Iowa State University

College of Agricultural and Life Sciences

College of Engineering

# Soil Wetness Measurement Method Development for Underground Construction Utilities on Farm Soils

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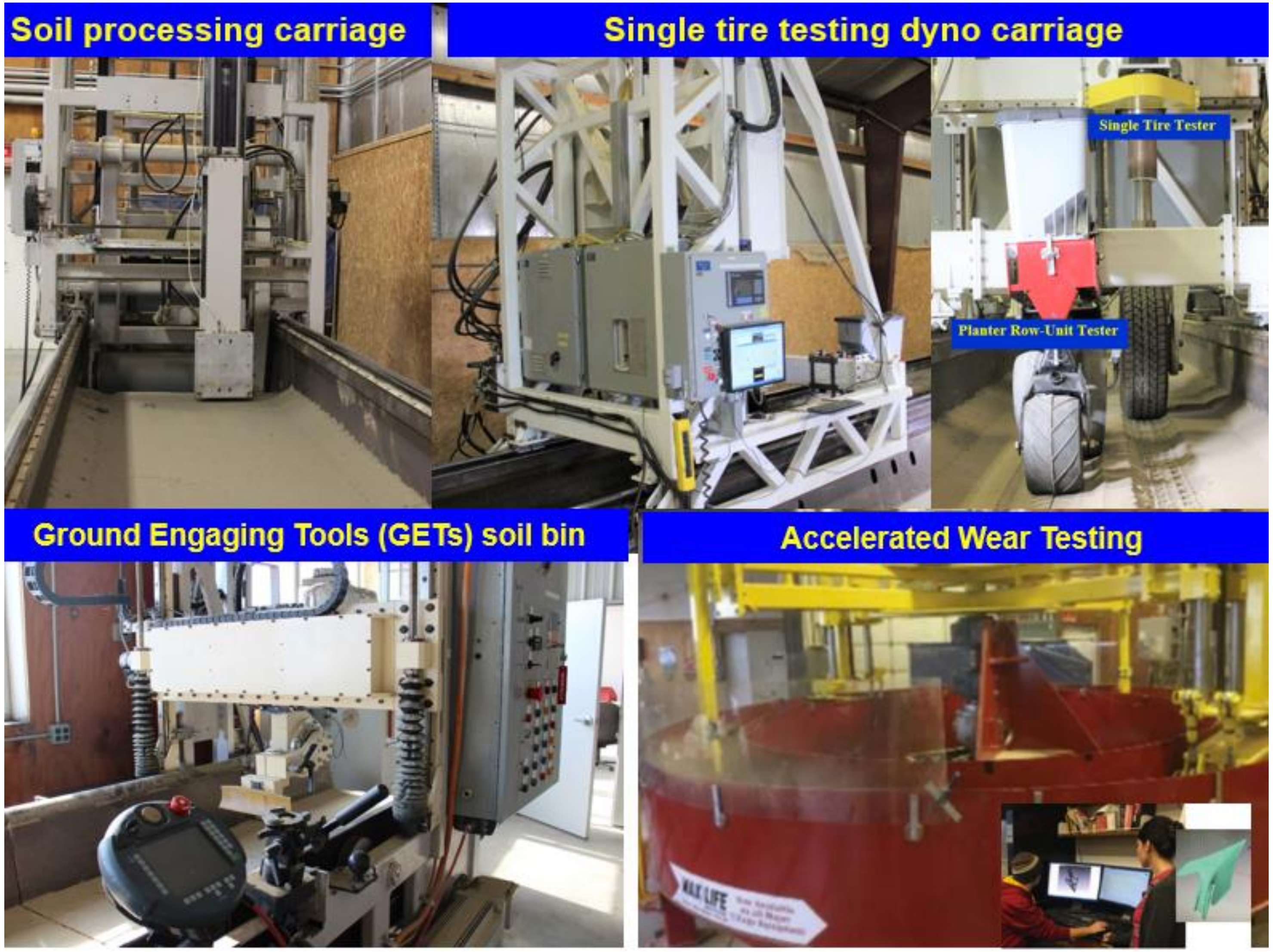
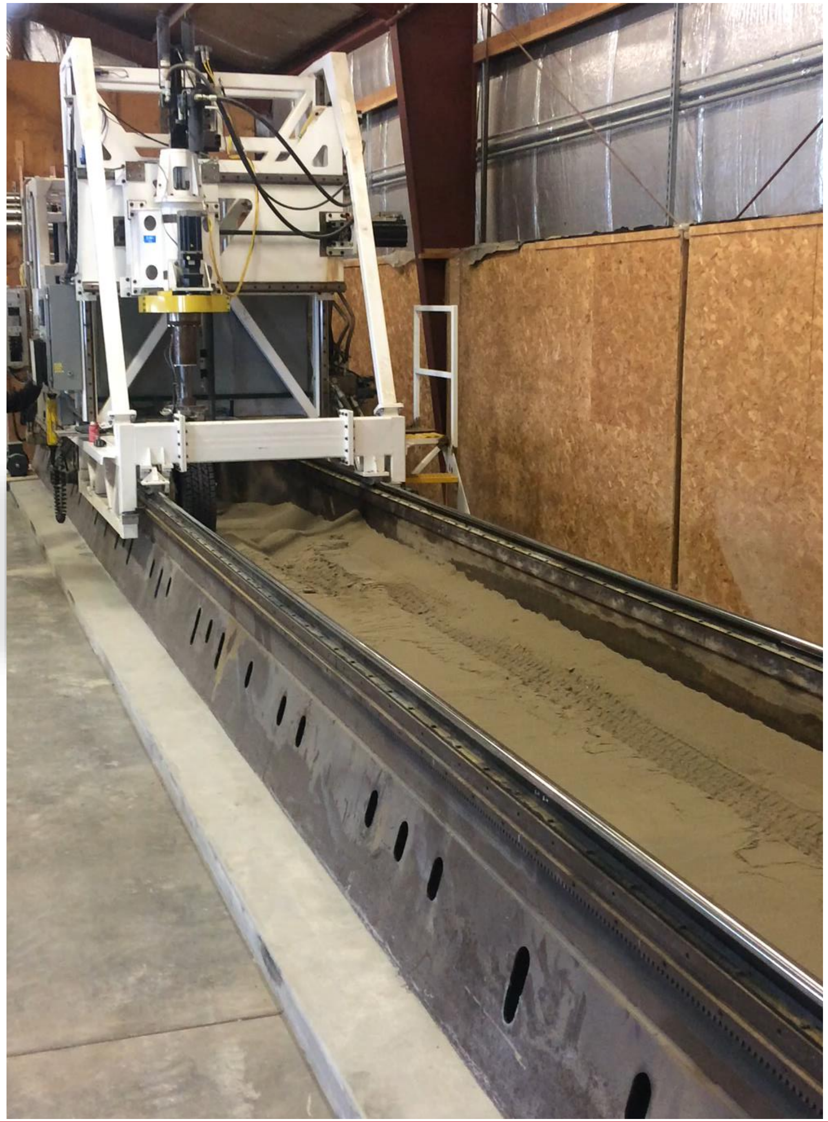
Report Iowa State Association of Counties, July 5, 2023

# Outline

- **Introduction on soil sustainability**
  - Prior studies
  - Short-term and long-term soil sustainability from underground construction
- **Soil wetness method development and results**
- **Summary and Q&A**

# Soil Machine Dynamics Laboratory (SMDL), Iowa State University



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# SMDL Dr Tekeste’s Team

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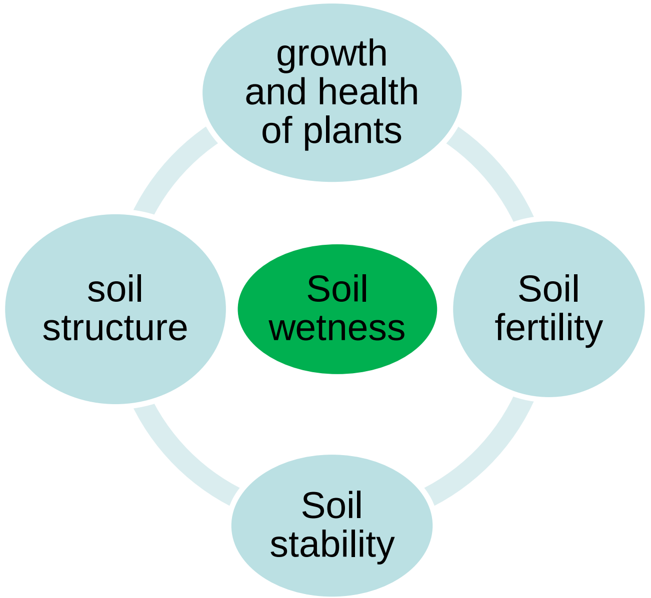
Saeth Sanchez
(Undergrad Research Assistant)

Mehari Tekeste
(Associate Professor, ABE, ISU)

# Introduction

- Soil wetness during field trafficking strongly affects the soil-plant-environment

- Wet soils have weak soil bearing capacity to support heavy load traffic, causing excessive soil compaction  and limiting root environment for optimal crop growth and yield



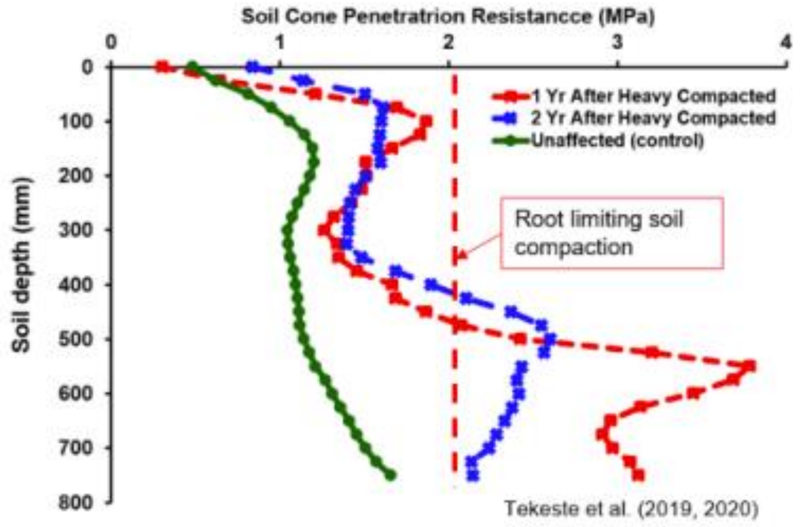




Figure-1 Soil penetration resistance after deep tillage (500-800 mm) applied in 2016

# Pipeline or Utilities Operations in Farms-Iowa Example (Now and Short-Term)

- DAPL (2016) ~ 346 miles (30-inches)
- New proposals (2023 and beyond) (Summit Carbon Solutions (681 miles), Navigators CO2 (810 mile)) (Four Times DAPL linear mileage in Iowa)
- **<u>Gap:</u>** Developing management plan on soil compaction and tillage
- Based on information ISU research, IUB feedback, and requests from growers/Iowa Counties Association and ISG
  - Proposal: Develop soil wetness measurement procedure for Soil Compaction Management Plan for Underground Utilities on Farms in Iowa

Working in soil moisture close to plastic limit

## Example – gaps Pipeline Right-Of-Way (ROW) Construction activities Impact on Soil Compaction and crop yield: Post Construction (DAPL& ISU Proposal- 2016)

6.2. TOPSOIL SEPARATION

As specified in Chapter 9, pa
installation will be separated a
excavation in reverse order to re
the topsoil, not to exceed 36 inch
If the actual depth of topsoil ex
workspace, Dakota Access will, u

6.8. RESTORATION AFTER SOIL COMPACTION AND RUTTING

In accordance with Chapter 9 paragraph 9.4(4), agricultural land compacted by heavy project equipment, including off right-of-way access roads, will be deep tilled to alleviate soil compaction upon completion of construction on the property. In areas where topsoil was

DAPL_AGRICULTURAL MITIGATION PLAN_03-10-2016 11

DAKOTA ACCESS, LLC (DAPL)

removed, tillage will precede replacement of topsoil. At least three passes with the deep tillage equipment shall be made (per chapter 9.4(4)a). Tillage shall be at least 18 inches deep in land used for crop production and 12 inches deep on other lands, (except where shallow tile systems are encountered), and shall be performed under soil moisture conditions which permits effective working of the soil. If agreed in advance, this tillage may be performed by the landowners or tenants using their own equipment.

Rutted land will be graded and tilled until restored as near as practical to its preconstruction condition. On lands where topsoil was removed, rutting will be remedied before topsoil is replaced.

[a] Iowa Administrative Code - 08/03/2016 Utilities Division [199]. Chapter-9

# EXAMPLE – GAPS NEW PROPOSALS UNDERGROUND UTILITIES MANAGEMENT PLAN ON FARM SOILS

**Gaps**

6.15. CONSTRUCTION IN WET CONDITIONS

The county inspector, in consultation with SCS and the landowner or person in possession of the land pursuant to a lease, if present, shall determine when construction should not proceed in a given area due to wet conditions. The county inspector shall have the sole authority to determine whether construction should be halted due to wet conditions.

Construction in wet soil conditions will not commence or continue at times when or locations where the passage of heavy construction equipment may cause rutting to the extent that the topsoil and subsoil are mixed or underground drainage structures may be damaged.

To facilitate construction in wet soils, SCS may elect to remove and stockpile the topsoil from the traveled way, install mats or padding, or use other methods acceptable to the county inspector.

- ASTM D1586-11 is not common on farm soils, cone is 60-degrees, sleeve-friction and hammer for civil engineering

least 18 inches deep in land used for crop production and 12 inches deep on other lands and shall be performed under soil moisture conditions that result in a maximum standard penetration test (SPT) reading of 300 psi pursuant to ASTM D1586-11 performed by a qualified person. Decompaction shall not occur in wet conditions. If agreed in advance, this tillage may be performed by the landowners or tenants using their own equipment.

Rutted land will be graded and tilled until restored as near as practical to its preconstruction condition. On lands where topsoil was removed, rutting will be remedied before topsoil is replaced.

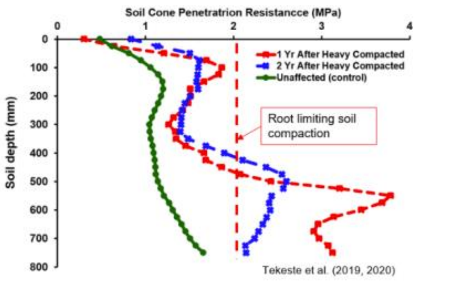
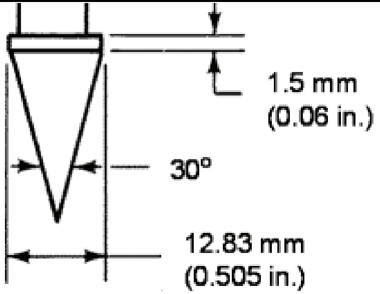



Figure-1 Soil penetration resistance after deep tillage (500-800 mm) applied in 2016




ASABE S3133.3_R2018

- Correlated to root growth and crop yield
- Management tool for soil loosening (hardpan detection) and depth of tillage

https://summitcarbonsolutions.com/frequently-asked-questions/

Submit carbon solutions Ag Mitigation Plan (2023)

# Problem Statement

- Earth moving machinery during underground construction activities on *wet soils* often creates negative effects on soil health for root-growth, the environment and limits the crop yield recovery

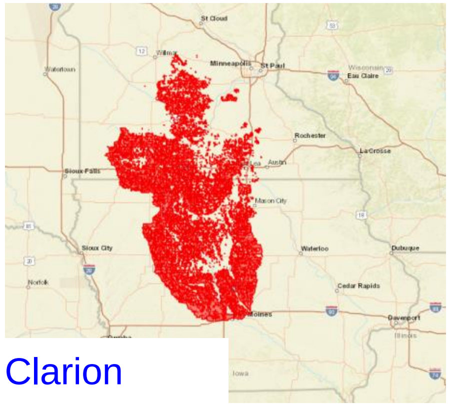
- The major challenges for soil sustainability during construction activities are
  - Working on wet soils, prone to excessive soil compaction and rutting
  - Mixing topsoil and subsoil
  - Decompaction methods for accelerated recovery

- Method to determine field soil wetness is needed for soils impacted by underground construction activities to establish
  (a) the relationship of in-situ soil water and precipitation from real-time data
  (b) define *degree of soil bearing capacity* at various ***soil wetness*** for minimizing heavy-load induced rutting

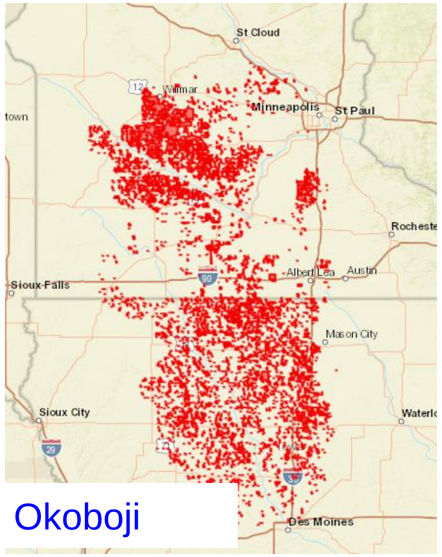
# Executive Summary

- Four classes of soil wetness defined using the ISU method of measuring soil wetness for field vehicle loading bearing capacity
- Rainfall events to the degree of saturation and number of days to drain to field soil vehicle bearing capacity is defined
- Relating the soil wetness to approximate soil rut depth and measuring in-situ soil moisture is proposed for near future

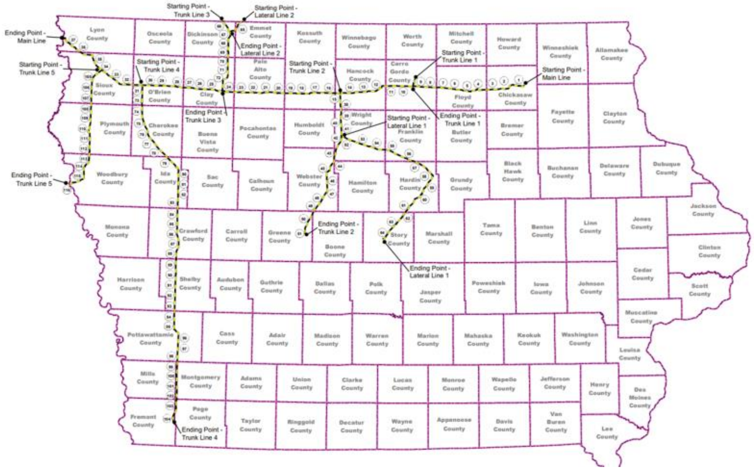
# Sampling of Soil Core Sites Relative to Iowa Regional and Hydrologic Map



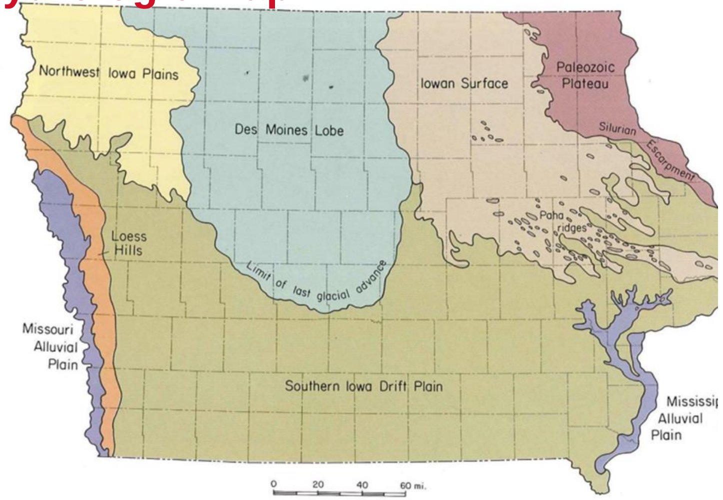

Clarion

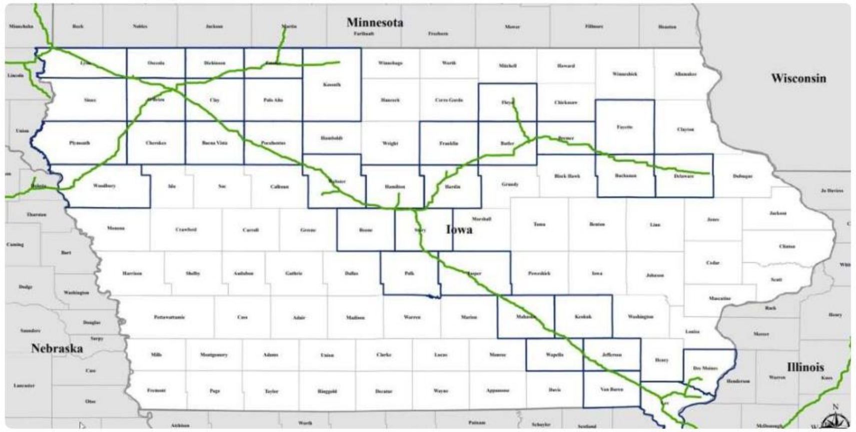



Okoboji

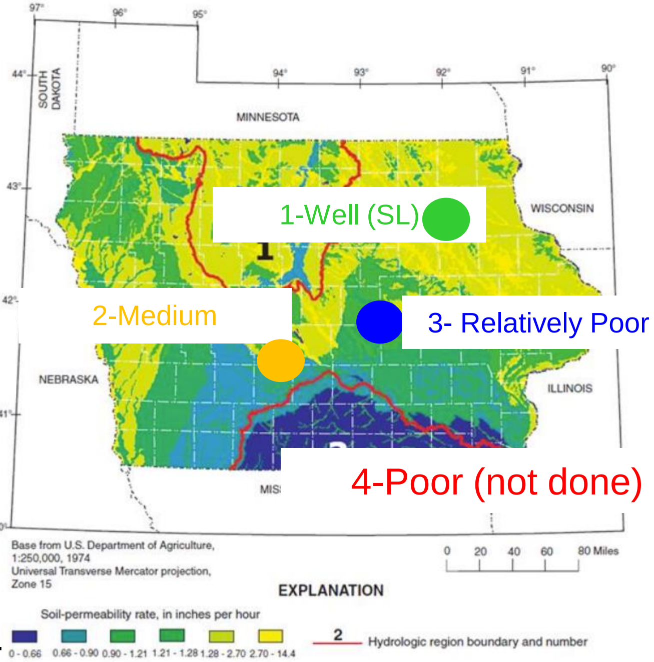


https://iub.iowa.gov/press-release/2022-02-15/proposed-summit-carbon-pipeline-overview-route-map-filed

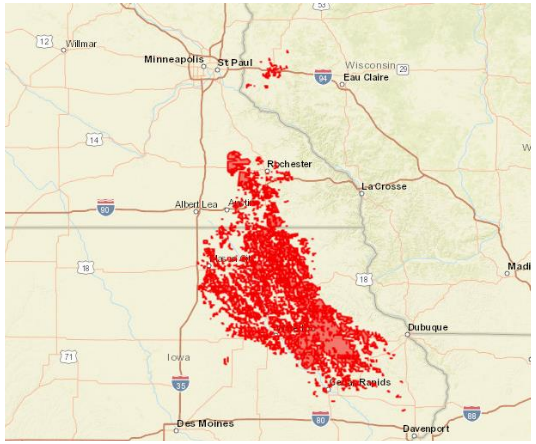


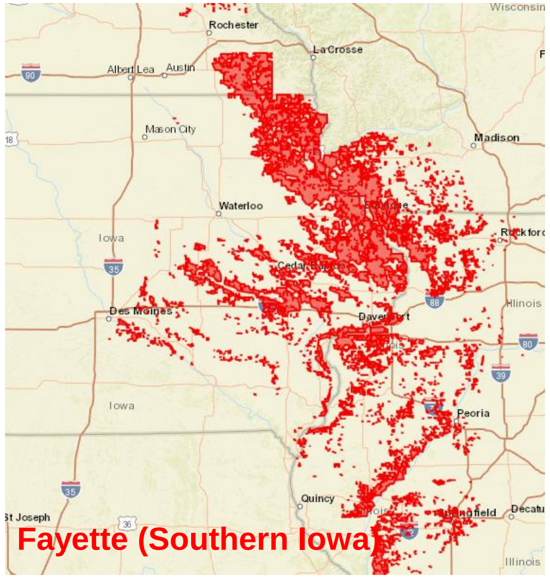

https://www.thegazette.com/energy/navigator-co2-pipeline-would-drop-linn-county-from-new-proposed-route/




Eash, 2021




Floyd series (Dubuque)

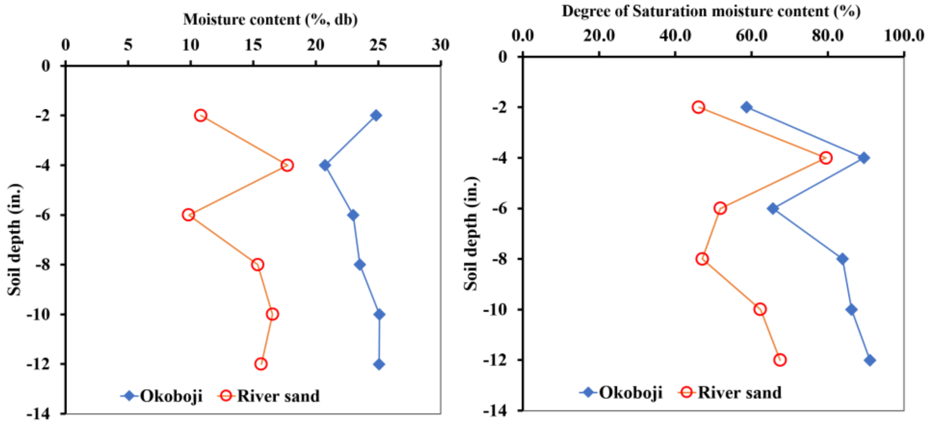



Fayette (Southern Iowa)

# Summary Soil Wetness Procedure Development for Soil Bearing and Rut Estimation (Feb,2023)

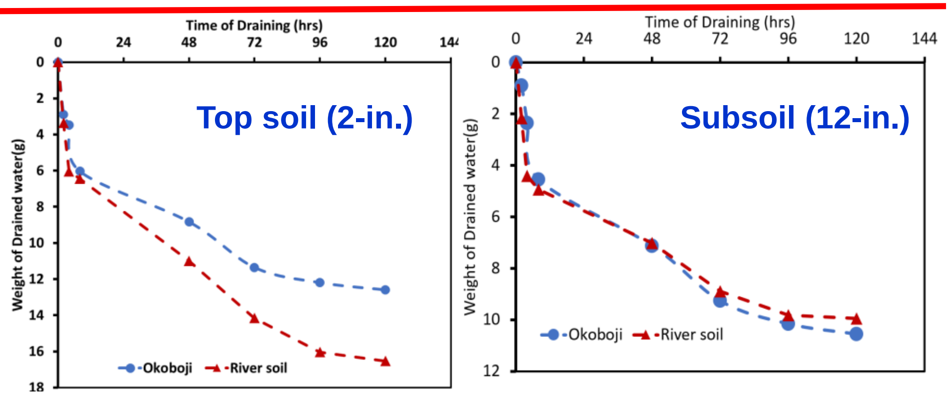

Soil core sampled from four soil series

Soil saturation and drainage experiment




Initial soil moisture and degree of saturation

- ✓ At 57% and 42% degree of saturation Okoboji and River sand soil supported 2-ton and 2WD JD 2950 (4.6 t 18.4-34 Rear axle) tractor traffick with low rut)




Initial soil moisture and degree of saturation

✓For poor-drained soil series (Okoboji series), 3-days was required to drained 2-in. equivalent precipitation

✓For well-drained sandy soil (Skunk river side), soil wetness reached to small tractor load bearing capacity in 3-days drainage

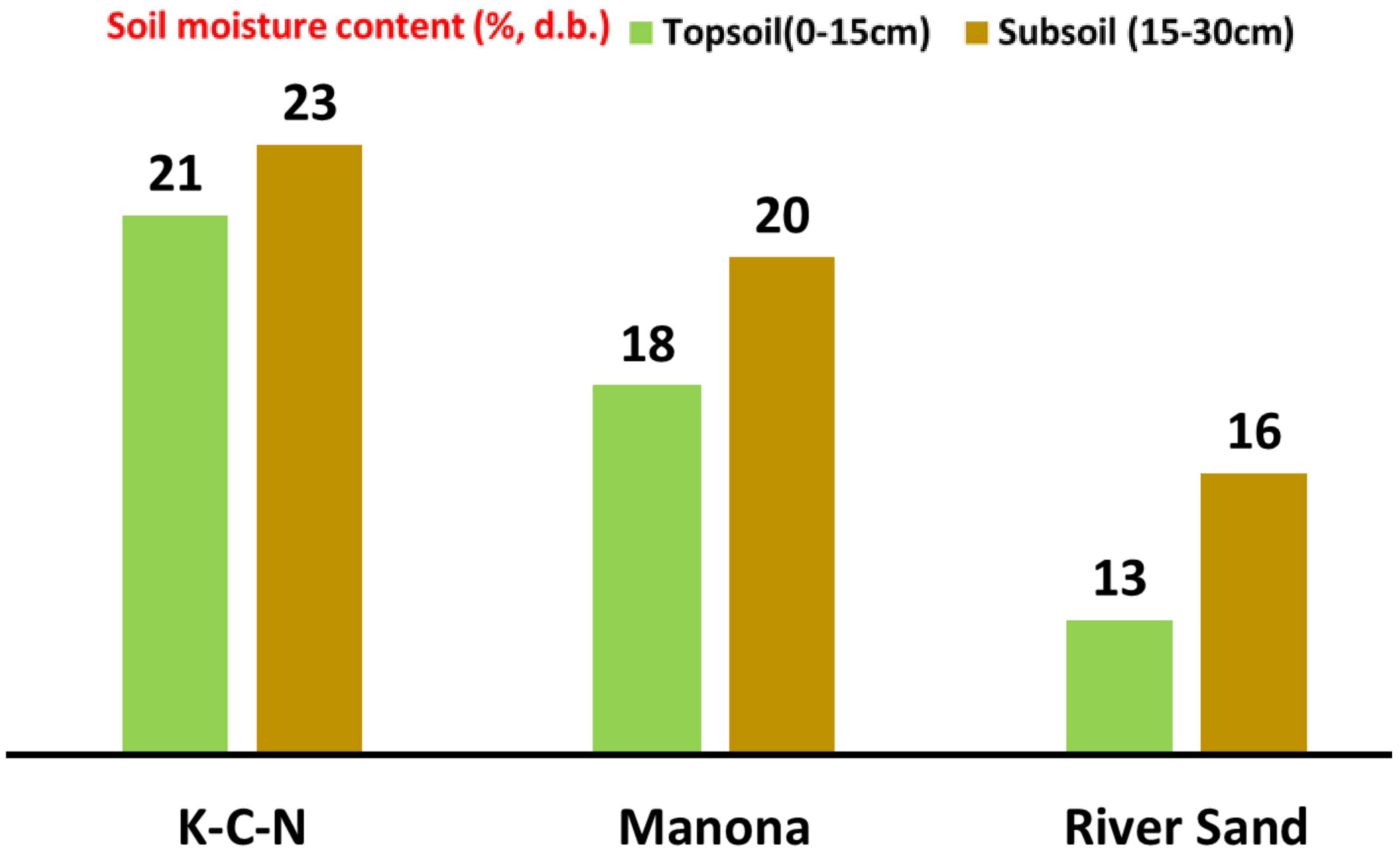
# Soil sampling (crop field – Okoboji, Clarion, and Nicollet, **Monona,** and river sand (skunk river)


(1) Okoboji silty clay loam (6),
(2) Clarion loam (L138C2), and
(3) Nicollet loam (L55)


(4) Spillville loam/Hanlon fine sandy loam (485/536) " River sand" (occasionally flooded)


[5] Monona (100B) silty clay loam, 2 to 5 percent slopes

# “Soil wetness” classes for allowable soil bearing on farm soils



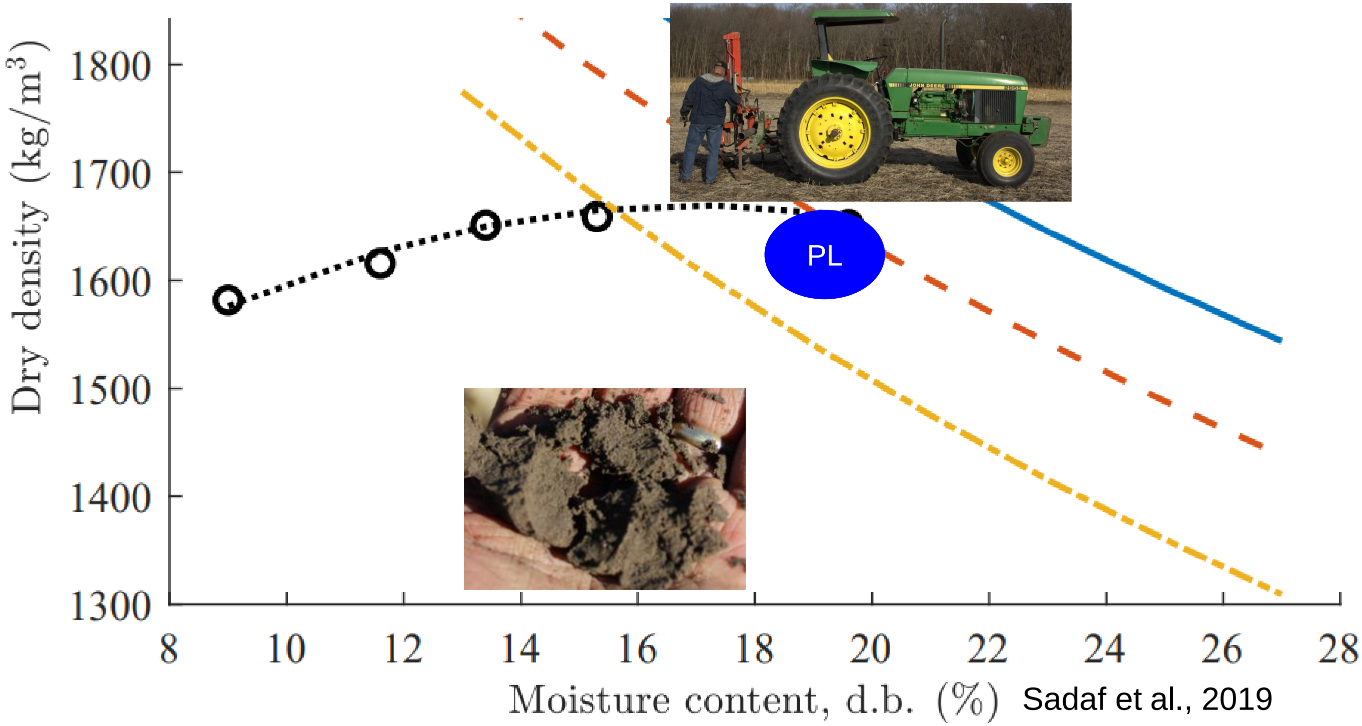

Note: Mean soil moisture content (%, d.b.) at the plastic limit for loam soil at ISU farm with dominant Clarion soil series, measured according to the ASTM D4318 was 23.2% (standard deviation 1.9% ) (Tekeste et al., 2016)

# Trafficability Soil Bearing “Support 2WD Tractor with Soil Core Sampler”– Soil Wetness

**Class-I: River sand” (14.5% MC) (FSL)**


**Class-II Monona silty clay loam (CLM)**


**Ground Contact Pressure (GCP) 10KLBS Rear Axle Load (16.9-38)**



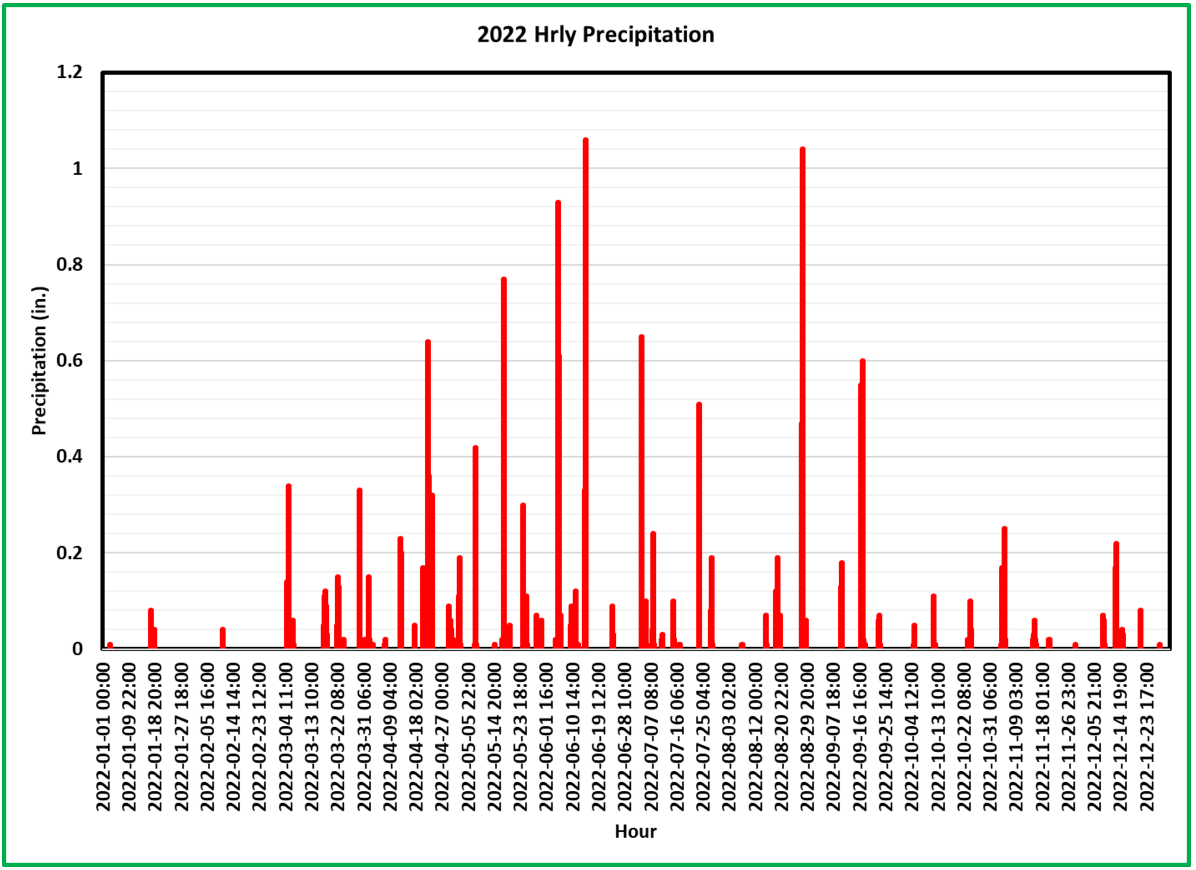

Sadaf et al., 2019

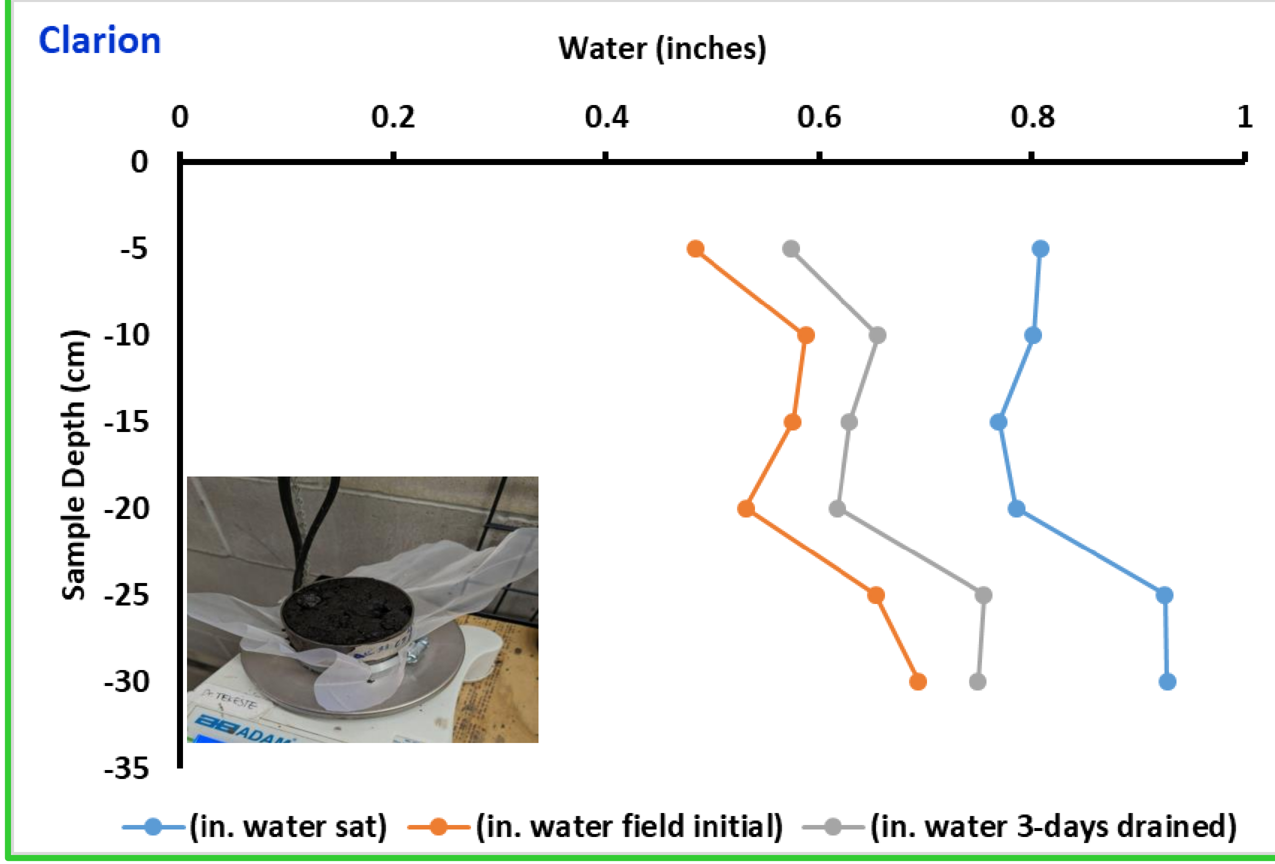
## Three “Soil wetness” classes for allowable soil bearing on farm soils

- FSL (“River Sand”): ***14.5%*** moisture content (0-50 cm)
- SCL (M): ***19%*** moisture content (0-50 cm)
- SCL-L (O-C-N): ***22%*** moisture content (0-50 cm) (scale: 0.95)

**Scale is defined as $MC/MC_{PL}$ [PL: OK 25.3%, CL 23.2%*,N: 20%] * Tekeste et al, 2019**

# Summary: Rainfall and soil wetness




| Stat | In. |
|---|---|
| Mean | 0.004 |
| Upper 95% Mean | 0.005 |
| Lower 95% Mean | 0.003 |
| Maximum | 1.06 |

Clarion (C) , Nicollet (N),Okoboji (O)

**Mean inches of water at saturation (2 inch soil depth)**

**Top soil (0-15 cm (6-in.) (**O-C-N) 0.85 inches

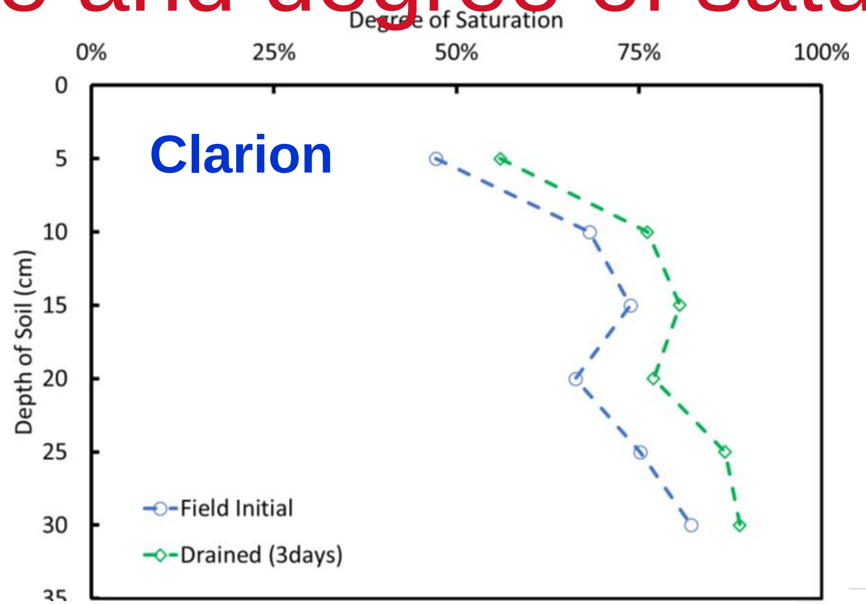
**Subsoil (15 – 30 cm (12-in.)) (**O-C-N) 0.89 inches

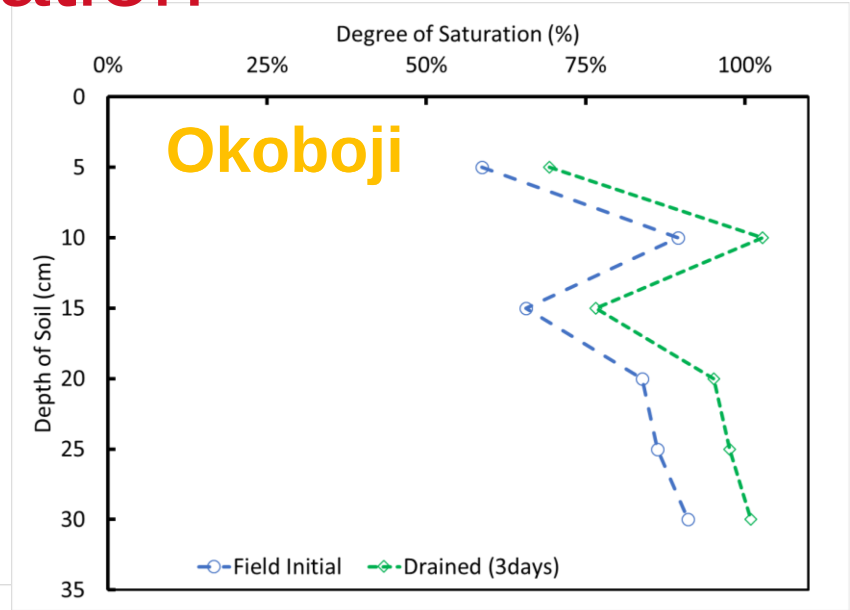
**Mean inches of water at after 3-days drained (2 inch soil depth)**

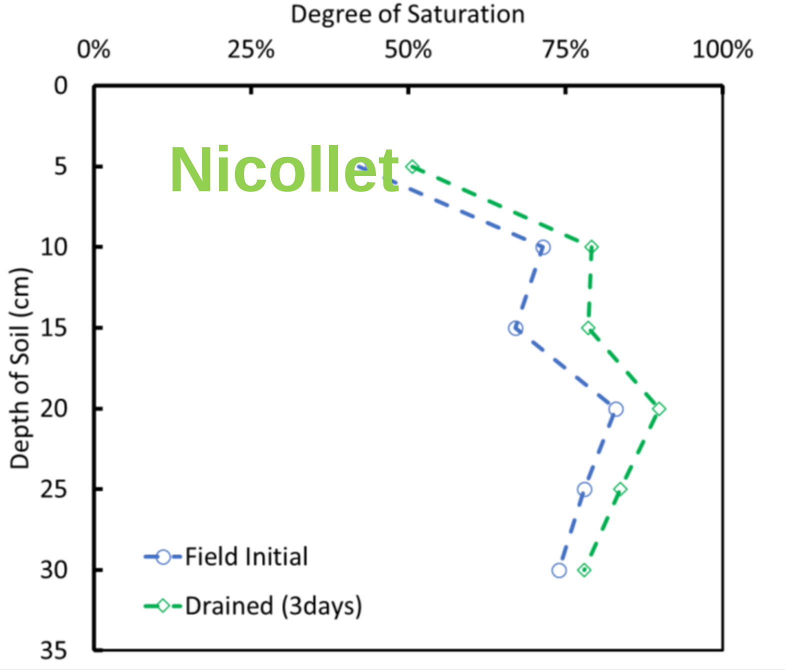
**Top soil (0-15 cm (6-in.): (**O-C-N) 0.67 inches

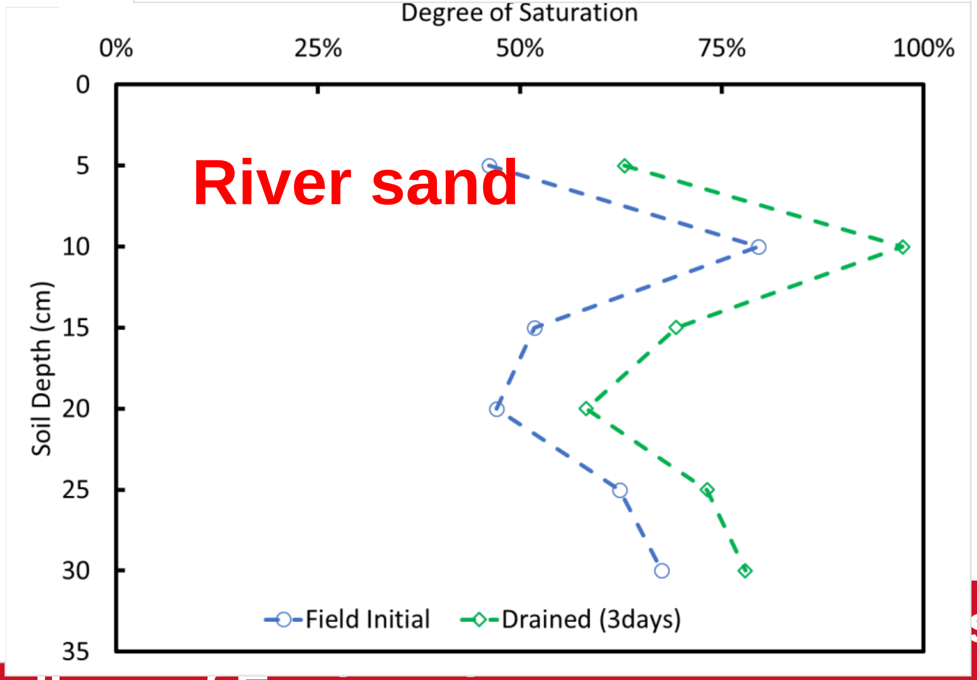
**Subsoil (15 – 30 m cm (12-in.)): (**O-C-N) 0.74 inches

# Drainage and degree of saturation



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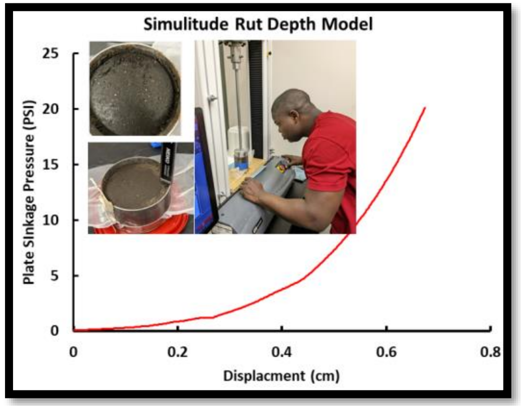
# Phase-II New Proposal

# Next Steps

1. New procedure can be developed to **measure soil moisture in-situ** to **compatible soil moisture state** , and define soil excessive rutting susceptibility class for pneumatic tire semi-truck pipeline transporting truck (**100 PSI**), and earth-moving crawler truck (**6 PSI**) at wet soil state



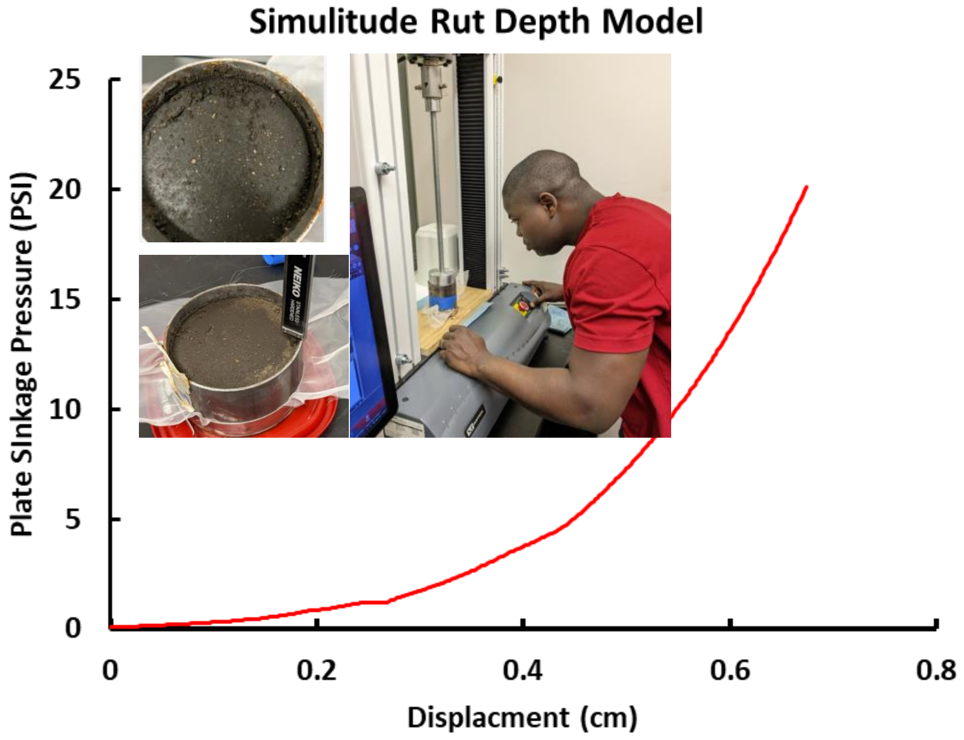

(1) Handheld ( <= 100 PSI)

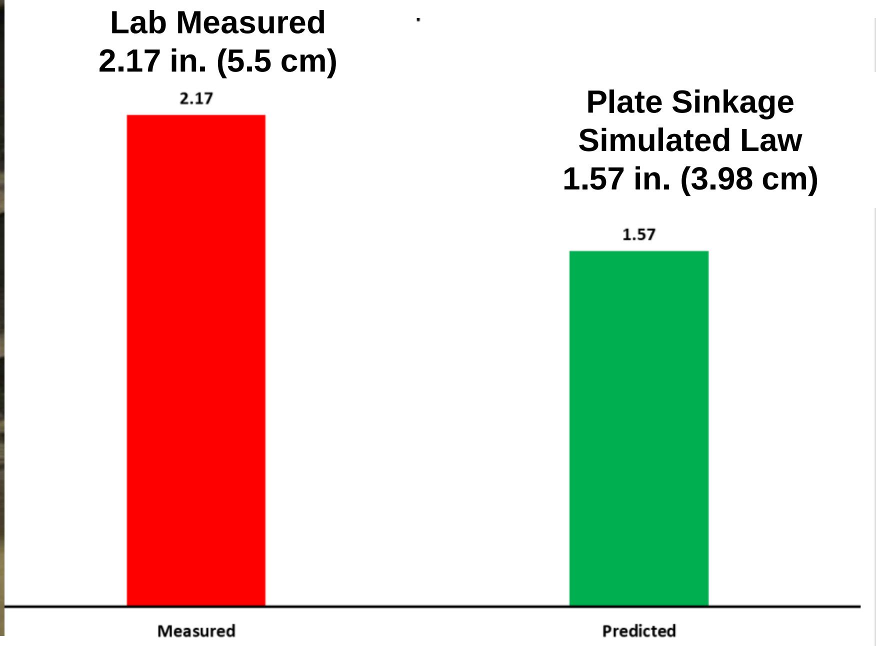
(2) Portable to truck (inspector truck)

- Training and evaluation of method at ISU farm (small scale)

# Laboratory method for rut depth to predict close to the field initial condition

## Laboratory Simulated Rut Sinkage




Row-Crop Tractor 4,790 lbs/per (480/80R50)@26PSI, rut depth = 5.5 cm (2.17 in.)

Relative error 27.7%

# Contact Information

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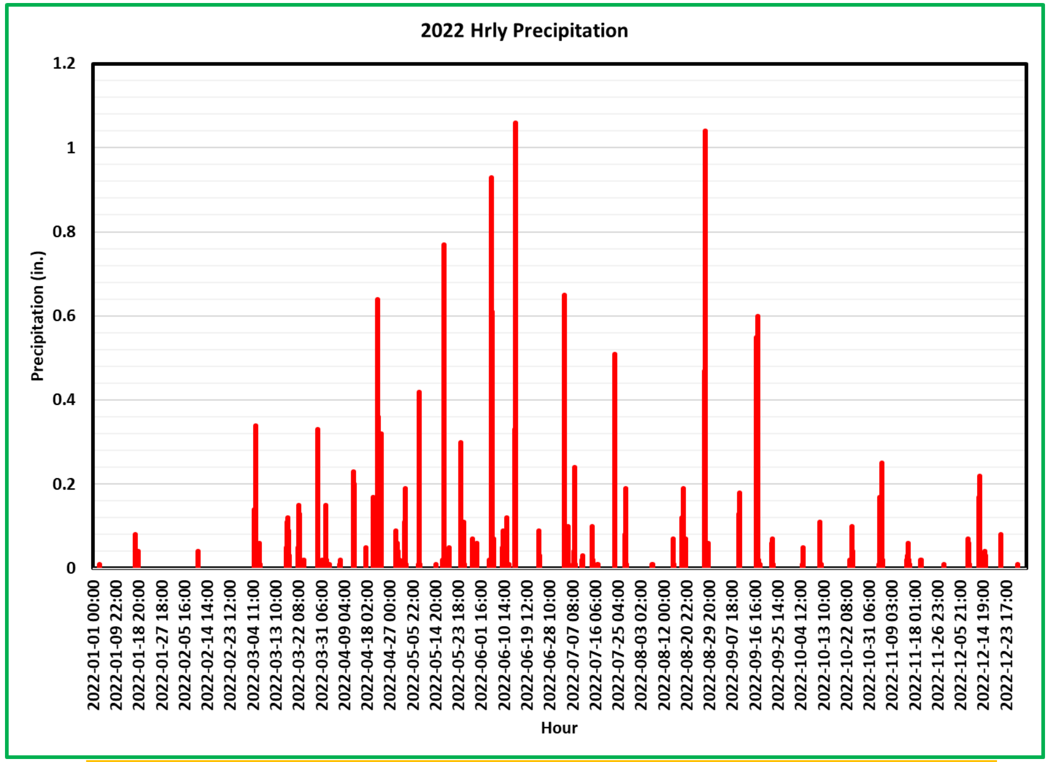
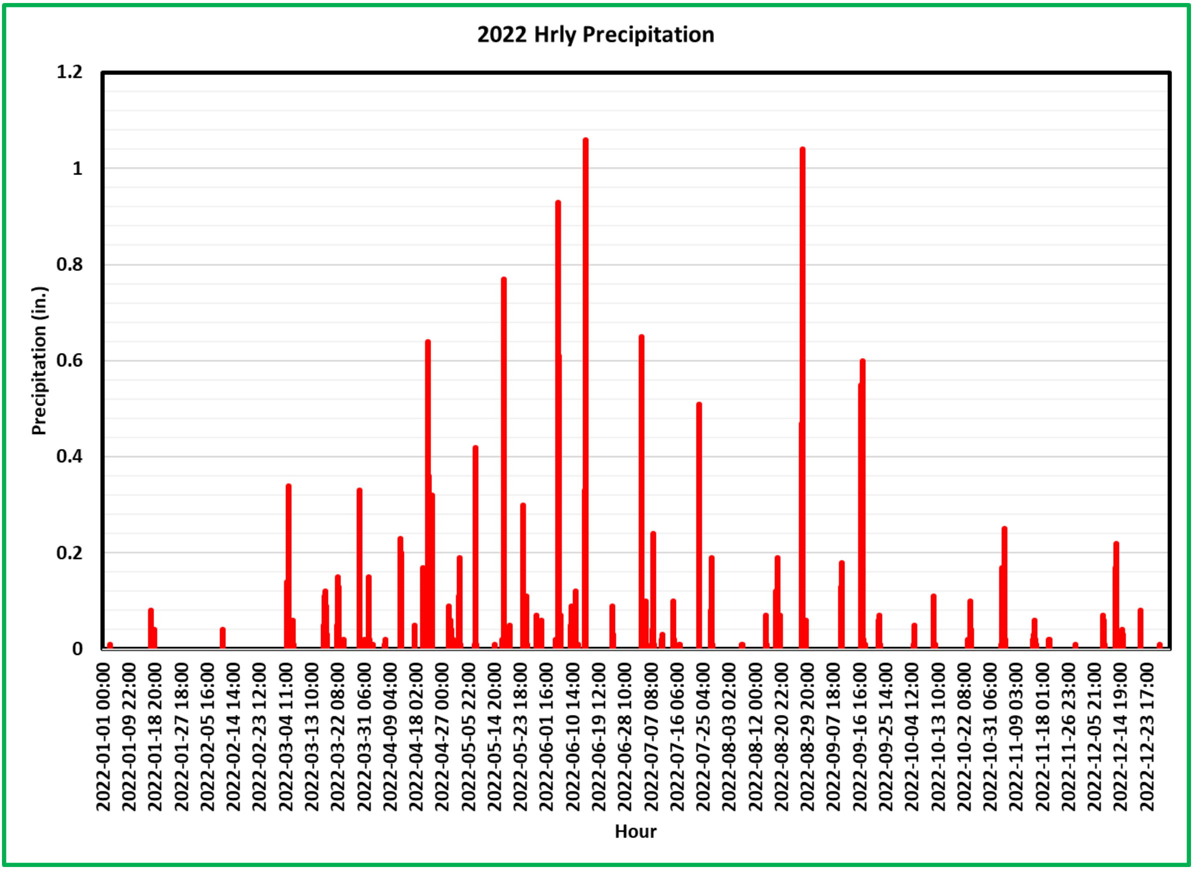
Cell:  (515) 686-7102
Email:  mtekeste@iastate.edu

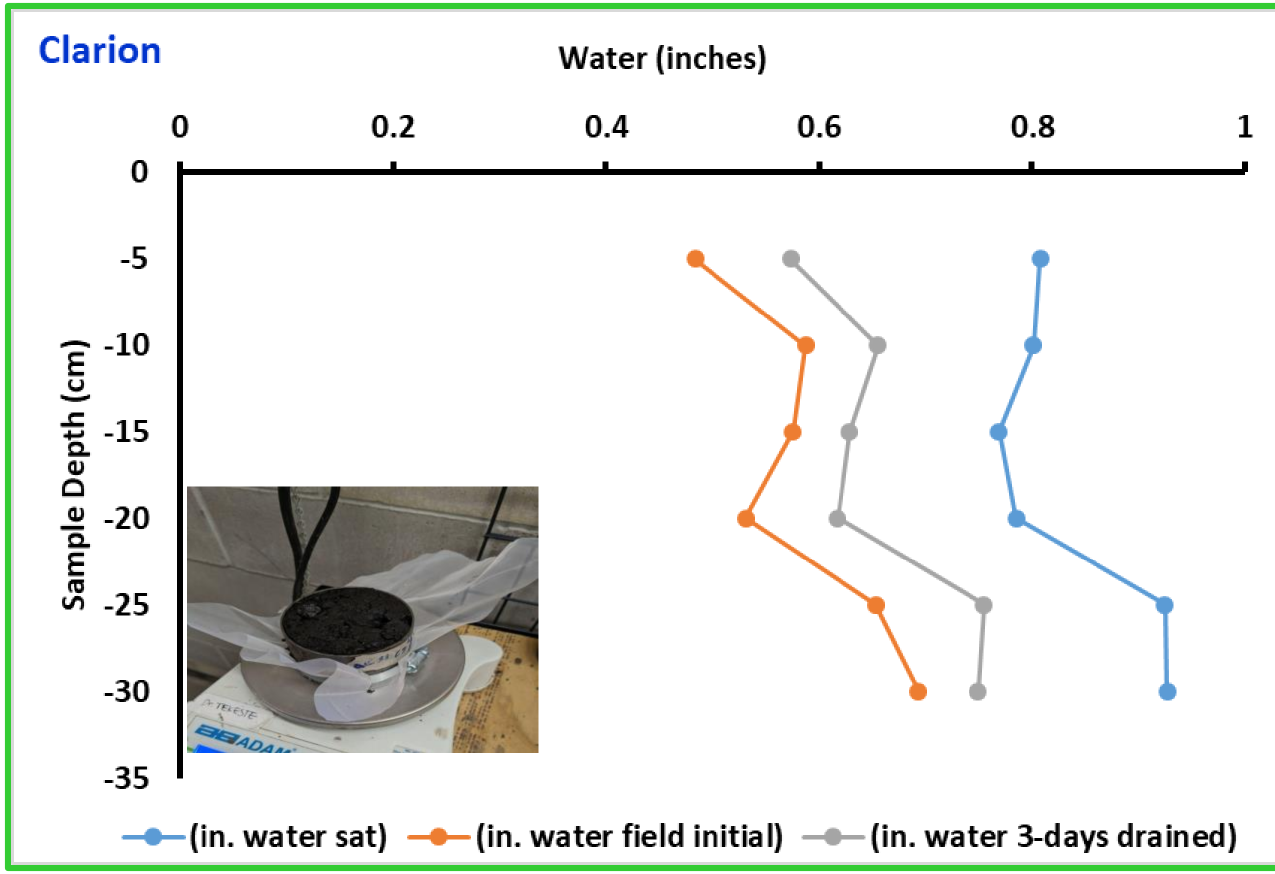
# Hourly Precipitation (ISU Close to Soil Sampling Site) (N = 8759)




| Stat | In. | mm |
|---|---|---|
| Mean | 0.004 | 0.101 |
| Upper 95% Mean | 0.005 | 0.119 |
| Lower 95% Mean | 0.003 | 0.082 |
| Maximum | 1.06 | 26.924 |

# Summary: Rainfall and soil wetness

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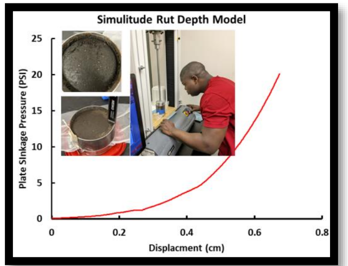
# Discussion - NEXT

1. Topsoil depth classification or sampling is necessary to implement the soil wetness classification to the pipeline impacts soils for four-classes
   - **<u>Action Item</u>**: Samples from south west / Steve's
2. New procedure can be developed to **measure soil moisture in-situ** to **compatible soil moisture state** , and define soil excessive rutting susceptibility class for pneumatic tire semi-truck pipeline transporting truck (**100 PSI**), and earth-moving crawler truck (**6 PSI**) at wet soil state

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