Can Manure Affect Soil Health?

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What Is Soil Health?

“The continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans” (NRCS)

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Why Soil Health?

Healthy soil holds more water (by binding it to organic matter), and loses less water to runoff and evaporation.

1% organic matter in the top 6 inches of soil would hold approximately 27,000 gallons of water per acre.

27,000 gallon/acre, 43,560 ft^2/acre, 7.481 gallon = 1 ft^3, so this is about 1" of water or rainfall!

How deep is corn root and soil?

Soil type, rainfall, infiltration vs. runoff, evaporation?

Reference:
https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1082147.pdf

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Background Information

The Missouri N340 Cover Crop Cost-Share Program is a state-wide effort to encourage adoption of cover crops, to improve water quality and soil health.

2016-17: over 1700 soil samples analyzed by the University of Missouri Soil Health Assessment Center (https://cafnr.missouri.edu/soil-health/)

The program presents a unique opportunity for systematic evaluation of soil health indicators, cover crop use, and manure application.

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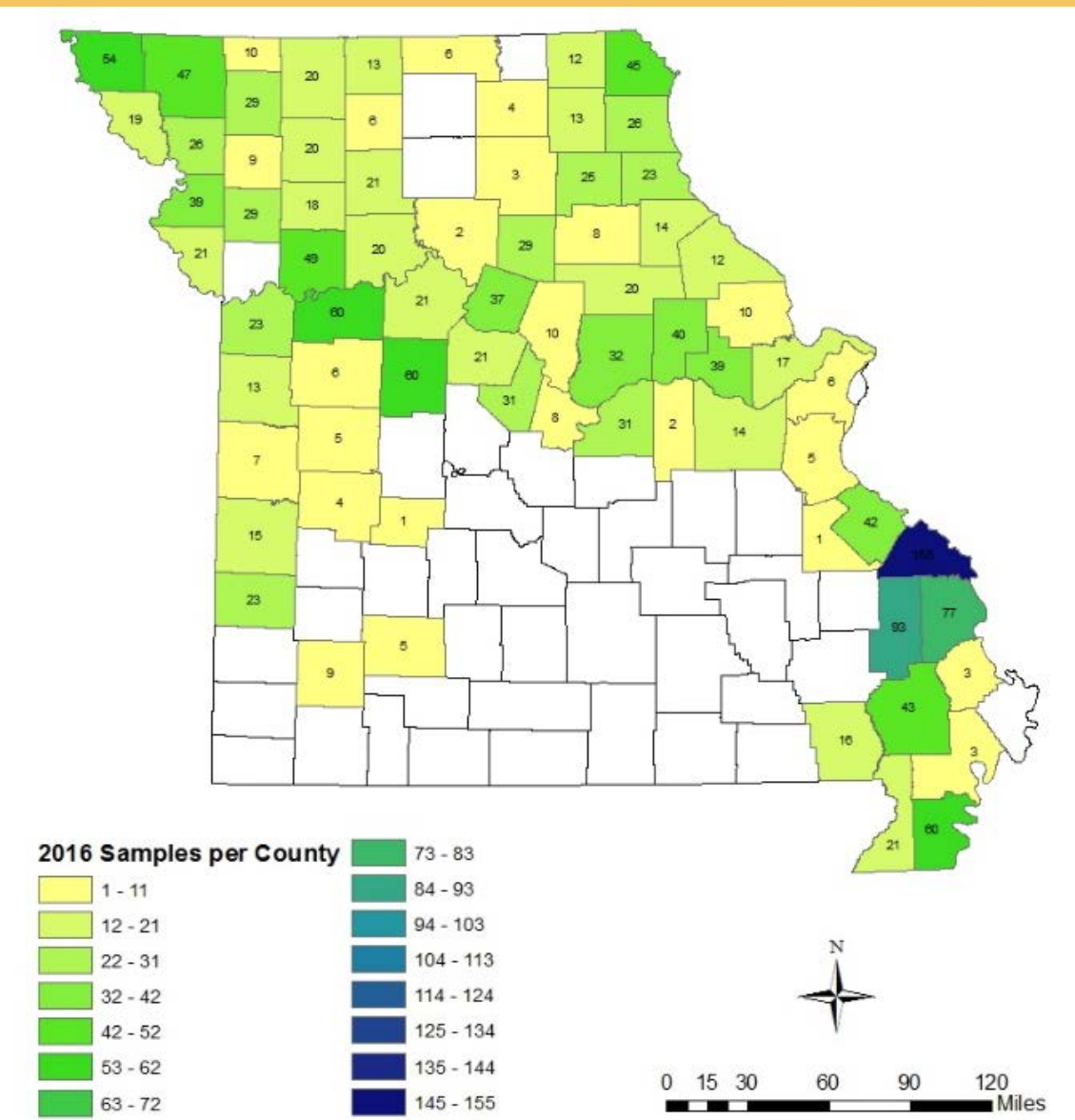
Number of samples collected under the 2016 Missouri Department of Natural Resources Cover Crop Cost-Share Program



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Questions / Objectives

Why is “Soil Health” getting people’s attention?

In contrast to the cover crop and no-till management, efficient use of livestock and poultry manure to increase soil productivity, resiliency to extreme growing conditions, has not been receiving much attention.

There remains a knowledge gap to recommend future research, demonstration, and policy in efficient use of manure relating to soil health and productivity.

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Soil Health Indicators?

Variables	What they mean and importance
Total organic carbon and active carbon	Organic contents has been shown to improve biological (e.g. greater diversity of micorbes), chemical (e.g. better nutrient cycling), and physical (e.g. improved water infiltration and holding capacity) soil properties.
Bray 1 phosphorus	An estimate of available P levels for plants. Too little P can impact yield and too much P can contribute to high nutrient loss and potential environmental issues.
Potentially mineralizable nitrogen	A measure of soil biological activity and efficiency. Too much nitrogen in the soil can also mean high losses.
Bulk density	Indicator of soil compaction and the soil functions of regulating water, producing biomass, and providing support for plants and structures. High bulk density would generally reduce soil productivity.
Water stable aggregate	Indicator of how soil particles bound together that resist breaking apart, even during wet soil conditions. It may be an indicator of soil water functions such as infiltration.

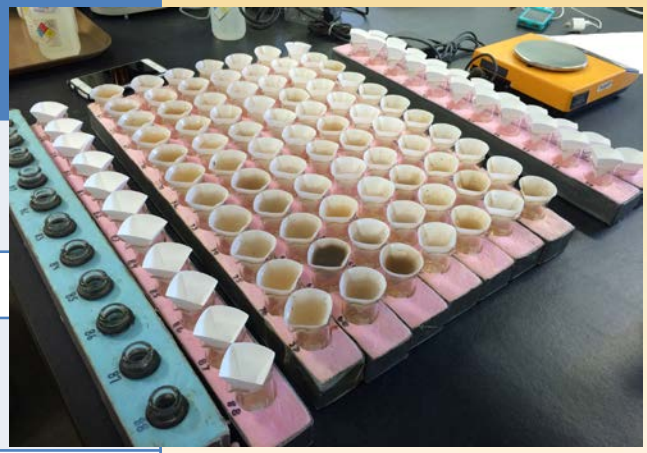
Test SOPs for the Indicators?

Physical properties

Indicator	Abbrev.	Method
Bulk density	BD	Core method
Water-stable aggregates	WSA	Wet-Sieving

Chemical properties

Indicator	Abbrev.	Method
Cation exchange capacity	CEC	1M ammonium acetate at pH7
Phosphorus	P	Bray 1
Potential of hydrogen	pH	1:1 soil:water
Total nitrogen	TN	Dry combustion by LECO FP-528 nitrogen analyzer



Source: Saranya Norkaew

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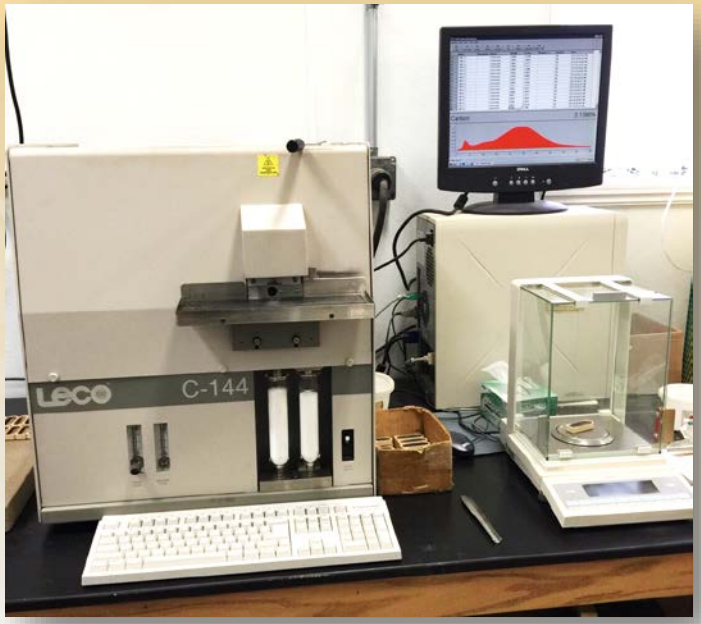
Test SOPs for the Indicators?

Biological properties

Source: Saranya Norkaew

Indicator	Abbrev.	Method
Active carbon	AC	Potassium permanganate test
Soil organic carbon	SOC	Dry combustion by LECO C-144 carbon analyzer
Potentially mineralizable nitrogen	PMN	7-days anaerobic incubation test at 40°C
Microbial biomass	MB	Bligh-Dyer lipid extraction



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Data Collected and Analyzed

1700 samples collected, 1000 samples data were analyzed for this report. Among these, 78 samples were reported to have applied manure fertilizer, which was a 7.8% ratio.

For the 1,000 samples, they were submitted from 71 counties. There were 29 counties indicated to have land applied manure, which included cattle, chicken, poultry and swine manure

Summary of sample size and type of manure applied collected under the Missouri Cover Crop Program.

Total sample	Soil-manure	Soil+manure	Cattle manure	Poultry manure	Swine manure	Not indicated
1000	922	78	28	39	9	2

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State-wide Soil Results

Although not statistically different, the soil samples with manure application is 9.4% higher in total organic carbon than soil without manure.

Some values seem confounding: Potential causes included soil disturbance due to mechanical incorporation tillage, soil types across the state, lack of multi-year sampling and data, and relatively low number of samples.

Summary of key soil variables for the state-wide soil samples.

	N	Organic carbon (%)	Active carbon (mg C/kg soil)	pH Water	Bray 1 P (ppm)	Mineralizable Nitrogen (ppm)	Bulk density (g/cm^3)	Water stable aggregates (%)
Overall	1000	1.81	484.6	6.47	52.4	78.2	1.21	30.2
Soil + manure	78	1.97	517.4	6.58	92.9**	81.4	1.22	29.7
Soil - manure	922	1.80	481.8	6.46	49.0	77.9	1.21	30.3

*Significant different $p<0.05$, **Significant different $p<0.01$.

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Comparison of Samples within County

The top three counties with manure fertilizer were Pettis (15 samples, all were poultry manure), Moniteau (10 samples, all were poultry manure), and Stoddard (7 samples, 6 cattle and 1 poultry manure).

The within-county comparisons seem to allow more homogeneous comparison at least by narrowing down to smaller region and with similar soils, and the results show.

Summary of soils characteristics for samples with and without manure application for the top three counties.

	n	Organic carbon (%)	Active carbon (mg C/kg soil)	pH Water	Bray 1 P (ppm)	Mineralizable Nitrogen (ppm)	Bulk density (g/cm^3)	Water stable aggregates (%)
Pettis+manure	15	1.94	530.1	6.45	56.9	74.5	1.25	24.9
Pettis-manure	29	1.91	522.0	6.56	47.1	81.4	1.24	24.8
Moniteau+manure	10	2.03	539.3**	6.72	60.1	75.7	1.19	24.9
Moniteau-manure	21	1.87	450.9	5.92	46.3	81.9	1.25	34.6
Stoddard+manure	7	2.36**	651.4**	6.01	344.2**	107.5**	1.23	31.0*
Stoddard-manure	12	0.93	247.1	6.19	52.6	38.8	1.08	22.8

*Significant different $p<0.05$, **Significant different $p<0.01$.

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Comparison of Samples within County

In general, manure applications increased the soil carbon contents ($P<0.01$ for total organic carbon in Stoddard country, and for active carbon in Moniteau and Stoddard counties).

Also, in general, phosphorus values were affected by the manure application, while the other variables were not as consistently affected.

For Stoddard county, known for its sandy soils, the land application of manure clearly increased the carbon contents, phosphorus, potentially mineralizable nitrogen, and water stable aggregates values ($P<0.05$ or $P<0.01$).

These findings confirm that the sandy soils contain less nutrients, and the impact of manure application can be easily observed as well. The higher phosphorus levels also pose a risk to polluting the water bodies.

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Additional Research Plot Data

(my Backup Plan)

Experimental field plots located on the University of Missouri campus, Sanborn Field, were established as early as 1888.

The field plots were designed to assess the effects of field management, rotating crops and application of manure on crop production.

The treatments included full fertility, full fertility-N, full fertility-P, 6 tons manure/acre-year, red clover (green manure), and no fertility. All plots were conventionally tilled.

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Old Research Plot – Missouri Sanborn Field

Source: J. Miles, R., J. R. Brown, 2011. The Sanborn Field Experiment: Implications for Long-Term Soil Organic Carbon Levels. Agronomy Journal. 103 (1), 268-278.

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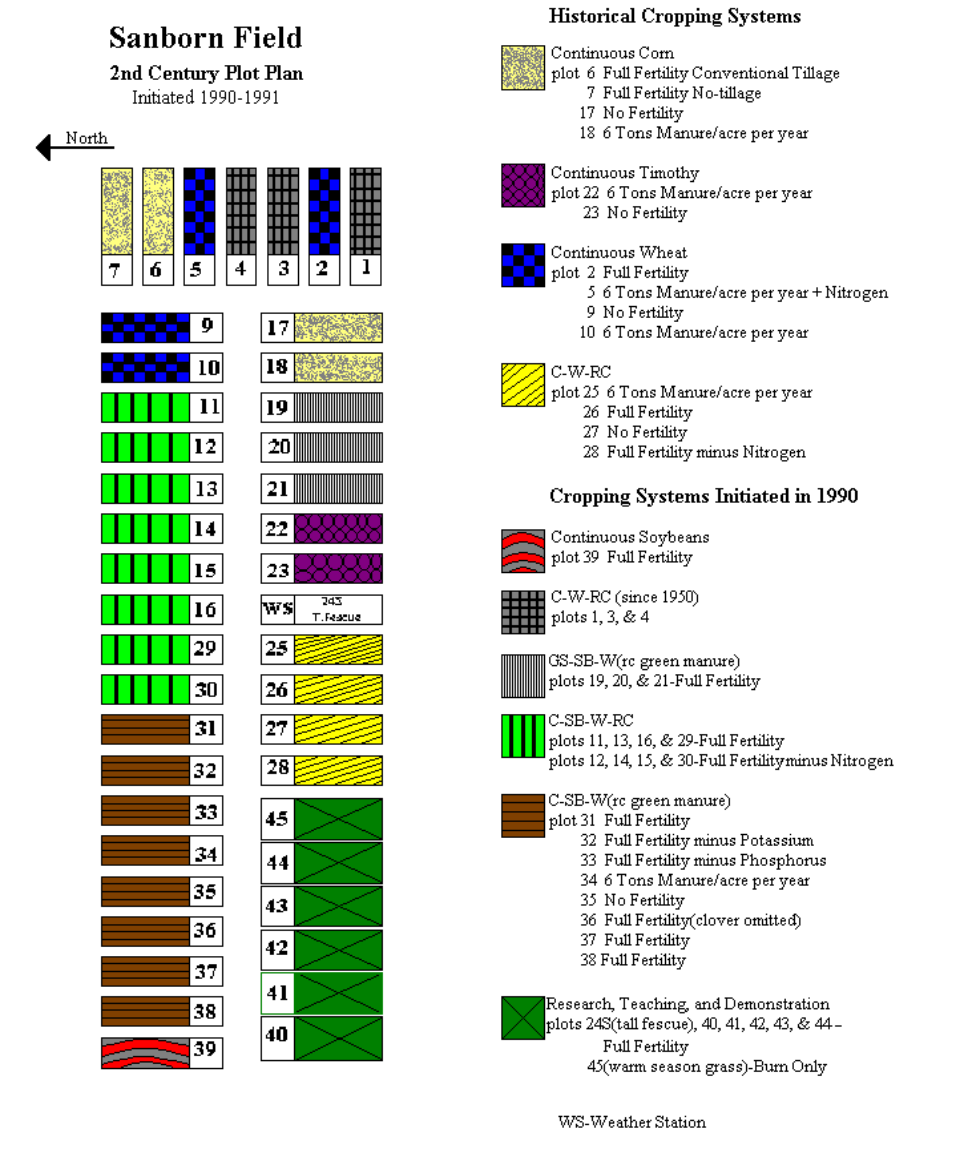
Old Research Plot – Missouri Sanborn Field

- **Cropping System**
- Continuous Monoculture Cropping
  - Corn
  - Soybeans
  - Wheat
  - Tall Fescue
  - Timothy
- Corn-Wheat-Red Clover
- Corn-Soybeans-Wheat-Red Clover
- Grain Sorghum-Soybeans-Wheat(rc)
- Corn-Soybeans-Wheat(rc)

- (rc)-red clover used as a green manure



Source: J. Miles, R., J. R. Brown, 2011. The Sanborn Field Experiment: Implications for Long-Term Soil Organic Carbon Levels. Agronomy Journal. 103 (1), 268-278.

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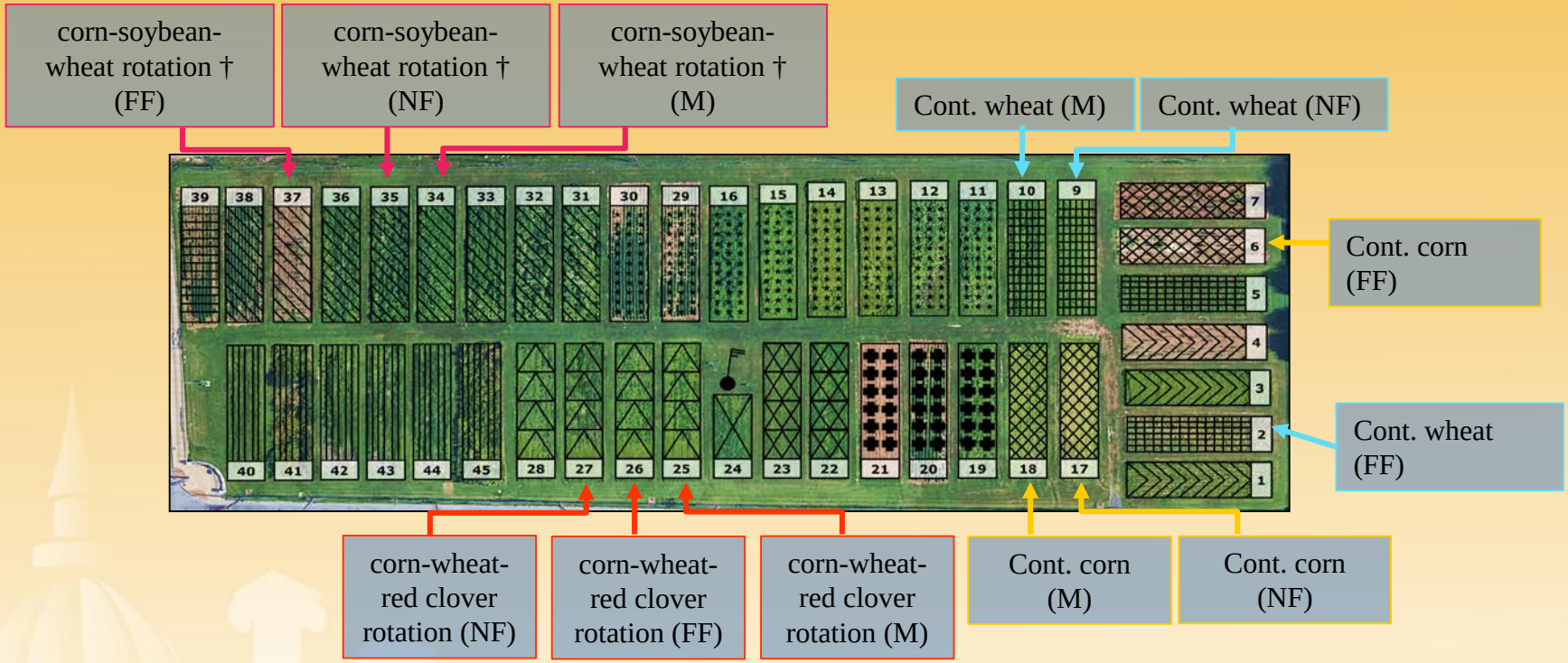
Old Research Plot – Missouri Sanborn Field

† Red clover as a green manure



NF: No fertilizer
FF: Full fertilizer
M: Manure

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Comparison of State-Wide and Experimental Plot Samples

The more uniform soil type and repeated experimental field plots provide a more controlled and homogenous comparison for the research of manure land application.

The Sanborn experimental field plot data shows more differences between the treatments of full-fertilizer, manure application, and no fertilizer.

Sanborn field plots were of similar soil type, have been receiving the same fertilizer treatments for at least 50 years, the organic carbon of soil with manure (M) is higher ($P<0.01$) than full fertility (FF) and no fertility (NF).

The experimental field plot agrees with the within-county comparisons, that the manure application was able to increase the soil carbon contents.

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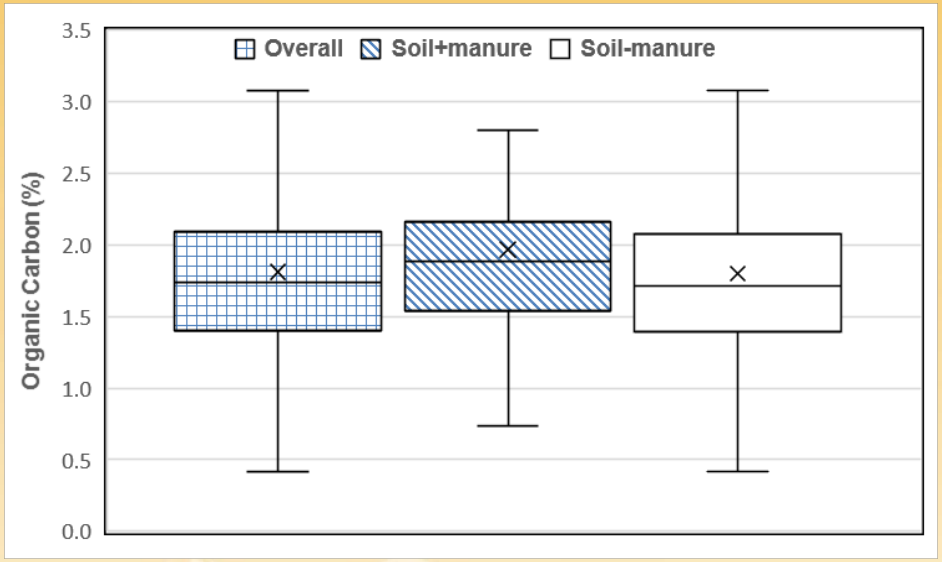
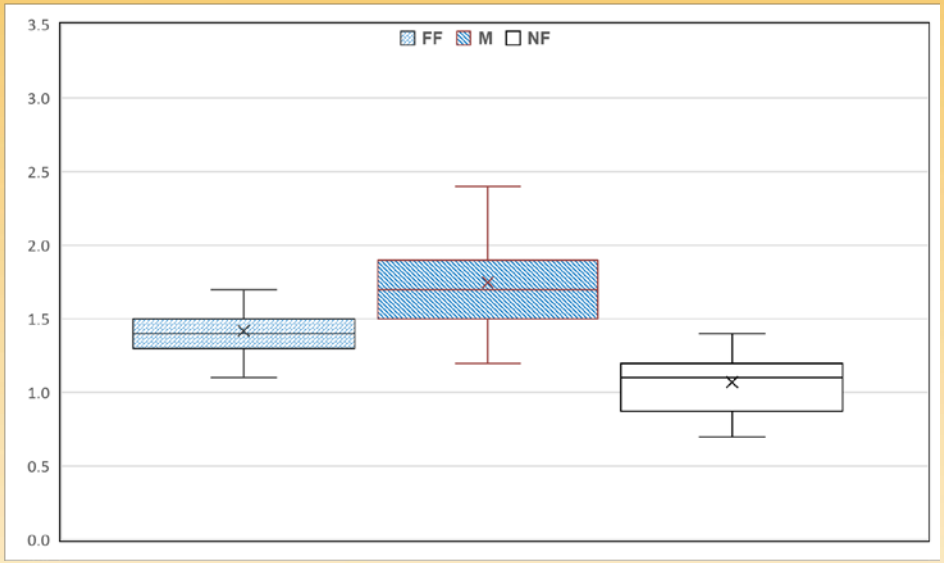
Organic Carbon Comparisons between State and Experiment Plot Data





Comparisons of organic carbon contents for the state-wide (Left) and Sanborn field plot soil samples (Right), the plots depict media (solid line), mean (x), quartile box, and minimum/maximum values.

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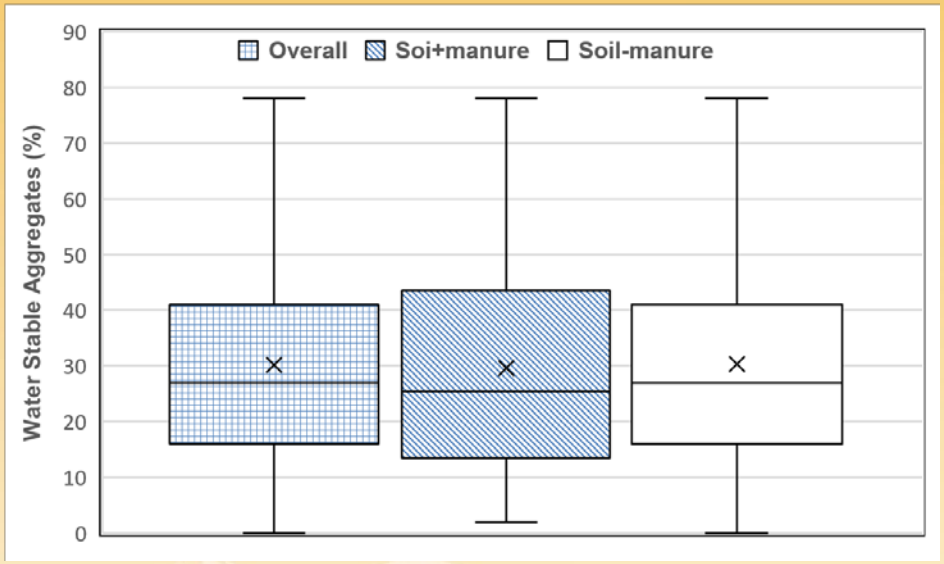
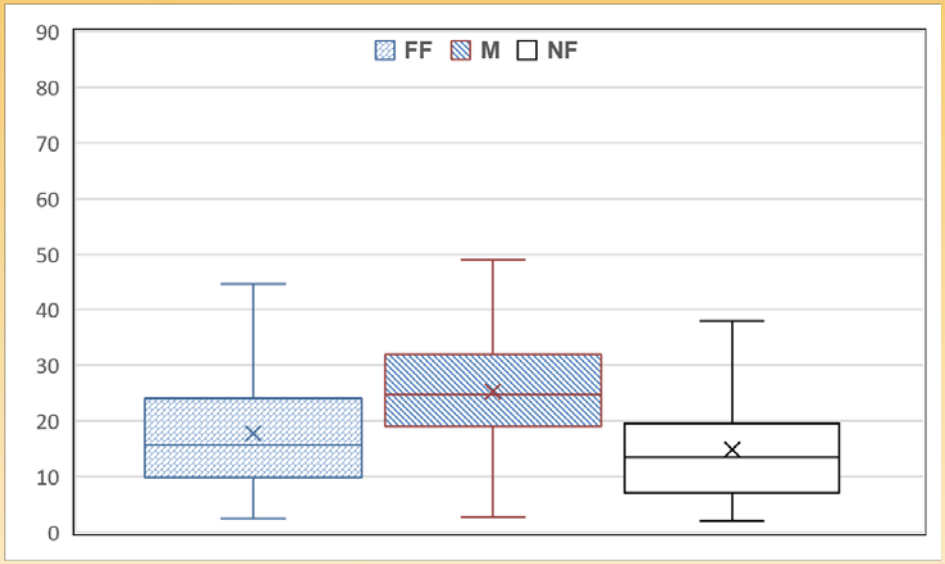
Water Stable Aggregates Comparisons between State and Experiment Plot Data





Water stable aggregates of state-wide and Sanborn field soil samples, the plots depict media (solid line), mean (x), quartile box, and minimum/maximum values.

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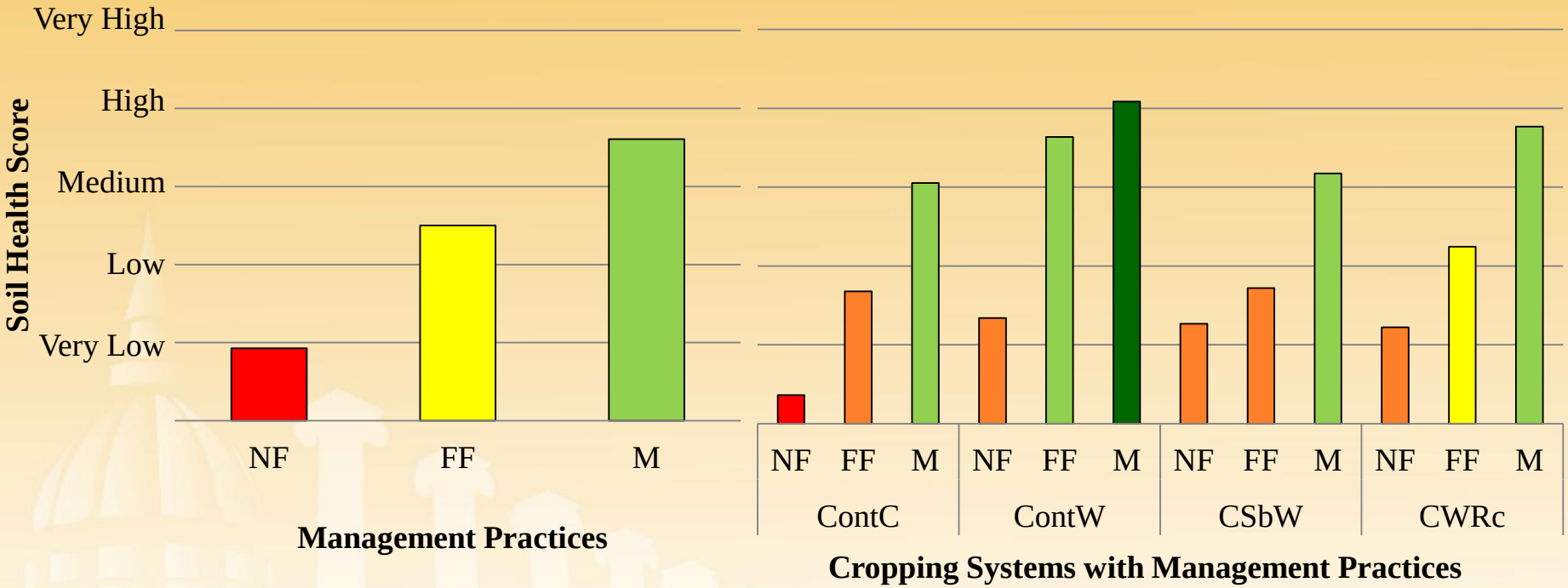
Effects of Management on Soil Health Score



Note: Score of Cornell Comprehensive Assessment of Soil Health (CASH)

Source: Saranya Norkaew

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Can Manure and Residue Affect Soil Organic Carbon Content?

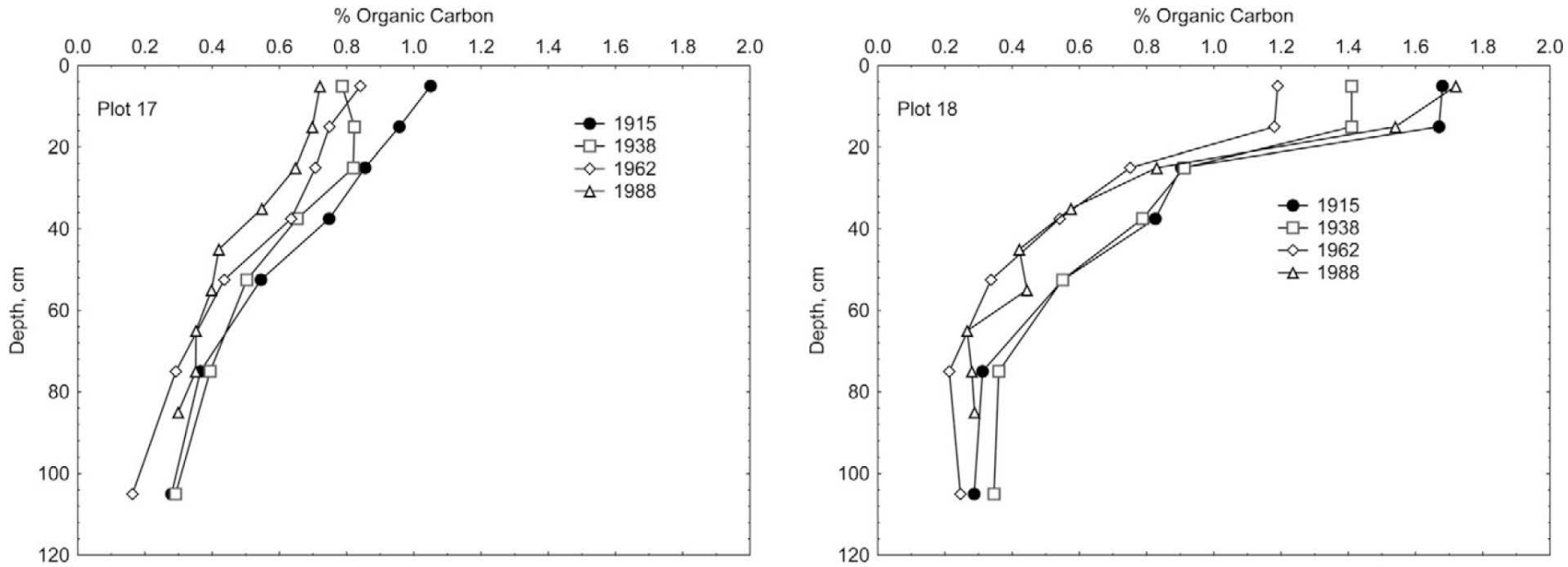

Fig. 2. Soil profile depth distribution of organic carbon with time for monoculture corn Plot 17 (control) and Plot 18 (manure).

Note: Residue was returned to fields after 1950s.

Source: J. Miles, R., J. R. Brown, 2011. The Sanborn Field Experiment: Implications for Long-Term Soil Organic Carbon Levels. Agronomy Journal. 103 (1), 268-278.

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Summary and Conclusions

No significant difference was found between the state-wide fields with and without manure application for total organic carbon, active carbon, pH, potentially mineralizable nitrogen, bulk density, and water stable aggregates; a significant difference was found only for phosphorus.

When compared within the counties, the manure applications increased the active carbon contents ($P<0.01$) for two of the top three counties where manure application data was collected.

The manure application also increased ($P<0.05$) organic carbon, phosphorus, potentially mineralizable nitrogen, and water stable aggregate for Stoddard county

Data set of controlled experimental field plots shows that manure application has resulted in higher soil organic carbon, active carbon, phosphorus, and water stable aggregates; and lower bulk density.

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Sanborn Field 130th Birthday

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Thank you!

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