UNIVERSITY OF MINNESOTA
EXTENSION

Extension Irrigation

SUMMARY REPORT

Dakota County Irrigation Scheduling Program

Joshua Stamper and Joshua Cook

SUMMARY

Nitrate-N contamination of groundwater in Dakota county is a common problem, and often is associated with the overuse of nitrogen fertilizer and irrigation of coarse textured soils. The recipe for groundwater contamination consistently involves N fertilizer beyond what the crop can assimilate and too much water moving through sandy soils. The objective of this project was to use irrigation water management as a means to educate irrigators about irrigation water management tools, and to engage growers in being part of the solution in curbing groundwater contamination from N fertilizers. The 2016 growing season was typified by above average rainfall, and excellent growing conditions. One of the downsides to this precipitation was the occurrence of leaching events. However, soil water balances for these fields indicate that irrigation events were a relatively minor contributor to leaching. Surveys also indicate immense potential to use nitrate-N in irrigation water to credit N rates in areas with existing groundwater contamination.

OBJECTIVE

Decrease the use of local groundwater supplies and the potential for nitrate groundwater contamination. Increase farmer's understanding of field-measured soil moisture and irrigation scheduling tools. By creating awareness and education of these tools, it would efficiently use local groundwater supplies and minimize the loss of fertilizer nitrogen to groundwater. To accomplish this, the following activities were undertaken:

1) Record, document, and collect soil moisture information in farmer's fields by the use of soil moisture sensors.,. Update the soil water balance in the irrigation scheduling checkbook based on the field measured soil moisture.
2) Provide weekly soil moisture updates from these tools to farmers to enhance their irrigation management decisions.
3) Compile and present the data in a final report that includes the aggregated data from pre and post projects surveys to assess behavioral and management changes.

METHODS

Extension staff met with growers early in the season to verify field maps, field access points, survey growers, and better understand the management systems are already in place. Irrigators were given choices of 4 different tools to use during the growing season.

- <u>Option 1</u>: Irrigation scheduling checkbook and weekly Time Domain Reflectometry (TDR) readings to help inform the growers about variability across fields and to provide site specific checkbook corrections. Growers enrolled in this option will pay $200 per pivot to the University of Minnesota as program income. UMN staff provide weekly field visits to collect soil moisture information to update irrigation scheduling checkbook.

- Option 2: Telemetry and soil moisture sensors: Install Aqua-Trac telemetry units which read Watermark sensors to provide growers with a simplified, “real time” measurement of soil water availability through the Ag Sense data portal. University of Minnesota will order, install, provide data interpretation and provide technical assistance. Growers will be responsible for all of the costs except for a $200 per field credit.
- Option 3: Private 3rd party irrigation consultation and instrumentation (Crop Metrics through local dealer): Growers will make payment for services directly to 3rd party service provider. Growers will be responsible for all of the costs of third party except for a $400 per field credit.
- Option 4: Tensiometer installation: Setup, installation, data interpretation and trouble-shooting throughout the first season is included. Growers enrolled in this option will pay $200 per pivot to the University of Minnesota.

The program signed on 14 growers accounting for 28 fields and the majority chose to use Option 1 (checkbook soil water balance), but all options were used at least once. The checkbook was maintained on all fields enrolled, even if the grower was relying on soil moisture sensors, tensiometers, or 3rd party services. This allowed for quantification of a water balance for all fields.

Use of the irrigation scheduling checkbook is an excellent way to track and forecast crop water need according to a soil water balance. The checkbook automates record keeping, allows for forecasting, and keeps track of leaching/runoff losses. However the irrigation Scheduling checkbook has limitations, particularly the frequent data entry. It is widely acknowledged that farmers do not like having to enter data every day to keep up the checkbook. Second, while the checkbook offers one of the most advanced ways to account for variation in water holding capacity in a soil profile, it does not allow users to account for soil variability **within** a field. Since some of the fields enrolled exhibited a wide range of soil textures we elected to also use a TDR 300 soil moisture sensor because of its portability and functionality. The instrument measures relative soil moisture, and records the xy coordinates. This quantifies the soil water variability within fields during weekly field visits.

RESULTS

The 2016 growing season was exceptionally wet, and was followed by a very warm and wet fall. Most growers acknowledged that this was one of their best growing seasons to date. Soybean yields were exceptional to record breaking, with little disease pressure despite the heavy rainfall. Corn yields were also exceptional, but low commodity prices limited profitability. Yield data for canning crops was not available.

Figure 1 below displays the general crop statistics for the program.

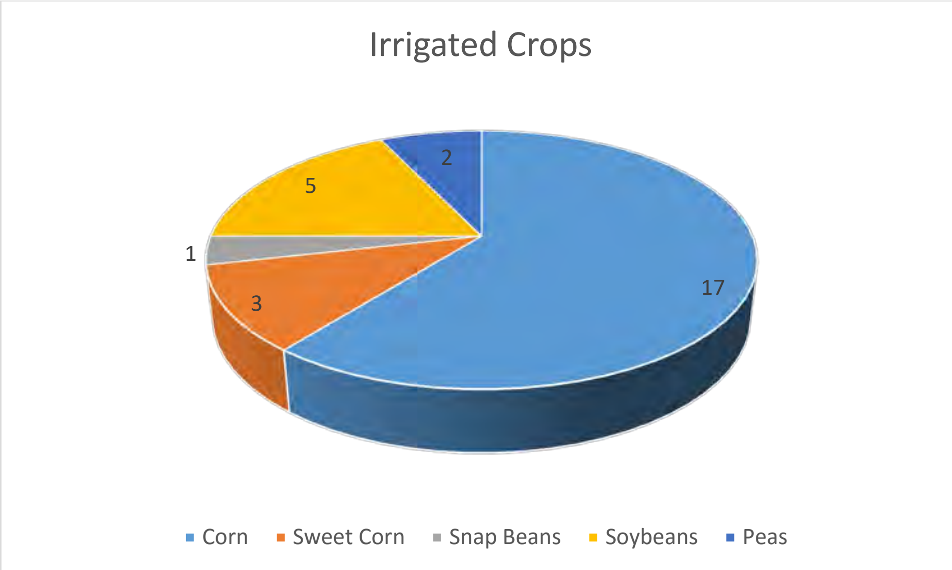


Figure 1. Corn and soybeans was the most common crops grown in the program, but canning crops like sweet corn, snap beans and peas were also grown. Note that several fields were double cropped with canning crops.

Irrigation water use was relatively low during the 2016 growing season. Average irrigation water use was less than 3.5 inches, which represented less than 25% of the total evapotranspiration (ET) demand during the growing season. Figure 2 displays the ranges in irrigation water use during the 2016 year.

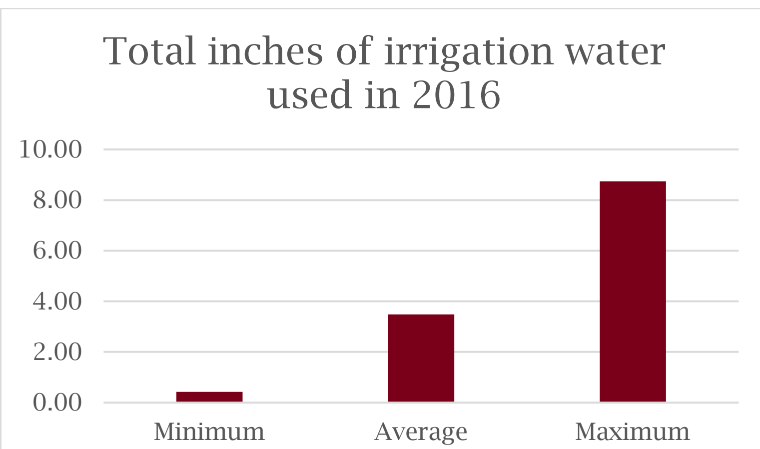


Figure 2 Irrigation water use across all 28 fields in 2016.

Water losses to leaching and or runoff were also calculated by the irrigation scheduling checkbook in Figure 3. It is important to keep in mind that this metric is just a daily time step of the water balance. If the soil profile is saturated and addition rain or irrigation is added, the water will either runoff, or will infiltrate, potentially leaching nitrates out of the root zone. The timing of these excessive water inputs can be more causal in leaching than just the total amount of water going into the season.

A water balance, in any particular soil, is like a rubber band. The greater the water holding capacity of the soil, the farther it can stretch. Loam soils that can hold the most water, are more dynamic than sandy soils which hold much less water. This capacity to supply water to plants also extends to a soils ability to retain rainfall. However, as rainfall intensity increases to a point that a soil is no longer able to infiltrate the water, runoff will occur. This is especially true on steep slopes.

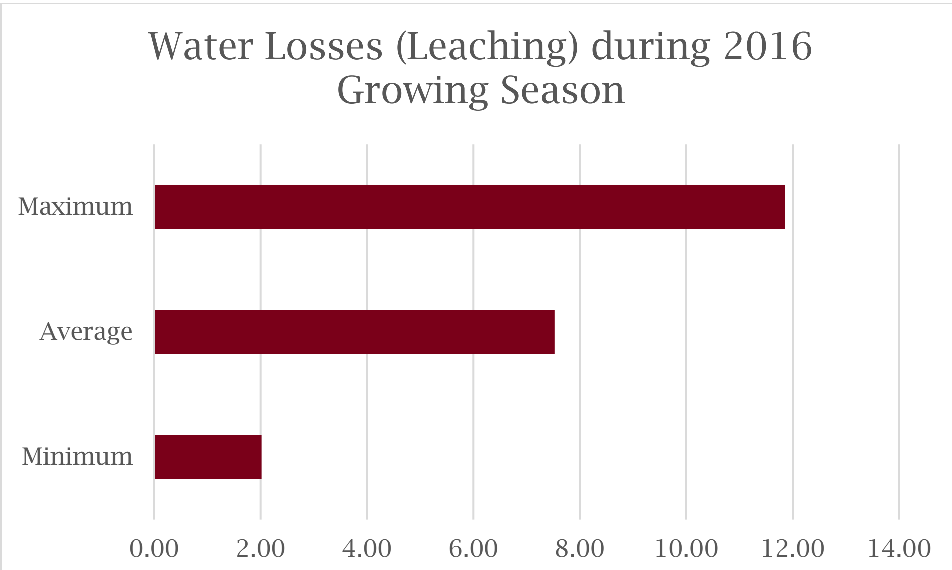


Figure 3 Water losses calculated by checkbook from May 15-Sept 15. Note that this includes periods with no vegetative growth/ET.

SURVEY RESULTS

Full results of the pre and post programs surveys are attached in the appendix of this document. The most interesting results are summarized below.

- More than half of the participants in the program were irrigating more than five fields. This group tended to embrace more of the advanced, telemetry based soil moisture systems.
- All growers wanted to know more about the nitrate-N in their irrigation water. This indicates that there is a knowledge gap that could be filled to help growers better use the nitrates in irrigation water to credit their nitrogen fertilizer rate. This would be an excellent opportunity for a local extension educator to collect samples early in the growing season so that irrigators could use this information to credit N fertilizer use.
- When asked about why they chose to participate in the program, the greatest percentage of irrigators expressed an interest in learning more about irrigation water management. As the season progressed, growers often asked more complex questions about the management of irrigation water. This indicates both the need for more timely education and the need for more hands on training.

- Irrigators were surveyed prior to and following the program about how valuable they thought that the program would be in terms of dollars per acre. This was to help understand the baselines for how to value these services that have not historically been offered in Minnesota. Prior to beginning the program, the average perceived value was 16.10 per acre (min $5/ac and max $30/ac). At the end of the program, the average perceived value was $13.47 per acre (min $0.75/ac and max $50/ac). This decline in perceived value could be related to several factors, but most growers acknowledged that when you do not need to irrigate that much, the return to that management time is diminished. It should also be noted that several growers had a hard time coming up with a value at the end of the season.
- Over 85% of irrigators used split application of N fertilizers, and half were using their center pivots to spoon feed N to the crops using fertigation.
- More than 75% of irrigators that participated indicated that they would enroll more acres in the future if the program was offered, and the participants that said that they would not enroll more, indicated that they had already enrolled all their irrigated acres.
- The growers whom used soil moisture sensors and telemetry (either from UMN Extension or 3rd party services) indicated that they wanted to have sensors in more fields, and several indicated that they wanted to integrate variable rate irrigation technology with their sensor technology.
- All growers indicated that the program was worth their time and offered the following comments to other irrigators that were not currently participating:
    - It's a good program to start with
    - A good chance to learn by trial and error
    - Checkbook verifies decisions
    - There are things to learn for everyone
    - It’s worth the Money. I have spent way more on things and gotten way less back
    - See if you can learn something new
    - Beneficial. Learning how to do the data entry and forecasting in checkbook was really useful
    - excellent return to the time invested
    - Always beneficial to learn more
    - Variable Rate Irrigation and N Rate is the future, but we need to embrace the soil sensor technology. once a sensor goes in, more will follow.
    - Pretty good. Always nice to have more in-season knowledge
    - Definitely consider it
- There was a large increase in understanding of Irrigation Water Management when comparing pre-project surveys to post-project surveys. Figure 4 presents irrigators understanding of irrigation water management prior to beginning the program. Figure 5 shows the increased understanding of irrigation water management after a season.

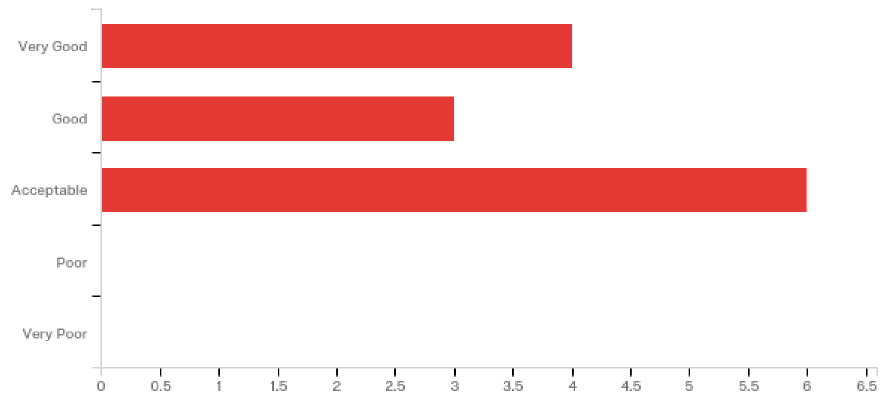


*Figure 4 Grower understanding of irrigation water management **before** the 2016 project in Dakota County*

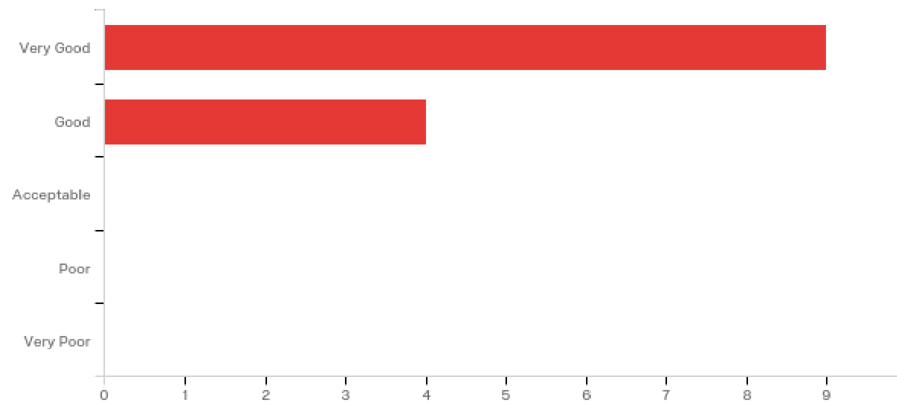


*Figure 5 Grower understanding of irrigation water management **after** the 2016 project in Dakota County*

CONCLUSION

There is still a large vacuum of technical support for irrigators in Dakota county. As can be observed from the comments in the follow up surveys, irrigators are hungry for more actionable data that can assist their decision making process. This data communication can come from a field technician leaving a checkbook printout on the shop door, an email or txt msg, or it can be from a smart-phone application that provides the grower real time soil moisture info. What is important, is that services like this one are flexible enough to provide growers with information that they find valuable. This is also an exciting time, with the increased use of cover crops to assist in the assimilation of excess nitrate left in the soil profile. An integrated approach that couple's N and water management with perennial and cover crops would be a logical progression of the current programming.

Nitrate contamination of drinking water is a pernicious problem in many parts of the country. Remediating groundwater contamination from nitrates is a slow and arduous process, but it can be done! There is no silver bullet to remedy nitrates in groundwater, but the right amount of buckshot has been shown to reverse the trends of high nitrates in groundwater. Hall and Merrick counties in Nebraska are excellent examples of this integrated, silver buckshot approach to remediating nitrate-N contamination in groundwater. Nitrogen fertilizer management and improved irrigation water management programs that are supported by Extension and the local natural resource districts in Nebraska have been credited with much of this success.

As Dakota County moves forward in the future, we hope that research-based extension programs can continue to be play a role in addressing nitrate-N contamination in groundwater and providing technical assistance to farmers.

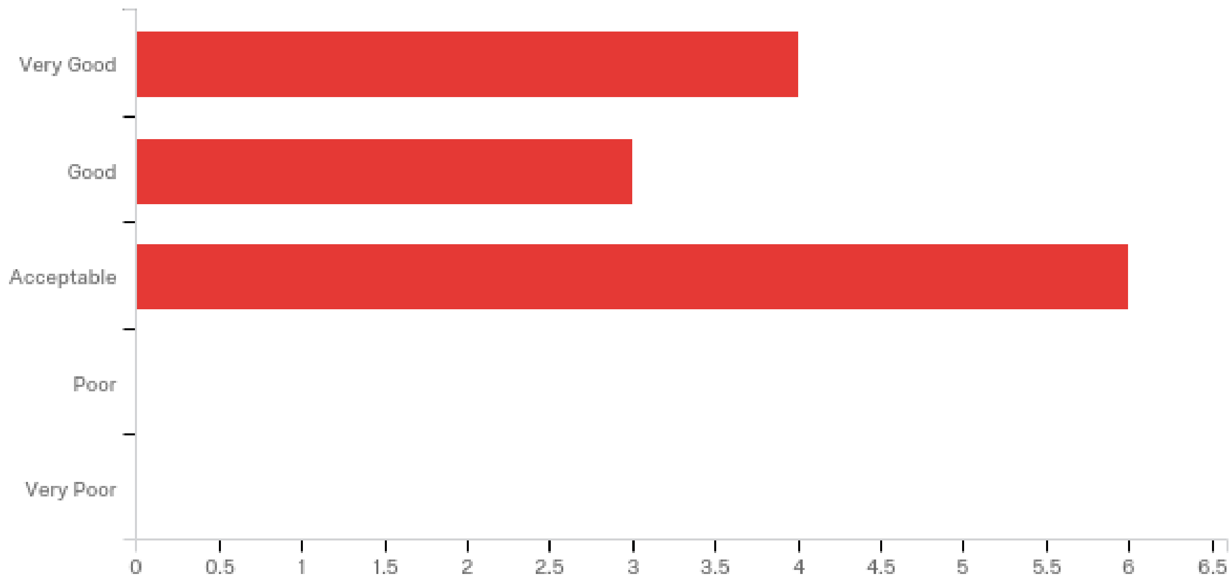
Attached are Appendices of supplemental information

Appendix A: Pre-program survey of irrigators participating

Appendix B: Post-program survey of irrigators participating

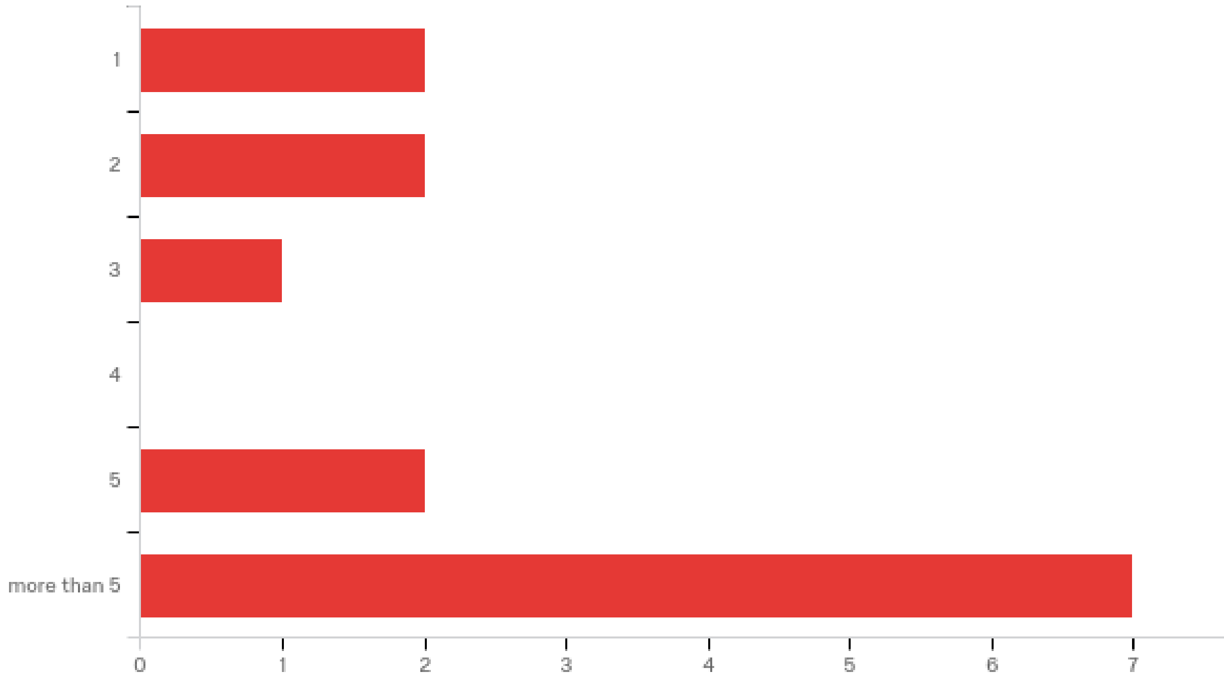
Appendix C: TDR 300 soil specific calibrations for Dakota County

Q1 - How well do you understand Irrigation Water Management now?



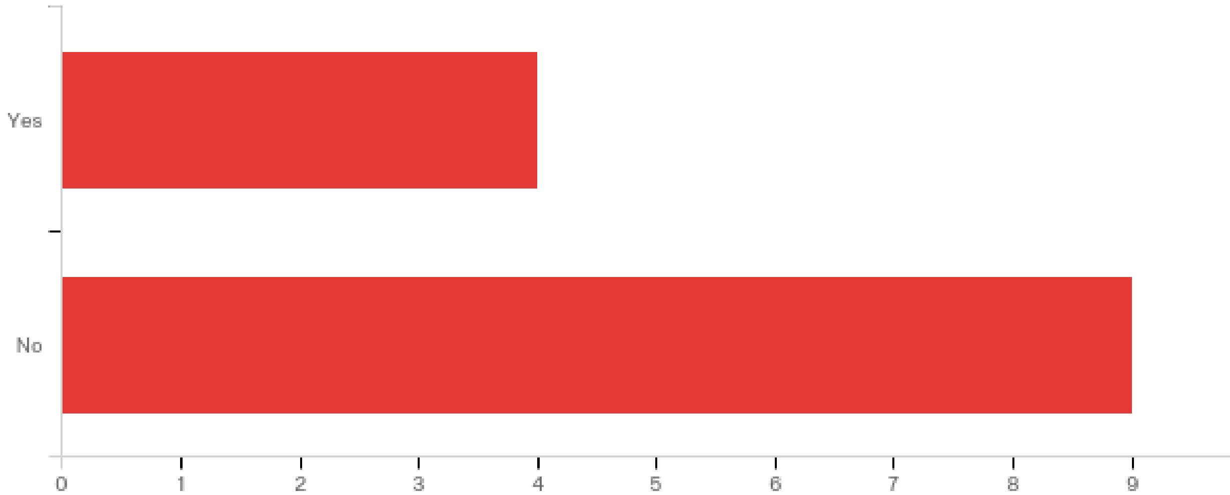
#	Answer	%	Count
1	Very Good	30.77%	4
2	Good	23.08%	3
3	Acceptable	46.15%	6
4	Poor	0.00%	0
5	Very Poor	0.00%	0
	Total	100%	13

Q2 - How many fields do you irrigate?



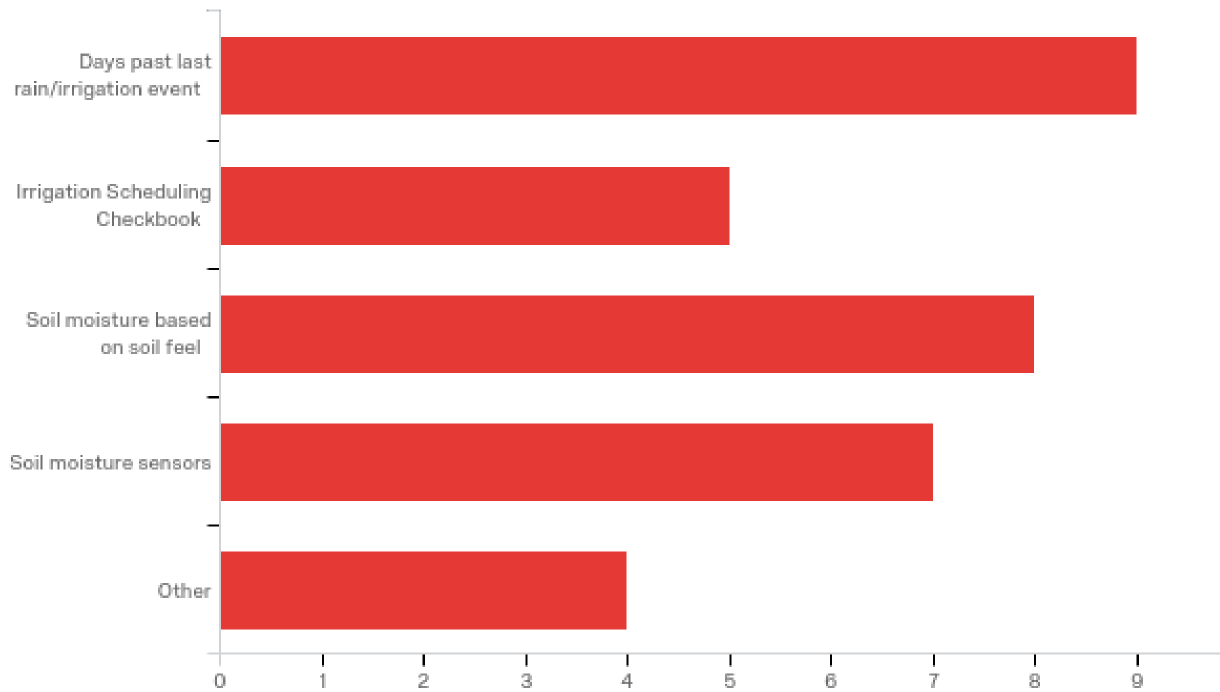
#	Answer	%	Count
1	1	14.29%	2
2	2	14.29%	2
3	3	7.14%	1
4	4	0.00%	0
5	5	14.29%	2
6	more than 5	50.00%	7
	Total	100%	14

Q3 - Are all fields managed the same regarding irrigation practices?



#	Answer	%	Count
1	Yes	30.77%	4
2	No	69.23%	9
	Total	100%	13

Q4 - What methods do you currently use to determine when to irrigate and/or how do you determine when stop irrigating? Choose all that apply.

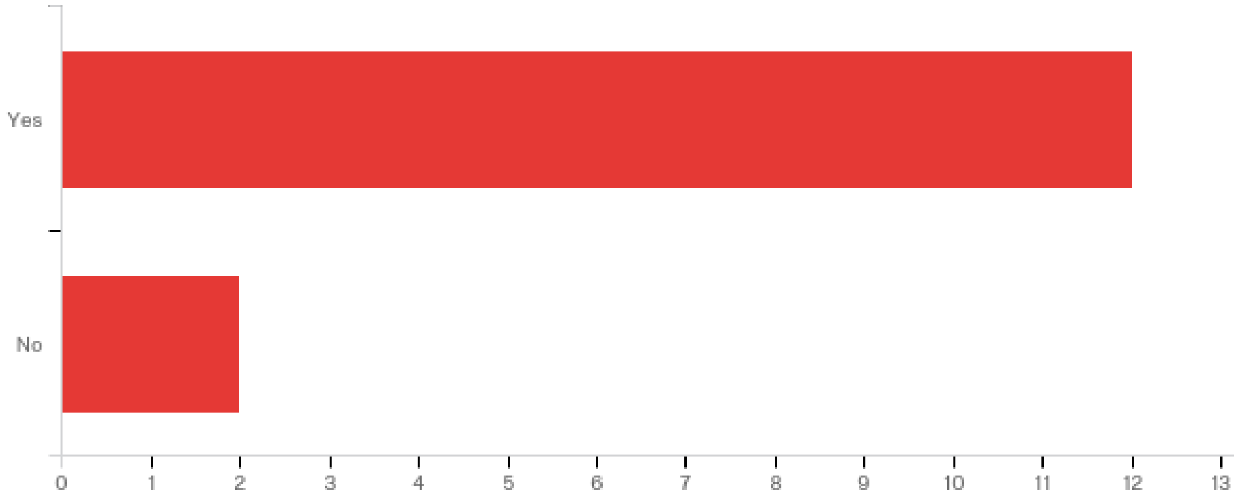


#	Answer	%	Count
1	Days past last rain/irrigation event	60.00%	9
2	Irrigation Scheduling Checkbook	33.33%	5
3	Soil moisture based on soil feel	53.33%	8
4	Soil moisture sensors	46.67%	7
5	Other	26.67%	4
	Total	100%	15

Q5 - Other Detail

Other Detail
gut feeling
Crop Growth Stage
Crop Appearance on gravel knoll

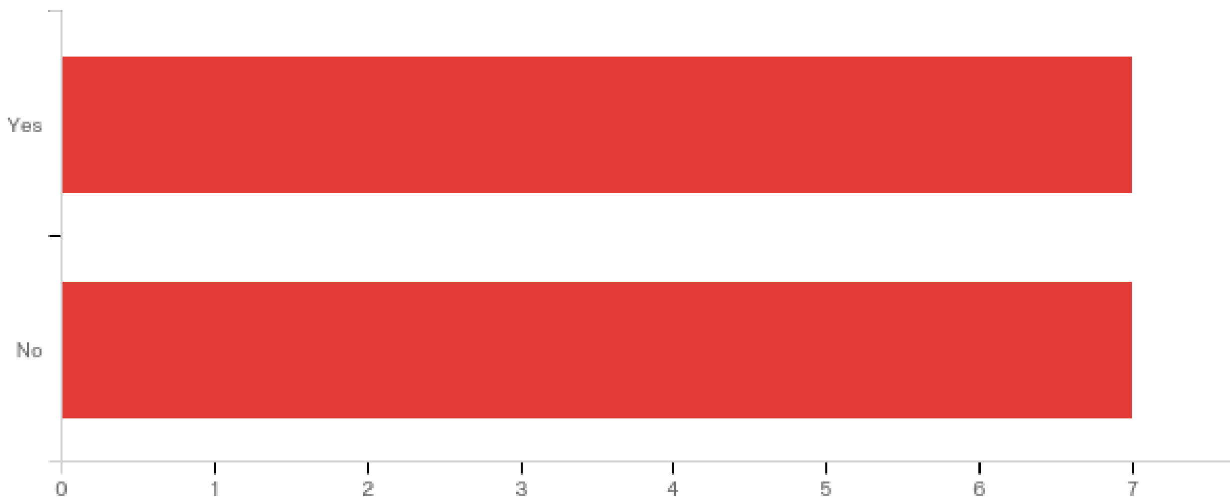
Q6 - Do you currently know what soil types or soil textures you have on all your irrigated fields?



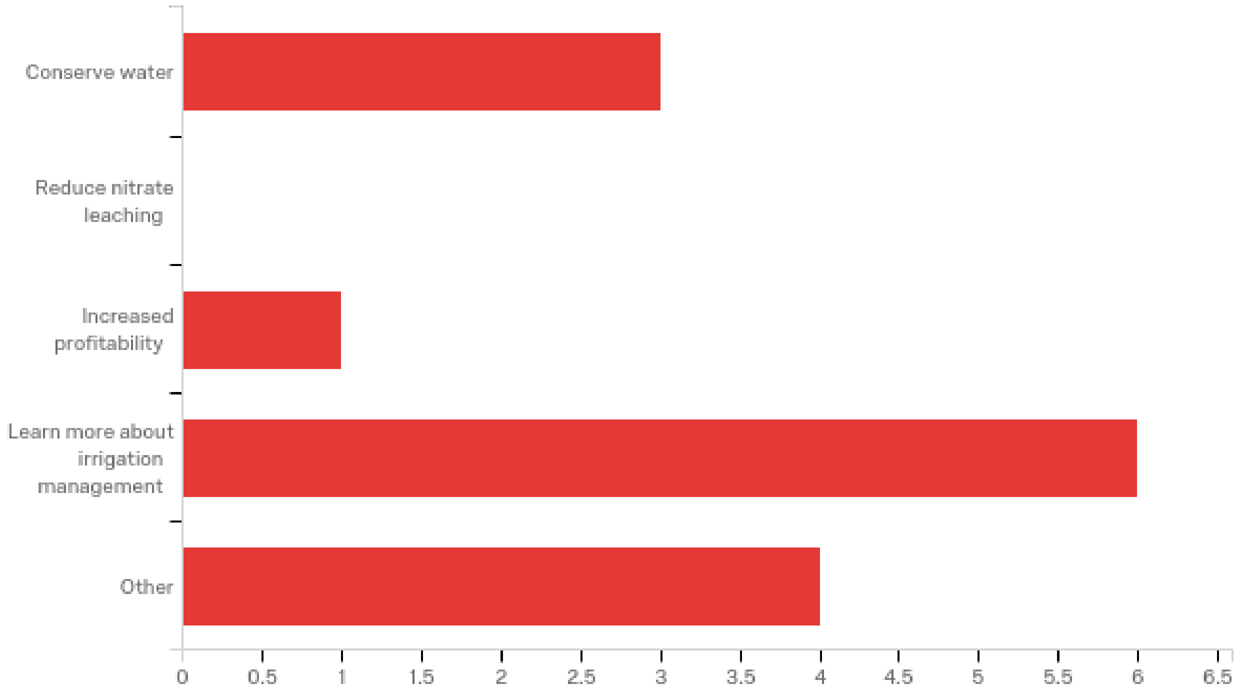
#	Answer	%	Count
1	Yes	85.71%	12
2	No	14.29%	2
	Total	100%	14

Q7 - Do you know the FC (Field Capacity) and PWP (Permanent Wilting Point) for the dominant soil type or soil texture?

#	Answer	%	Count
1	Yes	50.00%	7
2	No	50.00%	7
	Total	100%	14



Q8 - What is the main reason that made you decide to participate in this program?



#	Answer	%	Count
1	Conserve water	21.43%	3
2	Reduce nitrate leaching	0.00%	0
3	Increased profitability	7.14%	1
4	Learn more about irrigation management	42.86%	6
5	Other	28.57%	4
	Total	100%	14

Q9 - Other Detail

Other Detail
Wanted to see what new technologies are
Validate past practices
Want to learn what is new
Trying to be active in showing that you care

Q10 - How valuable do you think the Irrigation Water Management service will be to you in terms of dollars per acre?

Minimum: $5/acre

Maximum: $30/acre

Mean: $16.10/acre

How valuable do you think the Irrigation Water Management service will be t...
15
30
15
25
10
25
7.50
25
20
10
8
10
10
5-25

Q11 - Including N credits from manure and previous crops, what is the most common rate of N you apply on your irrigated fields?

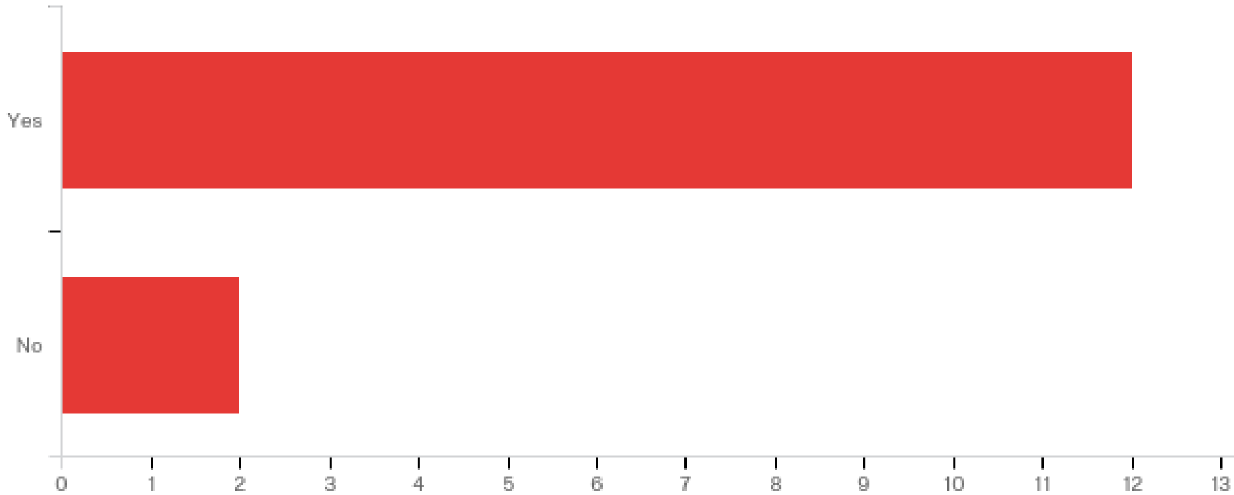
Minimum: 120 lbs N/ac

Maximum: 220 lbs N/ac

Mean: 172 lbs N/ac

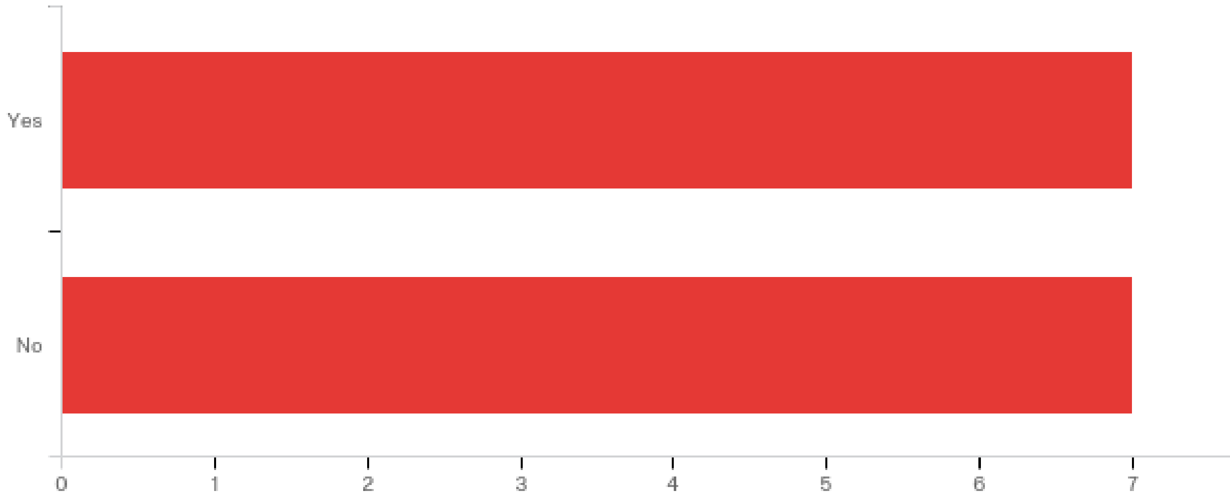
Including N credits from manure and previous crops, what is the most common...
210
180
180
180
190
180
130
150
220
200
120
100
190
180

Q12 - 1. Do you split apply your N fertilizer on your irrigated fields?



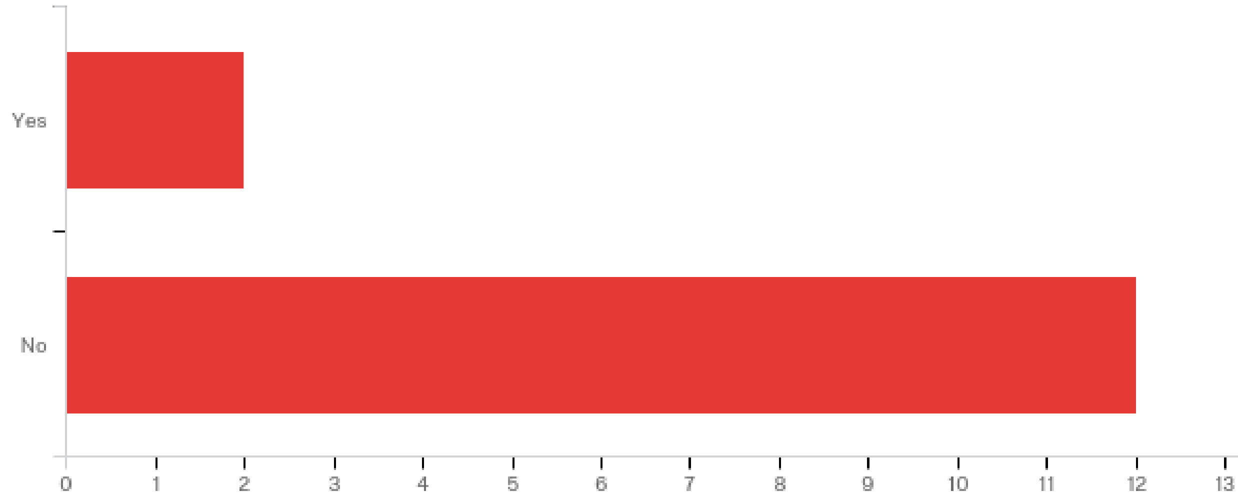
#	Answer	%	Count
1	Yes	85.71%	12
2	No	14.29%	2
	Total	100%	14

Q13 - Do you use fertigation?



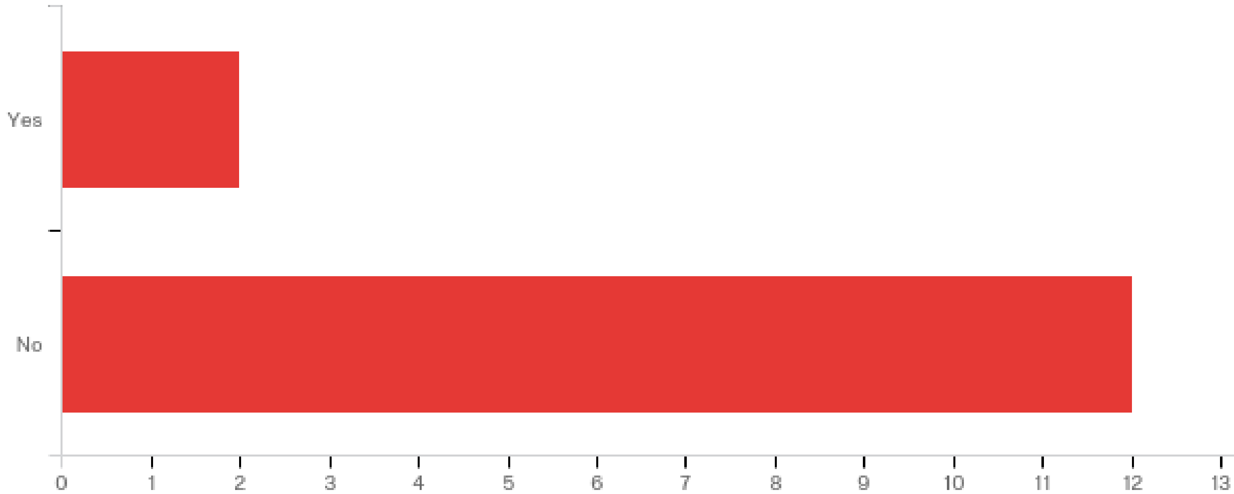
#	Answer	%	Count
1	Yes	50.00%	7
2	No	50.00%	7
	Total	100%	14

Q14 - Do you know the nitrate-N levels in your irrigation water?



#	Answer	%	Count
1	Yes	14.29%	2
2	No	85.71%	12
	Total	100%	14

Q15 - Do you test for nitrate-N in your irrigation water to credit your nitrogen application?



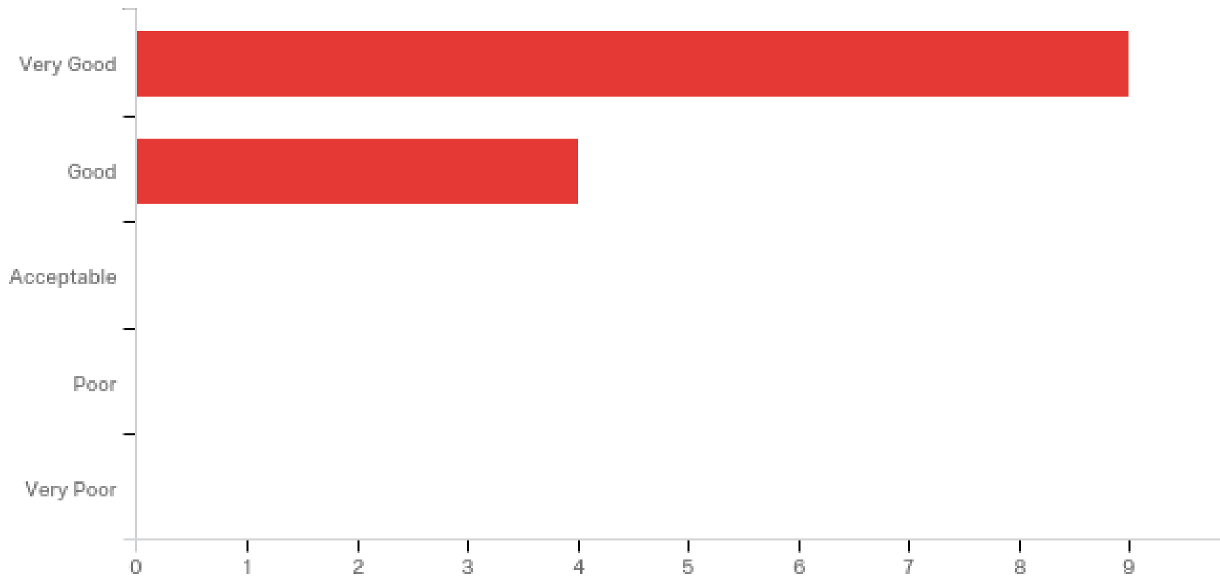
#	Answer	%	Count
1	Yes	14.29%	2
2	No	85.71%	12
	Total	100%	14

Q16 - Would you like University of Minnesota Extension to test the irrigation water and provide a credit for you?

#	Answer	%	Count
1	Yes	100.00%	14
2	No	0.00%	0
	Total	100%	14

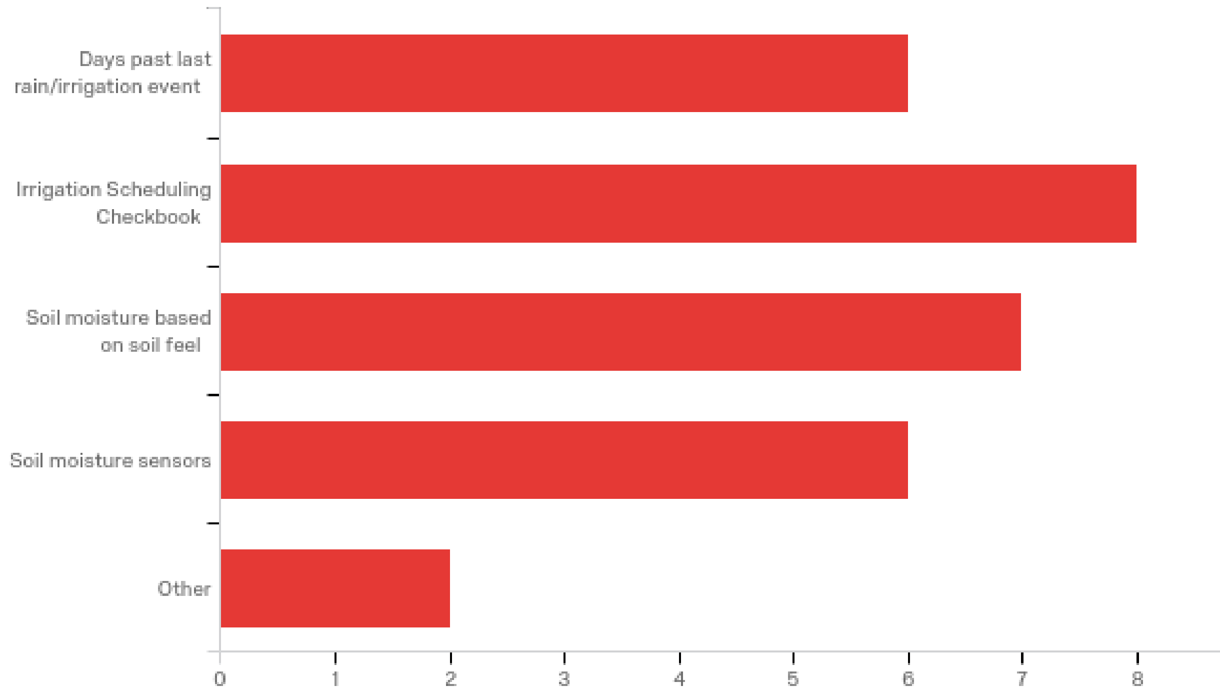
Appendix A to Final Report

Q1 - Based on what you learned this year, and thinking about how you will manage in the future, how well do you understand Irrigation Water Management now?



#	Answer	%	Count
1	Very Good	69.23%	9
2	Good	30.77%	4
3	Acceptable	0.00%	0
4	Poor	0.00%	0
5	Very Poor	0.00%	0
	Total	100%	13

Q4 - What methods do you currently use to determine when to irrigate and/or how do you determine when stop irrigating? Choose all that apply.



#	Answer	%	Count
1	Days past last rain/irrigation event	46.15%	6
2	Irrigation Scheduling Checkbook	61.54%	8
3	Soil moisture based on soil feel	53.85%	7
4	Soil moisture sensors	46.15%	6
5	Other	15.38%	2
	Total	100%	13

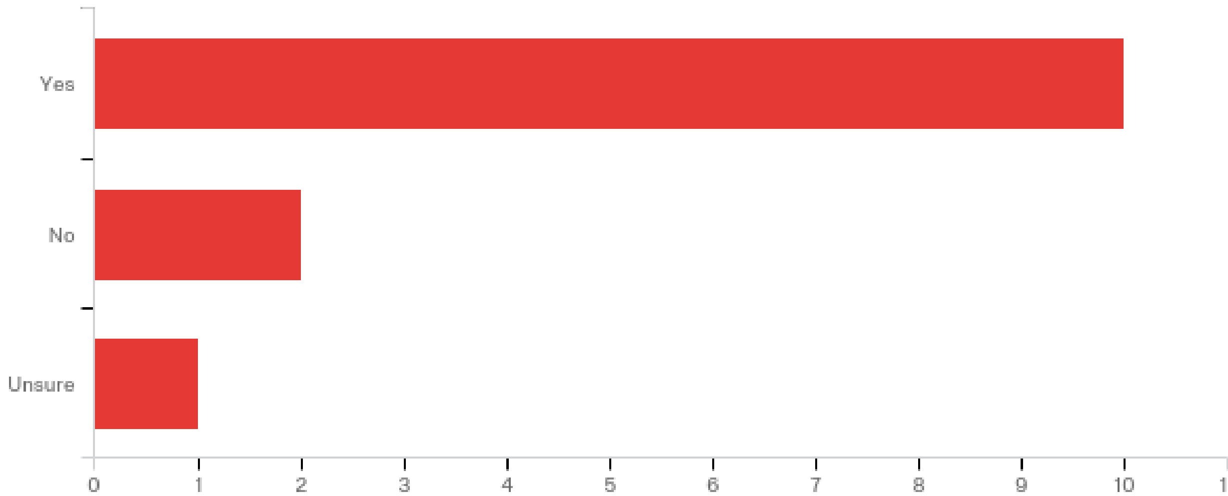
Q5 - Other Detail

Other Detail
Taking visual of plant health
Visual appearance of crops on gravel knob

Q10 - How valuable was the Irrigation Water Management service will be to you in terms of dollars per acre?

How valuable was the Irrigation Water Management service will be to you in...
4
10
5
25
minimal but valuable
15
20
$.75
5
Don't know
50
12
1.50

Q6 - Would you enroll more irrigated acres/fields if this program was offered in the future?

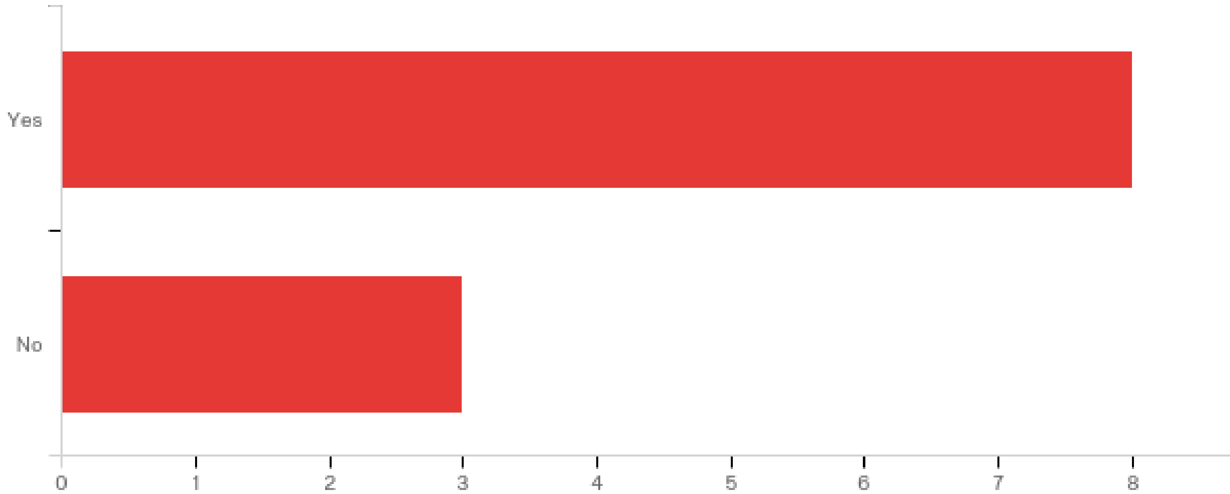


#	Answer	%	Count
1	Yes	76.92%	10
2	No	15.38%	2
3	Unsure	7.69%	1
	Total	100%	13

Q18 - Comments

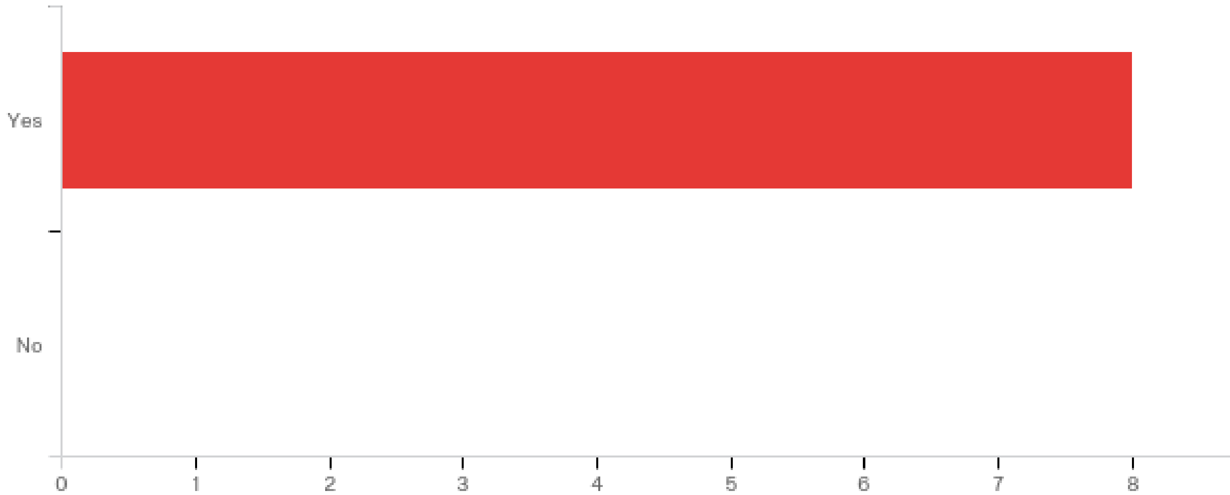
Comments
All irrigated acres are already enrolled
Want to use CropMetrics
No more acres to add
only if there was more $ for soil moisture probes
only have 6 pivots

Q7 - Did you increase your knowledge of soil water holding capacity as a result of the program?



#	Answer	%	Count
1	Yes	72.73%	8
2	No	27.27%	3
	Total	100%	11

Q8 - Did that help you make decision on when to irrigate?

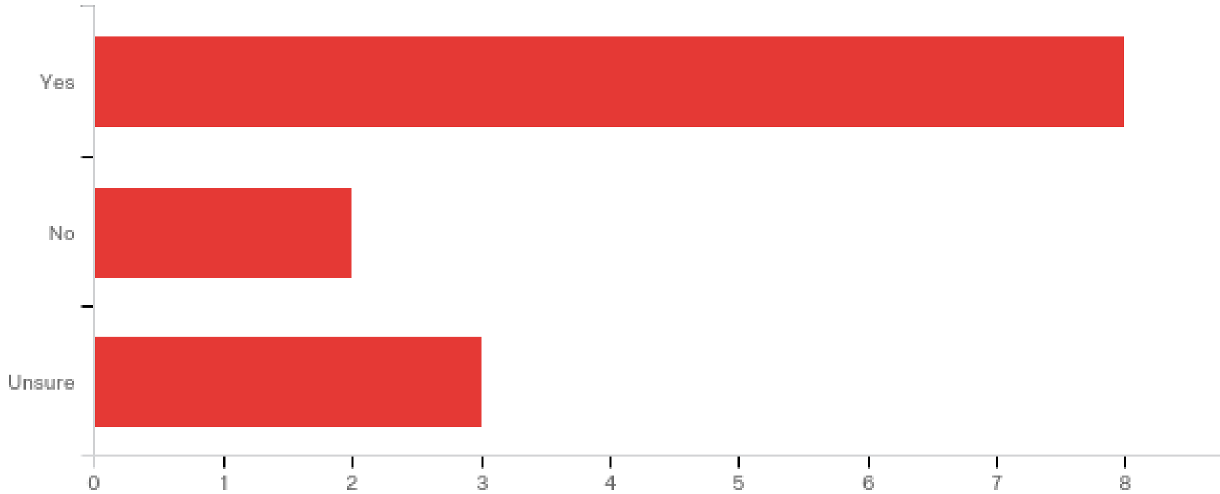


#	Answer	%	Count
1	Yes	100.00%	8
2	No	0.00%	0
	Total	100%	8

Q11 - Please elaborate on your answer:

Please elaborate on your answer:
Helped keep us from irrigating
It helped us to not irrigate several times, and it was useful to be able to forecast using the checkbook
100% this helped us decide not to irrigate
Real time data is really powerful

Q12 - If a process to become a certified irrigator were developed, would you be interested?

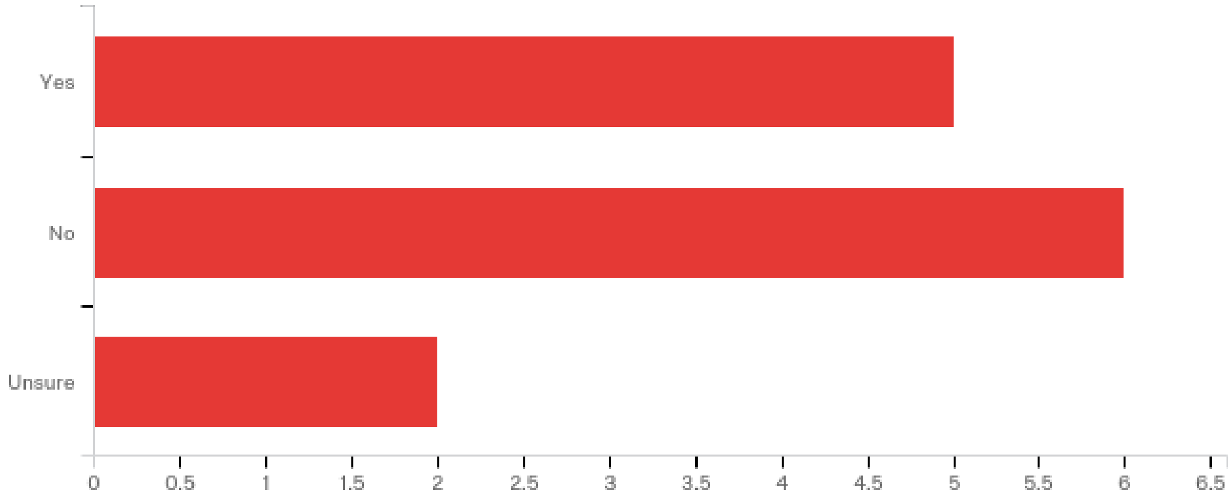


#	Answer	%	Count
1	Yes	61.54%	8
2	No	15.38%	2
3	Unsure	23.08%	3
	Total	100%	13

Q13 - What benefits would you want to gain in order to make certification worth your time?

What benefits would you want to gain in order to make certification worth y...
Discount on soil moisture sensors
be able to conserve water and N, and priority in future permit applications
The information
recognition from agencies that we are doing a good job
Knowledge and assistance with costs
Priority in technical assistance in paying for soil moisture sensors and telemetry
At my age, its not worth it
Priority in future permit applications
10% discount of yearly permitting fee
Reduction in permit fees and priority in new permit application approval

Q14 - Do you plan to change any management practices based on what you learned from this experience?

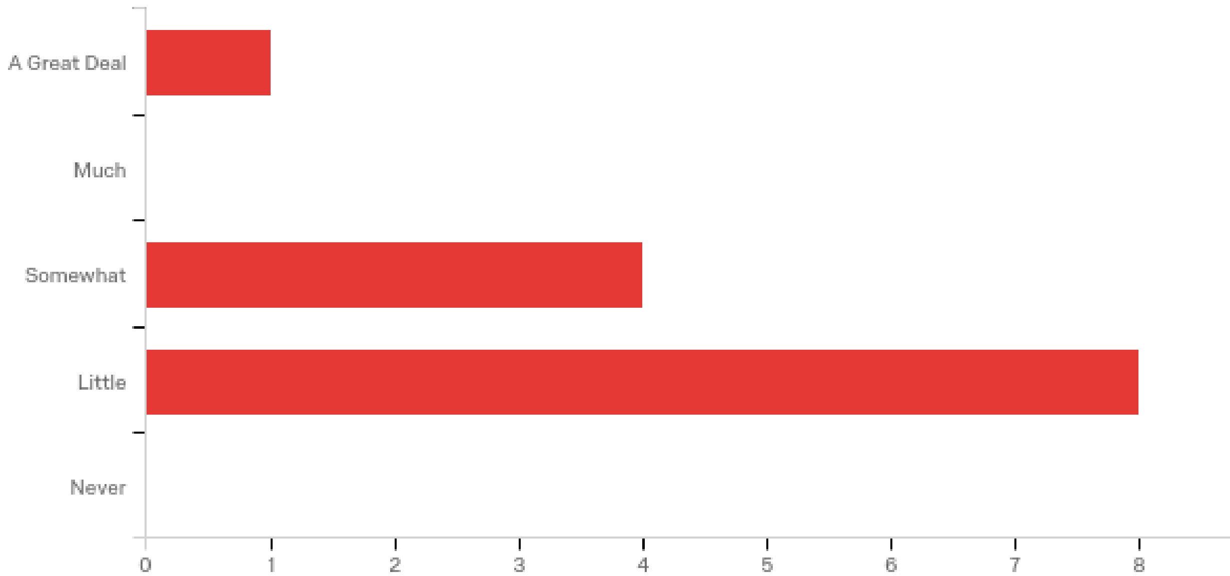


#	Answer	%	Count
1	Yes	38.46%	5
2	No	46.15%	6
3	Unsure	15.38%	2
	Total	100%	13

Q15 - What changes in management practices do you plan to make?

What changes in management practices do you plan to make?
Use soil probe and increase well capacity
Trying out a zone based VRI irrigation system in 2017
we now use the water water balance to decide when to irrigate
Adding cover crops and strip till
more variable rate planting

Q16 - As a result of this training, how much would you expect your farm profits to increase?



#	Answer	%	Count
1	A Great Deal	7.69%	1
2	Much	0.00%	0
3	Somewhat	30.77%	4
4	Little	61.54%	8
5	Never	0.00%	0
	Total	100%	13

Q19 - What would you say about the program to other irrigators?

What would you say about the program to other irrigators?
It's a good program to start with
A good chance to learn by trial and error
Checkbook verifies decisions
There are things to learn, for everyone
Its worth the Money. I have spent way more on things and gotten way less back
See if you can learn something new
Beneficial. learning how to do the data entry and forecasting in checkbook was really useful
excellent return to the time invested
Always beneficial to learn more
Variable Rate Irrigation and N Rate is the future, but we need to embrace the soil sensor technology. once a sensor goes in, more will follow.
Pretty good. Always nice to have more in-season knowledge
Definitely consider it

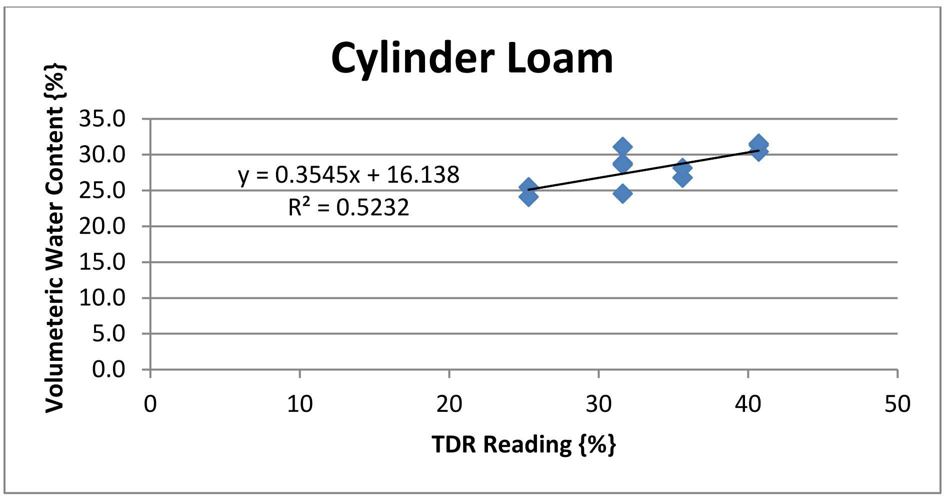
Soil Specific TDR 300 Calibration for Dakota County

Prepared by Kathryn LaBine

Samples were collected in the month of November 2016. At each site a Field Scout TDR reading is taken as well as a known volume of soil with wet and dry weights to follow. Data was collected in depths of 0 to 8 inches (top) and 8 to 16 inches (sub). The soils weights help determine the actual volumetric water content (VMC). Each soil type will have an R^2 and a slope equation that can be used to calibrate field readings.

Cylinder Loam

The biggest difference in the data collected occurred in the sub soil depths. Overall the TDR readings were higher than the VWC readings. These readings came from two sites.

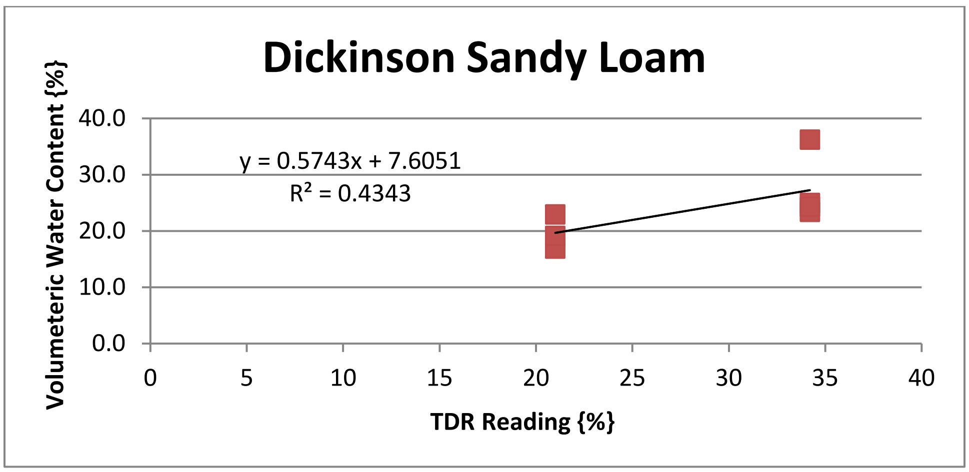


VWC [%]	TDR [%]
25.4	25.3
24.1	25.3
31.3	40.7
30.4	40.7
31.5	40.7
24.5	31.6
28.8	31.6
31.1	31.6
28.6	31.6
26.8	35.6
26.8	35.6
28.1	35.6

Dickinson Sandy Loam

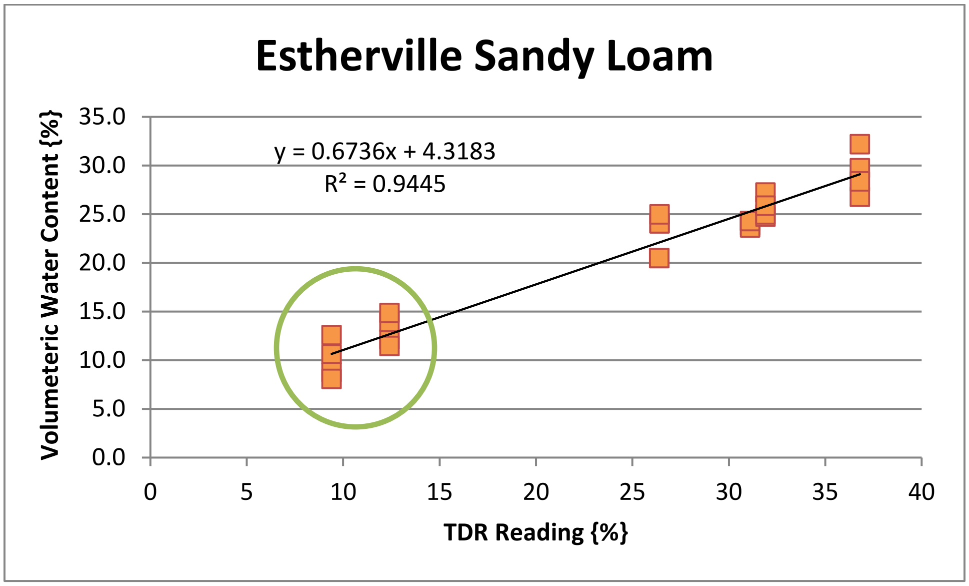
These soils are well drained, and very rarely flood. Found typically on uplands or stream terrace in valleys. Higher readings were taken from sub depth of the soil. Only one site is represented in this data.

VWC [%]	TDR [%]
16.9	21
19.1	21
23.0	21
25.0	34.2
23.4	34.2
24.3	34.2
36.3	34.2



Estherville Sandy Loam

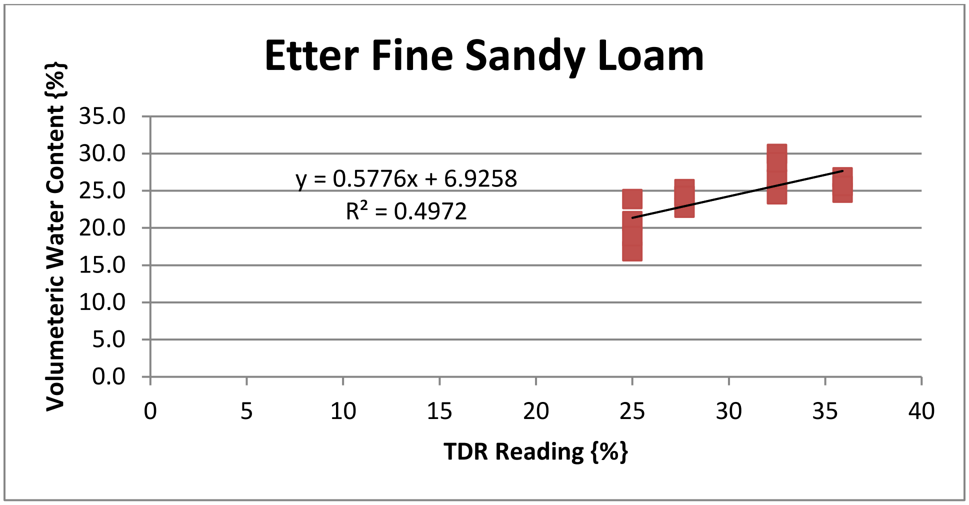
Somewhat excessively drained soils, the Estherville series can slope up to 70 percent. The data highlighted in green could possibly be another classification. The rest of the data falls within expectation of the soils characteristics. Three sites were measured for this data.



VWC [%]	TDR [%]
12.2	12.4
14.0	12.4
11.5	12.4
14.9	12.4
10.6	9.4
12.6	9.4
8.8	9.4
8.1	9.4
20.5	26.4
24.1	26.4
24.1	26.4
25.0	26.4
24.3	31.1
23.9	31.1
23.6	31.1
24.3	31.1
24.8	31.9
25.0	31.9
27.2	31.9
25.9	31.9
29.7	36.8
32.2	36.8
26.8	36.8
28.4	36.8

Etter Fine Sandy Loam

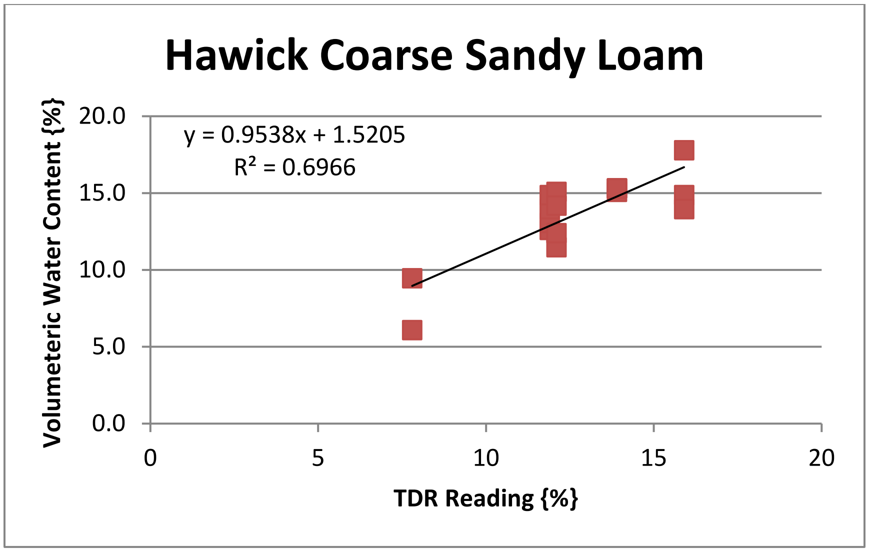
Etter series are well drained soils. This data reflects two sites in Dakota County.



VWC [%]	TDR [%]
22.7	27.7
25.2	27.7
24.3	27.7
26.8	35.9
24.8	35.9
25.7	35.9
16.9	25
23.9	25
20.9	25
18.9	25
24.5	32.5
29.9	32.5
26.6	32.5
28.8	32.5

Hawick Coarse Sandy Loam

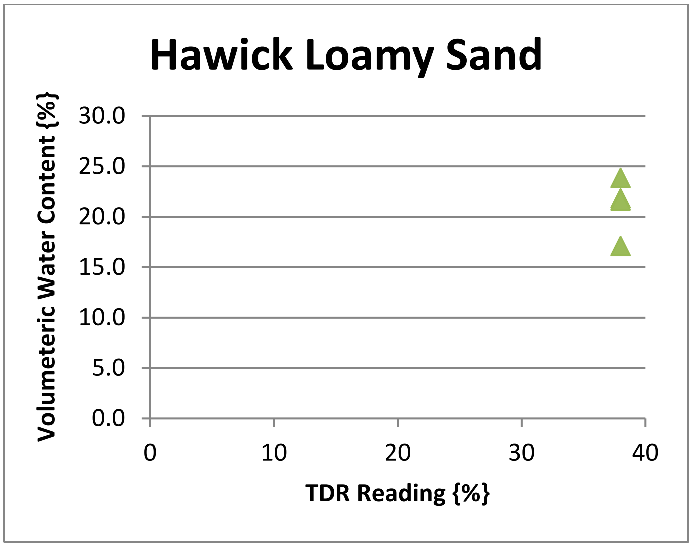
Found in excessively drained sandy outwash, this data represents three sites.



VWC [%]	TDR [%]
14.9	15.9
9.5	7.8
6.1	7.8
12.6	11.9
13.1	11.9
14.0	11.9
14.9	11.9
14.0	15.9
17.8	15.9
15.1	13.9
15.3	13.9
15.3	13.9
15.3	13.9
15.1	12.1
14.2	12.1
11.5	12.1
12.4	12.1

Hawick Loamy Sand

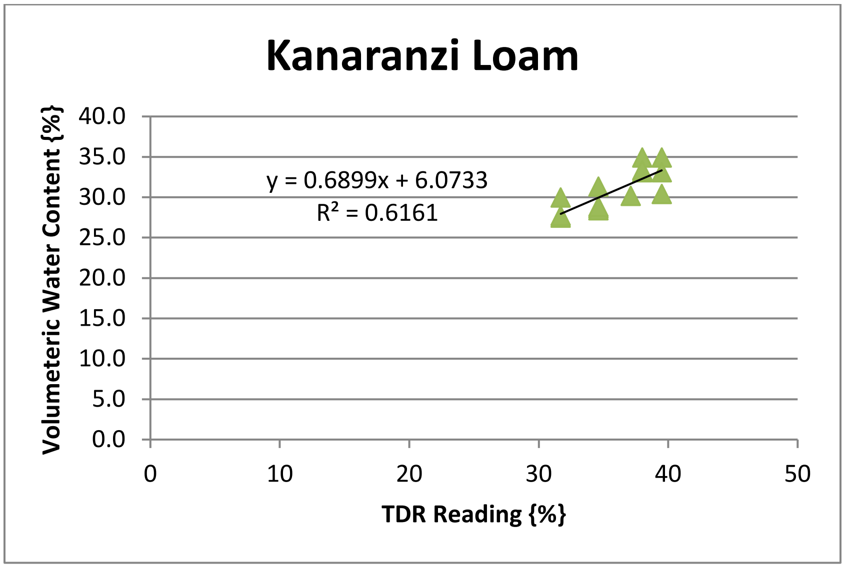
This data is from one site at one depth, therefore no slope or R^2 has been recorded.



VWC [%]	TDR [%]
23.9	38
21.8	38
17.1	38
21.6	38

Kanaranzi Loam

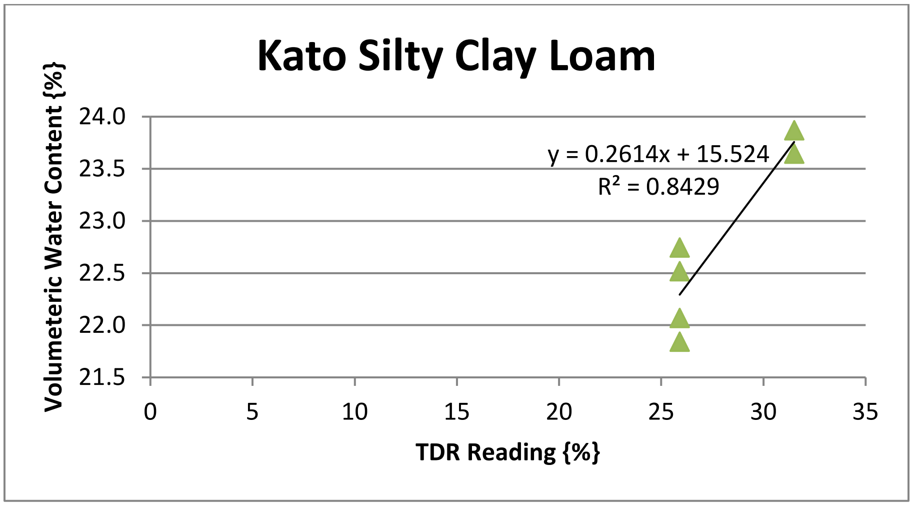
Found in outwash plains, the Kanarazi Loam is typically deep and well drained soil. This data represents two sites.



VWC [%]	TDR [%]
27.5	31.7
27.7	31.7
29.9	31.7
30.2	37.1
33.1	38
34.9	38
33.3	38
28.6	34.6
28.4	34.6
28.8	34.6
31.3	34.6
30.4	39.5
34.9	39.5
33.1	39.5

Kato Silty Clay Loam

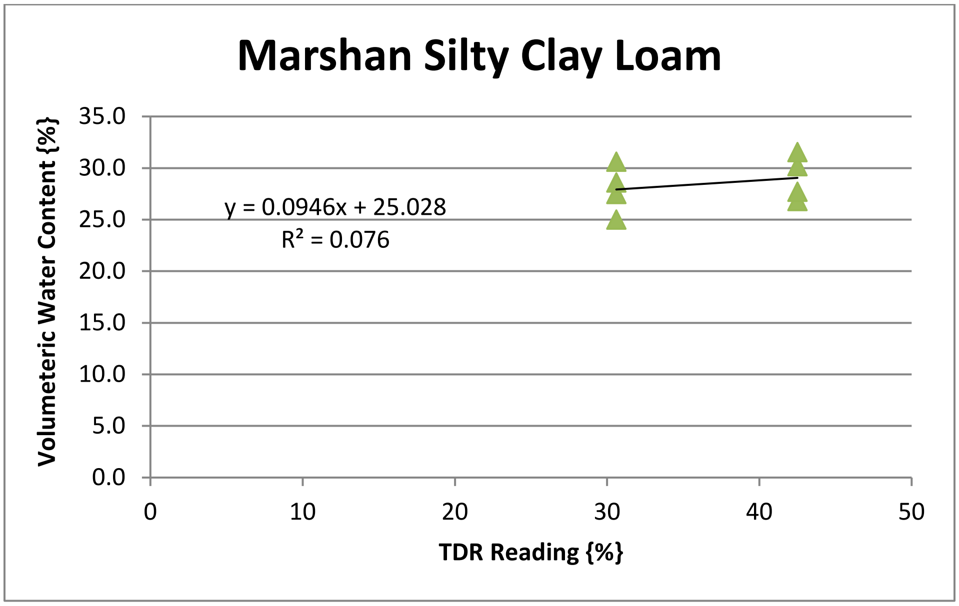
The Kato series is known to naturally have deep, poorly drained soils. This data is representing one site. The higher results are from the sub soil.



VWC [%]	TDR [%]
22.1	25.9
22.5	25.9
21.8	25.9
22.7	25.9
23.6	31.5
23.9	31.5

Marshan Silty Clay Loam

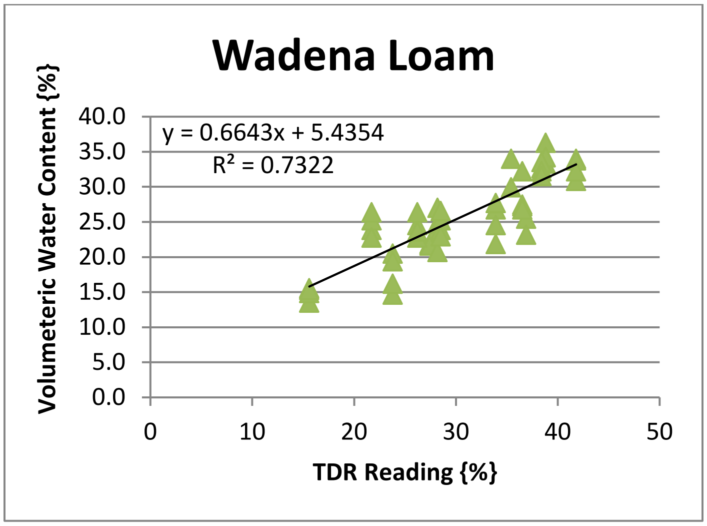
This series consists naturally of very deep and poorly drained soils. Data has been recorded from only one site.



VWC [%]	TDR [%]
25.0	30.6
27.5	30.6
30.6	30.6
28.6	30.6
30.2	42.5
31.5	42.5
26.8	42.5
27.7	42.5

Wadena Loam

Wadena Loam is characterized as well drained. Most sites had a comparable top soil results to the sub. The data was collected from seven different sites.

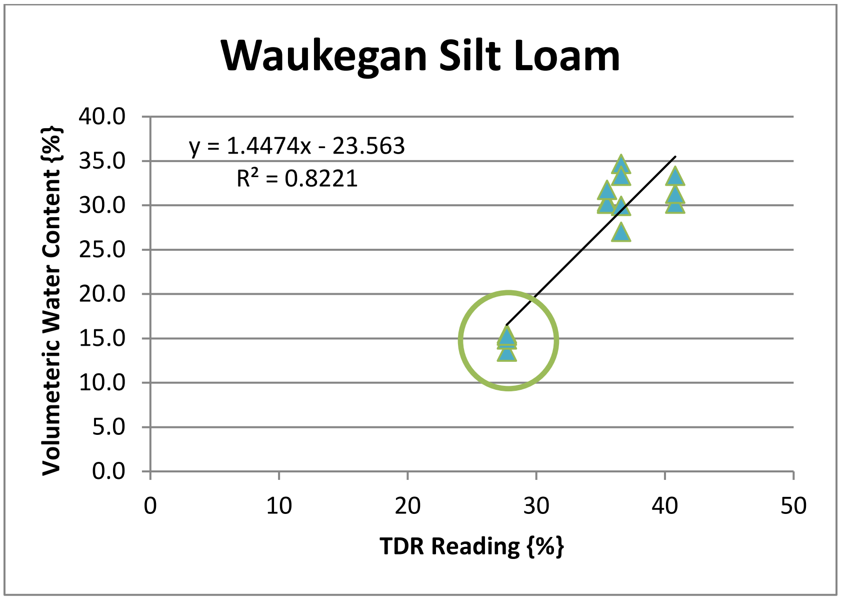


VWC [%]	TDR [%]
15.5	15.6
13.5	15.6
14.9	15.6
15.3	15.6
14.6	23.8
16.2	23.8
20.5	23.8
19.4	23.8
23.9	21.7
25.2	21.7
22.7	21.7
26.3	21.7
23.9	28.5
25.2	28.5
23.0	28.5
26.6	28.5
36.3	38.8
34.2	38.8
33.3	38.8
34.2	38.8
32.7	38.4
33.6	38.4
32.2	38.4
31.5	38.4

VWC [%]	TDR [%]
26.8	33.9
27.7	33.9
21.8	33.9
24.5	33.9
25.4	36.9
23.2	36.9
21.8	27.4
21.6	27.4
29.9	35.4
34.0	35.4
27.2	36.5
27.5	36.5
26.8	36.5
32.2	36.5
34.0	41.8
33.8	41.8
30.9	41.8
32.2	41.8
22.7	26.2
24.5	26.2
23.6	26.2
26.3	26.2
24.1	28.2
27.0	28.2
20.7	28.2
24.8	28.2

Waukegan Silt Loam

Waukegan Silt Loams are well drained soils. The data highlighted in green could possibly be another classification.



VWC [%]	TDR [%]
30.2	35.5
30.4	35.5
30.2	35.5
31.8	35.5
34.7	36.6
33.3	36.6
27.0	36.6
29.9	36.6
30.2	40.8
31.3	40.8
33.3	40.8
15.5	27.7
13.5	27.7
14.9	27.7
15.3	27.7