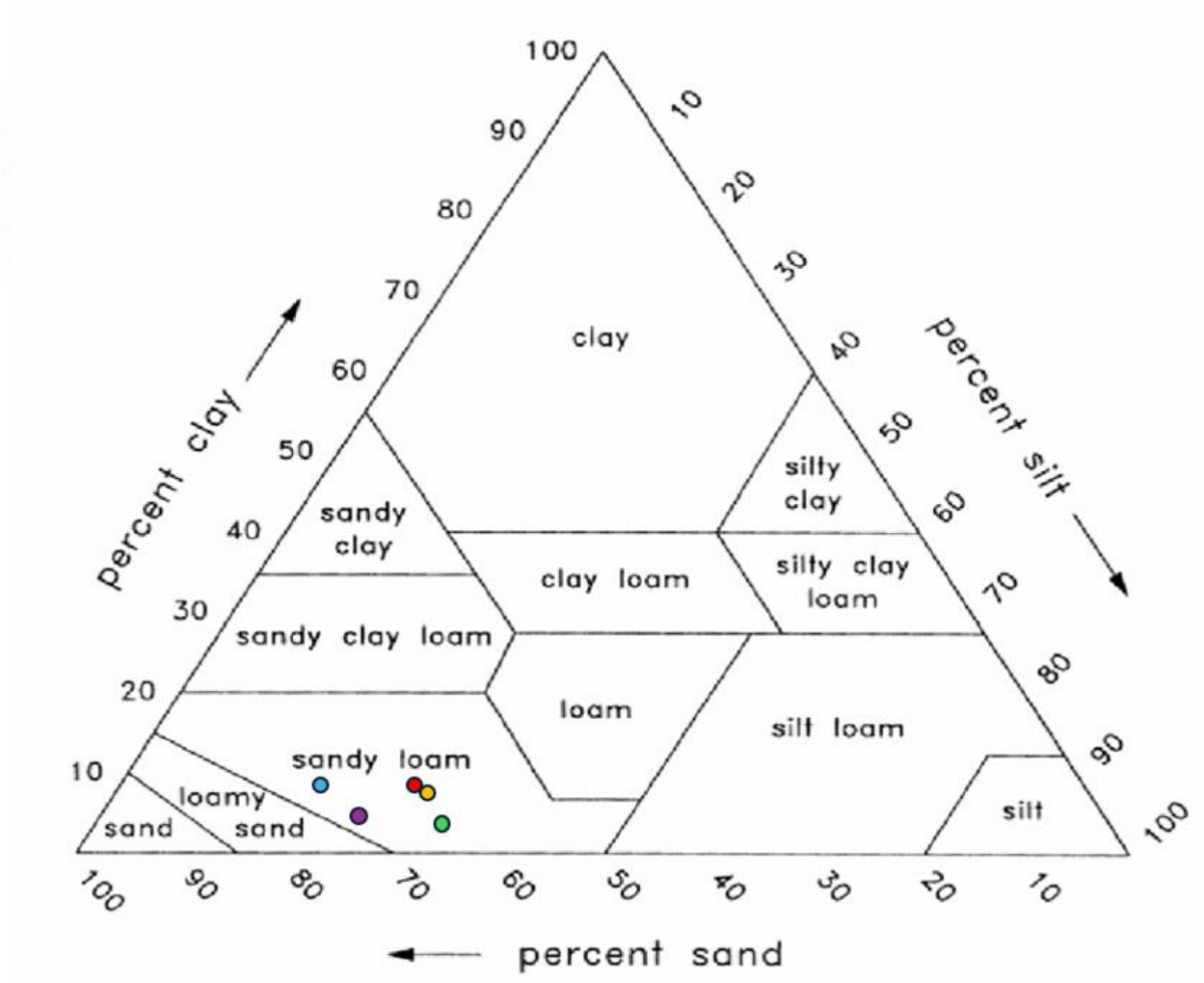
Biological (7)

- Soil Organic Matter (SOM)
- Extracellular Polymeric Substances (EPS)
- Carbon Stabilization and Decomposition (S and K)
- Carbon, Nitrogen, and Phosphorus Extracellular Enzymes (EEAs)

Chemical (8)

- Total Carbon (TC)
- Total Organic Carbon (TOC)
- Total Inorganic Carbon (TIC)
- Total Nitrogen (TN)
- Total Sulfur (TS)
- Total Phosphorus (TP)
- pH
- Electrical Conductivity

Old Main
Atmospheric
Gould
Gunny
Residence

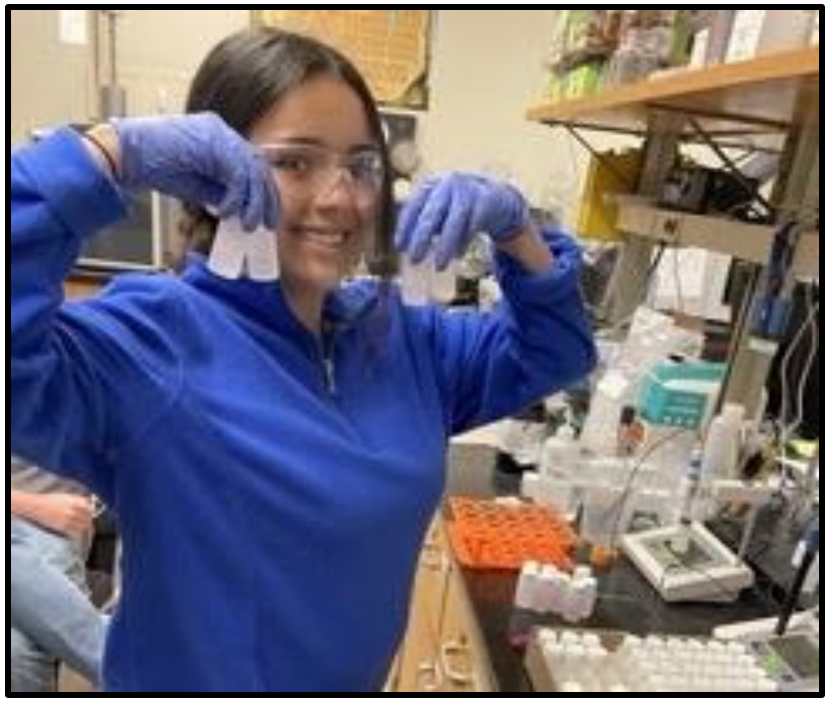


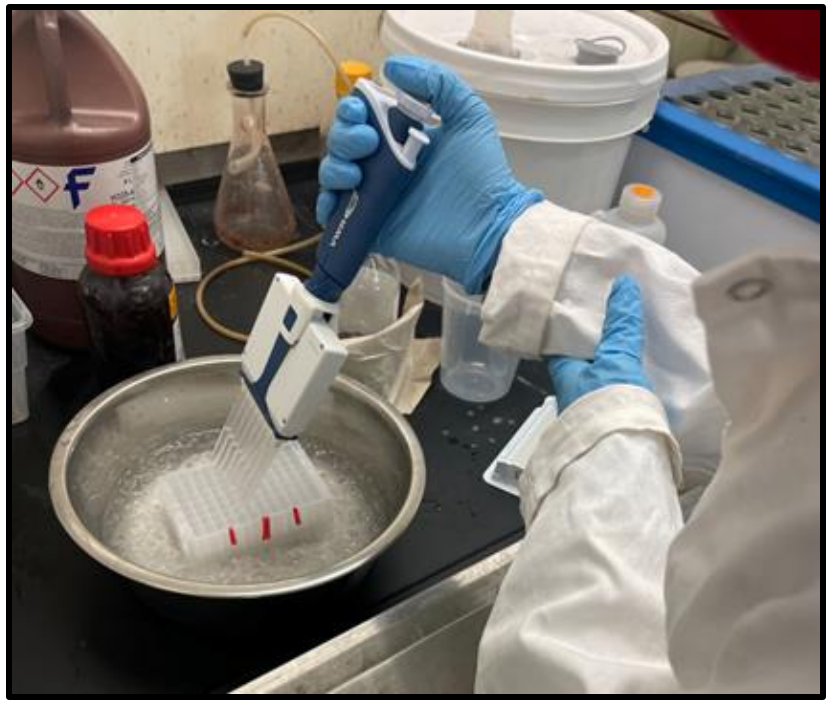
SANDY LOAM

SOIL TEXTURE

Field Sampling

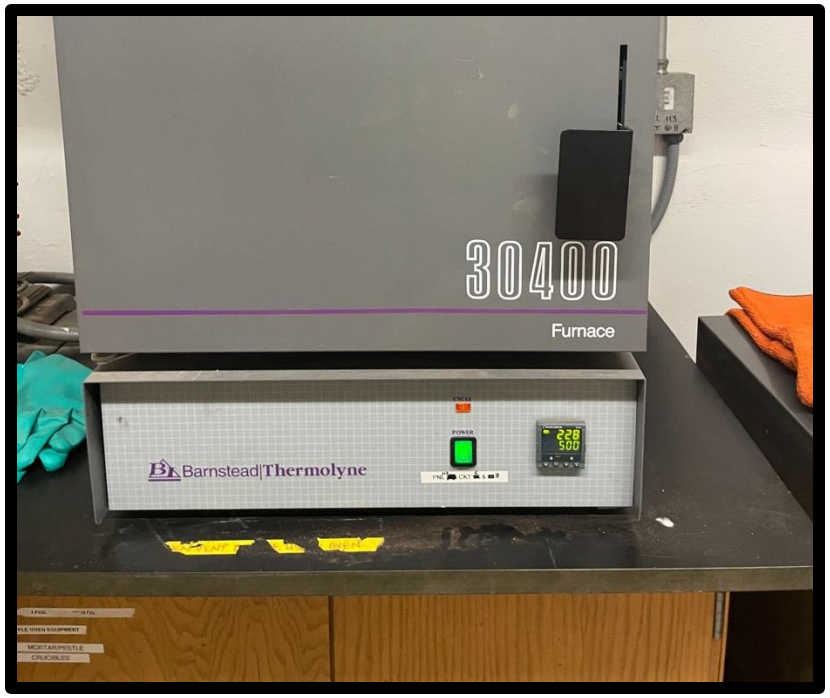
Blankenship Lab: EPS Extractions

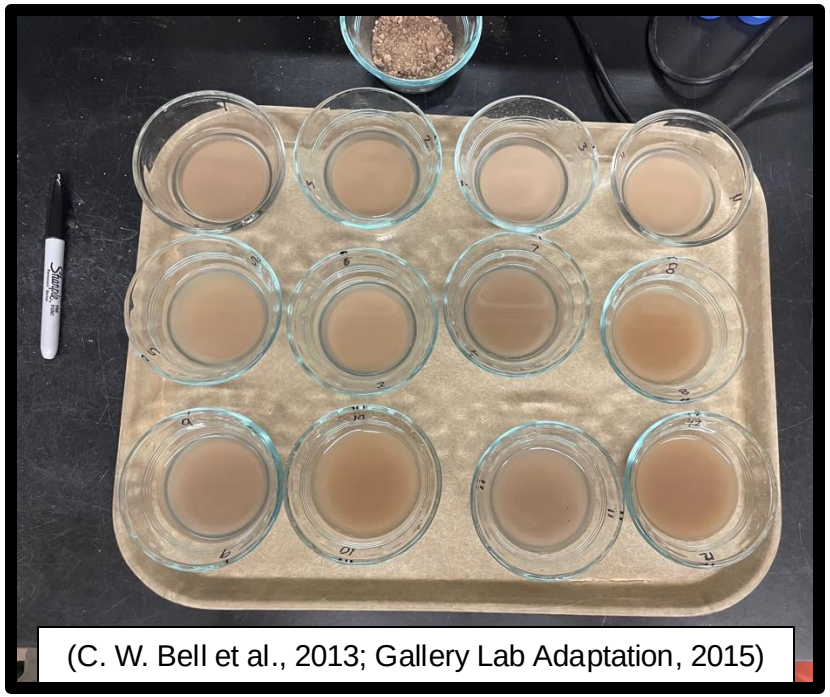




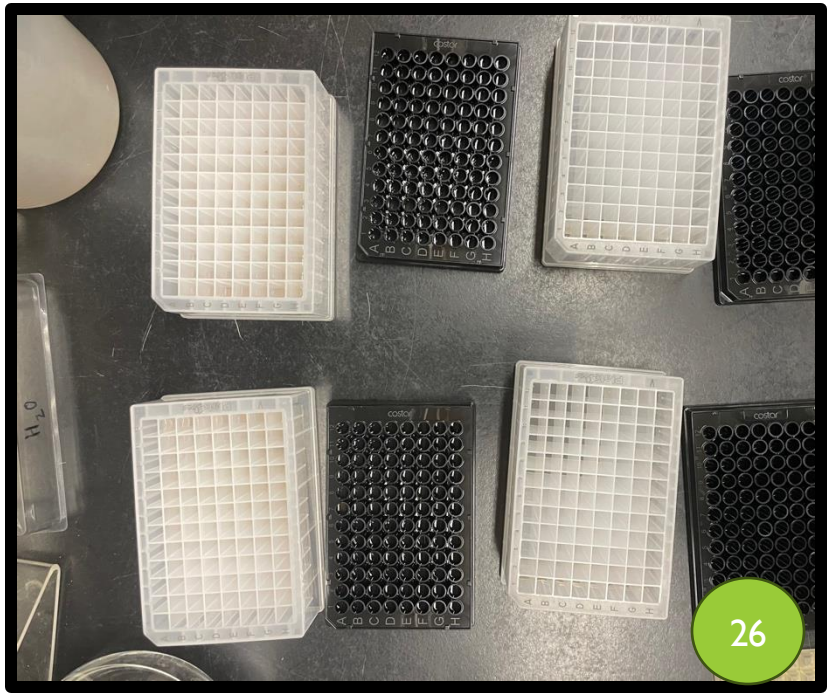
(Redmile-Gordon et al., 2014, Blankinship Lab Modification, 2023, and Masuko et al. 2005)

Gallery Lab: Extracellular Enzyme Assays



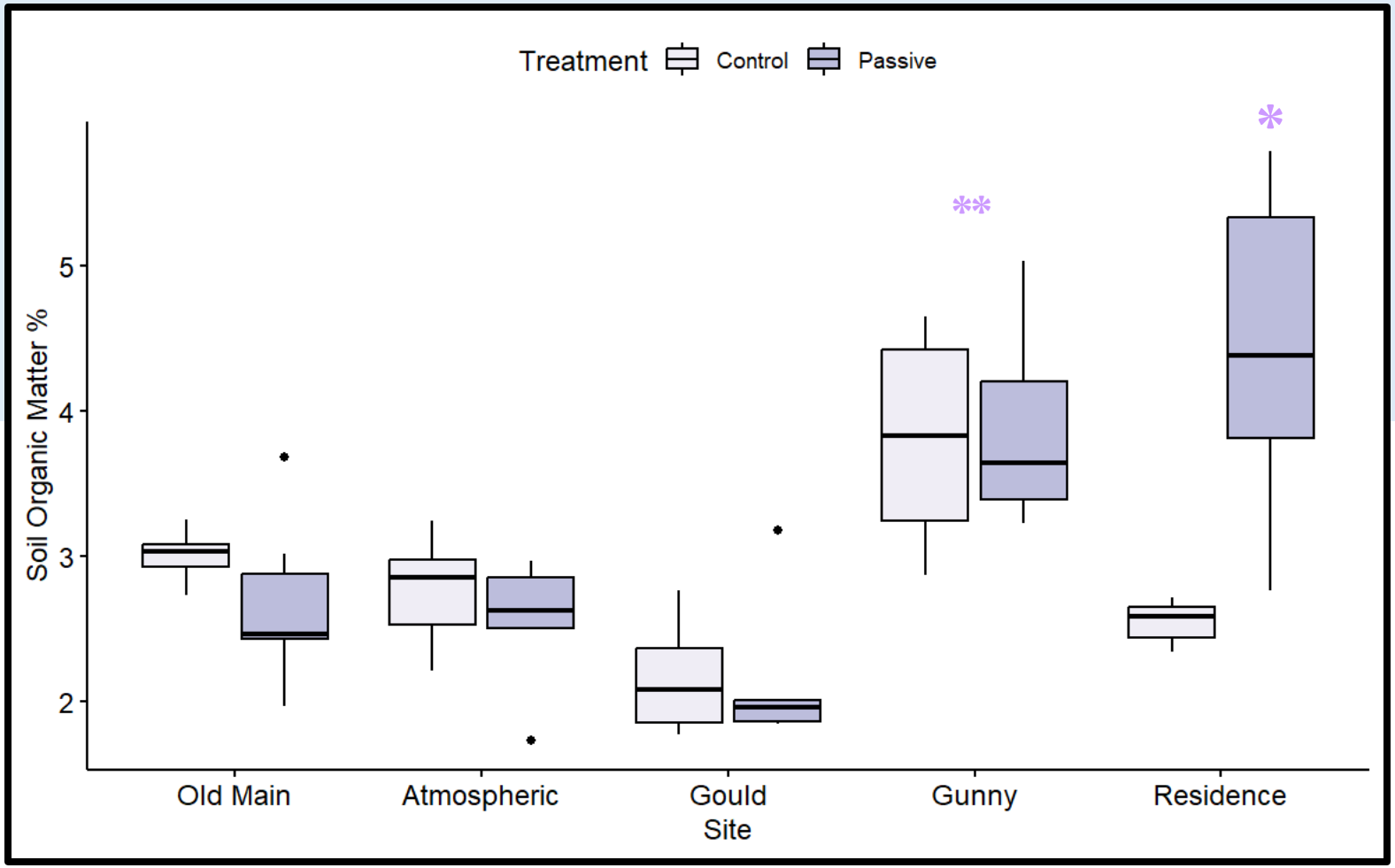


(C. W. Bell et al., 2013; Gallery Lab Adaptation, 2015)



BIOLOGICAL INDICATORS

SOIL ORGANIC MATTER IS INFLUENCED BY SITE



Gunny Park was likely influenced by recent construction, BSA, and conversion from grass turf

Season ✗

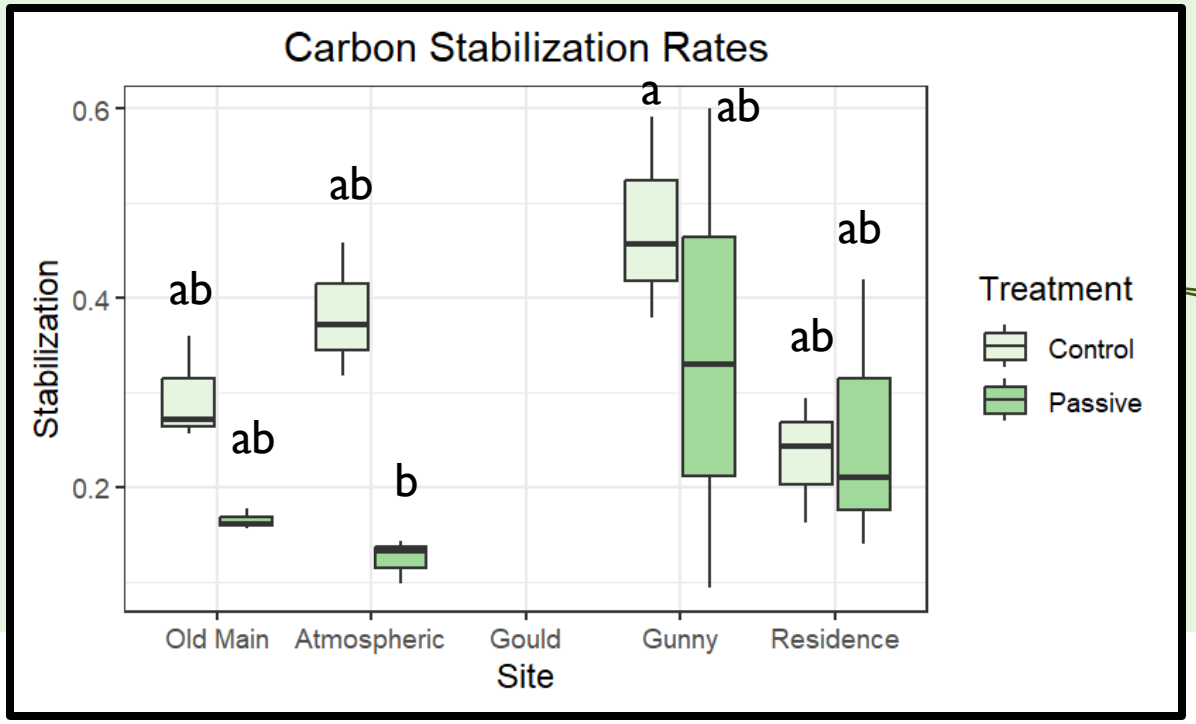
Treatment ✗

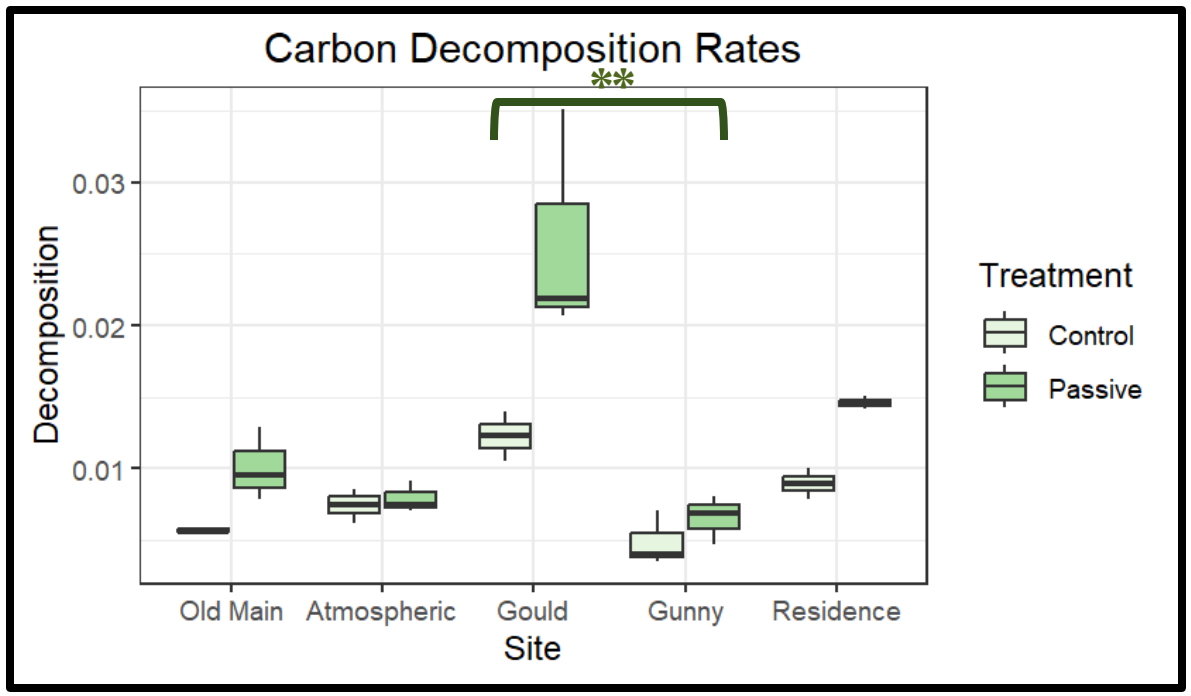
Site ✓

ANOVA
p-value: 0.024

WEST CONSULTANTS, 2024 , Sullivan et al., 2019, and USDA NRCS, 2014

CARBON STABILIZATION AND DECOMPOSITION IS INFLUENCED BY TREATMENT OR/AND SITE





Treatment ✓ **Site** ✗

ANOVA
p-value: 0.034

Treatment ✓ **Site** ✓

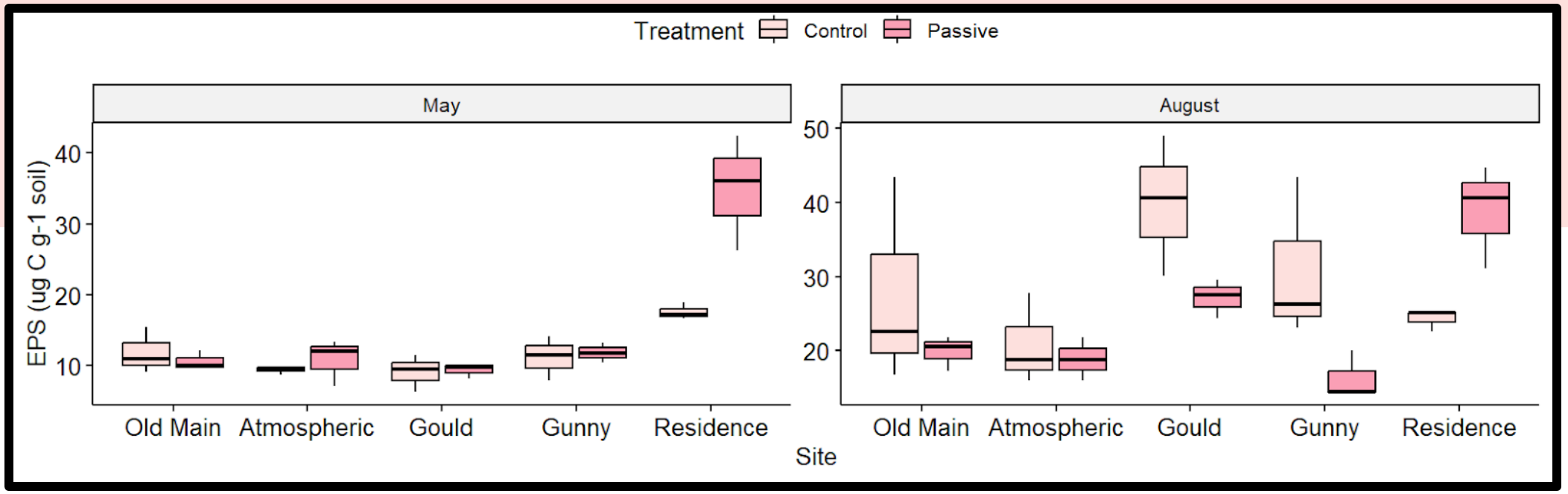
Kruskal-Wallis
p-value: 0.0327

Kruskal-Wallis
p-value:0.00219

Site and treatment supported carbon cycling and storage that's indicative of semi-arid regions

Keuskamp et al., 2013, and Bot & Benites, 2005

EPS WAS HIGHER POST MONSOON(AUGUST) AND INFLUENCED BY SEASON & SITE



Season

✓

Kruskal-Wallis p-value: 0.0173

Treatment

✗

Site

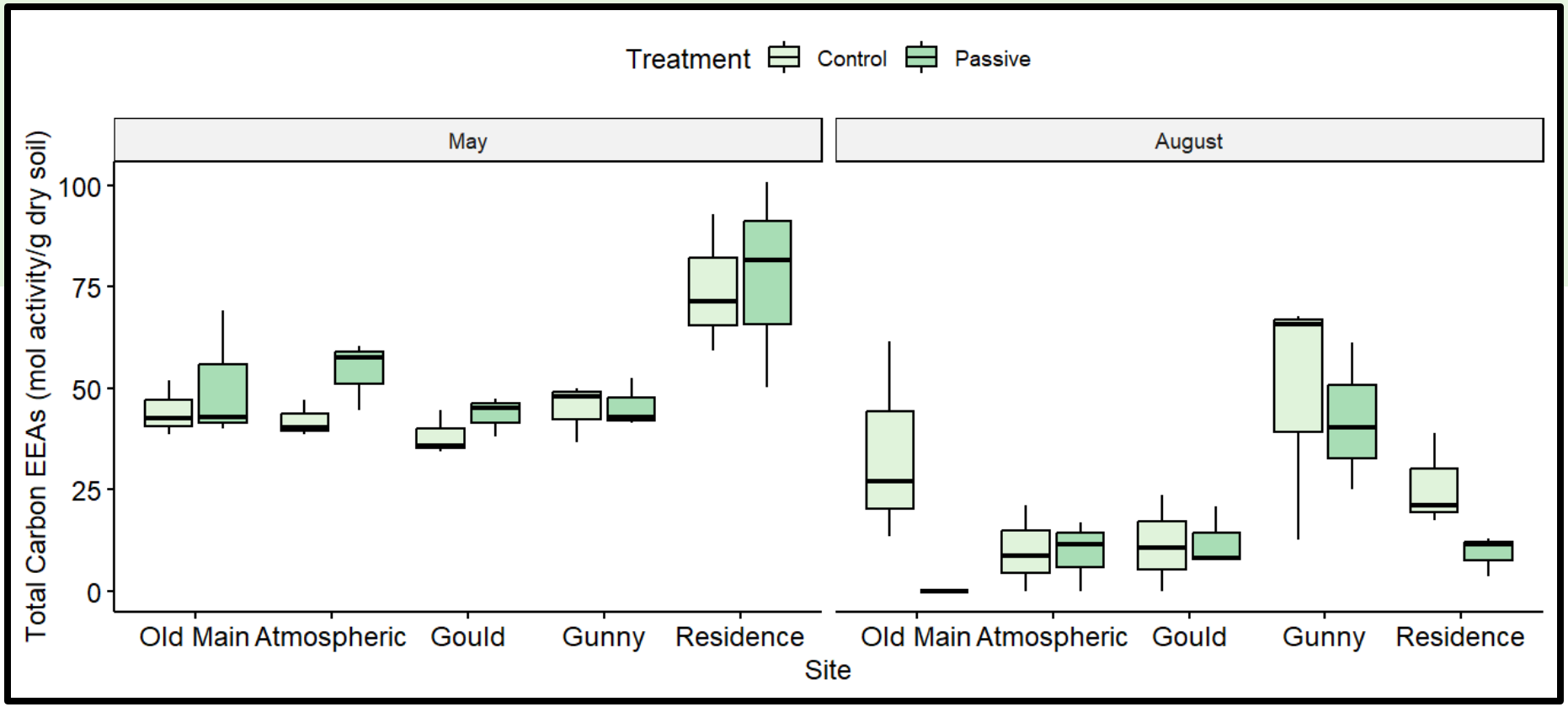
✓

Kruskal-Wallis p-value: 8.66E-08

Precipitation likely supported the carbon acquisition needed to promote EPS production and is variable between sites

Austin et al. 2004, Collins et al., 2014, Huxman et al. 2004, M. Redmile-Gordon et al., 2020

CARBON EEAS WERE LOWER POST MONSOON (AUGUST)



Season ✓

Kruskal-Wallis p-value: 6.28E-07

Treatment ✗

Site ✗

Precipitation likely shifted microbial communities and their consumption or increased "heavy metal inhibition"

Aponte et al., 2020, Chae et al., 2017, and de Nijs et al., 2018

CHEMICAL INDICATORS

SITE IS DRIVING MANY CHEMICAL VARIATION IN SOIL

Seasonal influences on Sulfur likely due to Wet Deposition

INDICATOR	SEASON	TREATMENT	SITE	DF	P-VALUE	F-STAT	Method
EC	X	X	X	4	0.0515	-	Kruskal-Wallis
TN	X	X	✓	4	3.0eE-08	-	Kruskal-Wallis
TS	✓	X	X	1	0.0191	-	Kruskal-Wallis
TC	X	X	✓	4	1.31E-08	-	Kruskal-Wallis
TOC	X	X	✓	4	0	13.57	ANOVA
TIC	X	X	✓	4	0	23.1	ANOVA

Schoenau & Malhi, 2015, Ziter & Turner, 2018, Raciti et al., 2011, and Pease et al., 2003

TAKE AWAYS

1. Site mostly influenced physical and chemical indicators

2. Seasonality and site influenced biological indicators differently

3. Treatment only affected carbon stabilization and decomposition.

Background

Research Objectives

Methods

Part One: Relational Indicator Analyses

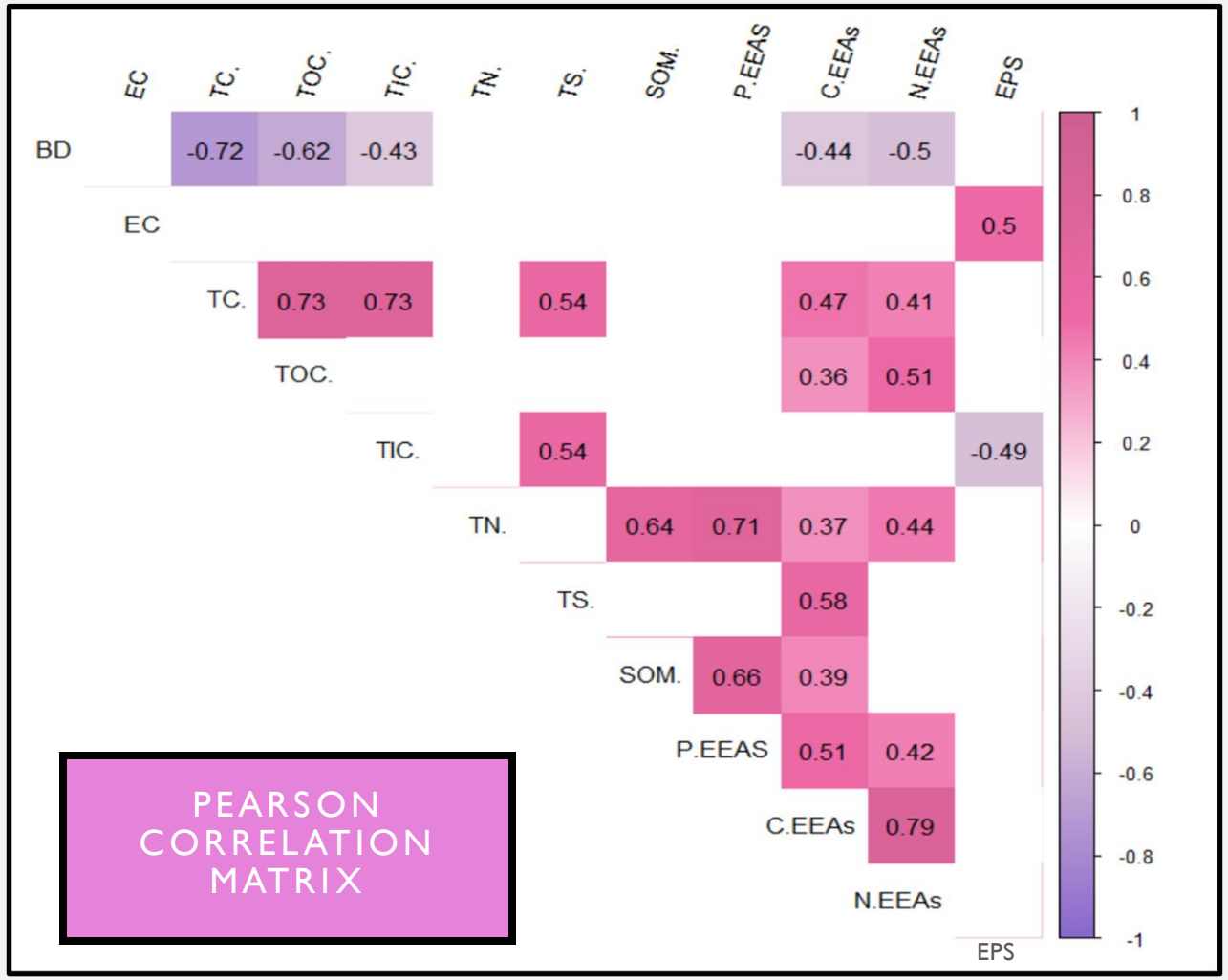
Part Two: Spatial and Temporal Drivers of Soil Health Indicators

Conclusion

Big Picture

SO, WHAT DOES ALL THIS MEAN?

HOW ARE SOIL HEALTH INDICATORS CORRELATED?



PEARSON CORRELATION MATRIX

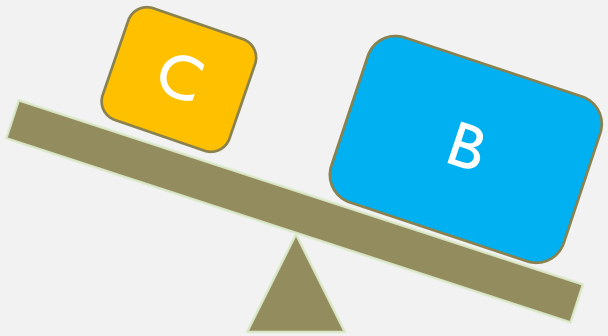
BIOLOGICAL AND CHEMICAL INDICATORS ARE POSITIVELY CORRELATED

&

PLAY ACTIVE ROLES IN SOIL CARBON CYCLING IN SEMI ARID SOILS!

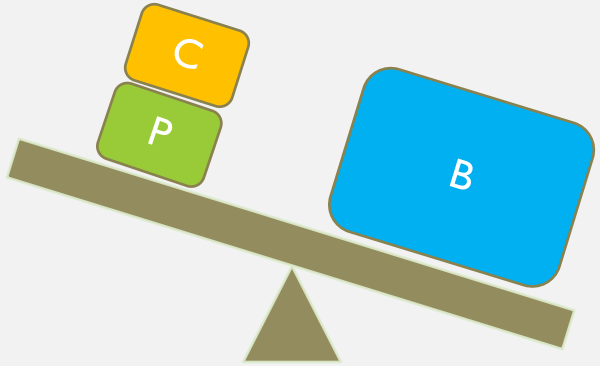
AGAIN YES!
Each factor inspired change or variation but primarily in biological soil health indicators!

Least Most



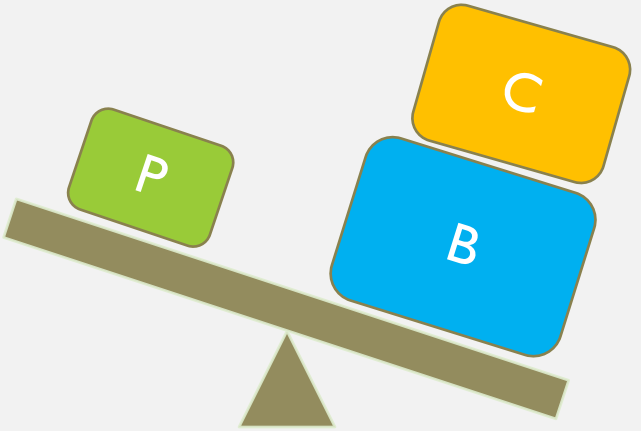
SEASON

Least Most



TREATMENT

Least Most



SITE

CONCLUSIONS

1. On a short time scale, GI's can harness seasonal water inputs and drive important biological, and chemical processes that likely improve the health of semi-arid urban soils.

2. Sites' histories & practices are also important in the shaping of the physical, biological, and chemical characteristics of soil health.

Caveats:

Treatments need more time to have an effect

Still looking at too many indicators!

Too many site difference

(management, age, plant,& topography, history)

Research better could account for other seasons influences (fall, winter, spring)

THIS MATTERS BECAUSE:

1. Nature based solutions like GI are defined by the UN Environmental Program as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."

These soil health indicators help us track GI's ability to supports environmental resilience in the face of climatic and anthropogenic change.

(IUCN, 2020, & Plasencia, 2022)

THANK YOU!

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BRIDGES

Storm to Shade

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