Manure Land Application and Soil Health Indicators

2016 Manure and Soil Health Working Group Data Brief

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Project Summary

A team of agricultural engineers and soil scientists investigated the correlation between soil health variables and land application of manure for soil samples collected in Missouri. The team assembled and analyzed data of soil health related variables and manure land application details, collected under the Missouri Cover Crop Cost-Share Program, although only a partial year of data is included in this brief. No significant difference was found between the 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. The lack of correlation is mostly likely because only a small portion of the state-wide samples were associated with manure land application, and the samples were highly variable in tillage, soil type, crop and manure type, and application rate and methods, and consistent, multi-year data from similar fields is limited. However, when the effects of manure land application was compared within 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 significantly increased ($p<0.05$) organic carbon, phosphorus, potentially mineralizable nitrogen, and water stable aggregate values for Stoddard county.

In order to better examine the effects of manure on soil characteristics, another set of data was examined. This dataset was collected from controlled experimental field plots with consistent tillage and repeated crop and fertilizer treatments. When comparing the plots that received full fertilizer, no fertilizer, and manure application, the effects of the manure land application clearly affected several key variables. The manure application resulted in higher soil organic carbon, active carbon, phosphorus, and water stable aggregates, and lower bulk density. These findings confirm that the benefits of manure application in increasing soil organic materials and improving soil aggregate ability can be seen at least from fields that were consistently treated. These findings regarding manure use and soil health

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indicators are important to be shared with stakeholders. While considering measurable economic and environmental impacts of nutrient and manure management, especially for increasing the carbon content in the crop fields, manure land application can be one of the recommended practices.

Soil Samples Collected and Analyzed

A state-wide effort to encourage adoption of cover crops to improve water quality and soil health is under-way in Missouri. The Missouri N340 Cover Crop Cost-Share Program (DNR, 2016) provides incentives to operators who implement specific cover crop management. The program presents a unique opportunity for systematic evaluation of soil health indicators, crop rotation and yield, and manure application. To date, over 1700 soil samples have been submitted to the University of Missouri Soil Health Assessment Center (https://cafnr.missouri.edu/soil-health/), Figure 1.

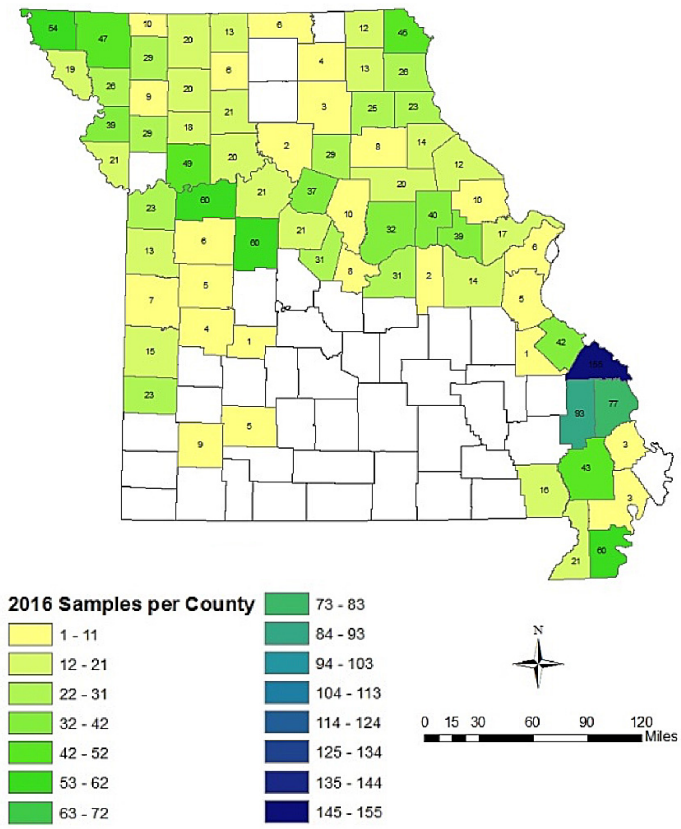

Figure 1. *Number of samples collected under the 2016 Missouri Department of Natural Resources Cover Crop Cost-Share Program.*

State-Wide Soil Sample Analysis

The main dataset analyzed was 1,000 results of the soil health and manure application data that were collected. In addition to the more typical soil nutrient (nitrogen, phosphorus, and potassium) values, many key soil health indicators including soil aggregate stability, total organic carbon, active carbon, exchangeable cations, bulk density, and water stable aggregates were also collected. The soil samples were shipped to the Missouri Soil Health Laboratory for analysis following standard methods reported in the USDA NRCS Soil Survey Laboratory Methods Manual (USDA, 2004). Some of the important management information collected from the various fields include field location (county), crop rotation, tillage use, sampling use, etc.

Experimental Field Plot Sample Analysis

An additional research dataset was also was collected from an historic experiment field, Sanborn Field in Columbia, MO. Recent research activities involve the University of Missouri Soil Health Assessment Center personnel and evaluations of more detailed soil health indicators. The plots were established as early as 1888, and were designed to assess the benefits of rotating crops and application of manure on crop production (Miles et al., 2011). The soil is primarily silt loam, which is in an area known as the central clay-pan till plains. A wide range of cropping systems were conducted at Sanborn Field. The fertilizer treatment included full fertility, full fertility minus nitrogen, full fertility minus phosphorus, 6 tons manure/acre-year, red clover as green manure, and no fertility. All plots included in this report were conventionally tilled. Four sets of soil samples were collected and analyzed for the complete soil characteristics to date. The sampling was conducted in May and September of 2014, and April and

August of 2016. Because there were so many treatments and such a long history, the results included in this report focus on overall full fertility, manure application, and no fertility, and especially their comparisons.

Effects of Manure on Soils

Figure 2 depicts the average total organic carbon values overall, and soil samples with (n=78) and without manure (n=922) applications. Although not statistically different, the soil samples with manure application are 9.4% higher in total organic carbon than soil without manure. Total organic carbon is an important indicator of soil health because the organic contents has been shown to affect biological, chemical, and physical soil properties (J. Miles and R. Brown, 2011). Total organic carbon and microbes help the soil filter, buffer, and transform inputs such as herbicides. Similar to the organic carbon, that active carbon values of the manure treated fields did not differ significantly from those that did not have manure application, but were 7.4% higher, Table 1. Unfortunately only a small portion (78 out of 1000 samples) of the state-wide samples were associated with manure land application, and considering the variability in soil type, crop and manure source, and application rate and methods, more data would be needed to systematically compare and contrast the soil samples that received and did not receive manure. In addition, since this was the first time such data was collected, the dataset lacks consistent, multi-year data from similar fields.

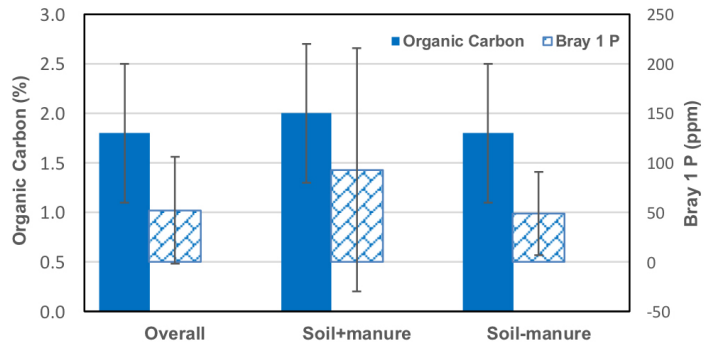

Figure 2. *Organic carbon and phosphorus contents of the state-wide soil samples, and with and without manure application.*

	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 $p<0.01$.

Table 1. *Summary of key soil variables for the state-wide soil samples.*

Most plants prefer a soil pH between 6.0 and 7.0. The average pH values of the overall and soil samples with and without manure application were within this range. Soil pH affects the solubility of plant nutrients and the nutrient holding capacity or cation exchange capacity (CEC) of the soil. The Bray 1 Phosphorus (B1P) test results are an estimate of available P levels for plants. Interestingly, the average phosphorus of soil samples with manure application was 92.9 ppm, which was almost twice the average value of soil without manure application (49.0 ppm), indicating a correlation between manure application and the amount of phosphorus in many manure fertilizers. Too much phosphorus in the field can cause plant nutrient imbalances, and more importantly, contribute to high nutrient loss and potential environmental issues. Potentially Mineralizable Nitrogen (PMN) is also a measure of soil biological

activity and efficiency. The average potentially mineralizable nitrogen value for soil with manure application was 81.4 ppm, which is 4.5% higher than the samples from fields that did not have manure application.

Bulk density (BD) is an indicator of soil compaction and the soil functions of regulating water, producing biomass, and providing support for plants and structures. On average, the overall samples and soils with and without manure application were identical. Water stable aggregates is an indicator of how soil particles bound together resist breaking apart, even during wet soil conditions. The mean water stable aggregates was 29.68% for the soil samples that had manure application, which is 0.6% lower than soil without manure application which averaged 30.28%. These values seem confounding since the soils that received manure application (and showed slightly higher carbon contents) did not have higher aggregate property. Potential causes include additional soil disturbance due to mechanical incorporation tillage, differences between soil types across the state, lack of multi-year sampling and data, and relatively low soil samples with manure application (n=78 out of 1000).

Comparison of Samples within County

A total of 1000 samples were included in this report, which were submitted from 71 counties during the 2016 period. The 78 soil samples reported to have applied manure were submitted from 29 counties. The top three counties with manure fertilizer were Pettis (15 samples, all poultry manure), Moniteau (10 samples, all poultry manure), and Stoddard (7 samples, 6 cattle manure and 1 poultry manure), Table 2. This dataset allows a more comprehensive comparison of the soil samples with and without manure application, that the sample size of soil with manure application is at least half the number of those without manure application. Also, in contrast to comparing the state-wide samples with and without manure application, Table 1, the within-county comparisons seem to allow more homogeneous comparison by narrowing data to smaller regions with similar soils.

In general, the manure applications increase 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, which is located at the Southeast corner of Missouri and 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 $p<0.01$, Table 2 and Figure 3). The

	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 within the county, **Significant different p<0.01 within the county.

Table 2. *Summary of soils characteristics for samples with and without manure application for the top three counties.*

mineralizable nitrogen is also a factor of soil health; the samples were incubated at 40°C under water for seven days and analyzed for ammonium. This variable can be indicative of the amount of nitrogen mineralized over a growing season. These findings confirm, first that the sandy soils contain less nutrients and are less dense than the other soils, and second that the impact of manure application can be easily observed as well. The higher phosphorus level also poses a risk to polluting the water bodies, especially when the soil moisture content, pH, and weather condition favors phosphorus loss from the soil.

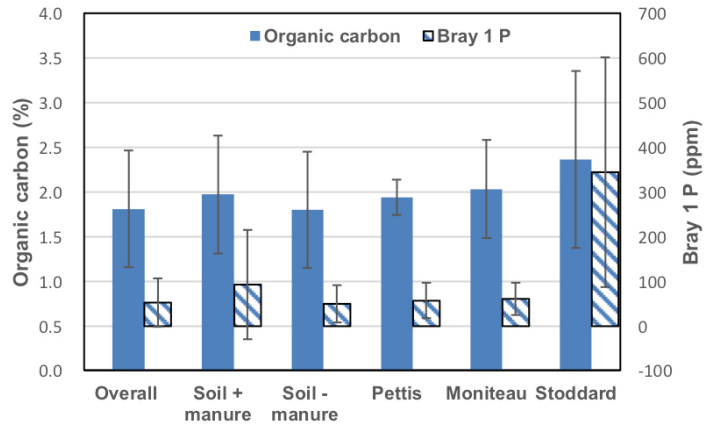

Figure 3. Comparisons of soil organic carbon and phosphorus contents, for state-wide and top three county data.

These findings provide an interesting comparison to the Sanborn field data regarding organic carbon and active carbon. It was reported that after initiation of crop residue return to the fields, manure only treatments nearly returned to 1915 organic contents in the surface soil after 38 years, and the increase was a result of the nutrients from the manure in concert with the residues (J. Miles and R. Brown, 2011). The authors also concluded that greater active carbon was observed with manure and higher input management systems, and the active carbon had a wide seasonal flux as a function of temperature and moisture fluxes on microbial activity within the soil. Unfortunately, there are no details regarding the amount of residue that remained in the fields or comparison of non-cover crop soil samples collected under the Missouri Cover Crop Cost-Share Program. Such data could provide more systematic comparisons and findings regarding the different critical management practices.

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. Due to the fact that the Sanborn field plots were of similar soil type, and more importantly, have been receiving the same fertilizer treatments and management program on the same plots for at least 50 years, the organic carbon of soil

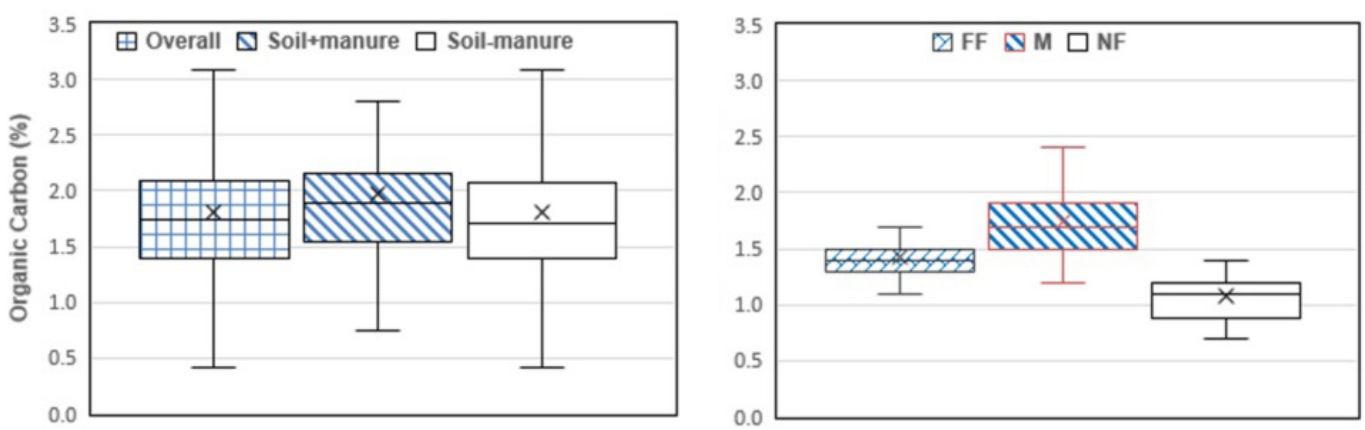

Figure 4. Comparisons of organic carbon contents for the state-wide and Sanborn field plot soil samples, the plots depict median (solid line), mean (x), quartile box, and minimum/maximum values. The state-wide samples (left) were state-wide average (overall), fields treated with manure (Soil+manure), and fields did not have manure application (Soil-manure). The field plot treatments (right) were full fertility (FF), manure (M), and no fertility (NF).

with manure (M) is higher (p<0.01) than full fertility (FF) and no fertility (NF), Figure 4. This experimental field plot agrees with the within-county comparisons, Table 2, that the manure application was able to increase the soil carbon contents.

The mean bulk density values for the state-wide soil samples with and without manure application are identical, averaged 1.22 and 1.21 g/cm3 respectively, Figure 5. However, when comparing the effects of manure application on bulk density, the plots that had manure application showed the lowest density value (p<0.01), followed by full-fertility and no fertility treatments, and the average values were 1.33, 1.35, and 1.40 g/cm3 respectively. Although the differences between the three treatments were relatively low, the manure application has shown to reduce overall soil density, which helps to improve soil aeration, and ability to regulate water and provide support for plants and structures.

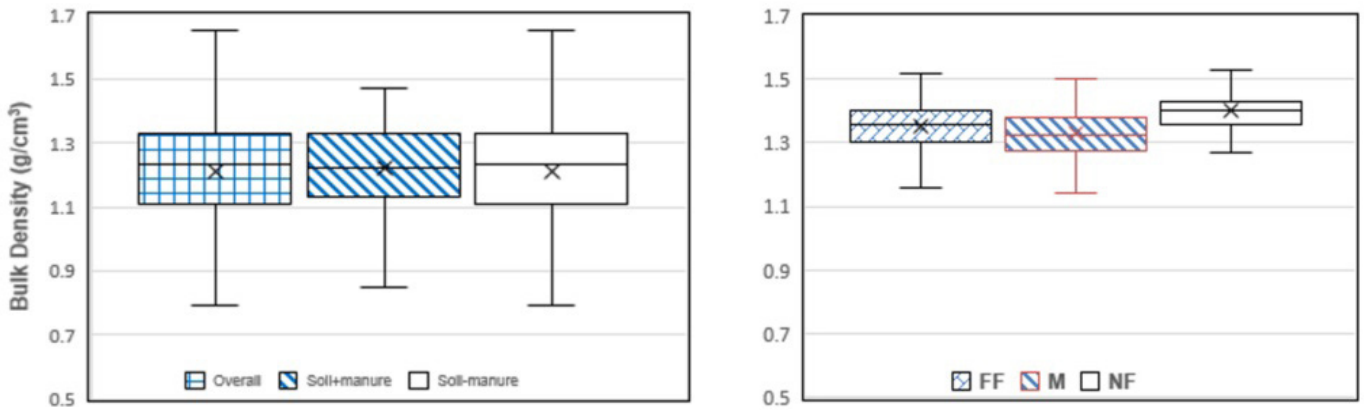

Figure 5. *Bulk density of state-wide and Sanborn field soil samples, the plots depict median (solid line), mean (x), quartile box, and minimum/maximum values. The state-wide samples (left) were state-wide average (overall), fields treated with manure (Soil+manure), and fields did not have manure application (Soil-manure). The field plot treatments (right) were full fertility (FF), manure (M), and no fertility (NF).*

An interesting finding observed in the Missouri Cover Crop Cost-Share program soil analysis is that the overall water stable aggregates value for soil with manure application was 0.6% (p>0.05) lower than those without manure application. Furthermore, even when comparing the two treatments within the top three counties with most manure application, only one county (Stoddard) showed a statistical difference in the water stable aggregates result, while the water stable aggregates of soil samples were 9.7% lower (p>0.05) than those without manure in Moniteau county. This is rather confusing yet important given the importance of the water stable aggregates characteristics. Although soil aggregate ability has been measured by many ways, it has been widely accepted that better aggregate stability can lead to reduced erosion, and increased soil biological activity, infiltration, and water holding capacity. The average water stable aggregates values for the experimental field plots were 17.7%, 25.3%, and 14.8% for the plots treated with full fertility (FF), manure, and no fertility (NF), respectively, Figure 6. This at least confirms under more controlled and repeated experiment settings, that the application of manure has at least increased the water stable aggregates by 7.6% and 10.8% when compared with full-fertility and no fertility treatment.

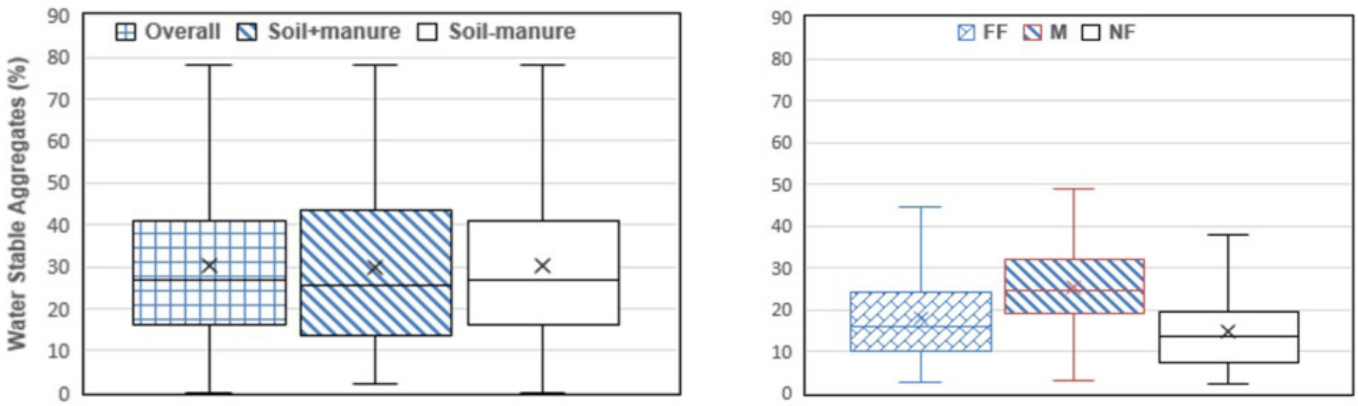

Figure 6. *Water stable aggregates of state-wide and Sanborn field soil samples, the plots depict median (solid line), mean (x), quartile box, and minimum/maximum values. The state-wide samples (left) were state-wide average (overall), fields treated with manure (Soil+manure), and fields did not have manure application (Soil-manure). The field plot treatments (right) were full fertility (FF), manure (M), and no fertility (NF).*

Conclusions

Based on the 1,000 soil samples analyzed under the Missouri Cover Crop Cost-Share Program and the University of Missouri Sanborn Field experimental plots, the overall effects of manure land application on soil characteristics were examined, especially those that have implications for soil health. In addition to the typical soil nutrient (nitrogen and phosphorus) variables, many key soil health indicators included in the program were total organic carbon, active carbon, exchangeable cations, bulk density, and water stable aggregates. When comparing the state-wide soil analysis results, only the phosphorus value was affected ($p<0.01$) by the manure application, while the other variables were not as consistently affected. However, when the soil analysis was compared within county for the top three most manure application counties, more significant differences were noticed. For Stoddard county, which is known for its sandy soils, the land application of manure significantly increased ($p<0.05$ or smaller) the carbon contents, phosphorus, nitrogen, and water stable aggregates values. The results also confirm that the sandy soils contain less nutrients, are less dense, and the impact of manure application can be easily observed. The more controlled experimental field plot data indicated a more obvious trend that the manure application affected key soil characteristics. When comparing the plots that received full fertilizer, no fertilizer, and manure application, the manure application resulted in higher soil organic carbon, active carbon, phosphorus, and water stable aggregate, and lowered the bulk density. These findings confirm that the benefits of manure application, in adding soil organic materials and improving soil aggregate stability, can be easily seen from fields that were consistently treated and tilled. The findings regarding manure use and soil health indicators are important for management of the soil and can contirbute to the many factors that need to be considered for increasing food production on a limited land base.

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