Mississippi Soybean Promotion Board
PROJECT NO. 62-2022
2022 FINAL REPORT

Project Title: Improving dryland soybean yield, profit, and health of dominant soils across Mississippi

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Executive Summary

The integration of cover crops and poultry manure into existing soybean cropping systems could potentially improve soil health in the east-central Mississippi. This study evaluated the influence of different cover crop species and fertilizer treatments on soil physical and soil chemical properties at the Pontotoc Ridge-Flatwoods Branch Experiment Station in Pontotoc County, MS. The study was initiated in October 2017 and carried out through October 2022. The field trials were conducted under no-tillage, rainfed conditions. The cover crop treatments included cereal rye, hairy vetch, winter wheat, mustard and cereal rye, and native vegetation. The three fertilizer treatments included poultry litter, commercial inorganic fertilizer and no fertilizer.

The field trials showed that the poultry litter and a few cover crop species affected some of the selected soil health indicators that can potentially improve soil health. The cover crop treatments resulted in an increasing trend of all the measured soil health indicators as compared to native vegetation. The soils amended with poultry litter reduced bulk density and increased the plant available water content. Poultry litter also has the potential to improve saturated hydraulic conductivity/infiltration rate in the topsoil. Cover crops decreased topsoil bulk density significantly. Among the cover crops, winter wheat, followed by vetch cover crops, has potentially decreased the bulk density compared to other cover crops and no cover crop treatment. Long-term use of cover crop can increase soil water storage and improve rain water use efficiency.

Poultry provided more N to soybeans than commercial fertilizer. Poultry litter sequestrated 8% more carbon content than the fertilizer treatment and 24% more than the no fertilizer treatment. Increased carbon content indicates that poultry litter has improved the organic matter in the soil. Continuous litter application for five years has significantly increased the phosphorus, potassium, sulfur, magnesium, calcium and zinc levels in the soil, creating a nutrient reservoir for the following crop.

Soybean planted in Mid-May grew better than planted two weeks later. plots receiving poultry litter produced 4 bu/ac for early planted soybean and 2 bu/ac for late planted soybean. Soybean was more healthy in the plots where cereal rye with mustard grown off soybean season. Averaged

leaf area index, plant height, and dry biomass of soybean planted on mid-May in plots of different cover crops at R6 stage was the greatest in plots treated with poultry litter, followed by commercial fertilizer and non fertilizer. The lowest yield was observed in native vegetation plots, which suggest that cover crop did play a role in soybean production. The greater yield was observed in plots planted cover crop NRCS mixture of mustard and rye, and vetch. Particularly, those cover crop plots treated with poultry litter produced the greatest yield, more number of pods contributed to the greater yield. No much difference in seed number and weight was found among either fertilizer treatments or cover crop treatments.

Another field trials at North Farm, Mississippi State University indicated soybean in the plots treated with high biosolid had 2 bu/acre more grain yield under cover crop than no cover crop. The plots even produced 3.8 and 1.5 bu/acre more in the absence of cover crop. Results suggest that integration of cover crop and poultry litter application can be cost-effective management practices that can help rejuvenate soil health after a certain period of time.

Background and Objectives

Soybean is the most important crop in Mississippi in both acreage and value. The Mississippi soybean harvested area was 2.19 million acres and had a total value of $1.104 billion, which surpasses other major crops combined. Because approximately 51% is grown under rain fed conditions, improving non-irrigated soybean yield, and reducing production costs will be critical strategies for Mississippi producers to remain profitable. The majority of the annual rainfall in Mississippi occurs in the fallow season in December through April. During the soybean growing season (May to September), insufficient and erratic rain is a major limitation for dryland soybean production often resulting in low and inconsistent grain yield. Researchers have demonstrated that a 1% increase in soil organic matter (SOM) can improve soil water holding capacity by 20%. Thus, any management practice that increases SOM is likely to improve soil water holding capacity and water infiltration rate and conserve more rainwater in the soil. The effectiveness of those practices to increase rain fed soybean yield and rainwater use efficiency have received little attention and the financial returns and costs of each option are also unknown. Dryland grain yield is a function of the interactive effects of management practices with soil types, weather patterns, and many ecological and geographic variables. Field trials alone are often not sufficient to account for all such interacting variables and determine management options that are optimal for different soils under various growing environments. However, the use of field-calibrated crop simulation models is considered a powerful tool for integrating the multitude of crop production variables and then selecting ideal management options with a given cropping-system scenario. The overall objectives are to identify cost-effective management practices to stabilize or improve dryland soybean yield and economic return in major soil types and growing environments across Mississippi. Mathematical models, in conjunction with field trials are used to determine the optimal soil conservation practices for improving the soil health across dominant soils in Mississippi.

Activity/Progress

Objective 1: Determine cost-effective management practices to stabilize or improve dryland soybean yield and economic return in major soil types and growing environments across Mississippi. This research will determine the effectiveness of cover crop during the fallow season, broiler litter, and municipal biosolids for improving soil health and increasing soil water infiltration, soil water holding capacity and organic matter, and minimizing runoff.

1.1 Field trials of Cover Crop and Brolier Litter at MSU Pontotoc Experiment Station in Pontotoc County

The Pontotoc field experiment was conducted since 2017, in collaboration with Dr. Mark Shankle. It is an eight-acre field which contains 2 types of soils, Atwood and Cascilla silt loam soils. In each year, five different cover crop species were planted with three different fertilizer treatments. The five cover crops consisted of: wheat, cereal rye, vetch, mustard/cereal rye, and native vegetation. The three fertilizer treatments were poultry litter, standard pelletized fertilizer, and no fertilizer. These were combined to create 15 different plots, which were replicated four times. We sampled plant samples, and both disturbed and undisturbed soil samples in the 60 plots to measure soil physical and chemical properties. Asgrow soybean (AG46×6) was planted in mid-May 15 each year at the seeding rate of 128,000 seeds/ac on 30 inch rows. We have installed TDR soil moisture sensors (Acclima Inc.) coupled to a datalogger (Campbell Scientific Inc.) and PR2 (dynamax Inc.) at depths of 0-6, 6-12, 12-18, 18-24, 24-36 inches.

Leaf area index of soybean fertilized with PL was much higher than soybean treated with inorganic fertilizer (Table 1-3). It appears soybean was more healthy in the plots where cereal rye with mustard grew off soybean season. The results revealed that cover crop played a role in nutrient retention and supply. Soybeans in those cover crop plots and the plots treated with poultry litter grew much better (Table 1 - 7). Soybean planted in mid-May grew better than planted two weeks later (Table 1).

There was no much difference in the chlorophyll content of soybean among different treatments (Table 8-10). It indicated that nitrogen was not deficiency no matter what fertilizer was applied, as cover crops were planted out of soybean seasons.

Table 1. Leaf area index of soybean planted 1 (mid May) and planted 2 (early June), in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter) in 2020.

Planted date		CR	CRm	NV	VE	WH	Avg
1	**Fert**	4.46	4.97	4.99	4.88	4.64	**4.79**
1	**None**	1.28	2.22	2.41	2.47	1.46	**1.97**
1	**PL**	5.56	6.96	5.63	5.86	6.16	**6.03**
	Avg	**3.76**	**4.72**	**4.34**	**4.40**	**4.09**	
2	**Fert**	2.96	3.17	2.99	3.09	2.30	**2.90**
2	**None**	1.93	2.11	2.04	1.97	1.74	**1.96**
2	**PL**	3.23	3.25	3.63	3.16	3.23	**3.30**
	Avg	**2.71**	**2.84**	**2.89**	**2.74**	**2.42**	

Table 2. Leaf area index of soybean planted on mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), measured at R6 stage on Aug. 17, 2021.

	CR	CRm	NV	VE	WH	Avg
Fert	2.69	3.00	2.32	2.54	4.00	**2.91**
None	1.68	1.61	1.94	3.14	1.74	**2.02**
PL	3.06	3.10	3.22	4.27	3.87	**3.50**
Avg	**2.47**	**2.57**	**2.49**	**3.32**	**3.20**	

Table 3. Leaf area index of soybean planted in early May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off-growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), measured at R5 stage on July 12, 2022.

	CR	CRm	NV	VE	WH	Avg
Fert	2.38	2.87	3.06	2.50	3.05	**2.77**
None	1.675	1.68	1.62	1.64	1.66	**1.65**
PL	3.36	2.97	4.11	3.33	3.80	**3.52**
Average	**2.47**	**2.50**	**2.93**	**2.49**	**2.84**	

Table 4. Plant height of soybean planted on mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), measured at R6 stage on Aug. 17, 2021.

	CR	CRm	NV	VE	WH	Avg
Fert	113.60	102.80	112.00	114.00	116.20	**111.72**
None	76.20	86.80	98.60	93.20	93.80	**89.72**
PL	121.20	122.40	124.40	141.20	115.80	**125.00**
Avg	**103.67**	**104.00**	**111.67**	**116.13**	**108.60**	

Table 5. Plant height of soybean planted in mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), measured at R5 stage on July 12, 2022

	CR	**CRm**	**NV**	**VE**	**WH**	**Avg**
Fert	75.00	71.75	74.00	68.70	76.15	**73.12**
None	59.70	65.60	61.75	62.60	65.60	**63.05**
PL	81.80	81.45	87.30	82.15	80.90	**82.72**
Average	**72.17**	**72.93**	**74.35**	**71.15**	**74.22**	

Table 6. Dry biomass of soybean planted on mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), measured at R6 stage on Aug. 17, 2021.

	CR	**CRm**	**NV**	**VE**	**WH**	**Avg**
Fert	10.16	9.62	8.50	13.47	6.84	**9.72**
None	5.59	6.88	8.77	5.81	2.64	**5.94**
PL	12.46	16.84	10.38	12.31	12.51	**12.90**
Avg	**9.41**	**11.11**	**9.22**	**10.53**	**7.33**	

Table 7. Dry total biomass (kg/m^2) at 65ºC of 5 plants and the plant numbers in 1 m long row, soybean was planted in mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), sampled on July 12, 2022.

	CR	**CRm**	**NV**	**VE**	**WH**	**Average**
Fert	6.32	6.49	6.69	5.97	6.31	**6.35**
None	5.02	5.67	5.77	5.63	4.86	**5.39**
PL	6.96	5.94	6.86	7.17	7.24	**6.83**
Average	**6.10**	**6.03**	**6.44**	**6.26**	**6.14**	

Table 8. The chlorophyll content of leaves of soybean planted 1 (mid May) and planted 2 (early June), in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter) in 2020.

Plant date		**CR**	**CRm**	**NV**	**VE**	**WH**	**Avg**
1	**Fert**	43.4	41.2	41.9	43.0	41.9	**42.3**
1	**None**	38.2	39.0	40.5	39.7	37.2	**38.9**
1	**PL**	42.7	43.4	44.3	44.1	43.0	**43.5**
	Avg	**41.4**	**41.2**	**42.2**	**42.3**	**40.7**	
2	**Fert**	45.3	45.8	46.1	46.7	45.0	**45.8**
2	**None**	43.0	44.2	43.3	42.7	44.0	**43.4**
2	**PL**	45.9	45.7	46.4	45.9	45.6	**45.9**
	Avg	**44.7**	**45.2**	**45.2**	**45.1**	**44.9**	

Table 9. The chlorophyll index of leaves of soybean planted on mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), measured at R6 stage on Aug. 18, 2021.

	CR	**CRm**	**NV**	**VE**	**WH**	**Avg**
Fert	44.0	41.6	39.4	40.3	44.0	**41.9**
None	43.7	39.8	40.1	41.2	40.9	**41.1**
PL	43.0	46.3	42.2	44.8	44.8	**44.2**
Avg	**43.6**	**42.6**	**40.5**	**42.1**	**43.2**	

Table 10. The chlorophyll index of leaves of soybean planted on early-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off-growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), measured at R5 stage on July 12, 2022.

	CR	**CRm**	**NV**	**VE**	**WH**	**Avg**
Fert	42.51	42.24	42.37	42.25	43.06	**42.48**
None	42.00	40.86	40.41	40.48	41.32	**41.01**
PL	43.01	43.49	43.10	43.60	44.14	**43.47**
Average	**42.51**	**42.19**	**41.96**	**42.11**	**42.84**	

Each plot was mechanically harvested on late September or early October, and the soybean grain yield was measured and calculated based on measured grain gravimetric moisture ranging from 12-15% (Table 11, 12 and 17). Averaged across all cover crop treatments, plots receiving poultry litter produced 4 bu/ac for early planted soybean and 2 bu/ac for late planted soybean. Averaged across all fertilizer treatments, there was no difference in grain yield for different cover crop plots. The highest yield was observed in plots planted cover crop NRCS mixture of mustard and rye, and vetch. Significant difference in yield was also found in the two cover crop plots receiving either inorganic or organic fertilizer, while plots treated with poultry litter produced higher yield. It appears that the fields planted NRCS mixture of mustard and rye, and vetch off soybean growing season and fertilized with poultry litter could produce higher grain yield. The greater yield was contributed from more number of pods (Table 16), instead of the the weight of 1000 seeds (Table 14) and the number of seeds (Table 15).

Table 11. The grain yield (bushel/acre) of soybean planted 1 (mid May) and planted 2 (early June), in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter) in 2020.

Plant date		NV	CR	CRm	VE	WH	Avg
1	**None**	34.5b	29.6b	36.2c	31.9c	29.3b	**32.3**
1	**Fert**	47.1a	48.6a	45.4b	43.5b	49.9a	**46.9**
1	**PL**	51.2a	48.5a	53.5a	52.5a	48.4a	**50.8**
	Avg	**44.3**	**42.2**	**45.0**	**42.6**	**42.5**	
2	**None**	33.7b	34.0b	34.7b	32.1b	33.2	**33.5**
2	**Fert**	50.9a	48.0a	49.7a	50.0a	48.2	**49.4**
2	**PL**	50.8a	51.5a	52.8a	52.6a	49.5	**51.4**
	Avg	**45.1**	**44.5**	**45.7**	**44.9**	**43.6**	

Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

Table 12. Grain yield (bu/ac) based on dry weight at 65ºC of 5 plants and the plant numbers in 1 m long row, soybean was planted on mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), sampled on Sept. 16, 2021.

	CR	CRm	NV	VE	WH	Avg
Fert	79.37	83.03	57.26	74.54	83.51	68.46
None	45.64	51.19	41.46	60.58	50.51	49.88
PL	85.19	64.92	75.10	91.97	90.81	81.60
Avg	70.07	66.38	57.94	75.69	73.87	

Table 13. Dry total biomass (kg/m^2) at 65ºC of 5 plants and the plant numbers in 1 m long row, soybean was planted on mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), sampled on Sept. 16, 2021.

	CR	CRm	NV	VE	WH	Avg
Fert	1.02	1.06	0.76	0.95	0.99	0.63
None	0.57	0.65	0.54	0.76	0.64	0.63
PL	1.14	0.98	1.01	1.18	1.14	1.09
Avg	0.91	0.89	0.77	0.96	0.92	

Table 14. Dry weight of 1000 seeds 5 plants at 65ºC (kg) and the plant numbers in 1 m long row, soybean was planted on mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), sampled on Sept. 16, 2021.

	CR	CRm	NV	VE	WH	Avg
Fert	109.93	111.95	98.05	111.90	121.24	110.00
None	109.08	107.79	106.37	107.32	114.56	109.02
PL	107.13	76.49	110.61	116.26	119.29	105.96
Avg	108.72	98.75	105.01	111.83	118.00	

Table 15. Number seeds per pod based on 5 plants, soybean was planted on mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), sampled on Sept. 16, 2021.

	CR	CRm	NV	VE	WH	Avg
Fert	3	3	3	3	3	3
None	2	2	2	2	3	2
PL	3	3	2	2	3	3
Avg	2	3	2	3	3	

Table 16. Number pods per plant based on 5 plants, soybean was planted on mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), sampled on Sept. 16, 2021.

	CR	CRm	NV	VE	WH	Avg
Fert	86	93	64	83	83	82
None	49	57	45	61	57	54
PL	91	90	77	94	81	86
Avg	75	80	62	79	72	

In 2022, we randomly sampled five plants in each of all plots, then oven dried at 65ºC for two days, weighted and calculated grain yield based on the plant numbers we counted in 1 m long row at 30 in row space. The yield data in Table 17 might be greater than the data from combined harvested soybeans. Table 17 clearly shows that the plots amended with poultry litter had the greatest yield compared with the plots without fertilization (59.57 vs. 34.12 bu/ac) or the plots applied with commercial inorganic fertilizer (59.57 vs. 51.86 bu/ac). As we averaged data for each cover crop across fertilizer treatments, the lowest yield was observed in native vegetation plots, which suggest that cover crop did play a role in soybean production. The great yield was found in plots with cereal rye and mustard, followed by winter wheat. It is different for the impact of the cover crop; the low yields in plots with native vegetation and cereal rye resulted from both smaller numbers of seeds and pods of their plants. Not much difference in seed weight was found among either fertilizer treatments or cover crop treatments.

Table 17. Grain yield (bu/ac) based on dry weight at 65ºC of 5 plants and the plant numbers in 1 m long row, soybean was planted in mid-May in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), sampled on Sept. 23, 2022.

	CR	**CRm**	**NV**	**VE**	**WH**	Average
None	35.62	36.60	26.32	35.00	37.05	34.12
Fert	49.92	56.56	44.57	50.78	57.47	51.86
PL	49.40	67.11	52.72	63.01	65.63	59.57
Average	44.98	53.42	41.20	49.59	53.38	

As averaged soil water content in topsoil (0-35 cm) of all plots planted different cover crops for each of fertilizer treatment, we found soil water content of poultry litter plots was lower than other two treatments in May 2021 (Table 18), probably because poultry litter application produced more and larger cover crop and soybean which consumed more water in soil (Table 1-8 and 13). Because the lower water content increased soil water storage capacity, in addition, the plots received poultry liter had greater Ksat values (Table 20) which indicate rain water can get into water quickly, therefore, it is beneficial for those plots to store more rain water for meeting soybean water requirement during critical growing stages.

Table 19 shows that soil water content in Vetch plots were lower than other cover crops, also in May before soybean grew up. No much difference in soil water content among the cover crop treatments after June, 2021.

Table 18. The soil volumetric water content of topsoil (0-35 cm) in plots receiving Fert (inorganic fertilizer), PL (poultry litter) and nothing (None) on different dates (Month/Day) in 2021.

Treatment	**5/14**	**5/18**	**5/19**	**5/20**	**5/24**	**5/26**	**5/27**	**6/3**	**6/17**	**7/1**	**7/16**	**8/3**	**8/17**	**9/1**	**9/16**
Fert	0.36	0.30	0.35	0.36	0.36	0.35	0.36	0.35	0.36	0.35	0.34	0.33	0.32	0.37	0.39
None	0.36	0.33	0.35	0.34	0.34	0.35	0.36	0.34	0.34	0.34	0.34	0.33	0.32	0.37	0.38
PL	0.22	0.27	0.29	0.31	0.32	0.33	0.33	0.34	0.35	0.33	0.32	0.32	0.31	0.36	0.37

Table 19. The soil volumetric water content of topsoil (0-35 cm) in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter), measured on different dates (Month/Day) in 2021.

Treatment	**5/14**	**5/18**	**5/19**	**5/20**	**5/24**	**5/26**	**5/27**	**6/3**	**6/17**	**7/1**	**7/16**	**8/3**	**8/17**	**9/1**	**9/16**
CR				0.37	0.36	0.37	0.34	0.34	0.34	0.34	0.33	0.31	0.30	0.36	0.37
CRm			0.35	0.34	0.34	0.33	0.33	0.33	0.34	0.33	0.33	0.32	0.31	0.36	0.35
NV		0.33	0.35	0.35	0.35	0.35	0.35	0.35	0.36	0.34	0.34	0.34	0.33	0.38	0.40
VE	**0.17**	**0.22**	**0.29**	**0.29**	**0.29**	**0.32**	**0.33**	**0.33**	**0.35**	**0.32**	**0.32**	**0.30**	**0.30**	**0.35**	**0.38**
WH	0.33	0.35	0.35	0.34	0.36	0.36	0.36	0.37	0.36	0.36	0.35	0.35	0.33	0.38	0.38

We took soil samples at the depths of 0-5 cm and 5-10 cm on 3 June 2021, then measured saturated soil hydraulic conductivity (Ksat) in late July and early Aug. 2021. The Ksat values shown in Table 20 indicates how fast rain water could get into soil. The Ksat values were identical for all plots grown different cover

crops, which indicated that cover crops have not yet been able to change Ksat. Poultry litter increased Ksat by 8% (1.49 vs. 1.38 cm min^{-1}) compared with the soil received commercial fertilizer. In other words, the fields treated with poultry litter could allow more rain water percolate into soil faster, it is in particular critical for intensive rainstorms. Intensive rainfall and intermittent drought frequently occur in the region. Therefore, more rain water retained in soil help in the mitigation of intermittent drought.

Table 20. The saturated soil hydraulic conductivity (unit: cm min^{-1}) in plots of different fertilizer treatments, receiving Fert (inorganic fertilizer) and PL (poultry litter) in late July and early Aug. 2021.

	CR	CRm	NV	VE	WH	Avg
Fert	1.5155	1.3311	1.3986	1.3166	1.3595	1.3843
None	1.4166	1.4717	1.4313	1.3727	1.4466	1.4278
PL	1.4285	1.4285	1.4940	1.6103	Not test	1.4903
Avg	1.4535	1.4104	1.4413	1.4332	1.4031	

Applying poultry litter for five years improved Ksat as compared to no fertilizer treatment (0.03 vs 0.02 cm.min^{-1}) as well as fertilizer treatment (0.03 vs 0.02 cm.min^{-1}) (01). The comparatively Low Ksat values of inorganic fertilizer and no fertilizer plots were due to the high bulk density. Although not significantly different, the cereal rye and mustard (mix) followed by vetch increased the Ksat at the depth 0-5 cm (0). Like that, winter wheat and cereal rye increased the Ksat but there was no significant difference among the cover crop species.

Poultry litter has the ability to reduce soil compaction by making the soil fluffier and healthy. The soil bulk density was significantly reduced with the application of poultry litter as compared to other fertilizer treatments at each depth 0-5 and 5-10 cm (Table 21). The cover crop showed no effect on bulk density in the topsoil (0-5 cm) but cereal rye cover crop significantly reduced the bulk density at the depth 5-10 cm as displayed in (022).

Winter wheat followed by vetch cover crops have reduced the wilting point water content at the 5-10 cm depth as compared to other cover crop treatments. There was a significant interaction between the cover crop and fertilizer treatment on soil water holding capacity and wilting point water content at each of the depths 0-5 and 5-10 cm. Cover crop showed a little effect on the plant available soil water content, but winter wheat resulted in a higher soil available water content for crop use at 0-5 cm depth. Poultry litter could significantly increase the soil water holding capacity by providing a soil cover which has led to conservation of soil moisture. The addition of poultry litter to soil surface has proven to increase the percentage of water content availability for crop use compared to other fertilizer treatments. There was no noticeable

Cover crop Treatment	Bulk density †	Soil water holding capacity	Permanent wilting point	Available water content	KSAT
	$g.cm^{-3}$	%	%	%	$cm.min^{-1}$
0-5 cm depth					
NV ¥	1.14 a	26.30	16.12	10.16	0.0157
CR	1.18 b	26.68	16.87	9.88	0.0018
WH	1.18 b	27.13	16.81	10.32	0.0059
VE	1.19 b	26.14	16.87	9.87	0.026
CRm	1.15 a	26.01	16.49	9.52	0.02
5-10cm depth					
NV	1.36 b	27.32 b	19.70 b	7.62	0.0156
CR	1.29 c	26.94 b	19.93 b	7.00	0.017
WH	1.39 ab	24.61ab	16.84 ab	7.76	0.018
VE	1.39 ab	24.06 ab	17.24 ab	7.03	0.005
CRm	1.41 a	28.46 a	21.19 a	7.26	0.0017

significant interaction between the cover crop and fertilizer source on plant available soil water content.

Table 21. Main effects of fertilizer treatments on mean soil bulk density, soil water holding capacity, permanent wilting point, available water content and saturated hydraulic conductivity at two soil depths 0-5 and 5-10 cm in 2022.

†Variables in column with no letters are not significant at the 0.05 level using Fisher's protected LSD.

Fertilizer Treatment	**Bulk density †** $g.cm^{-3}$	**Soil water holding capacity** %	**Permanent wilting point** %	**Available water content** %	**Ksat ¥** $cm.min^{-1}$
0-5 cm depth					
None	1.20 a	25.97	16.10	9.90	0.027
Fertilizer	1.17 a	26.47	16.53	9.93	0.021
Poultry Litter	1.14 b	27.28	17.26	10.02	0.034
5-10 cm depth					
None	1.40 a	23.95 b	17.66 b	6.29 b	0.0053
Fertilizer	1.38 a	27.54 a	19.87 a	7.67 b	0.01
Poultry Litter	1.33 b	27.34 a	19.42 a	8.05 a	0.02

Table 22. Main effects of cover crop on mean soil bulk density, soil water holding capacity, permanent wilting point, available water content and saturated hydraulic conductivity at two soil depths 0-5 and 5-10 cm in 2022.

†Variables in column with no letters are not significant at the 0.05 level using Fisher's Protected LSD.

The addition of poultry litter has increased the total carbon content and total nitrogen content (Table 23). The poultry litter application sequestered 8.1% more carbon than the inorganic fertilizer and 24% more than the no fertilizer treatment (0). The soils amended with manure retained 86% more carbon in the topsoil (0-5 cm) as compared to the 5-10 cm depth. The results revealed that N content was significantly increased in the 0-5 cm depth, but no changes were observed below 5 cm.

Poultry litter had significantly affected the soil pH in the topsoil (0-5 cm) (**Error! Reference source not found.**). With an exception to winter wheat cover crop at the 5-10 cm depth, no other over crop showed any significant effect on soil pH, but vetch followed by cereal rye and mustard (mix) showed reduced soil pH as compared to other cover crop treatment at both depths (0).

The application of poultry litter has tremendously increased the cation exchange capacity (CEC) of soil at two depths 0-5 and 5-10 cm (023). Cover crop did not show any positive influence on the cation exchange capacity at both depths as displayed in 0. Although not significant, the vetch cover crop has increased CEC as compared to other cover crops. Improved CEC indicates that the soil fertility is being increased. There was no significant interaction between the cover crop and fertilizer source at any depth.

Fertilizer Treatment	Total carbon † %	Total nitrogen %	Soil pH	Cation exchange capacity
0-5 cm depth				
None	1.39 b	0.16 b	5.68 a	7.95 b
Fertilizer	1.59 b	0.19 a	5.35 b	9.05 a
Poultry Litter	1.72 a	0.20 a	5.64 a	9.36 a
5-10 cm depth				
None	0.86	0.09	6.02	8.09 b
Fertilizer	0.91	0.10	5.85	8.69 a
Poultry Litter	0.92	0.10	6.00	8.63 a

Table 23. Main effects of fertilizer treatments on mean total carbon, total nitrogen, soil pH and cation exchange capacity at two soil depths 0-5 and 5-10 cm in 2022.

†Variables in column with no letters are not significant at the 0.05 level using Fisher's Protected LSD.

Table 24. Main effects of cover crop on mean total carbon, total nitrogen, soil pH and cation exchange capacity at two soil depths 0-5 and 5-10 cm in 2022.

Cover crop Treatment	Total carbon† %	Total nitrogen %	Soil pH	Cation exchange capacity
0-5 cm depth				
NV ¥	1.46	0.16	5.70	8.46
CR	1.54	0.19	5.62	8.53
WH	1.50	0.18	5.66	8.54
VE	1.56	0.18	5.38	9.62
CRm	1.75	2.00	5.46	8.72
5-10 cm depth				
NV	0.88	0.09	5.99	7.96
CR	0.88	0.10	6.02	8.67
WH	0.85	0.10	6.18	7.77
VE	0.91	0.09	5.69	9.42
CRm	0.94	0.10	5.90	8.52

†Variables in column with no letters are not significant at the 0.05 level using Fisher's Protected LSD.
¥ Abbreviations: NV - Native Vegetation, CR - Cereal Rye, WH - Winter Wheat, VE - Vetch, CRm - Cereal Rye and Mustard (mix).

Soils amended with poultry litter application for continuous five years showed higher concentrations of phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), creating a reservoir of nutrients for future crop production.

As averaged across all fertilizer treatments, significantly higher concentrations ($p<0.0001$) of P, K, Mg, S and Ca were observed in the surface depths 0-5 and 5-10 cm of the plots integrated with poultry litter as compared to fertilizer treatments (**Error! Reference source not found.**25). H igher sodium levels were observed in the soils amended with manure at two depths 0-5 and 5-10 cm. Cover crop did not show any significant effect on P, K, Mg, Ca, S, Ca and zinc at any depth (**Error! Reference source not found.**26).

Table 25. Main effects of fertilizer treatments on mean phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), sodium (Na) and zinc (Zn) in $mg.kg^{-1}$ at two soil depths 0-5 and 5-10 cm in

Fertilizer Treatment	**P †**	**K ¥**	**Mg**	**Ca**	**S**	**Na**	**Zn**
0-5 cm depth							
None	18.8 b	316.40 b	213.33 b	1924.27 b	27.33 b	29.87 b	3.29
Fertilizer	132.27 a	345.73 b	202.93 b	1960.4 b	51.73 a	33.07 b	14.47
Poultry Litter	147.57 a	488.89 a	285.29 a	2097.00 a	46.14 a	45.14 a	16.29
5-10 cm depth							
None	7.87 c	233.07 b	201.33 b	2256.40	21.07	32.93 b	2.19
Fertilizer	15.6 b	220.40 b	190.93 b	2359.60	36.93	36.27 b	3.71
Poultry Litter	23.47 a	322.93 a	240.00 a	2267.60	39.07	50.93 a	3.6

2022.

† Means followed by different letters in column are significantly different at the 0.05 level and variables with no letters are not significantly different.

Table 26. Main effects of cover crops on mean phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), sodium (Na) and zinc (Zn) in $mg.kg^{-1}$ at two soil depths 0-5 and 5-10 cm in 2022.

Cover crop Treatment	**P †**	**K ¥**	**Mg**	**Ca**	**S**	**Na**	**Zn**
0-5 cm depth							
NV ¥	129.33	387.11	240.22	2011.56	38.22	34.67	13.31
CR	75.78	410.67	232.00	1979.11	40.44	37.11	10.91
WH	83.11	346.67	230.44	2050.22	37.33	36.00	9.91
VE	100.89	397.11	240.22	2015.78	51.33	39.11	11.38
CRm 107.33		377.11	229.11	1913.56	40.89	33.33	11.13
5-10 cm depth							
NV	19.56	251.11	206.89	2142.67	34.22	41.33	4.18
CR	13.33	287.78	216.67	2396.67	30.22	40.44	3.24
WH	14.44	235.78	197.56	2243.33	28.00	38.22	2.53
VE	15.33	259.33	219.33	2394.44	38.44	42.44	2.84
CRm	15.56	260.00	213.33	2295.55	30.88	37.77	3.02

†Variables in column with no letters are not significant at the 0.05 level using Fisher's Protected LSD.
¥ Abbreviations: 1. NV - Native Vegetation, CR - Cereal Rye, WH - Winter Wheat, VE - Vetch, CRm - Cereal Rye and Mustard (mix)

1.2 Studies of Cover Crop, Chicken Litter and Biosolid at MSU North Farm in Oktibbeha County

This experiment was initiated in 2016 on a Marietta sandy loam and Leeper clay loam soils to determine the effects of timing and rates of broiler litter and bio-solid class A relative to inorganic fertilizer N on the soil water and rain water use efficiency and grain yield of soybean in the presence or absence of winter cover crop. Experimental design was a split-split plot replicated three times. The main plots were cover crop vs. no cover crop residue, the split plots were fall vs. spring application and the split-split plot included bio-solid, broiler litter, inorganic fertilizer and a control (**CK**, unfertilized). Biosolid was applied at the rate of 3 tons/acre in both fall (**Fall Agro BS**) and spring (**Agro BS**) from 2016-2019, broiler litter at the rate of 3 tons/acre was applied only in spring 2017 (**Agro Litter**). Winter cover crop was planted in November each year and chemically killed using Roundup on April next year. Pelleted biosolid and poultry litter at agronomic rate of 6 ton acre^{-1} and inorganic N fertilizer at the rate of 196 Ibs N acre^{-1} were applied to corn in 2019 growing season in the presence and absence of cover crop residue.

Cover crop cereal rye was planted on 10 Oct, 2019 and chemically terminated on 15 April, 2020. Soybean group 4 variety Asgrow (AG4835) was planted on 5 May, 2020 at the seeding rate of 130,000 plant per acre with 38" row spacing. Nothing was applied to any treatment to determine the impact of the residual nutrients on soybean production. Soybean was defoliated on 16 September 2020 and harvested for grain on October 8, 2020. Grain samples were collected during harvest for each plot and will be analyzed for grain nutrient concentration and grain protein. Soybean was grown in 2017 and 2020 under residual nutrient from broiler litter and biosolid applied to corn (2016), cotton (2018) and corn (2019). At harvest on 10/5/2020, the two middle rows were harvested using two rows combine. Total of 36 plots were harvested.

In 2020, soybean was grown in residual plots. No fertilizer, biosolid or poultry litter was applied. The fertilizer treatments mentioned as below and in table 27 represent the treatments from 2016 to 2019. Soybean in the plots treated with high biosolid had 2 bu/acre more grain yield under cover crop than no cover crop. The plots even produced 3.8 and 1.5 bu/acre more in the absence of cover crop. No difference was observed between cover crop and without cover crop for the inorganic fertilizer treatment. It is not surprising if soybean grain yield be greater in the absence of cover crop than in the presence of cover crop residues. Because major part of residual nutrient, particularly N, was utilized by cover crop. The cover crop was winter wheat in which the residue decomposes very slow and nutrients most likely released late in the season and they might not be available to soybean plants at peak demand (flowering and pod forming growth stages, mainly in June) during growing season. In this case the presence of cover crop is disadvantage agronomically.

Table 27. The grain yield (bushel/acre) of soybean with and without cover crop cereal rye, soybean growth relied on residual nutrients in plots of different fertilizer treatments implemented from 2016 to 2019.

Plant date	**CK**	**High BS**	**Agro BS**	**Agro Litter**	**Agro Fert**	**Fall Agro BS**	**Avg**
No cover	71.11	64.08	67.62	62.98	67.98	65.88	**66.61**
Cover	67.21	66.39	63.73	61.31	67.11	62.40	**64.69**

After the termination of cover crops in May 2022, undisturbed core soil samples at the depths of 0-5 cm and 5-10 cm were collected in all the plots of all treatments. Along with core sampling, loose soil samples were also collected at the depths of 0-5 cm, 5-10 cm, 10-15 cm, and 15-30 cm. A portion of these loose soil samples was air-dried and sieved through a 2 mm sieve to run a chemical analysis and to determine the particle size distribution. The core sampling was done to measure bulk density, field capacity, permanent wilting point, and saturated hydraulic conductivity.

As Table 28 shows, the soil bulk density at the 0-5 depths were significantly affected by the integration of cover crops in the crop system. The Ksat was significantly increased when integrated with the peas cover crop at the depth 5-10 cm. The FC and PAW were increased when integrated with cover crops as compared to no cover crop treatment at the soil depth 0-5 cm. The mixed cover crop treatment (rye + peas + radish) has significantly increased the FC and PAW in comparison with other cover crop treatments. At the soil depth 5-10 cm, the cover crop treatments resulted in higher FC and PAW as compared to the no cover crop treatment (**Error! Reference source not found.**).

Table 28. Main effects of cover crops on mean bulk density, soil water holding capacity, permanent wilting point, available water content and saturated hydraulic conductivity (Ksat) at depth 0-5 cm and 5-10 cm, May 2022.

Cover crop Treatment	**Bulk density †**	**Soil water holding capacity**	**Permanent wilting point**	**Available water content**	**Ksat ¥**
	$g.cm^{-3}$	**%**	**%**	**%**	**$cm.min^{-1}$**
0-5 cm depth					
NCC	1.43 a	26.94	16.89	10.05 b	0.0125
Peas	1.35 b	26.45	16.07	10.50 b	0.0032
Rye	1.33 b	27.50	17.00	10.51 b	0.0010
Mixed	1.38 b	29.05	18.49	10.56 a	0.0025
5-10 cm depth					
NCC	1.48	27.70	20.23	7.47	0.00031 b
Peas	1.48	29.09	20.86	8.23	0.001 a

Rye	1.41	30.87	23.21	7.66	0.00078 b
Mixed	1.45	29.42	19.48	9.94	0.0042 b

†Variables in column with no letters are not significant at the 0.05 level using Fisher's Protected LSD.

Total carbon (TC) was increased by the rye and the mixture of cover crops as compared to other cover crop treatments at the depth 0-5 and 5-10 cm. Soil organic matter is significantly affected by the integration of cover crops under different cropping systems at two depths 0-5 and 5-10 cm.

The cover crop integration significantly affected pH at the depth 5-10 cm. The cropping system also had a significant impact on the soil pH. Peas and rye cover crop could reduce the soil pH as compared to no cover crop treatment (Table 29).

Cover crop affected the magnesium content at the depth 5-10 cm. Of the micro-nutrients that were measured, zinc and manganese were least affected by the addition of cover crops at any depth. Although, not significantly different, the phosphorus content was found to be increased with the integration of peas cover crop and cover crop mixture increased the potassium levels in the topsoil (0-5 cm) (0).

Table 29. Main effects of cover crop on mean total carbon, total nitrogen, soil pH, cation exchange

Cover crop Treatment	**Total carbon %**	**Total nitrogen %**	**Soil pH**	**Cation exchange capacity**	**Organic Matter**
0-5 cm depth					
NCC	1.87	0.21	8.03	21.80	1.30 b
Peas	1.82	0.26	7.95	23.80	1.35 b
Rye	1.82	0.22	7.96	24.00	1.49 a
Mixed	1.83	0.27	8.04	24.04	1.39 b
5-10 cm depth					
NCC	1.66	0.21	8.10 b	25.03	1.02 b
Peas	1.56	0.21	8.20 a	25.00	1.00 b
Rye	1.63	0.20	8.18 a	25.59	1.13 a
Mixed	1.66	0.22	8.20 a	25.78	1.11 a

capacity and organic matter under two cropping systems at depth 0-5 cm.

†Variables in column with no letters are not significant at the 0.05 level using Fisher's Protected LSD.

Table 30. Main effects of cover crop on mean soil chemical health indicators under two cropping systems at depth 0-5 cm.

†Variables in column with no letters are not significant at the 0.05 level using Fisher's Protected LSD.
¥ Abbreviations: P- Phosphorus, K-Potassium, Mg- Magnesium, Ca- Calcium, Mn- Manganese, Na- Sodium and Zn – Zinc.

Objective 2: Application of mathematical models, in conjunction with field trials in Objective 1,

Cover crop Treatment	**P**	**K**	**Mg**	**Ca**	**Mn**	**Na**	**Zn**
0-5cm depth							
NCC	97.13	207.25	86.38	4265.88	42.75	22.50	3.83
Peas	99.75	217.31	88.60	4392.88	45.19	24.75	3.86
Rye	92.87	216.56	87.12	4443.93	43.31	23.00	3.77
Mixed	96.44	233.63	88.81	4437.94	44.12	23.44	3.65
5-10 cm depth							
NCC	52.75	135.00	54.00	4435.00	42.17	21.75	2.07
Peas	52.19	137.19	54.75	4743.94	41.94	24.19	1.93
Rye	54.44	154.88	61.63	4829.24	43.25	22.43	2.1
Mixed	52.37	176.12	61.12	4864.19	44.12	24.12	1.9

to determine the optimal soil conservation practices for improving the soil health score across dominant soils in Mississippi.

Simulation research using model RZWQM2 under long-term diverse weather conditions assisted field experiments to determine the following results which was difficult or impossible for field studies to obtain: (1) planting cover crop (CC) reduced drainage deep percolation by 69 mm (11%), 53 mm (15%), and 51 mm (21%) and increased evapotranspiration by 79 mm (55%), 81 mm (57%), and 73 mm (56%) in wet, normal, and dry years, respectively; (2) planting CC decreased surface evaporation by 38 mm (24%) for soybean growth periods. As compared with no CC scenario, model estimates indicated planting CC increased soybean yield by 4% (134 kg ha^{-1}; approximately 2 bu $acre^{-1}$) and improved soybean water use efficiency (WUE) by 9% (0.64 vs. 0.59 kg m^{-3}). Long-term use of winter wheat CC, if managed similarly, can increase soil water storage and improve rain water use efficiency without sacrificing soybean growth.

RZWQM2 model also determined the effect of wheat winter cover crop (WCC) on net nitrogen (N) mineralization and nitrate leaching in a 80-yr (1938 to 2017) corn-soybean rotation and soil water balance and dynamic under future 60-yr (2020-2079) climate conditions, in Mississippi Blackland Prairie. Based on the annual soil N dynamics, the model also estimated nitrate losses as deep percolation during wheat, corn, and soybean growth periods between WCC and winter fallow (WF) under different seasonal rainfall patterns, 'wet', 'normal', and 'dry' years.

80-yr of RZWQM2-simulation demonstrated that, compared to winter fallow system, planting winter wheat cover crop (CC) into a corn-soybean system increased annual N mineralization by 15% (19 Ibs N ac^{-1}), improved annual denitrification by 9% (1 Ibs N ac^{-1}), and reduced annual nitrate loss to deep percolation by 20% (15 Ibs N ac^{-1}). On the basis of a full year simulation, the wheat winter CC grown from early October to early April led to a 24% reduction in nitrate-N leaching (14 Ibs N ac^{-1}). The efficacy of wheat winter CC in reducing nitrate leaching was better in wetter than dry winter months. Incorporating wheat winter CC into corn-soybean rotation is effective for promoting nitrogen mineralization and reducing nitrate loads to drainage deep percolation in humid regions.

Impacts and Benefits to Mississippi Soybean Producers

This research directly impacts 51% of the total soybean production in the state which is not irrigated (1.12 million acres with a value of $0.56 billion). With a 4% and 8% increase by cover crop and poultry litter in dryland yield and 5% decrease in costs, the profitability can be expected to rise by about $32 and $64 per acre. Beyond the economic impact, soil organic matter and soil health were also improved.

End Products since the project was funded in 2020:

Publications and Manuscripts:

(1) Chang, T., G. Feng, V. Paul, A. Adeli, J. Brooks, and J. Jenkins. 2023. Soil health assessment for different tillage and cropping systems to determine sustainable management practices in a humid region. *Soil & Tillage Research* (in pressing).

(2) Zhang, Y., G. Feng, T. Chang, G. Bi, and J. Jenkins. 2023. Effects of organic farming systems on soil total organic carbon, nutrients and soil health under high tunnel conditions. *Soil Sci. Soc. Am. J.* (submitted).

(3) Chang, T., G. Feng, V. Paul, A. Adeli, and J. Brooks. 2022. Soil health assessment methods: progress, application and comparison. *Advances in Agronomy,* 172: 129-200.

(4) Effect of Poultry Litter Applications on Soil Physical Properties on the website of Mississippi-crops.com, 2021. The work was reported in MSU Extension publication, the newsletter (goes by 1600 emails) of Mississippi Crop Situation and posted on the blog and tweets with 2500 followers, LinkedIn about 700 more exposures.

(5) Poultry litter's efficiency as fertilizer studied | The Western Producer. July 22 issue of Western Producer, 2021.

(6) The surprising power of chicken manure" news story on the Agronomy, Crops and Soils web pages: soils.org, agronomy.org and crops.org and CSA news (May, 2021). The MSPB work and the articles as above were reported by 41 Canadian and American social media, reached over 3.6 million people, and the publicity was worth almost $10K.

(7) Feng, G., H. Tewolde, B. Zhang, N. Buehring, A. Adeli. 2021. Soil physical and hydrological properties

as affected by a five-year history of *broiler litter* applied to a cotton-corn-soybean rotation system. *Soil Science Society of American Journal*.1-14.

(8) Feng, G. and S. Anapalli. 2022. Integrating models with field experiments to enhance research: cover crop, manure, tillage, and climate change impacts on crops in a humid climate. In ASA, CSSA, SSSA Books, editors: Wendroth, O., K. Kersebaum, and L. Ahuja, Volume 10 of the Advances in Agr Systems Modeling on Modeling Soil-Plant-Climate-Management Processes and Their Interactions in Cropping Systems, Challenges for the 21st Century. *Li, Y.* D. Tian, G. Feng, W. Yang and L. Feng. 2021. Climate change and cover crop effects on water use efficiency of a corn-soybean rotation system. *Agricultural Water Management* 255 (2021) 107042. https://doi.org/10.1016/j.agwat.2021.107042.

(9) Yang, W., G. Feng, A. Adeli, H. Tewolde, and Z. Qu. 2021. Simulated long-term effect of wheat cover crop on soil nitrogen losses from no-till corn-soybean rotation under different rainfall patterns. *Journal of Cleaner Production* 280: 124255. https://doi.org/10.1016/j.jclepro.2020.124255.

(10) Yang, W., Feng, G., Read, J., Ouyang, Y., and Li, P. 2020. Impact of cover crop on corn-soybean productivity and soil water dynamics under different seasonal rainfall patterns. *Agronomy Journal*, 112: 1-15. DOI: 10.1002/agj2.20110.

(11) Li, X., G. Feng, H. Tewolde, A. Adeli, and J. Jenkins. 2020. Effect of improved soil organic matter using poultry litter on field water holding capacity of silt loam soils. *Land Degradation and Development* (internal review).

(12) Feng, G., and R. Sui. 2020. Evaluation and calibration of soil moisture sensors in undisturbed soils. *Transactions of the ASABE*. 2020. 62(2): 1-11. https://doi.org/10.13031/trans.13428

<u>Presentations and Published Abstracts:</u>

(1) Khanal, P., G. Feng, Y. Huang and H. Ming. 2023. Analysis of big spatiotemporal data: soybean acreage and yield prediction in the southeast USA. Spring Undergraduate Research Symposium. Mississippi State University, Starkville, MS. April 14, 2023.

(2) Kovvuri, R.N., G. Feng, G. Bi, M. Shankle, and H. Tewolde. 2023. Cover cropping and poultry litter improve soil physical and hydraulic properties in dryland conditions. The Annual Mississippi Water Resources Conference, Starkville, MS. March 28-30, 2023.

(3) Khanal, P., G. Feng, Y. Huang and H. Ming. 2023. Predicting planted acreage and yield of soybean in wet, normal and dry years in Mississippi state using APEX model. The Annual Mississippi Water Resources Conference, Starkville, MS. March 28-30, 2023.

(4) Kovvuri, R.N., G. Feng, G. Bi, A. Adeli, and J. Jenkins. 2023. Improved soil health with cover cropping and crop rotation. The Annual Mississippi Water Resources Conference, Starkville, MS. March 28-30, 2023.

(5) G. Feng. 2023. Agriculture in Mississippi state: challenge, opportunity, perspective and solutions. The 87th Annual Mississippi Academy of Sciences meeting. Biloxi, MS. Feb. 23-24, 2023.

(6) Kovvuri, R.N., G. Feng, G. Bi, A. Adeli, and J. Jenkins. 2023. Soil health as influenced by the integration of cover crops in different cropping systems in North-central Mississippi. Mississippi Academy of Sciences Annual Meeting, Biloxi, MS. Feb. 23-24, 2023.

(7) Feng, G., and Y. Ouyang. 2023. Agronomic Management Practices for Soil, Water and Nutrients Conservation in a Humid Region. ASABE 2023 International Soil Erosion Research Symposium.

Aguadilla, Puerto Rico. Jan 8-13, 2023.

(8) Feng, G. 2022. Interactions between surface, vadose and ground water as affected by crop rotation and irrigation. International symposium entitled "Field and Modeling Research on Exchange between Vadose and Ground Water: Progress, Challenges, and Solutions" at the ASA-SSSA-CSSA Annual Meeting, Baltimore, Maryland. Nov. 5-8, 2022 (invited).

(9) Kovvuri, R.N., G. Feng, G. Bi, H. Tewolde, and M. Shankle. 2022. Influence of poultry litter and integration of cover crops on dryland soybean production. The ASA-SSSA-CSSA Annual Meeting, Baltimore, Maryland. Nov. 5-8, 2022.

(10) Kovvuri, R.N., G. Feng, G. Bi, A. Adeli, and J. Jenkins. 2022. Influence of cover crops on soil physical and chemical properties in North-central Mississippi. The ASA-SSSA-CSSA Annual Meeting, Baltimore, Maryland. Nov. 5-8, 2022.

(11) Feng, G. 2022. Developing sustainable, healthy and climate-resilient agroecosystems. Nottingham Trent University, Nottinghamshire, United Kingdom. Oct. 26, 2022 (Invited).

(12) Kovvuri, R.N., G. Feng, G. Bi, M. Shankle, and H. Tewolde. Effects of integrating cover crop and poultry litter on dryland soybean production and soil hydraulic properties. Fall Graduate Research Symposium. Mississippi State University, Oct. 22, 2022.

(13) Ekanem, E., and G. Feng. 2022. Constructing a wet sieve apparatus to measure soil aggregate size. Summer Undergraduate Research Symposium. Mississippi State University, Aug. 2, 2022.

(14) Kovvuri, R.N., G. Feng, G. Bi, M. Shankle, and H. Tewolde. 2022. Effects of integrating cover crops and poultry litter on dryland soybean yield and soil hydrologic properties. The 4^{th} Annual Summer Science & Engineering Research Symposium, Mississippi Academy of Sciences. Mississippi State University. June 8, 2022 (https://msacad.org/).

(15) Gamagedara, Y., G. Feng, and N. Wijewardane. 2022. Comparison of vis-NIR and MIR spectroscopy for estimation of total carbon and nitrogen using a Mississippi soil dataset. The 4^{th} Annual Summer Science & Engineering Research Symposium, held by Mississippi Academy of Sciences. Mississippi State University. June 8, 2022 (https://msacad.org/).

(16) Feng, G. 2021. Invited oral presentation: Effectiveness of Organic Agriculture Practices in Improving Soil Organic Matter and Soil Health. International symposium entitled "Soil Organic Matter Dynamics and Soil Health: Honoring the Contributions of Dr. Cynthia Cambardella" at the ASA-SSSA-CSSA Annual Meeting, Salt Lake City, UT. Nov. 8, 2021.

(17) Feng, G. 2021. Invited oral presentation: Biochar Use Strategies for Sustainable Crop Production and Soil Health. International symposium entitled "Biochar for Sustainable Soil Health: Perspectives and Opportunities" at the ASA-SSSA-CSSA Annual Meeting, Salt Lake City, UT. Nov. 10, 2021.

(18) Chang, T., G. Feng, A. Adeli, V. Paul, D. Reginelli, and J. Jenkins. 2021. Soil health as affected by long-term application of poultry litter and cropping patterns under humid subtropical climates. Agronomy Abstract. the ASA-SSSA-CSSA Annual Meeting, Salt Lake City, UT. Nov. 7-11, 2021.

(19) Zhang, Y., G. Feng, G. Bi, S. Yu, D. Reginelli, and J. Jenkins. 2021. Sustainable organic farming system for improving soil nutrients management and soil chemical health. Agronomy Abstract. the ASA-SSSA-CSSA Annual Meeting, Salt Lake City, UT. Nov. 7-11, 2021.

(20) Chang, T., G. Feng, A. Adeli, V. Paul, D. Reginelli, and J. Jenkins. 2021. Soil health as affected by long-term wheat cover crop in no-till and conventional tillage systems. Agronomy Abstract. the ASA-SSSA-CSSA Annual Meeting, Salt Lake City, UT. Nov. 7-11, 2021.

(21) Zhang, Y., G. Feng, G. Bi, S. Yu, D. Reginelli, and J. Jenkins. 2021. Effects of Organic Farming Systems on Soil Health. Agronomy Abstract. the ASA-SSSA-CSSA Annual Meeting, Salt Lake City, UT. Nov. 7-11, 2021.

(22) Chang, T., G. Feng, A. Adeli, V. Paul, D. Reginelli, and J. Jenkins. Spatial variability of soil chemical properties following long-term poultry litter application. ASA Southern Branch Annual Virtual Meeting. Jan. 30, 2021.

(23) Chang, T., G. Feng, V. Paul, D. Reginelli, and J. Jenkins. Effects of cover crops on soil health and sustainability of corn-soybean cropping system under future climate change scenarios. ASABE Annual International Virtual Meeting. July 11-14, 2021.

(24) Zhang, Y. G. Feng, G. Bi, S. Yu, D. Reginelli, and J. Jenkins. Measuring soil hydraulic conductivity, aggregates and other hydraulic properties and evaluating the sustainability of agricultural land use. ASABE Annual International Virtual Meeting. July 11-14, 2021.

(25) Zhang, Y. G. Feng, G. Bi, S. Yu, D. Reginelli, and J. Jenkins. Sustainable organic farming system for improving soil aggregates, infiltration and water retention capacity to minimize effects of drought and flood. ASABE Annual International Virtual Meeting. July 11-14, 2021.

(26) Chang, T., G. Feng, V. Paul, D. Reginelli, and J. Jenkins. Soil health as affected by long-term no-till wheat cover crop, corn, and soybean rotations in the Southeast United States. ASABE Annual International Virtual Meeting. July 11-14, 2021.

(27) Feng, G., H. Tewelde, A. Adeli, and D. Reginelli. 2020. Invited oral presentation: advances in 4Rs research on manure application to row crops for improving soil health in the Southeastern USA. International symposium entitled "Emerging Needs in 4Rs Nutrients Research" at the ASA-SSSA-CSSA virtual international meeting, Nov. 9, 2020.

(28) Chang, T., V. Paul, G. Feng, A. Adeli, and H. Tewolde. Impact of poultry litter on soil chemical health in four agroecosystems in Mississippi. Agronomy Abstract. ASA-CSSA-SSSA International Annual Virtual Meeting. Nov. 9, 2020.

(29) Pan, X., G. Feng, S. Samiappan, Z. Wang, Y. Gao, Z. Meng, X. Dang, J. Wang, and Y. Han. 2020. Automated mapping of land use/land cover in Google Earth engine platform using multispectral sentinel-2 and MODIS. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2021.

(30) Chang, T., V. Paul, G. Feng, A. Adeli, and J. Brooks. 2020. Determining a minimum dataset for assessing soil health in Mississippi. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(31) Zhang, Y. G. Feng, G. Bi, and S. Yu. 2020. Soil physical health after four-year of organic fertilizer application under greenhouse in the South United States. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(32) Paul, V., T. Chang, G. Feng, and A. Adeli. 2020. Soil health assessment methods: a comparative study. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(33) Zhang, Y. G. Feng, G. Bi, and S. Yu. 2020. Effects of cover crops on soil physical health in South American organic farming systems. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(34) Li, Y. G. Feng, H. Tewolde, M. Yang and F. Zhang. 2020. Long-Term Effects of Biochar on Fertility, Physical and Hydrological Properties and crop Yield of Dissimilar Soils in Mississippi State. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(35) Gao, F. G. Feng. 2020. Impact of climate change and cropping systems on groundwater recharge in a humid region. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(36) Li, Y. G. Feng, and H. Tewolde. 2020. Soil water characteristic in relation to textural composition and organic matter content under biochar application. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(37) Chang, T., V. Paul, and G. Feng. 2020. Methods for assessing the impact of soil amendments and cover crops on soil health. The Annual Mississippi Water Resources Conference, Jackson, MS. March 31-April 1, 2020.

(38) Feng, G., Li, X., and Reginelli, D. How high can we go: defining and reaching the threshold for soil organic matter to improve soil water holding capacity? EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-9678, https://doi.org/10.5194/egusphere-egu2020-9678, 2020.

(39) Feng, G., Han, Y., Ouyang, Y., and Jing, W. Sustainable management of groundwater for mitigation of declining water tables in the Mid-South United States: challenges and potential solutions, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-6055, https://doi.org/10.5194/egusphere-egu2020-6055, 2020.

(40) Feng, G. and D. Reginelli. 2020. Improving dryland soybean yield, water use efficiency, and health of dominant soils across Mississippi. The Annual Mississippi Water Resources Conference, Jackson, MS. https://www.wrri.msstate.edu/abstract.php?y=2020.

(41) Han, Y., G. Feng, Y. Ouyang, W. Jin, Z. Liu, and J. Jenkins. 2020. The influence of agricultural water management practices on groundwater table and recharging in Big Sunflower Watershed. The Annual Mississippi Water Resources Conference, Jackson, MS. https://www.wrri.msstate.edu/abstract.php?y=2020.

(42) Zhang, Y., G. Feng, G. Bi, and S. Yu. 2020. Impact of long-term organic fertilizer on soil physical health of high tunnels in the Southern United States. The Annual Mississippi Water Resources Conference, Jackson, MS. March 31-April 1, 2020.

(43) Heng, T., G. Feng, D. Reginelli, X. He, F. Li, and J. Jenkins. 2020. Impact of conventional and water-saving irrigation schemes on soybean yield in Big Sunflower River Watershed. The Annual Mississippi Water Resources Conference, Jackson, MS. https://www.wrri.msstate.edu/abstract.php?y=2020.