Increasing soybean field drainage systems to allow farming operations earlier in wet springs and reduce nutrients and soil losses

PROJECT NO: 62-2023

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Rationale/Justification:

Soybean is the most important crop in MS in both acreage and value. In 2021, the MS soybean harvested area was 2.22 million acres and had a total value of $1.49 billion. The majority of the annual rainfall in MS occurs in the fallow season from December to April. Flooding or waterlogging has been one of the major concerns that could potentially lead to planting delay, and losses in yield, soil and nutrients through surface runoff and leaching. Installation of agricultural drainage tiles can potentially result in large returns by improving crop productivity and conserving soil and nutrients. In MS, some farmers have started to invest in drain tiles. In East MS, drain tiles installation has now become a practice. In general, tiles are buried 2-3 feet deep, spaced 30-100 feet apart, and sloped at 0.1% or about a 1-2 feet drop over 1000 feet. Most drainpipes are around 4 inches in diameter and can run into 6-8 inches. Drain tiles are designed to drain the excess water from the fields within 24 to 48 hours following rain. The flow velocities range from 0.5 to 1.4 feet per second based on the soil type. In fine sands and silt soils, the flow rate is 1.4 feet per second and in clayey soils, the flow rate is 0.5 per second.

Before installing the drain tiles, growers should have knowledge regarding the soil characteristics of the location such as soil saturated hydraulic conductivity, infiltration and holding capacity. They need to make assessments about the pipes having the correct spacing and slope for effective drainage. Once installed, drain tiles offer various potential benefits, such as early planting, less plant water and nutrient stress, high crop productivity, efficient harvesting, high soil infiltration, and better soil aeration. Fields with good drainage systems can facilitate the integration of cover crops and other conservation practices. To understand how drainage could influence the water table in the soil, there is a need to look at the various forms of soil water. The amount of water that can be drained out of the soil depends on the amount of drainable pore space, which is influenced by soil texture and structure. Thus, any management practice that increases the drainable pore spaces will likely improve soil water holding capacity and infiltration rate and conserve more rainwater in the soil. The effectiveness of drainage system and management practices in increasing drainage efficiency, soil infiltration and water holding capacity, soybean yield, water and nutrient productivity have received little attention, and the financial returns and costs of each option are also unknown. Management practice that can help improve these components is the integration of different cover crops and poultry litter in the existing drainage and cropping systems. Measuring the hydraulic and physical properties of soil, such as field capacity, plant available water, saturated hydraulic conductivity, and soil texture and aggregates, is necessary to understand the impact of cover crops, poultry litter and drainage system on soil health. The improved soil health can further help us determine the drainage conditions of the soil.

Objective 1. Determine cost-effective drainage system design, and best management practices to increase existing drainage tiles efficiency, reduce runoff and loss of soil and nutrients, improve soil infiltration and water holding capacity, and surface water harvest. Our goal is to assist growers make their wet fields drier in spring so that they are able to enter fields and conduct farm operations including planting earlier than current practice. This research will also determine the effectiveness of drainage systems along with cover crops during the fallow season, soil amendments such as broiler litter, municipal biosolids and biochar for improving soil health, water and nutrients productivity, soybean yield and economic return in major soil types and growing environments across MS.

1.1 The field on a private farm (Good Farm) in Noxubee county

Quarter 1: Activities listed for this quarter

The annual rainfall exceeded 1125 mm in 3 out of 4 years over the past 100 years in Mississippi Black Prairie. As high as 70% of the average annual rainfall occurs during the off-crop season between late fall to spring. Farmlands without a proper drainage system is subjected to ponding. This causes water logging/ponding in agricultural fields affects the soil health with decreased porosity, and consequently resulting in delayed planting and yield loss. Drainage of excess water on agricultural lands is beneficial in improving soil health, reducing soil compaction, nutrient loss, erosion, and increasing soil aeration. This study is aimed to investigate the effects of implementing tile-drain, cover crop and application of poultry litter on water balance, hydrological processes and the number of more days the growers could conduct field operations in wet spring on a commercial farm using geospatial modeling. Application of tile drain is fairly common in the Midwestern United States, whereas it is not prevalent in Mississippi. Hydrologic assessments of tile drain systems have never been done before in Mississippi.

The study was implemented on a 176 ha of the Good Farms located in Noxubee County, MS. The dominant soils in this region contain great percentage of clay and silt, in addition, the soil profile often comprises of a chalk layer at a various depth. Soil types belong to hydrologic soil group D that are poorly infiltrated with an infiltration rate of 3.3 mm/hour. The wet seasons and soil types often delay field preparation until late April or early May that prevent from planting cash crops, terminating cover crop, applying fertilizer, and cultivating fields.

Field survey was conducted for runoff channels and existing subsurface drainage pipes on Good Fam in March, 2023. We used a Garmin GPS unit with 0.01 m resolution and determined the locations of all severe runoff and existing subsurface drainage pipes.

Fig. 1. Many runoff channels as shown on Good Farm were found in March, 2023

The field at the left side in Fig. 1 was selected for monitoring runoff and soil water and nutrients balance. Five ISCO automatic runoff collectors have been purchased. We are going to order soil moisture sensors.

Fig. 2. Outlet of existing subsurface drainage pipes on Good Farm in March, 2023

There are three outlets of existing subsurface drainage pipes that we found. We are going to take water sample samples at the outlets and measure nutrients.

We learned the Advanced Drainage Systems, Inc (ADS) installed subsurface drainage pipes in a field on North Farm at Mississippi State. The PI has contacted Dr. Darrin Dodds to visit the field since January, 2023. It is our intention to collaborate with Dr. Dodds and monitor drainage and other soil water balance components in this field for the project.

Quarter 2: Activities listed for this quarter

September 13, 2023: five automatic runoff collectors (ISCO Inc., Lincoln, NE) as shown below were installed at the edge of a soybean field at Good Farm. The collectors can automatically measure runoff volume and rate, rainfall, and take runoff water and sediment samples for lab analysis.

Oct. 5, 2023: five treatments were implemented. The treatments are poultry litter (2 ton/acre); poultry litter (2 ton/acre) with gypsum (2 ton/acre); poultry litter (2 ton/acre) with coal biochar (2 ton/acre); poultry litter (2 ton/acre) with gypsum (2 ton/acre) and coal biochar (2 ton/acre). Each treatment is composed of cover crop and without cover crop. Row space is 30 in, 3000 feet long.

Oct. 16, 2023: cover crop, cover crop, elbon cereal rye, was planted at 100 pound per acre.

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Quarter 3: Activities listed for this quarter

The runoff collectors along with its associated rain gauge started automatically measure the amount of rainfall and runoff. The device was set up to collect runoff samples once rainfall is over 1 inch. We have runoff samples ready for chemical analysis.

1.2 The field on North Farm (Mississippi State University)

Quarter 3: Activities listed for this quarter

The Advanced Drainage Systems Inc (ADS, IL, https://www.adspipe.com/) installed subsurface drainage tiles in a field at MSU North Farm 3 years ago. It took 2 years to have the soil settled down, it is the time we could test the system. Dr. Darrin Dodds is in charge of the field, he has agreed to allow us to install sensors and evaluate the subsurface drainage system. Half of the field is irrigated, half is rainfed. there are treatments of no title, 15 ft and 20 ft spacing tiles in 30 inch depth, in total around 30 plots with 16 rows of 30 inch spacing and 200 feet long. We are in the process of preparing for USDA-ARS purchase request forms to order flow meter, water table meter, and soil moisture sensors. We have created the drainage system map as shown in Fig. 4.

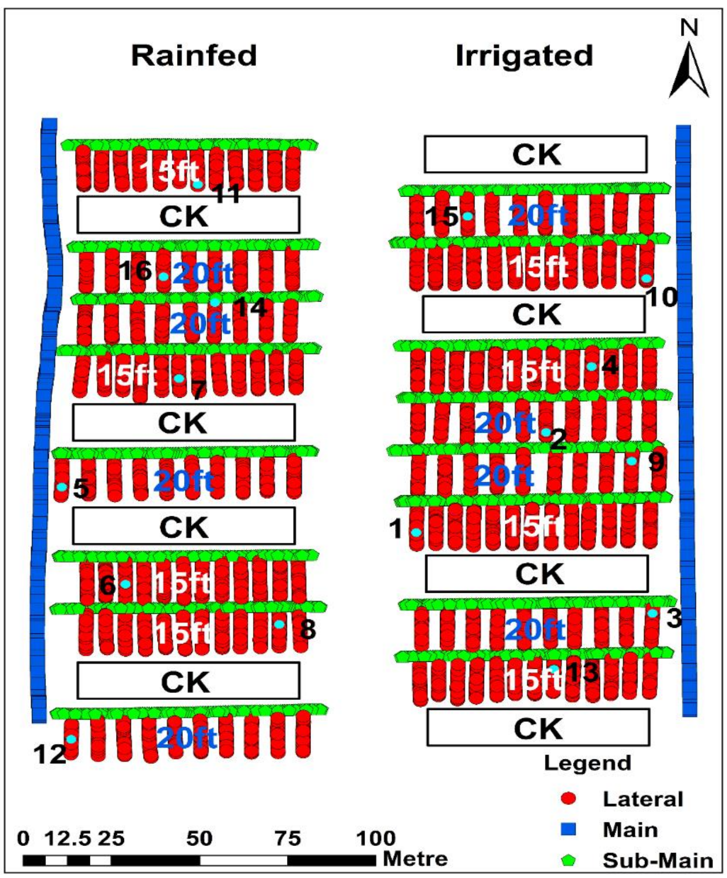

Fig. 4. The layout of drainage titles in irrigated and rainfed fields with three treatments: CK is no drain tiles installed; 15 ft is 15 ft space between lateral tiles; 20 ft is 20 ft space between lateral tiles.

Fig. 5. Excess water was always ponded on soil surface during spring in the field before drainage system was installed.

Fig. 6. Rainfed main treatment with drainage system.

Fig. 7. Irrigated system for the irrigated main treatment with drainage system.

Fig. 8. Drainage system outlet at the edge of each of 16 plots and the outlet of the main pipes to the stream.

Objective 2. Apply hydrology and agroecosystem models, in conjunction with commercial farm field trials in Objective 1, to determine optimal drainage system/production/management options for consistent and high soybean yield across typical MS weather conditions and in dominant soil types based on 100-year daily weather records and on predicted daily weather in future 50 years.

Quarter 1: Activities listed for this quarter

Agricultural Policy and Environmental Extender Model (APEX) and Soil and Water Assessment Tool (SWAT) that were developed by USDA-ARS will be employed for this project. The two models are capable of simulating various hydrologic and water quality outputs for different management scenarios are used in this study. The objectives of this study are to suggest a cost-effective and optimum drainage solutions while improving soil and water quality and providing agronomic benefits for farmers. The research which contributed to a dryer field in spring is beneficial to the farmers who could begin field operations at an early date. Results from this study could provide an insight in choosing optimum design of a tile drainage system along with its best management practice to improve drainage for poorly drained soils and induce runoff for effective on-farm tailwater recovery and reuse.

Quarter 2: Activities listed for this quarter

We have set up the models on the domain of Good Farm with approximately 470 ha as shown in Figure 4.

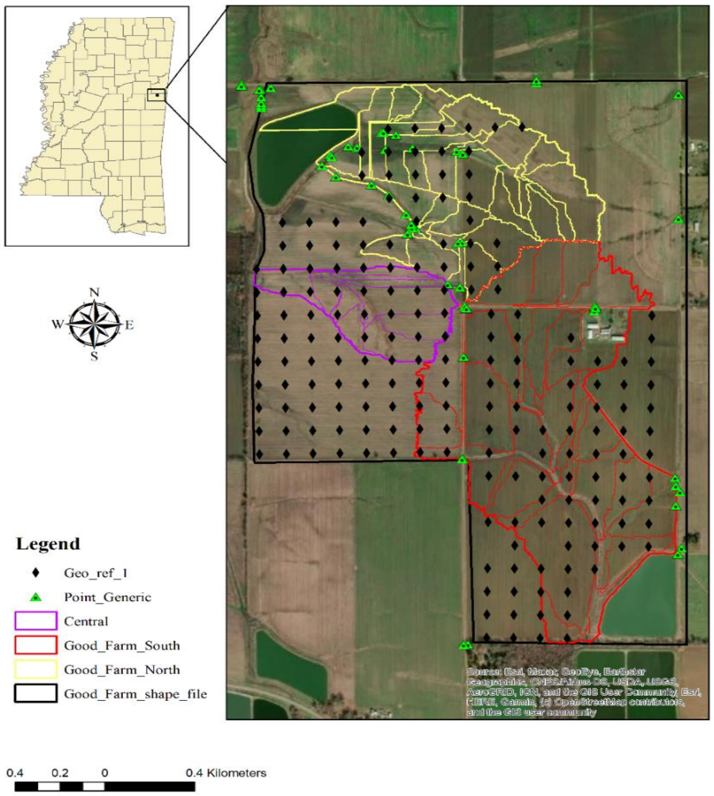

Fig. 9. The model domain on Good Farm.

The model required data of topography, soils, weather, and management were prepared. The Good Farm land use characteristics include agriculture and ponds (NW and SE) are shown in Fig. 1. Soils associated to the farm are silty clay and chalk in some under layers. The primary Data Inputs that are used in the model are, Digital Elevation Models (DEM Higher resolution) (MARIS 1m x 1m), land-use, land-cover (LULC) (USDA-2019), soil – SSURGO database (NRCS, 2019), precipitation and temperature (NOAA, 2019), and crop management practices (MAFES, 2019).

The delineation of Digital Elevation Model produced three major watersheds on the farm. The runoff in the watersheds as shown in yellow and red color were collected in the two ponds in the figure. The runoff of the watershed in pink color will be collected by the 6 automatic runoff collectors we installed at the edge of the field.

Quarter 3: Activities listed for this quarter

Prepared input parameters for simulation study using HYDRUS-3D and DRAINMOD models.

Objective 3. Conduct economic analysis using results of field trials (Objective 1) and simulation studies (Objective 2) to compare the cost and return of using drainage systems, soil organic amendments or/and cover crop in comparison with conventional management practices. The goal is to help soybean growers in different MS environments determine the long-term profit-maximizing management practices for given soil types, topography, precipitation patterns, and other climate conditions found on their farms.

Quarter 1, 2 and 3: Activities listed for this quarter

Wait for data to conduct economic analysis, no activity yet.

End Products (Authors in bold are PI/CoPIs):

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 & Till Res.* 233 (2023) 105796: 1-14. https://doi.org/10.1016/j.still.2023.105796.

(2) *Kovvuri, N.*, **G. Feng**, **G. Bi**, **A. Adeli**, and J. Jenkins. 2023. The effect of cover crops on soil water retention and all other soil physical properties. *Vadose Zone Journal* (under review).

(3) **Feng**, **G.**, Y. Ouyang, W. Jin, and **Y. Huang**. 2023. The role of changing land use and irrigation scheduling in mitigation of groundwater depletion in a humid region. *Ag Water Mangt*. 291 (2024) 108606. https://doi.org/10.1016/j.agwat.2023.108606.

(4) *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).

(5) *Dai, W.*, **G. Feng**, **Y. Huang, H. Tewolde, M. Shankle**, and J. Jenkins., 2023. Cover crops and poultry litter impact on soil structural stability in dryland soil of Southeastern United States. *Journal of Cleaner Production* (Under Review).

(6) *Dai, W.*, **G. Feng**, **Y. Huang, A. Adeli**, and **J. Jenkins**., 2023. Impact of cover crop management on soil aggregate stability, size distribution and related factors. *Soil & Till Res.* (Under Review).

Presentations and Published Abstracts:

(1) **Feng, G.**, Y. Ouyang and D. Reginelli. 2023. An on-farm circular water use approach for reducing soil, water and nutrient loss and sustainable soybean production in an integrated cover crop and poultry litter cropping system. International symposium entitled “Advancements in Water Management and Irrigation Strategies for Sustainable Crop Production and Ecosystem Resilience” at the ASA-SSSA-CSSA Annual Meeting, St. Louis, M. Oct. 30, 2023 (invited presentation).

(2) *Khanal, P.*, **G. Feng**, *Y. Huang*, P. Liu and D. Reginelli. 2023. Assessing farmland wetness and accessibility, runoff and drainage in the Southeast USA. The ASA-SSSA-CSSA Annual International Meeting, St. Louis, MO. Oct. 29-Nov. 1, 2023.

(3) *Kovvuri, R.N.*, **G. Feng**, **G. Bi**, M. Shankle, and H. Tewolde. 2023. Soil health, soybean growth parameters as influenced by the integration of cover crops and poultry litter on upland soils. The ASA-SSSA-CSSA Annual International Meeting, St. Louis, MO. Oct. 29-Nov. 1, 2023.

(4) *Kovvuri, R.N.*, **G. Feng**, **G. Bi**, **A. Adeli**, and J. Jenkins. 2023. Impact of different cover crops and crop rotation on soil physical and soil chemical health. The ASA-SSSA-CSSA Annual International Meeting, St. Louis, MO. Oct. 29-Nov. 1, 2023.

(5) *Khanal, P.*, **G. Feng**, **Y. Huang**, and P. Liu. 2023. Investigating the influence of rainfall and other weather-forcing factors on soil moisture and soybean yield using the APEX Model. Mississippi Academy of Sciences Summer Science & Engineering Symposium. Mississippi State University, Starkville, MS. July 25, 2023.

(6) *Khanal, P.*, **G. Feng**, **Y. Huang**, and P. Liu. 2023. APEX model-based analysis of rainfall and soil water storage on soybean leaf area index, biomass, and yield. Summer Undergraduate Research Symposium. Mississippi State University, Starkville, MS. Aug. 2, 2023.

(7) *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.

(8) *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.

(9) *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.

(10) *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.

(11) **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.

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

(13) *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.