Soil health in the Southern Great Plains: management challenges and solutions for production agriculture in a changing climate

Dr. Cait Rottler
Dr. Gretchen Sassenrath

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Where we are

Northwest Hub
Corvallis, OR
Northwest Region
Northern Plains Region
Northern Forests Hub
Houghton, MI
Northeast Hub
Durham, NH
Northeast Region
California Hub
Davis, CA
Northern Plains Hub
Fort Collins, CO
Midwest Hub
Ames, IA
Midwest Region
Southwest Region
California Region
Southeast Hub
Raleigh, NC
El Reno, OK
Southwest Hub
Las Cruces, NM
Southern Plains Hub
Southeast Region
Southern Plains Region
PACIFIC OCEAN
ATLANTIC OCEAN
Gulf of Mexico
Northwest Region
Alaska
Hawaii
Southwest Region
Caribbean Hub
Rio Piedras, Puerto Rico
Caribbean Region

What we do

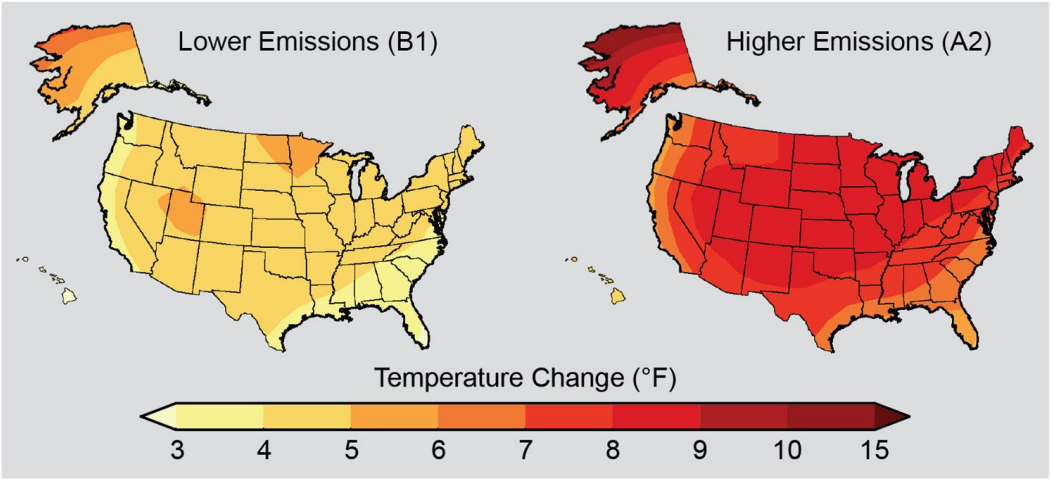
Mission: Synthesize and deliver science-based, region-specific information and tools through existing networks of USDA agencies and partners to help land managers make climate-informed decisions

Why we exist

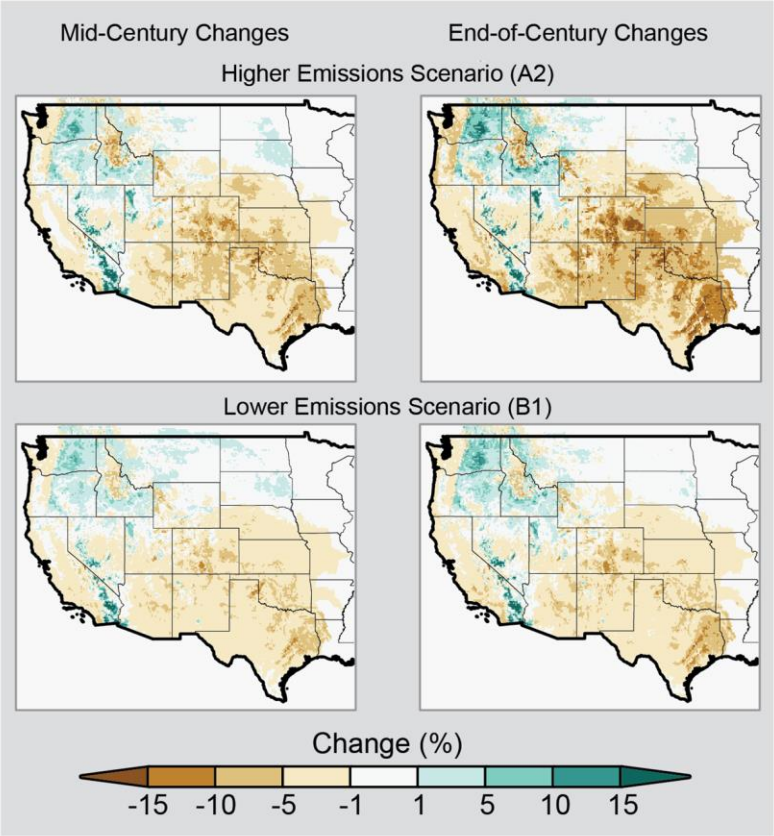
Commodity	Kansas	Oklahoma	Texas	Southern Plains
		Billion$		
Crops	**6.984**	**1.876**	**7.367**	**16.227**
Wheat	2.474	0.946	0.618	4.038
Corn	2.297	0.203	1.454	3.954
Horticultural[1]	0.093	0.268	1.738	2.101
Cotton		0.052	1.619	1.671
Hay	0.359	0.271	0.958	1.588
Sorghum	0.579	0.034	0.743	1.356
Soybean	1.102	0.048	0.037	1.187
Livestock	**11.477**	**5.254**	**18.009**	**34.740**
Beef cattle	10.153	3.403	13.013	26.569
Poultry, eggs	0.088	0.961	2.325	3.374
Dairy	0.482	0.164	1.698	2.344
Swine	0.697	0.656	0.239	1.592
Total Agriculture	**18.461**	**7.130**	**25.376**	**59.966**

[1] Includes vegetables, fruits, nuts, nursery, greenhouse, floriculture, and sod.

Projected Temperature Change



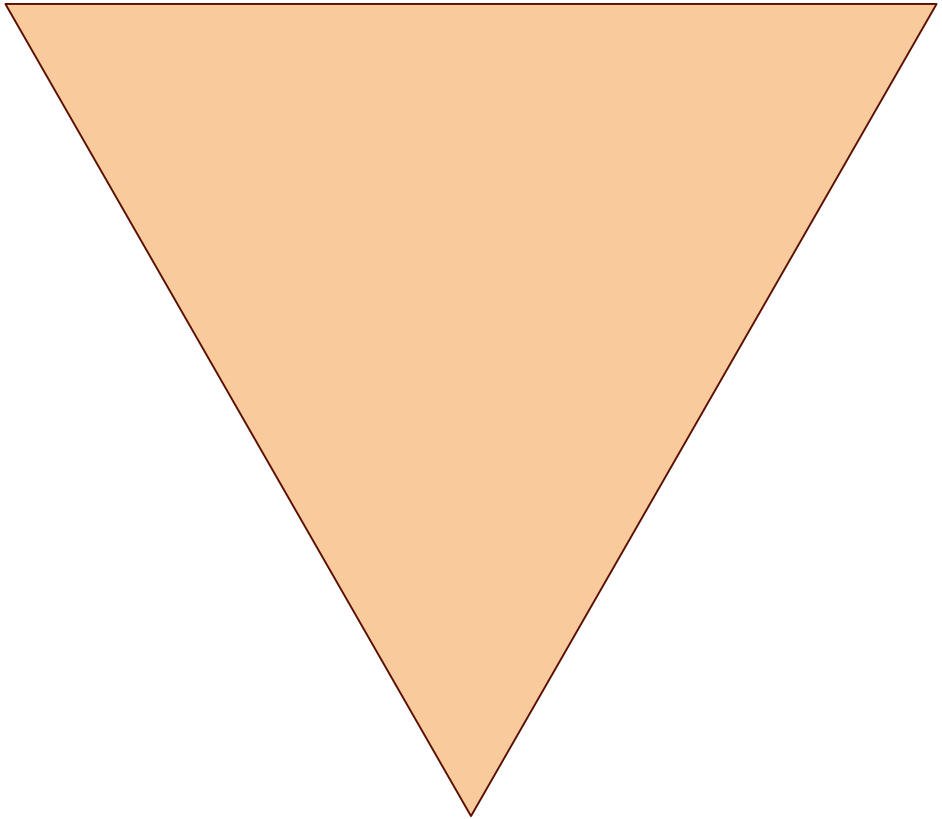
Projected Changes in Soil Moisture for the Western U.S.



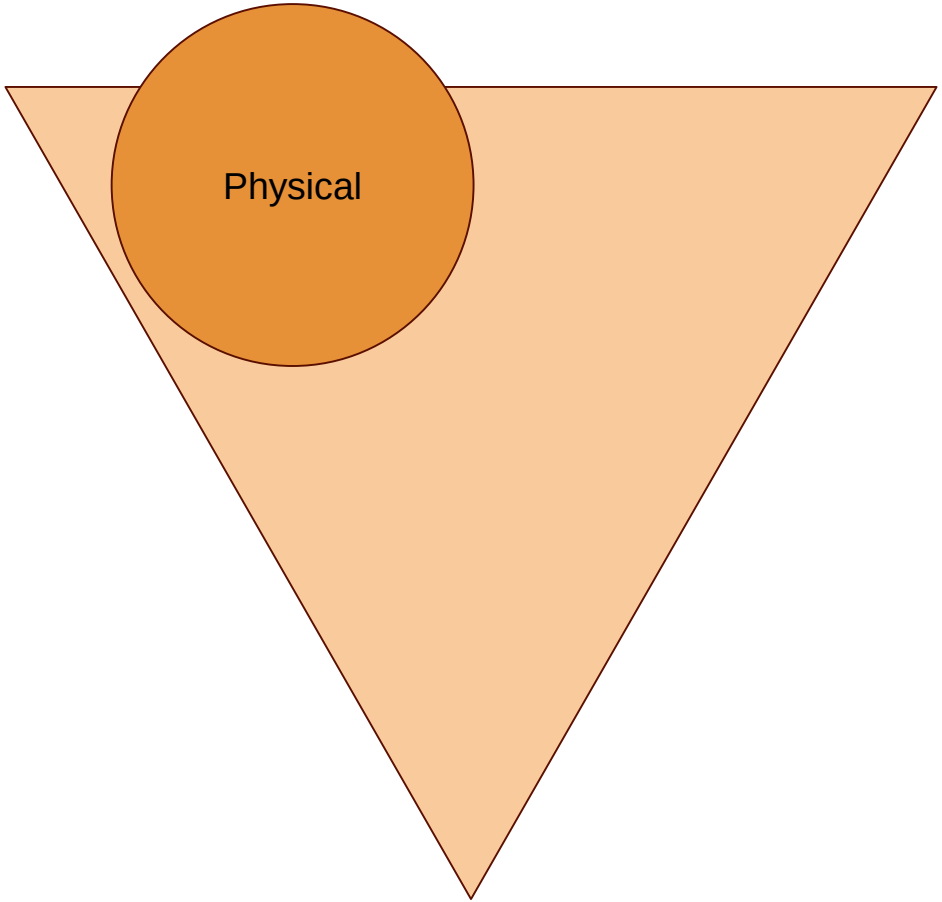
Soil Health Management

Managing for soil health has been shown to improve:

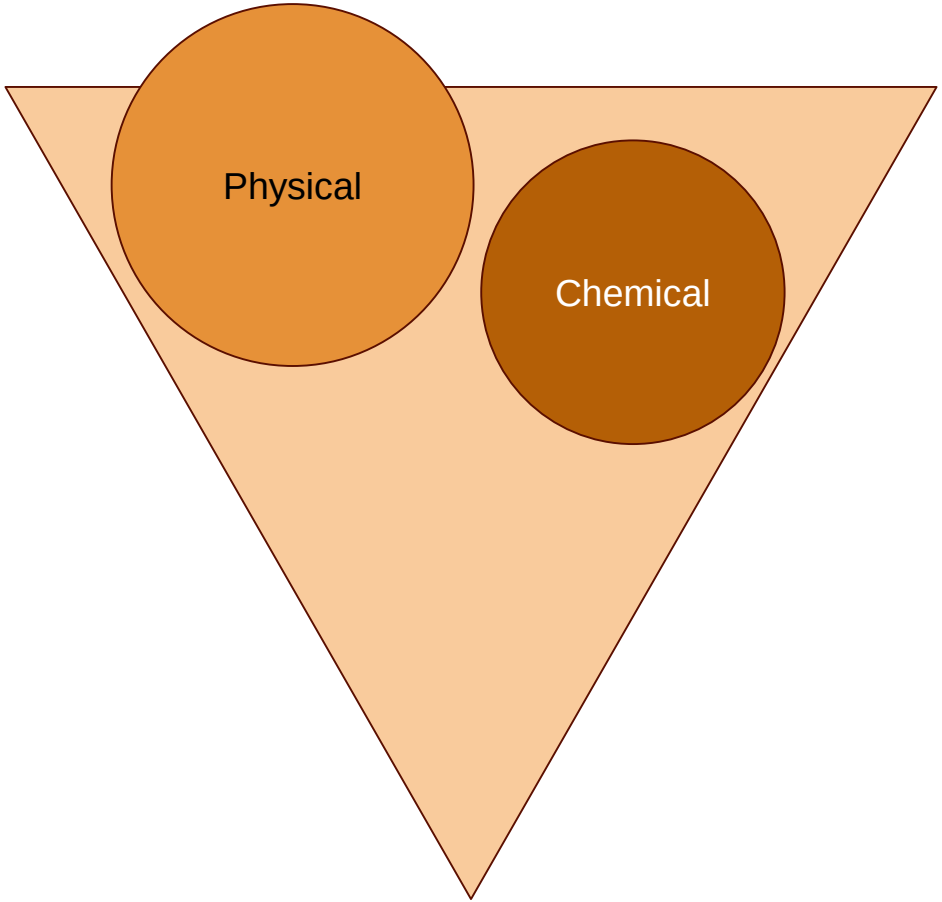
- ➔ Nutrient retention
- ➔ Soil structure
- ➔ Water holding capacity
- ➔ Soil loss



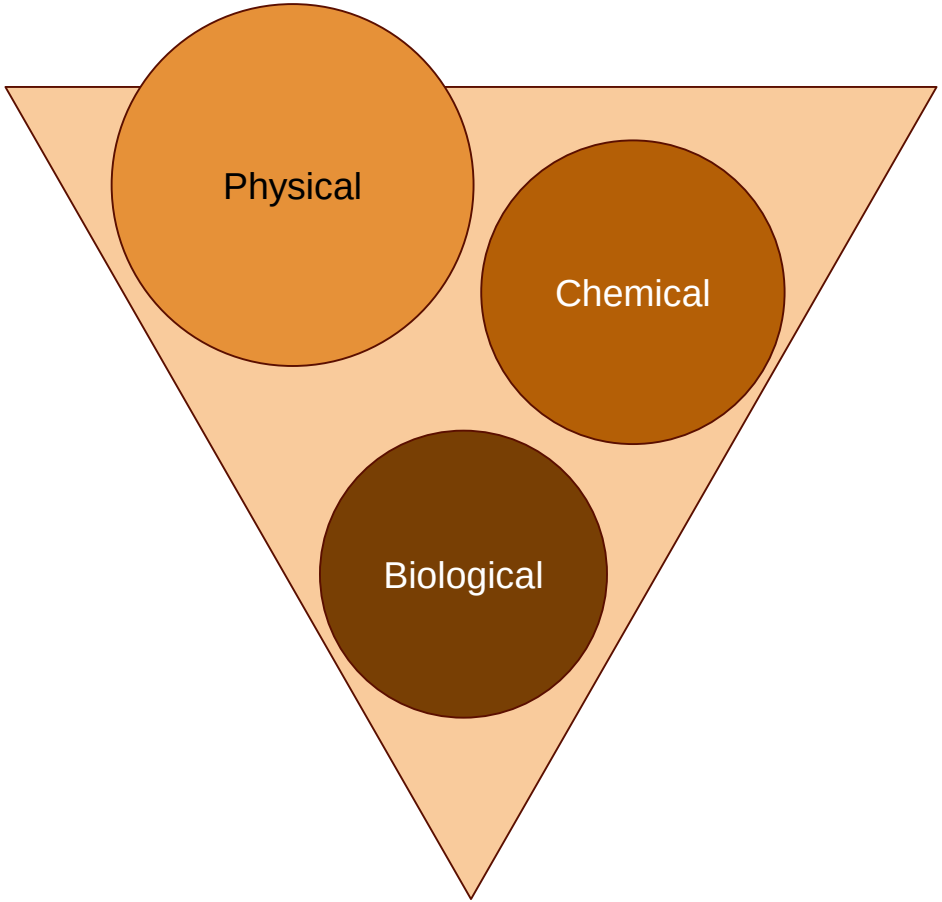
Soil Health



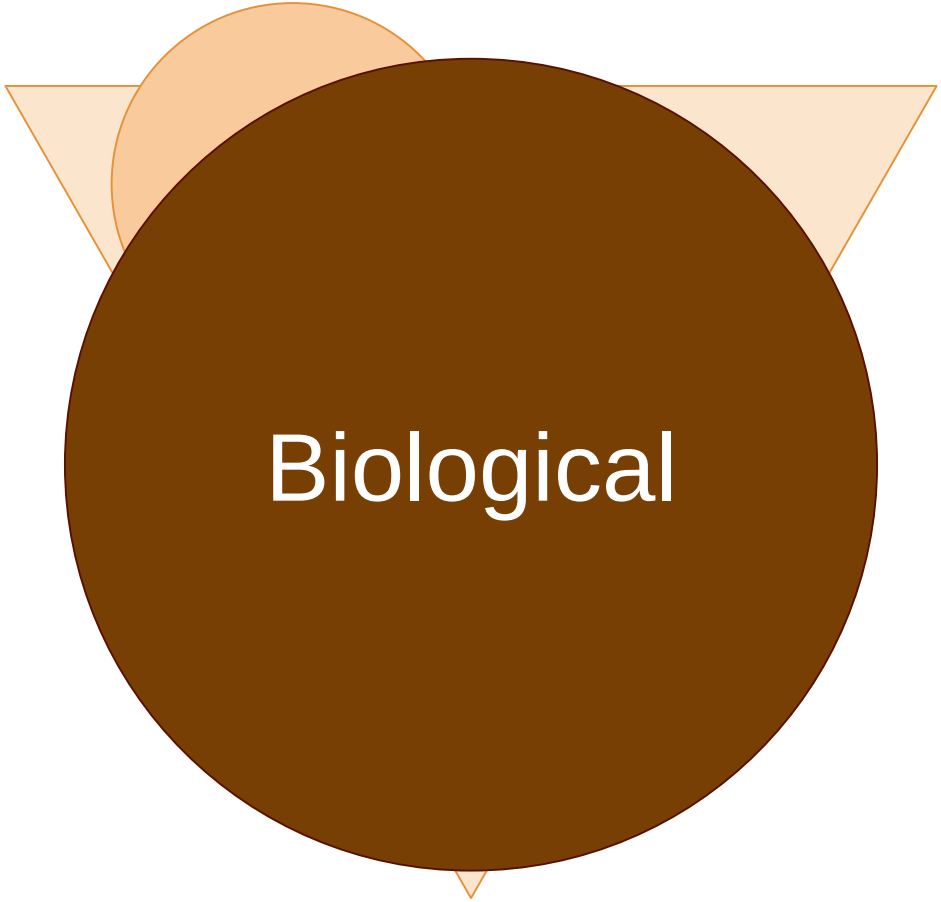
Soil Health



Soil Health

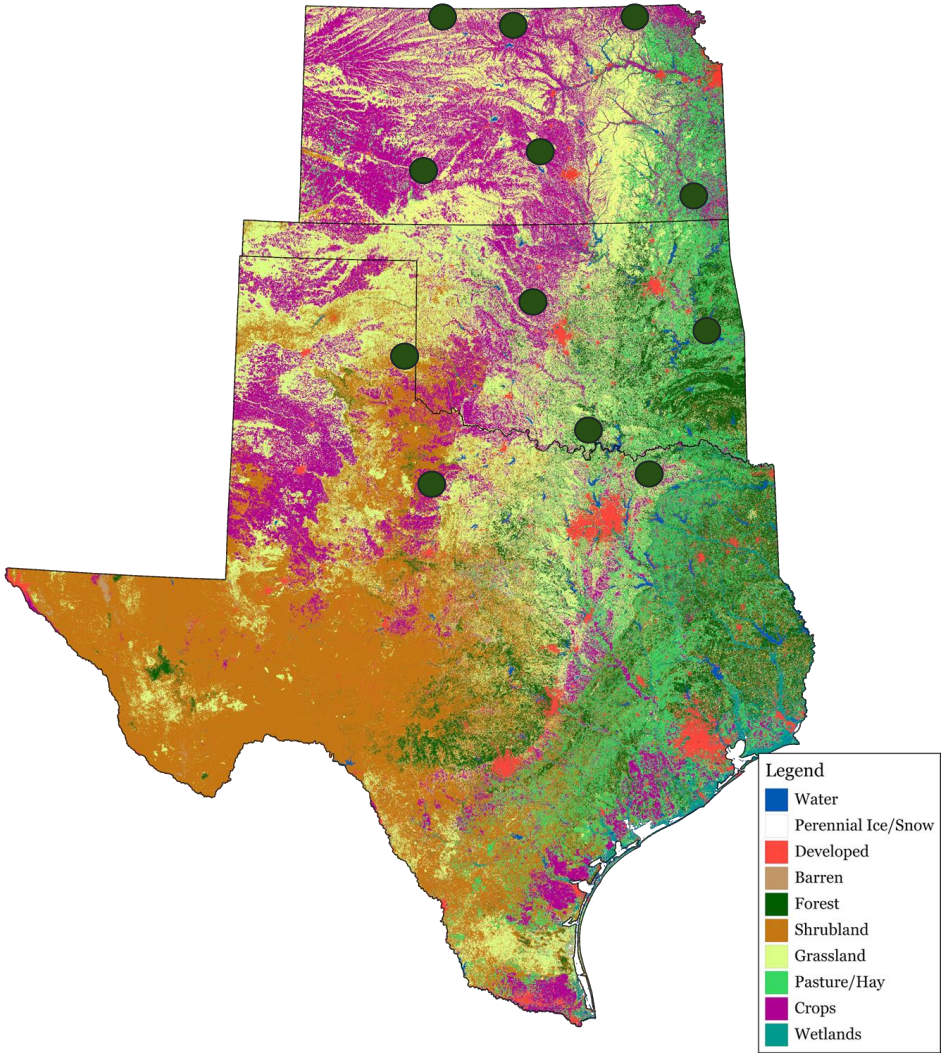


Soil Health

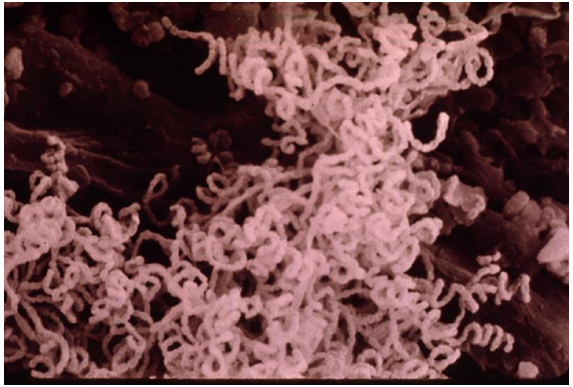


Soil Health

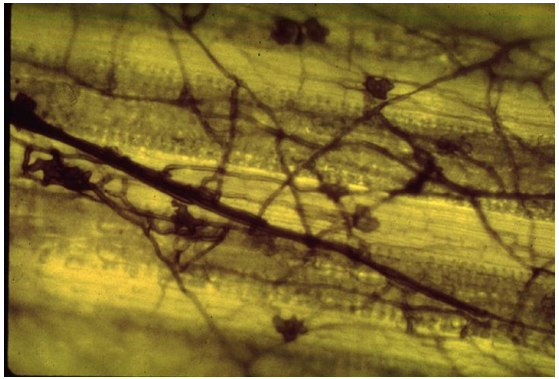
The role of microbial communities in soil health and crop yield


Legend
Water
Perennial Ice/Snow
Developed
Barren
Forest
Shrubland
Grassland
Pasture/Hay
Crops
Wetlands

Microbial communities: more than “bugs in the soil”



Actinomycetes (bacteria)



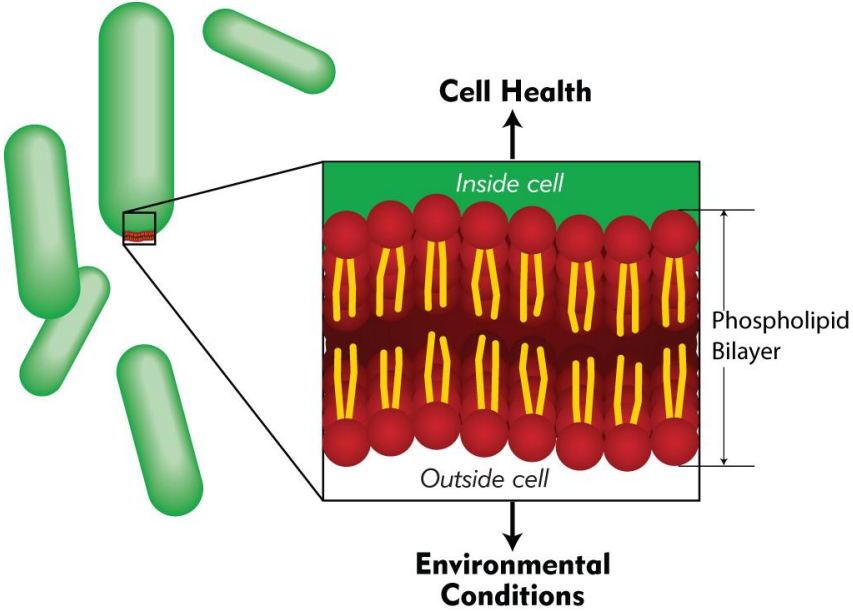
Fungi

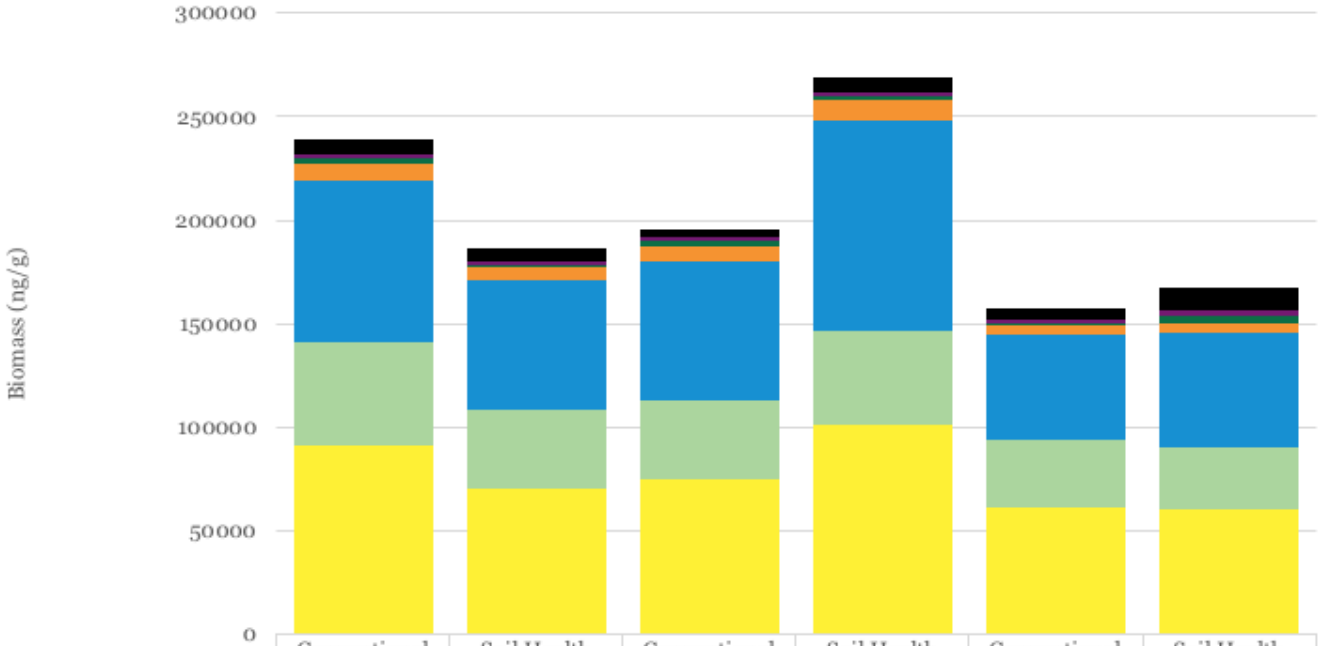
Protozoa

Phospholipid fatty acids (PLFAs)

- Present in cell membranes or walls of both pro- and eukaryotic cells
- Many different versions
- Some are reliably functional group or clade-specific
- Commonly used to indicate different types of soil microbes

NOT *unique* indicators: some can belong to multiple microbial groups, plants, or animals



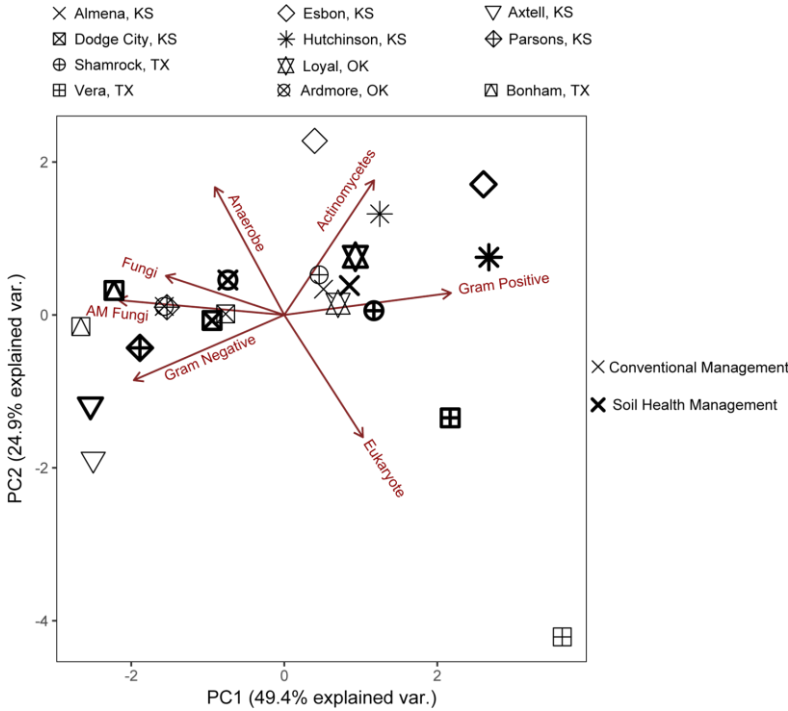


	Pair 1		Pair 2		Pair 3	
	Conventional Management	Soil Health Management	Conventional Management	Soil Health Management	Conventional Management	Soil Health Management
Other	7763.57	6187.26	4183.07	7420.26	5227.6	11208.04
Protozoa	1292.1	1667.04	1537.86	1575.51	1495.93	3097.31
Saprophytes	2830.98	1382.16	3187.74	1656.31	1379.19	3232.6
Arbuscular Mycorrhizal	8126.53	5763.2	6958.1	10485.55	4485.61	4969.07
Gram (-)	77671.28	62780.28	67427.76	101567.67	50841.39	54510.24
Actinomycetes	50095.55	37887.3	38018.38	45231.02	32914.44	30236.52
Gram (+)	91363.87	70509.47	74607.21	100864.01	60786.27	60389.83

Gram (+) Actinomycetes Gram (-) Arbuscular Mycorrhizal Saprophytes Protozoa Other

Functional group	Biomass, plfa ng/g		% of total biomass	
	Conventional Management	Soil Health Management	Conventional Management	Soil Health Management
Total Living Biomass	**157,055.34**	**169,755.27**		
Total Bacteria	**140,899.26**	**150,207.17**	**89.71**	**88.48**
Gram (+)	75,585.78	77,254.44	48.13	45.51
Actinomycetes	*40,342.79*	*37,784.95*	*25.69*	*22.26*
Gram (-)	65,313.48	72,952.73	41.59	42.98
Total Fungi	**8,989.38**	**9,162.96**	**5.72**	**5.4**
Arbuscular Mycorrhizal	6,523.41	7,072.61	4.15	4.17
Saprophytes	2,465.97	2,090.35	1.57	1.23
Protozoa	**1,441.96**	**2,113.29**	**0.92**	**1.24**
Other	**5,724.74**	**8,271.86**	**3.65**	**4.87**

Principal components analysis (PCA) of microbial functional groups on conventional and soil-health management fields



“It’s interesting, but it’s also kind of useless for how much you pay for it and how long it takes. You get all this information, but you can’t really do much with it.”

Improving the return on time and financial investment in PLFA analyses

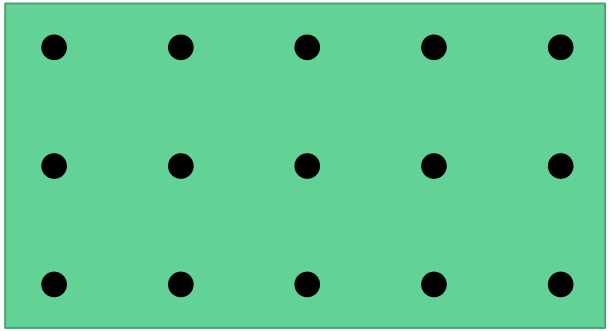
1) What is the optimum number of samples for a PLFA analysis?

Improving the return on time and financial investment in PLFA analyses

1) What is the optimum number of samples for a PLFA analysis?

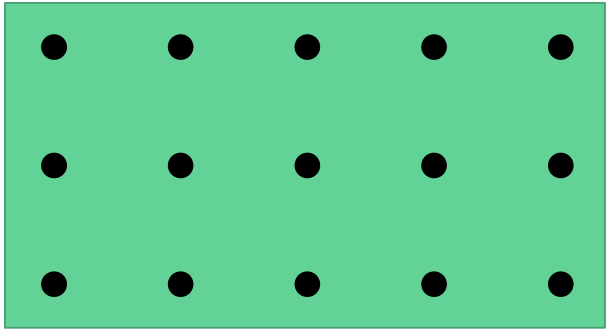
2) How is microbial community structure (as measured by PLFA analysis) related to crop yield?

Optimizing sample size



75 acres

$$\frac{75 \text{ acres}}{15 \text{ samples}} = 5 \text{ acres/sample}$$



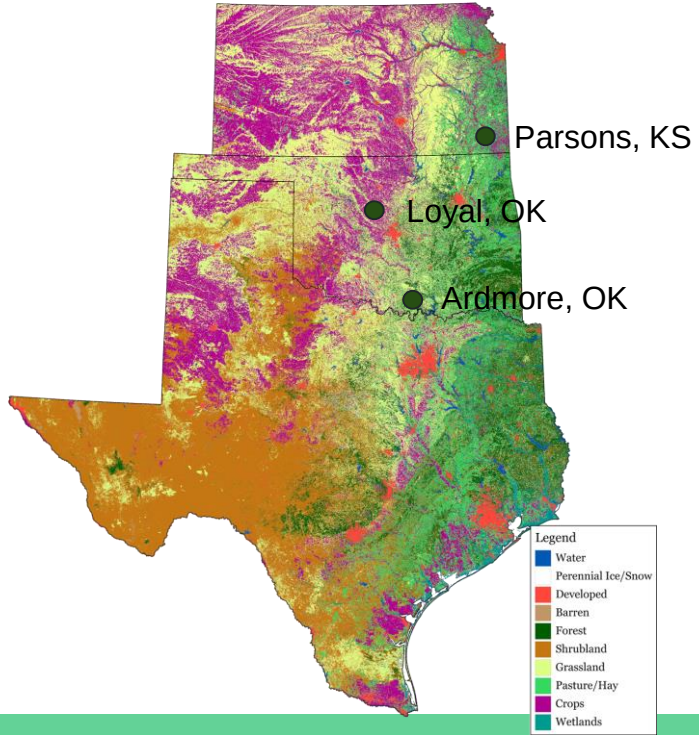
30 acres

$$\frac{30 \text{ acres}}{15 \text{ samples}} = 2 \text{ acres/sample}$$

Is 10-15 samples enough for every field, or do bigger fields require more samples?

Methods

Collect 30 samples from 3 fields of different sizes at 3 sites in KS and OK.



Methods

Collect 30 samples from 3 fields of different sizes at 3 sites in KS and OK.

Analyze each sample individually

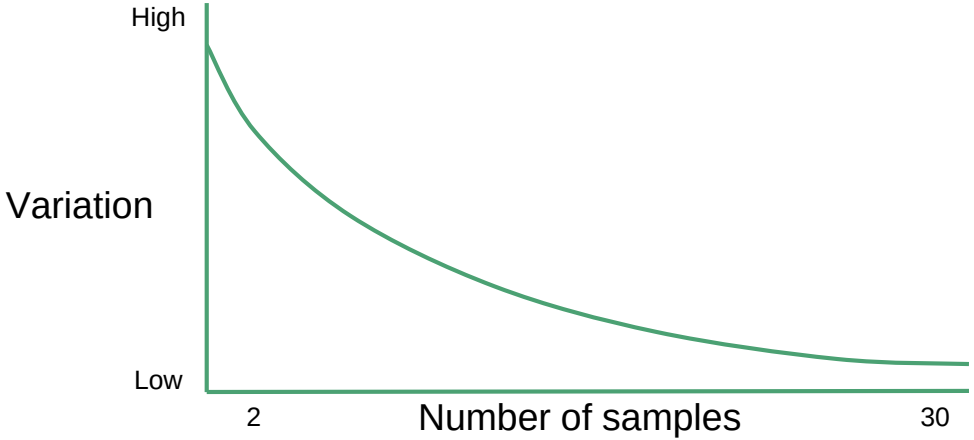
Functional Group	Biomass, PLFA ng/g	% of Total Biomass
Total Bacteria	**1881.75**	**37.48**
Gram (+)	**1182.99**	**23.56**
Actinomycetes	358.71	7.14
Gram (-)	**698.76**	**13.92**
Rhizobia	50.72	1.01
Total Fungi	**399.36**	**7.95**
Arbuscular Mycorrhizal	**123.64**	**2.46**
Saprophytes	**275.72**	**5.49**
Protozoa	**45.75**	**0.91**
Undifferentiated	**2694.32**	**53.66**

Methods

Collect 30 samples from 3 fields of different sizes at 3 sites in KS and OK.

Analyze each sample individually

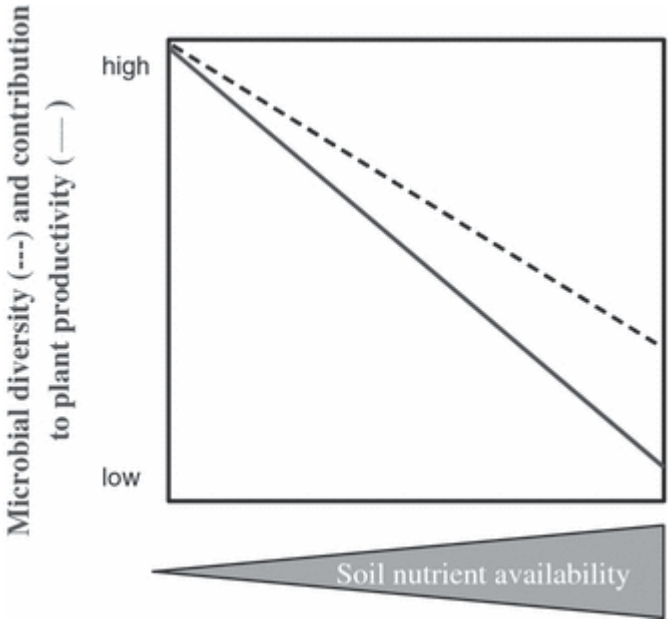
Use statistical analyses to quantify trade-off between number of samples required and characterizing community accurately



Microbial community structure & crop yield

Is there a correlation between microbial community structure and crop yield?

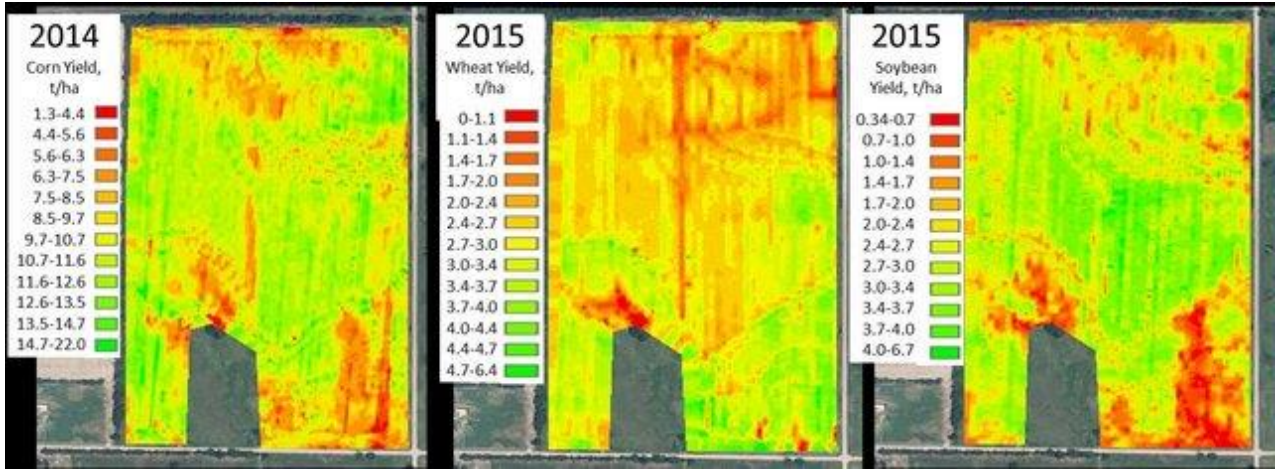
- Arbuscular mycorrhizal fungi
  - Increased productivity
  - Increased drought tolerance
  - Increased soil moisture/plant moisture availability
- Other fungi, bacteria
  - Increased protection from pathogens
  - Reduced herbivory
  - ...



From Van Der Heidjen *et al.* (2007), *Ecology Letters*

Microbial community structure & crop yield

Objective: Determine if yield is correlated with microbial community attributes



Methods

Collect 30 soil samples from 3 fields in Parsons, KS (same samples as previous study)

Analyze each sample individually (PLFA and neutral lipid fatty acid (NLFA))

Functional Group	Biomass, PLFA ng/g	% of Total Biomass
Total Bacteria	**1881.75**	**37.48**
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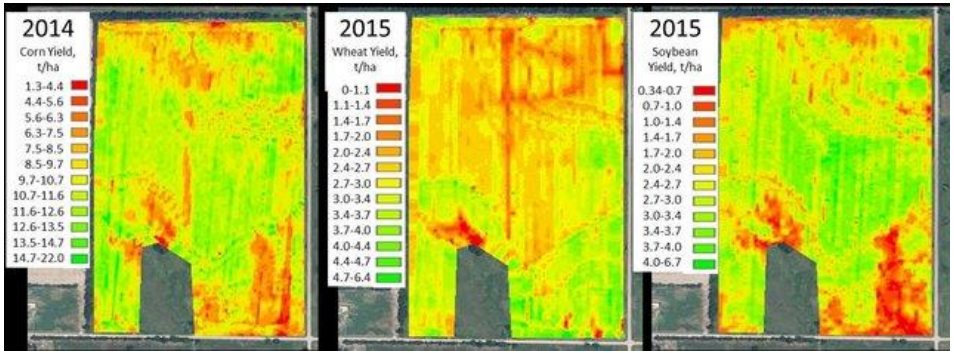
Collect yield data for crops



Methods

Collect 30 soil samples from 3 fields in Parsons, KS (same samples as previous study)

Analyze each sample individually (PLFA and neutral lipid fatty acid (NLFA))

Collect yield data for crops

Test for significant correlations between microbial functional groups and crop yield

Future Directions

Potential expansion of crop yield study

- Different crops
- Larger sample size of fields
- Other regions of the state

Questions?

GRAZINGLANDS RESEARCH LAB
FORT RENO

USDA
Climate Hubs

K-STATE