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MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT NO. 62-2018
2018 ANNUAL REPORT

TITLE: Stabilizing dryland soybean yield and profit in dominant soils across Mississippi

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REPORT OF PROGRESS/ACTIVITY

Progress for Objective 1

Cover crop and application of poultry litter and biosolids may help dryland grain production by making the soil fluffier (reducing bulk density), and increasing organic matter, moisture holding capacity and infiltration rate, and improving aggregate stability and water use efficiency. In order to identify effective management practices for stabilizing or increasing dryland soybean yields and water use efficiency, we started evaluating management of broiler litter, municipal biosolids, and cover crop during the fallow season in 16 soil types at 7 locations/growing environments across east and western Mississippi (**Fig. 1-2**).

<u>Sensor installation and soil and plant measurements</u>

We have installed soil matric potential sensors (Watermark, Irrometer) and TDR soil moisture sensors (Acclima Inc.) coupled to a datalogger (Campbell Scientific Inc.) at depths of 0-6, 6-12, 12-18, and 18-24 inches at sites near Brooksville, Pontotoc, and Stoneville. An infrared radiometer was installed above the soybean canopy at Brooksville and Pontotoc to measure canopy temperature in an effort to detect soil-plant water status.

Soybean developmental growth stage, plant height, canopy cover, plant dry biomass, and gravimetric soil moisture are measured biweekly by harvesting plants from 3 30-cm-long row sections in each plot, along with soil samples using a soil probe to measure the gravimetric soil moisture. Leaf Area Index is also measured every 16 days using a Decagon Inc. AccuPar LP-80.
Soil aggregates, field capacity, plant permanent wilting point water content, saturated hydraulic conductivity, and on-site infiltration rate were measured in the field at MSU Verona Experiment Station in this Spring.

<u>Irrigation Study at MSU Brooksville Station in Noxubee County</u>

The study was conducted at a 3-acre, furrow-irrigated field which contains Brooksville silty clay soil. Irrigated and rainfed treatments are replicated three times and randomized in the two blocks of wheat cover crop and non-cover crop. As a result, we have three irrigated and three rainfed non-cover crop plots as well as three irrigated and three rainfed wheat cover-crop plots. Irrigation is applied as root zone soil moisture reaches 50% of plant-available water. The amount of each irrigation event is equivalent to 50% of field capacity for each irrigation treatment. For the 2018 growing season, we irrigated 5 times based on soil moisture measurements.

Table 1: Irrigation amounts applied at MSU Brooksville Station	
Date	**Irrigation Amount (mm)**
6/6/2018	60
6/25/2018	65
7/10/2018	89
7/26/2018	82
8/6/2018	86

Maturity group IV cultivar Asgrow 4632 was planted at 120,000 seeds per acre on May 3, 2018. Row spacing was 38 inches. On November 6, 2017, 80 lb/acre of wheat was planted in the cover crop section of this field. Before burndown of the wheat cover crop, we took biomass measurements to estimate the cover crop biomass in the field. We also took initial soil moisture and nutrient samples to continuously monitor the field characteristics throughout this study. A water balance will also be calculated to determine cover crops' effect on soil moisture and soybean water consumption. We are taking plant phenology data, plant height, and cover and LAI data throughout the growing season. All those measurements have been taken 8 times throughout the growing season.

Table 2: Yield results from Irrigation Study at MSU Brooksville Station	
Plot	**Yield (bu/ac)**
Wheat Cover Crop Irrigated Plots	32
Wheat Cover Crop Non-Irrigated Plot	31
No Cover Crop Irrigated Plots	31
No Cover Crop Non-Irrigated Plots	31

Chicken Litter Study at MSU Verona Experiment Station in Lee County

We have evidence that fertilizing soybean with poultry litter results in more grain yield than fertilizing with traditional synthetic fertilizers. The grain yield benefit may last an additional 2 to 3 years with one relatively high application of 3 ton/acre. In other words, the soybean yield benefit of applying 1 ton/acre every year for 3 years may be the same as applying 3 ton/acre one year followed by none the following 2 to 3 years. The unused nutrients remain in the soil and become available to soybean in the following seasons.

In 2015-2017, MG 4 soybean was planted on a Leeper sandy loam soil in May of each year in plots with a history (2010-2014) of 1 and 3 ton/acre poultry litter applications and crop rotation schemes. The rotation schemes in 2010-2011-2012-2013-2014 consisted of CMBBM, CMCBM, CCCCC, and CCMMB, where C=cotton, M=corn, and B=soybean. Planting density was 137,000 seeds/acre on 38-inch-wide rows. The design is a randomized complete block with a split-plot treatment arrangement where rotation treatments during the first phase of this research were assigned to main plots and litter applications to subplots. Treatments are replicated four times. For the 2018 growing season, measurements were conducted 6 times for canopy cover, growth stage, plant height, LAI, biomass, and soil water and nutrient contents.

As Table 3 shows, in comparison with commercial inorganic fertilization application, poultry litter addition for 4 consecutive years reduced bulk density by 6%, and significantly increased field capacity and plant available water content by 20% and 41%, respectively. Saturated hydraulic conductivity and infiltration rate of the soil amended by poultry litter were approximately three and two times that of the soil that received inorganic fertilizer. These results suggest that poultry litter application is an effective management practice for promoting more rain water to percolate into soil and increasing soil water holding capacity. This option could contribute to stabilizing or increasing dryland soybean yield and profit in dominant soils across Mississippi. There were no significant differences in soil physical and hydraulic properties among different rotations.

Table 3. Means of bulk density (ρ_b), field capacity (FC), plant available water content (AWC), saturated hydraulic conductivity (Ksat), and infiltration rate, as influenced by poultry litter and inorganic fertilizer applications to soybean field, Verona, MS.

	ρ_b	FC	AWC	Ksat	Infiltration
Treatment	g cm^{-3}	%	%	10^{-5} m s^{-1}	mm h^{-1}
Control	1.43 a	31.07 b	18.80 b	0.16 b	700.63 b
Fertilizer	1.42 a	30.69 b	18.76 b	0.32 b	926.24 b
Poultry litter	1.34 b	36.80 a	26.36 a	0.92 a	1636.00 a

† Means followed by the same letter within a column are not significantly different at $P<0.05$

Table 4. Means of bulk density (ρ_b), field capacity (FC), plant available water content (AWC), saturated hydraulic conductivity (Ksat), infiltration rate, as influenced by rotations under poultry litter and inorganic fertilizer applications to soybean, Verona, MS.

	ρ_b	FC	AWC	Ksat	Infiltration
Rotation	g cm^{-3}	%	%	10^{-5} m s^{-1}	mm h^{-1}
CCMMBB	1.41 a	33.60 a	23.18 a	0.53 a	993.99 a
CCCCCB	1.40 a	32.00 a	20.34 a	0.28 a	1101.37 a
CMCBMB	1.41 a	33.88 a	21.26 a	0.33 a	1247.14 a
CMBBMB	1.37 a	31.93 a	20.44 a	0.71 a	1007.98 a

† Means followed by the same letter within a column are not significantly different at $P<0.05$

Cover Crop Study at MSU Pontotoc Experiment Station in Pontotoc County

The Pontotoc field experiment was continued this year in collaboration with Dr. Mark Shankle. It is an eight-acre field which contains Atwood and Cascilla silt loam soils. In the fall of 2017, 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 45 of the 60 plots to measure initial physical soil properties, as well as soil nutrients and soil moisture before spring planting of soybeans. We also took cover crop biomass samples to measure the amount of cover crop biomass that was present in the plots.

Asgrow soybean (AG46×6) was planted on May 1, 2018 at the seeding rate of 128,000 seeds/ac on 30-inch-wide rows. During the growing season, we have been monitoring biomass, plant height and cover, LAI, and soil water content in wheat and native plots. Before soybean harvest, we will collect soil samples again in the same 45 plots to determine soybean water consumption, as well as collect yield data from those plots. We have collected both soil and plant samples 10 times throughout the 2018 growing season.

Cover Crop Study at Stoneville Experiment Station in Washington County

A study of cover crop was initiated on a sandy loam and a clay loam soil in an approximately 3-acre field in 2017. Currently, irrigation and rainfed treatments with four random replicates are implemented. A cover crop of tillage radishes was planted in November of 2017. Soybean variety Asgrow Ag4232 was planted on April 20, 2018 with a row spacing of 38 inches. Soil physical, hydraulic and chemical properties were measured last year. Crop phenology, LAI and cover, biomass, plant height, and crop water use have been measured 6 times and will be throughout this growing season. The plots were harvested on September 21, 2018, and yield results will be reported during the next quarter report. The total water balance will also be reported for the daily crop water use efficiency in the next report.

Studies of Chicken Litter and Cover Crop at Delta Conservation Demonstration Center (DNDC) in Washington County (Soybean will be planted next year)

The objective of this study is to determine whether poultry litter applied in the fall accompanied by winter cover crops can result in benefits to soybean grain yield, soil health, and water use efficiency comparable to spring-applied poultry litter. The study is a 2x2x2 full factorial experiment consisting of fall- vs. spring-applied poultry litter, with winter cover crop vs. no cover crop, and no-till vs. conventional or minimum tillage systems. A farm standard treatment is included for comparison. The soil is a silty clay loam on a nearly 40-acre field planted to corn. Each year in 2016 and 2017, non-composted raw broiler litter was applied to supply about 50% of the total nitrogen requirement for optimal corn grain production; the other 50% was supplied from commercial synthetic N fertilizers. A mix of three winter cover crop species (cereal rye, Austrian winter peas, and tillage radish) was drill-planted in October 2015, 2016, and 2017. The design is a randomized complete block with four replications. Each main plot is a strip of approximately 1100-ft-long rows. Tillage is assigned to main plots, cover crops to sub-plots and cover crops to sub-sub-plots.

Grain yield and soil health data will be collected to assess treatment differences. The field will be rotated to soybean in 2018 without litter or synthetic fertilizer applications. The primary objective in 2018 will be to test cover crop benefits to soybean yield and water use efficiency. Crop phenology data, as well as soil moisture measurements were made 4 times during the 2018 growing season. Once the field has been harvested, the water balance and yield results will be published.

Progress for Objective 2:

We applied agroecosystem RZWQM2 models, in conjunction with field trials, to determine cover crop benefits for consistent dryland soybean yield in dominant soil types across typical Mississippi weather conditions. We measured soil water content, nitrate, and organic carbon as well as cover crop, corn and soybean N uptake, height, cover, leaf area index, aboveground biomass, and grain yield. Then those data were used to calibrate and validate the RZWQM2 model. We applied the calibrated agroecosystem model to conduct an 80-yr (1938-2017) simulation study and determine the long-term impacts of a wheat cover crop from October to April on water balance, nitrogen, and water use efficiency in a rainfed and no-tilled corn and soybean cropping system.

Long-term simulation demonstrated that average annual percolation under the wheat cover crop system was decreased by 9%, 11%, and 12% in wet, normal, and dry years over 8 decades compared to the plots without cover crop. Evaporation during crop vegetative growth period under cover crop plots was 25% less than under no cover crop plots over 8 decades. Crop evapotranspiration under cover crop was increased by 6% during corn growth period and by 3% during soybean growth period. Corn and soybean yields were increased by 5% and 4% (134 kg/ha; approximately 2 bu/acre) in the cover crop-based cropping system. Compared to the plots with no cover crop, the WUE for corn and soybean were respectively improved by 12% and 9% (0.64 vs. 0.59 kg m^{-3}) for the plots with cover crop, due primarily to the decrease in soil evaporation. This study suggests that incorporating wheat cover crop between summer crops rotation is a promising practice to reduce deep percolation, restrict soil evaporation, and improve crop water and nitrogen use efficiency in the dryland system.

Growing a winter wheat cover crop between harvest and planting of soybean improved soil organic carbon (SOC) by 15%. Application of poultry litter increased SOC ranging from 0.6 to 2.6%. A significant positive linear relationship was found between total carbon (TC) and field capacity (FC) of silt and silty loam soils as TC exceeded 1%. We found that a 1% increase in soil TC can improve soil water holding capacity by 13%.

For different soil textures, a strong linear positive relationship was found in coarser soils (clay<20%). The soils at Brooksville had higher carbon content (mean value 1.59%) and higher FC (34.64%), partly due to manure application than unmanured soils from Stoneville (TC of 0.92% and FC of 30.40%) in Mississippi State. We suggest soil carbon should be increased over 1% by applying manures and biochar or by other means to improve soil water holding capacity and overall soil health.

This study also used the actual historical data of dryland soybean production from the state of Mississippi to estimate the soybean water response. Given that precipitation is the only source of water supply, rainfalls are generally random across years; this dataset can be viewed as a natural experiment of soybean water response. Soybean yield data are collected from the USDA RMA (Risk Management Agency) for 76 out of the 82 Mississippi counties spanning the period 1991 to 2014. Precipitation data are obtained from the PRISM (Parameter-elevation Relationships on Independent Slopes Model) Climate Data at 4 km grids and then aggregated to county level. A piecewise nonparametric quantile regression is utilized to estimate how the potential soybean yield changes with precipitation level. Our interest is the conditional quantiles (upper 99%, 95%, and 90%) of yields rather than the mean yields. That is because at a given precipitation level, the yields can still be limited by other growing factors such as temperature, disease, pests, weeds, management, technology, and so forth. The more useful information for producers is what maximum yields can possibly be achieved under a certain amount of water supply, given that all other factors are properly managed. The results show the potential soybean yields first increase with precipitation, and reach maximum at the range of 800-1000 mm. After that, the potential yields decrease when precipitation further increases. At low precipitation level, such as under 400 mm, the potential yields are around 35 bu/acre. With adequate precipitation, such as 800 mm, the potential yield can reach up to 55 bu/acre. But excessive precipitation causes potential yields to drop again. The optimal precipitation also varies with temperature. In cooler years (average daily temperature below 23°C), the optimal precipitation is around 700 mm, while in warmer years (average daily temperature above 23°C), the optimal precipitation is slightly above 800 mm. These findings provide useful guidelines of optimal irrigation water requirements and cropping system planning for Mississippi soybean production.

Progress for Objective 3:

The RZWQM2 simulated data will be incorporated with the soybean price and cover crop cost information to build a soybean profit function, and solve for the profitability maximization problem using mathematic programming techniques under various constraints (budget, water capacity, *etc*.). The final output will be an interactive budget table, giving the specific cover crop recommendations under different soils, water costs, and soybean sale prices. The soybean profit functions and the budget table can provide guidelines for producers to determine the economic cover crop and nutrients management options under various weather and market conditions. Those results should allow producers to accurately weigh returns from increased yields against potential management costs on their specific fields. That provides a tool to more precisely manage their farm and improve profitability in soybean production.

End Products in 2018

Presentations:

(1) **Feng, G.**, Y. Wei, and D. Reginelli. 2018. The effectiveness of cover crop and poultry litter in improving soil organic matter and water use efficiency. International symposium entitled "Effects of Soil Health Management Practices on Soil-Plant-Water Relations in a Changing Climate" at the ASA-CSSA meetings in Baltimore, MD, Nov. 5, 2018.
(2) **Feng, G.** October 13, 2018. Application strategies of animal and industrial by-product for soil health and agricultural sustainability. College of Resources and Environment, Nanjing Agricultural University, Nanjing, China.
(3) Ouyang, Y. and **G. Feng**. 2018. A Pond and Irrigation Model (PIM) for simultaneously predicting crop irrigation demand and pond water availability: A case study in Mississippi. 2018 UF Water Institute Symposium "Sustainable water resources, complex challenges, integrated solutions. Shaping our water future". February 6-7, 2018. University of Florida, Gainesville, FL.
(4) **Feng, G.** October 18, 2018. Eco-hydrological process-based integrated water resources management for water security in agroecosystem. International Symposium of Ecohydrology and Water Security: Opportunities & Challenges from Developing Countries, Xi'an, Shaanxi, China. October 16-18, 2018.
(5) **Feng, G.**, F. Gao, Y. Ouyang, and P. Dash. 2018. Evaluating surface available water as alternative and developing sustainable groundwater management practices using coupled SWAT-MODFLOW modeling. 2018 UF Water Institute Symposium "Sustainable water resources, complex challenges, integrated solutions. Shaping our water future". February 6-7, 2018. University of Florida, Gainesville, FL.
(6) **Feng, G.** October 23, 2018. The role of agri-hydrological models in precision water management. The Agri-hydrological Models and Precise Water Management Workshop, China Agricultural University, China. October 22-30, 2018.
(7) Ouyang Y., J. Zhang, **G. Feng**, and F. Gao. 2018. Assessment of past and future rainfall impacts on hydrological processes in the Lower Mississippi River Basin. April 22-25, the 2018 America Water Resources Association Spring Conference - GIS and Water Resources X, Orlando, FL.

(8) Gao, F., **G. Feng**, P. Dash, Y. Ouyang, and J. Jenkins. 2018. Evaluating the effects of irrigation management practices on groundwater recharge and storage in Mississippi Delta. The Annual Mississippi Water Resources Conference, Jackson, MS. April 3-4, 2018.
(9) **Feng, G.** October 27, 2018. Agri-hydrological models for irrigated and rainfed corn, cotton and soybean water management. Farmland Irrigation Research Institute, Chinese Academy of Agricultural Sciences, Henan, China.
(10) Gao, F., **G. Feng**, P. Dash, P., and Y. Ouyang. 2018. Impact of different ratios of surface water and groundwater for row crops irrigation on groundwater level in Mississippi Delta. Oral presentation at the 2018 Mississippi Water Resources Conference in Jackson, Mississippi, USA, April 3-4, 2018.
(11) Yang, W., **G. Feng**, A. Adeli, and J. Jenkins. 2018. Long-term effect of cover crop on water use efficiency in manured and rainfed soybean-corn rotations. The Annual Mississippi Water Resources Conference, Jackson, MS. April 3-4, 2018.
(12) **Feng, G.**, Y. Wei, A. Adeli, and D. Reginelli. 2018. The role of cover crop in improving rainwater and nutrient use efficiency for a no-tilled dryland corn and soybean rotation system. The 21th World Congress of Soil Science, Rio de Janeiro, Brazil. Aug. 12-17, 2018.
(13) Gao, F., **G. Feng**, and Y. Ouyang. 2018. Impact of landuse change on groundwater recharge and discharge. Agronomy Abstract. America Society of Agronomy Annual Meeting, Baltimore, MD. Nov. 4-7, 2018.
(14) Li, X., **G. Feng**, H. Tewolde, and D. Reginelli. 2018. Effect of improved soil organic matter using cover crops and poultry litter on water holding capacity of dominant Mississippi soils. Agronomy Abstract. America Society of Agronomy Annual Meeting, Baltimore, MD. Nov. 4-7, 2018.
(15) Yang, W., **G. Feng**, A. Adeli, and J. Jenkins. 2018. Modeling long-term effect of wheat cover crop on soil water budgets, yield, and water use efficiency in a rainfed corn and soybean rotation. Agronomy Abstract. America Society of Agronomy Annual Meeting, Baltimore, MD. Nov. 4-7, 2018.

Publications and Manuscripts:

(1) Tang, Q., **G. Feng**, D. Fisher, H. Zhang, Y. Ouyang, A. Adeli, and J. Jenkins. 2018. Rain water deficit and irrigation demand of major row crops in the Mississippi Delta. ASABE 61(3): 927-935. https://doi.org/10.13031/trans.12397.
(2) **Feng, G.**, Y. Ouyang, A. Adeli, J. Read and J. Jenkins. 2018. Rainfall deficit and irrigation demand for major row crops in the Blackland Prairie of Mississippi. *Soil Sci. Soc. Am. J.* 82: 423-435. doi:10.2136/sssaj2017.06.0190.
(3) Gao, F., **G. Feng**, Y. Ouyang, H. Wang, D. Fisher, A. Adeli, and J. Jenkins. 2017. Evaluation of reference evapotranspiration methods in arid, semi-arid and humid regions. Journal of the American Water Resources Association (JAWRA). 53(4), 791-808. DOI:10.1111/1752-1688.12530.
(4) Zhang, B., **G. Feng**, L. Ahuja, X. Kong, Y. Ouyang, A. Adeli and J. Jenkins. 2018. Soybean crop-water production functions in a humid region across years and soils determined with APEX model. *Agricultural Water Management* 204: 180-191. https://doi.org/10.1016/j.agwat.2018.03.024.
(5) **Feng, G.**, and R. Sui. 2018. Evaluation and calibration of soil moisture sensors in undisturbed soils of Mississippi. *Transaction of ASABE* (submitted).
(6) Shekhar, S., P. Dash, A.K. Saraf, and **G. Feng**. 2018. Influence of changes in land use and land cover, and precipitation patterns on the groundwater storage changes in the Mississippi River Watershed (USA) from 2003-2015. (submitted).
(7) Gao, F., **G. Feng**, M. Han, P. Dash, J. Jenkins, and C. Liu. 2018. Simulating spatiotemporal variability of surface water resources in Mississippi Delta using coupled SWAT-MODFLOW model. *Water 11*(3), 528. https://doi.org/10.3390/w11030528.
(8) Gao, F., **G. Feng**, Y. Ouyang, J. Jenkins, and C. Liu. 2018. Simulating weekly available streamflow and pond water resources potential in Mississippi Delta. *Agricultural Water Management.* (submitted).
(9) Yang, W., **G. Feng**, A. Adeli, K.C. Kersebaum, J. Jenkins and P. Li. 2018. Long-term effect of cover crop on

rainwater balance components and use efficiency in a no-till upland soil for a rainfed corn and soybean rotation. *Agricultural Water Management*. (accepted).

(10) Yang, W., **G. Feng**, H. Tewolde, A. Adeli, and P. Li. 2018. Simulation of soil nitrogen dynamics in corn-soybean system under rainfall variations. *Science of Total Environment*. (under internal review).

(11) Yang, W., **G. Feng**, J. Read, Y. Ouyang, and P. Li. 2018. The role of winter cover crop in rainfed cropping system in the humid climate with frequent drought summers: rainfall storage, drainage, and water use efficiency. *Agronomy Journal*. (under internal review).

(12) Yang, J., W. Ren, Y. Ouyang, **G. Feng**, B. Tao, J. Granger, and K. P Poudel. 2019. Projection of 21st century irrigation water requirement across the Lower Mississippi Alluvial Valley. *Agricultural ater Management* 217: 60-72. https://doi.org/10.1016/j.agwat.2019.02.033 .

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Fig. 1. Locations of the seven experiment sites for the MSPB project.

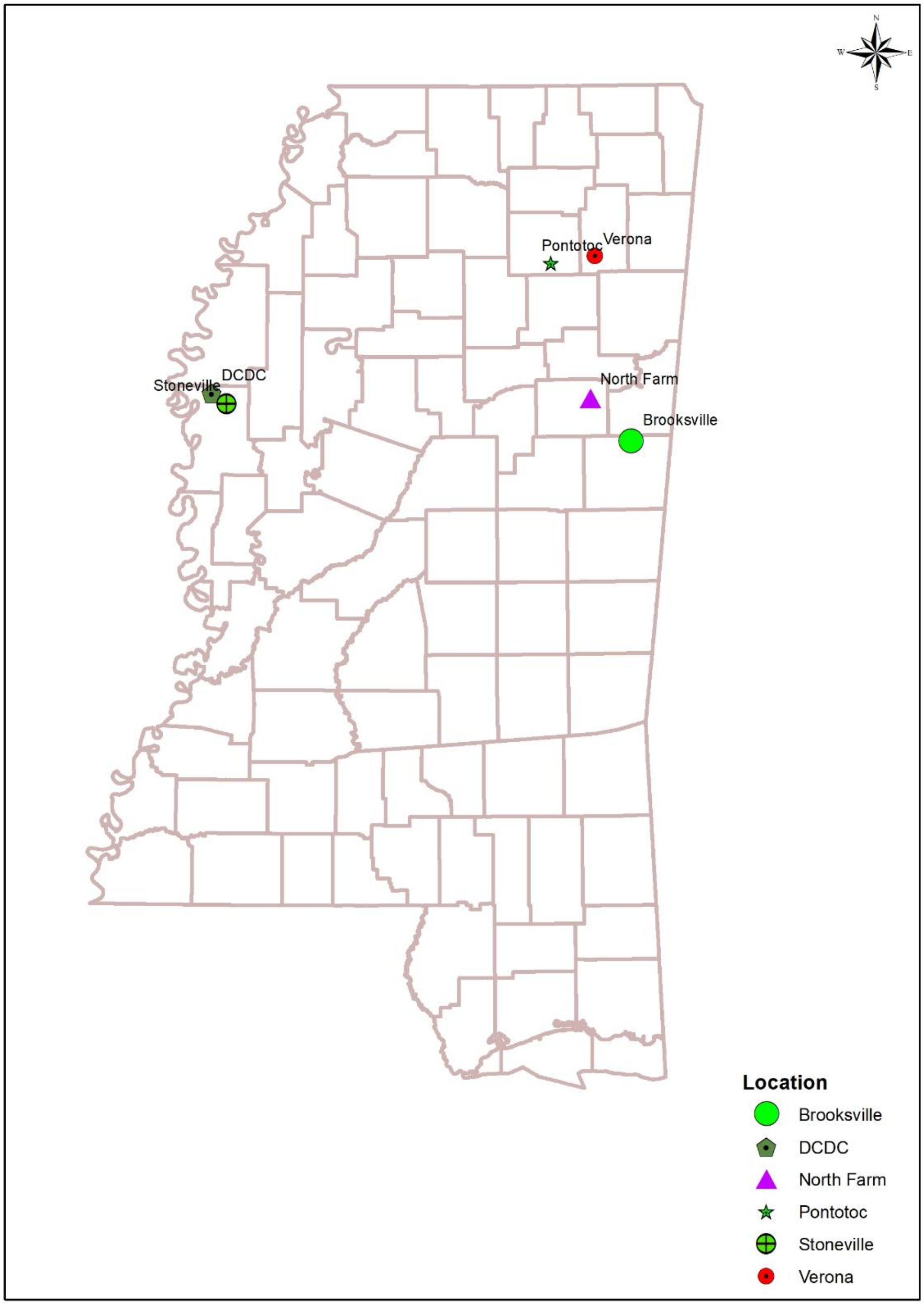

Fig. 2. Soil types and field boundary and acreage of the four experiment sites located in east-central Mississippi, Blackland Prairie.