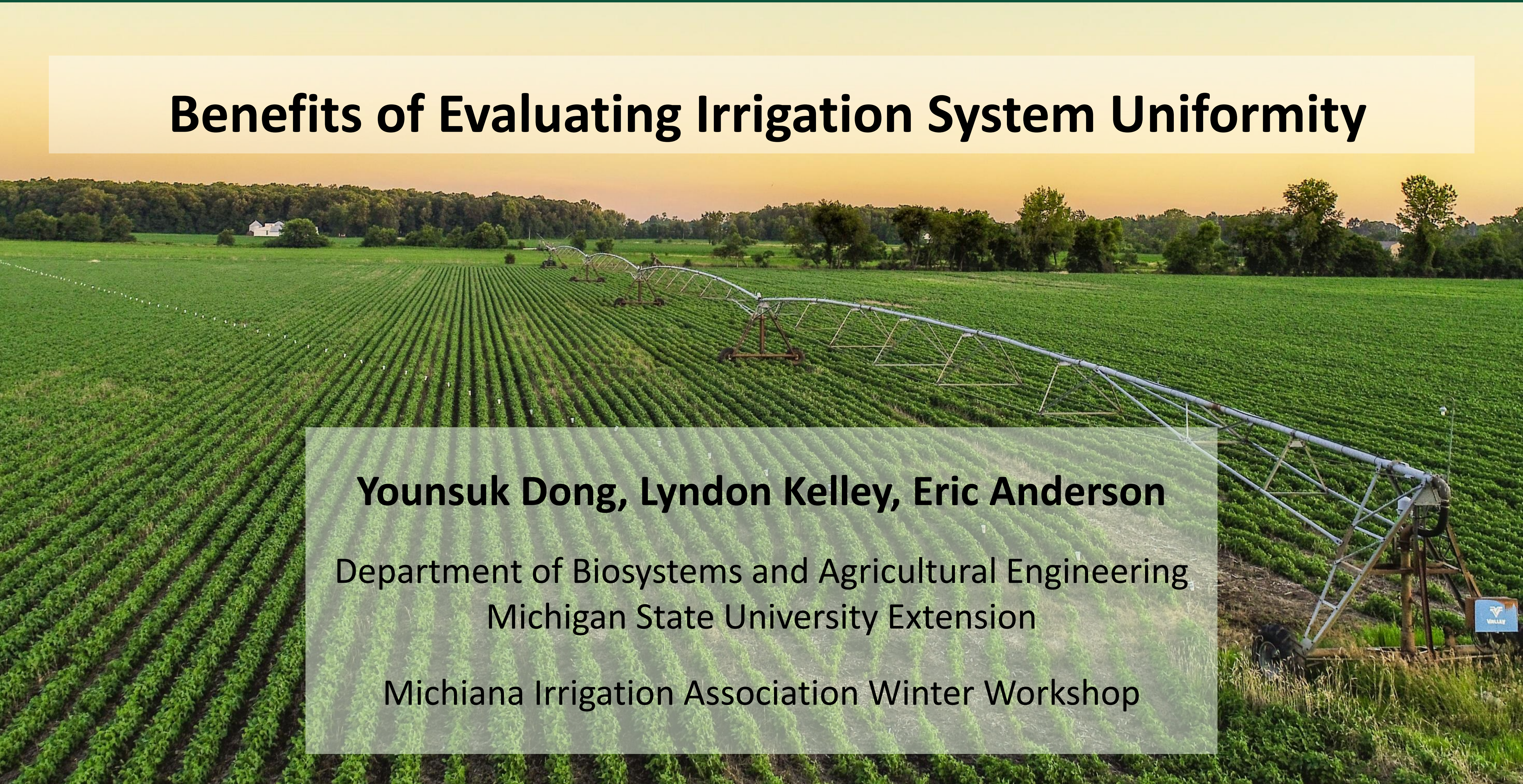


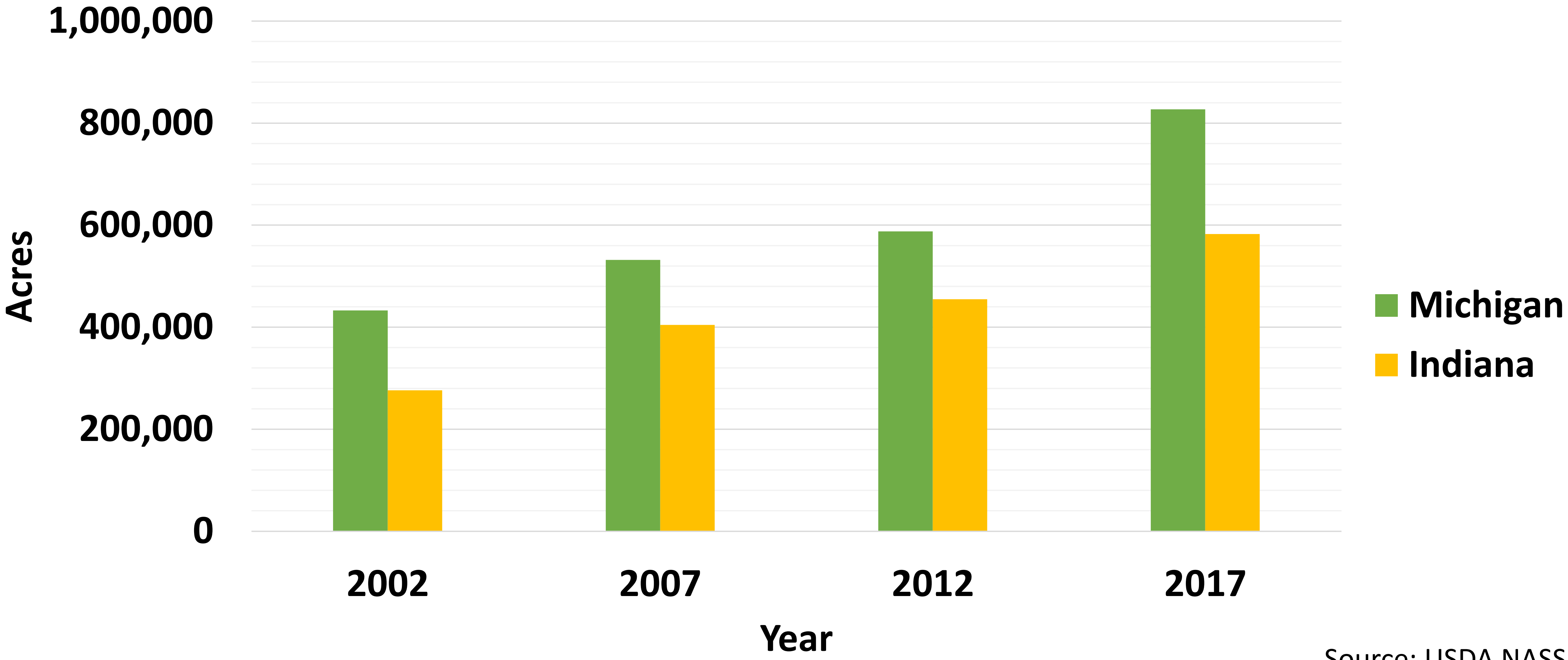
Benefits of Evaluating Irrigation System Uniformity

Younsuk Dong, Lyndon Kelley, Eric Anderson

Department of Biosystems and Agricultural Engineering
Michigan State University Extension

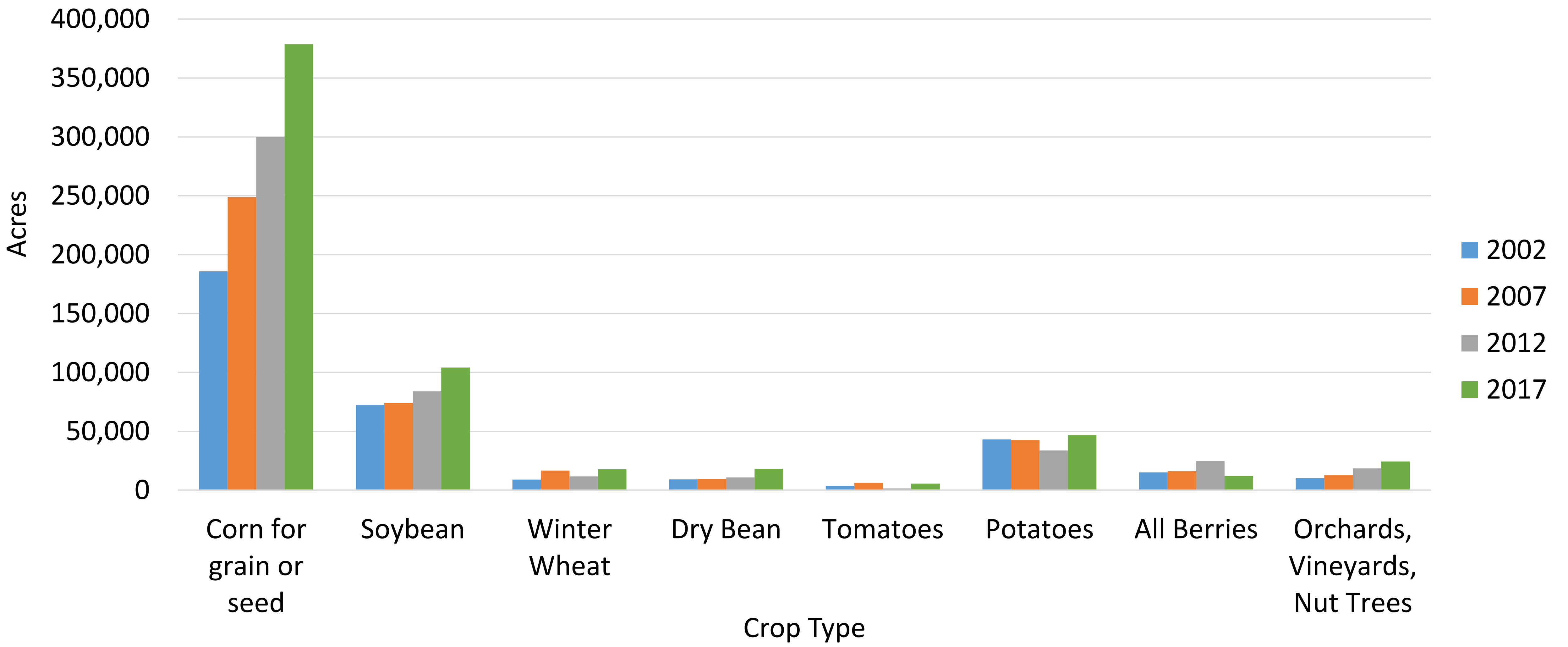
Michiana Irrigation Association Winter Workshop

Irrigated Acres – Michigan and Indiana



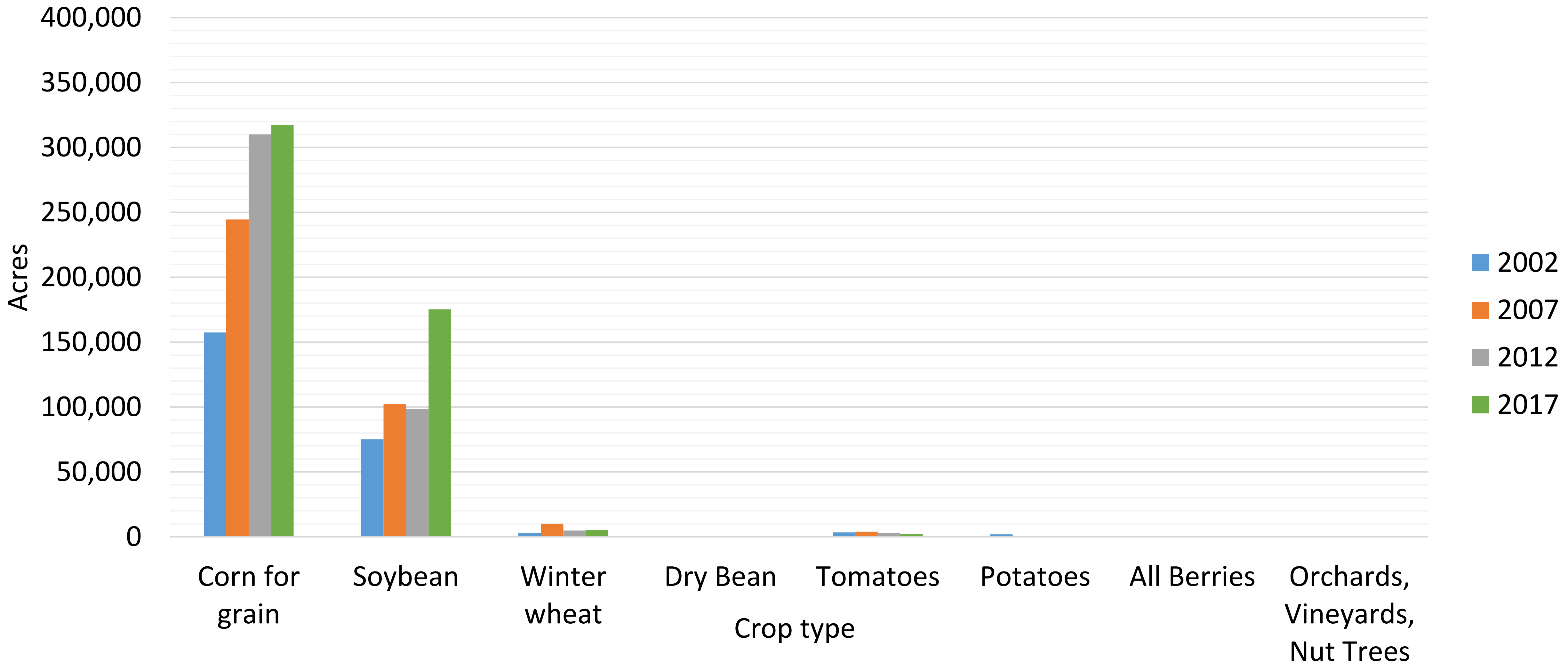
Source: USDA NASS

Michigan – Irrigated Acres by Crop Type



Source: USDA NASS

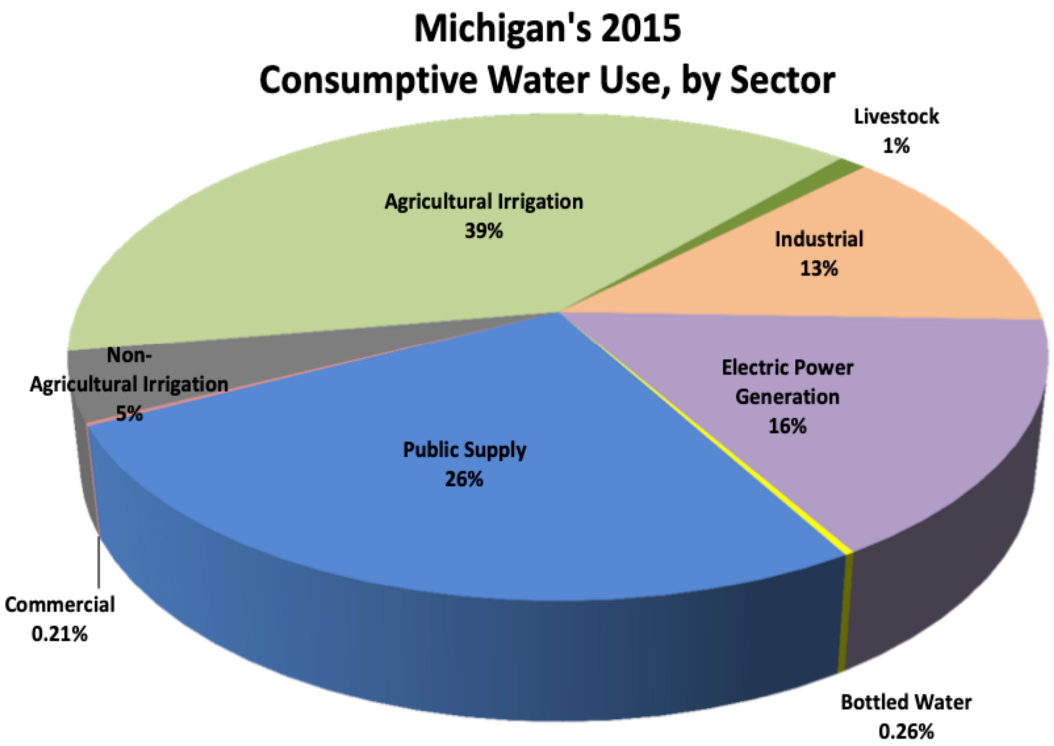
Indiana – Irrigated Acres by Crop Type



Source: USDA NASS

Agricultural Irrigation Water Use in Michigan

- 39% of Michigan's 2015 consumptive water use. (EGLE, 2017).
- Agricultural water withdrawal in 2019: 106 billion gallons (MDARD, 2020).



EGLE, 2017

Importance of Checking Irrigation System Uniformity

- Uniformity has a direct impact on the overall application efficiency.
- Poor water distribution can result in over- and under-irrigated areas.
- Under-irrigation can reduce crop yield and grain quality.
- Over-irrigation can cause runoff, soil erosion, and leaching water and nutrients below the root zone.
- Low uniformity can negatively impact on a farm’s net return and environmental impacts.

Irrigation System Evaluation Methods

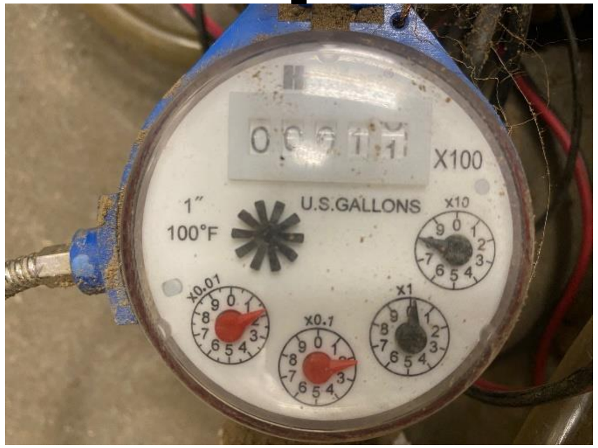
Pressure gauge & Doppler flow meter
(Flow and Pressure Measurement)

Catch cans
(Uniformity)

Unmanned Aerial Vehicle
(Faulty sprinkler detection)

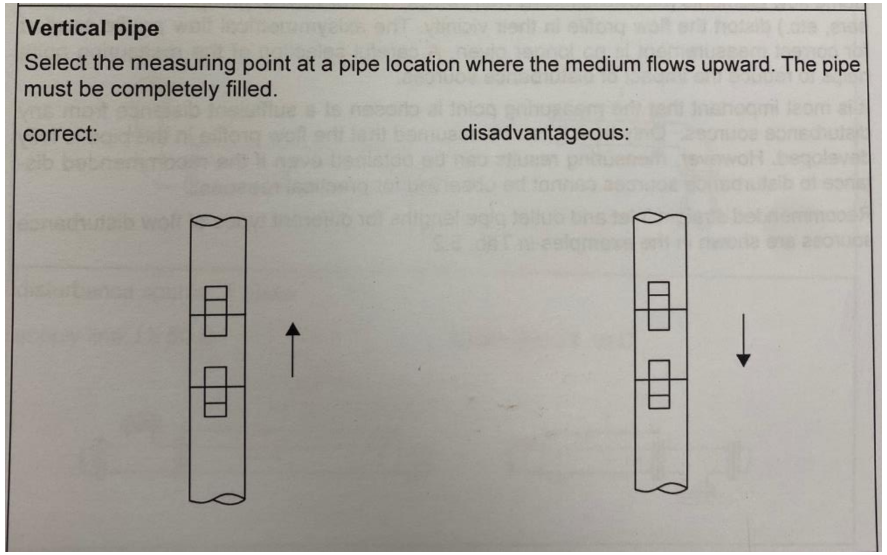
Flow Measurement

Flow Meter



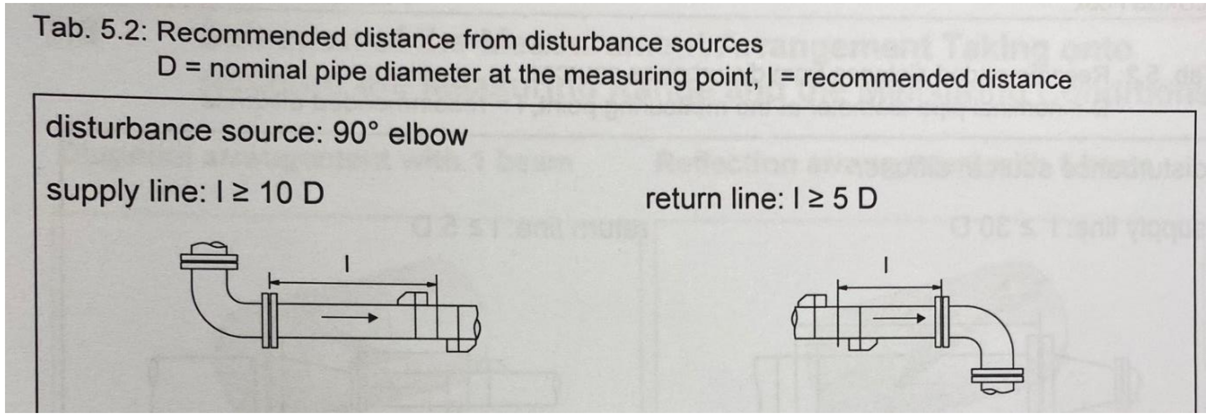
Flow Meter + Datalogger

Flow Measurement


Vertical pipe

Select the measuring point at a pipe location where the medium flows upward. The pipe must be completely filled.

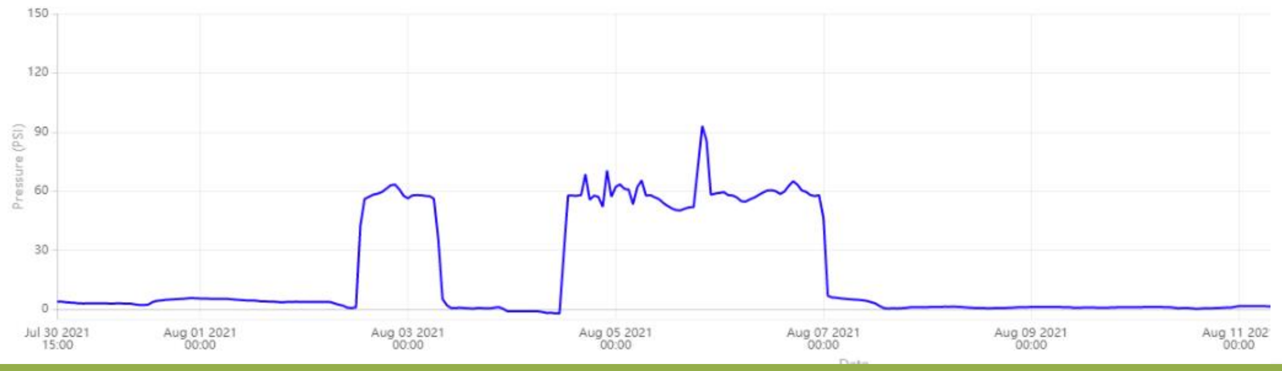
correct: disadvantageous:


Tab. 5.2: Recommended distance from disturbance sources
D = nominal pipe diameter at the measuring point, l = recommended distance

disturbance source: 90° elbow	
supply line: l ≥ 10 D	return line: l ≥ 5 D

Ultrasonic Flow meter

Water Pressure Measurement



Catch Can Testing

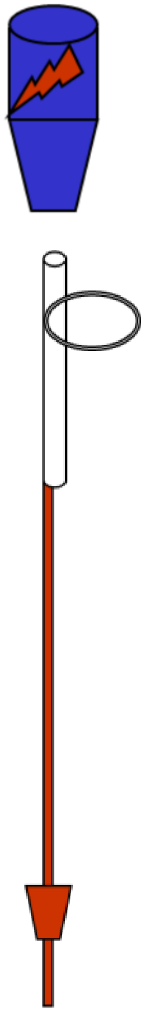
Irrigation System Evaluation

Catch Can Testing

Catch can be built with:

- 32 oz. disposable soda cup.
- ½” PVC pipe cut in 4” section can be drilled with ¼” hole 1” from end.
- 13” plastic cable zip tie.
- Steel (step-in) fence post

Also, need a 500 ml graduate cylinder to measure the volume of water.



Typical 32 oz. soda cup has a 10 cm diameter opening.

ml reading	mm of application	inch of application
10	0.13	0.05
20	0.26	0.10
30	0.39	0.15
40	0.52	0.20
50	0.65	0.25
60	0.78	0.30
70	0.91	0.36
80	1.04	0.41
90	1.17	0.46
100	1.30	0.51
110	1.43	0.56
120	1.56	0.61
130	1.69	0.66
140	1.82	0.71
150	1.95	0.76
160	2.08	0.81
170	2.21	0.86
180	2.34	0.91
190	2.47	0.96
200	2.60	1.01
210	2.73	1.07
220	2.86	1.12
230	2.99	1.17
240	3.12	1.22
250	3.25	1.27
260	3.38	1.32
270	3.51	1.37
280	3.64	1.42
290	3.77	1.47
300	3.90	1.52

ml reading	mm of application	inch of application
310	4.03	1.57
320	4.16	1.62
330	4.29	1.67
340	4.42	1.73
350	4.55	1.78
360	4.68	1.83
370	4.81	1.88
380	4.94	1.93
390	5.07	1.98
400	5.20	2.03
410	5.33	2.08
420	5.46	2.13
430	5.59	2.18
440	5.72	2.23
450	5.85	2.28
460	5.98	2.33
470	6.11	2.39
480	6.24	2.44
490	6.37	2.49
500	6.50	2.54
510	6.63	2.59
520	6.76	2.64
530	6.89	2.69
540	7.02	2.74
550	7.14	2.79
560	7.27	2.84
570	7.40	2.89
580	7.53	2.94
590	7.66	2.99
600	7.79	3.04

https://www.canr.msu.edu/irrigation/upoads/files/16-Catch-Can-Stands-for-Rain-Gauges-and-Uniformity-Check-Evaluating-Irrigation-06.25.20.pdf

Catch Can Testing

Most system apply within 85% of the expected application

MSU Extension Irrigation System Evaluation Tool, 1-23-07

Farm Name [redacted] Farm

System Uniformity Coefficient = 79

System Identification: Cornering Arm System on [redacted] Farm-Behind House

Cornering Arm Extended

Good System uniformity coefficient are 85 or greater

Deviation from desired application = -0.04

Application is 4 % under expectation

System Settings

Application rate (in)	0.5	Wind speed (mph)	4 mph
Percent timer Setting (%)	19	Wind Condition (variable or steady)	steady
Operating Pressue (psi)			

Rate of application calculator

Time from start to end of application at highest rate section of system (min.)	22	Inches/Hour	1.25
Rate of application for the highest rate section of system (minute /one inch)	48.00		

		Average Application (cm)	1.164
Length of evaluation area (ft)	1340	Average Application (in)	0.46
Catch Can Spacing Distance (ft)	10		
		Average catch, collected only (ml)	88.95
number of cans data collected from	129	*70% average catch can (ml)*	*59.94*
number of cans set	134	Evaluation area, full circle (acres)	122.82
		catch can openning area (sq cm)	76.977
Diameter of catch can (cm)	9.9	catch can openning area (sq in)	11.767

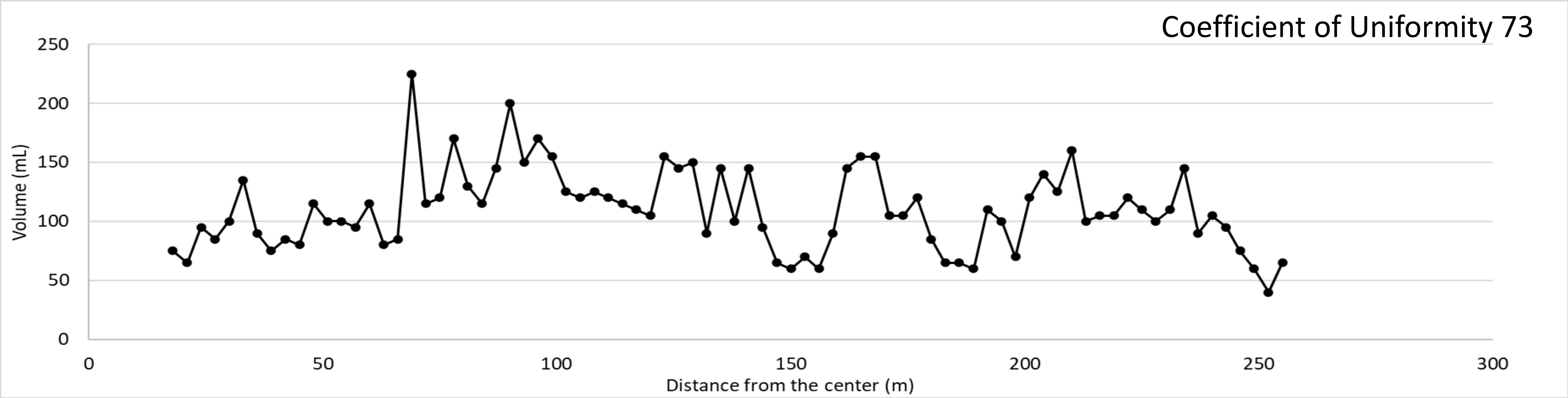
catch can number	Distance from center point	catch volume in ml	Data adjustment	Comments	Water volume (cm)	Water volume (in)	% applied of average	Deviation from average (%)	Area covered per catch can (acres)	Area covered per catch can (% of total)	Weighted Deviation
1	10		88.95		1.156	0.455	99.26%	-0.74%	0.01623	0.01%	0.0001
2	20		88.95		1.156	0.455	99.26%	-0.74%	0.02885	0.02%	0.0002
3	30		88.95		1.156	0.455	99.26%	-0.74%	0.04327	0.04%	0.0003
4	40		88.95		1.156	0.455	99.26%	-0.74%	0.05770	0.05%	0.0005
5	50		88.95		1.156	0.455	99.26%	-0.74%	0.07212	0.06%	0.0006
6	60		88.95		1.156	0.455	99.26%	-0.74%	0.08655	0.07%	0.0007
7	70	125	0.00		1.624	0.639	139.48%	39.48%	0.10097	0.08%	0.0011
8	80	75	0.00		0.974	0.384	83.69%	-16.31%	0.11539	0.09%	0.0008
9	90	115	0.00		1.494	0.588	128.32%	28.32%	0.12982	0.11%	0.0014
10	100	105	0.00		1.364	0.537	117.16%	17.16%	0.14424	0.12%	0.0014

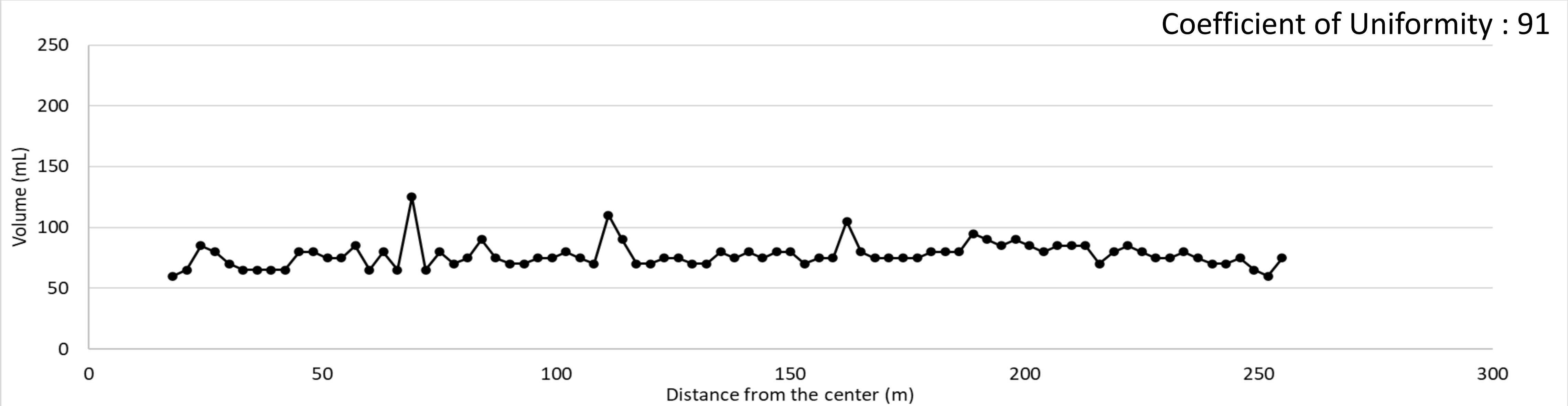
Page 1

Data Entry | Uniformity Graph

http://msue.anr.msu.edu/uploads/236/43605/lyndon/Uniformity_Spreadsheet_6.11.xls

Irrigation System Evaluation – Case study





Coefficient of Uniformity

This method accounts for the increased area coverage of each sprinkler head as one moves away from the center.

$$CU = \left[1 - \frac{\sum_{i=1}^{n}(X_i - \bar{X})}{n\bar{X}}\right] * 100\%$$

X_i is the water depth collected from the i^{th} catch can (mm/h).
X is the average of water depth collected in all catch cans (mm/h).
n is the total number of catch cans.

Distribution Uniformity

Distribution uniformity (DU), an indication of how uniform the spray of the system is, compares the lowest one-quarter of depth in the catch cans to the overall depth of the catch cans.

$$DU = \frac{D_{lq}}{\bar{D}} * 100$$

Dlq is the average of the lowest one-quarter of measure depth.
D is the average of water depth collected in all catch cans.

Scheduling Coefficient

Scheduling coefficient (SC) is a run time multiplier that shows the amount of extra water that needs to be applied to get the dry areas of the field wet.

$$SC = \frac{1}{DU} * 100\%$$

DU is distribution uniformity.

Irrigation System Evaluation – Case study

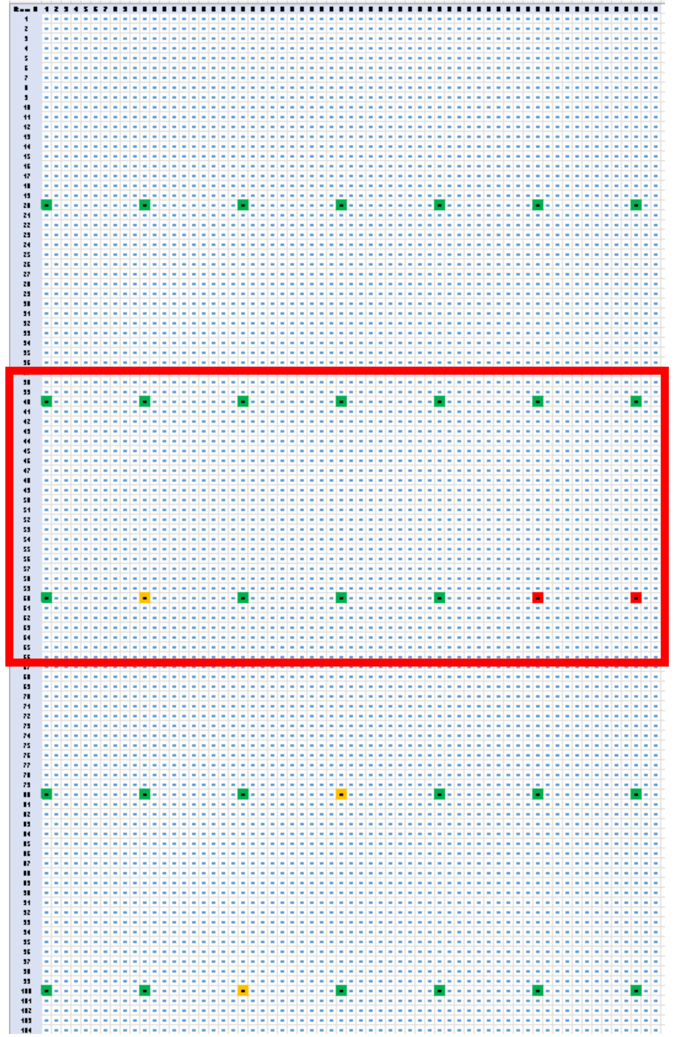
Scheduling Coefficient was reduced from 1.3 to 1.1 inch.

- **Water savings for each inch applied due to improved uniformity:** 0.2 inches.
- **Annual average irrigation applications in corn and soybean production:** 6 inches.
- **Total irrigation saving per year:** B x C = 1.2 inches.
- **Range of irrigation power costs in Michigan:** $3.16 - $7.50 /acre/inch.
- **Annual total energy saved (100-acre size field, energy cost $5.33/acre/inch):** $5.33/acre/inch x 100 acres x 1.2 inches = $640.
- **Total sprinkler package cost (part only):** $3,000.
- **Payback period:** 4.7 years.

Other benefits: *Conserve freshwater and energy.*
Reduce over-irrigation/nitrate leaching below the root zone.

Drip & Solid Set Irrigation System Evaluation

Drip Irrigation System Evaluation



Uniformity Efficiency: 80%

Row #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
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If the uniformity of your irrigation system is poor,

Ensure your irrigation system runs at the correct water pressure.

- Operating outside of the specified water pressure of your drip tubes can result in poor distribution uniformity.
- The longer the drip tube, the greater the water pressure loss due to friction.

If the uniformity of your irrigation system is poor,

Inspect the emitter if it is clogged.

- Emitters can be clogged by many things such as sand, mineral deposits, insects, and water quality (high calcium carbonate and iron in your water source).
- Consider flushing the lines regularly and watch for contaminants.

Photo credit: UCANR

If the uniformity of your irrigation system is poor,

Check for equipment wear.

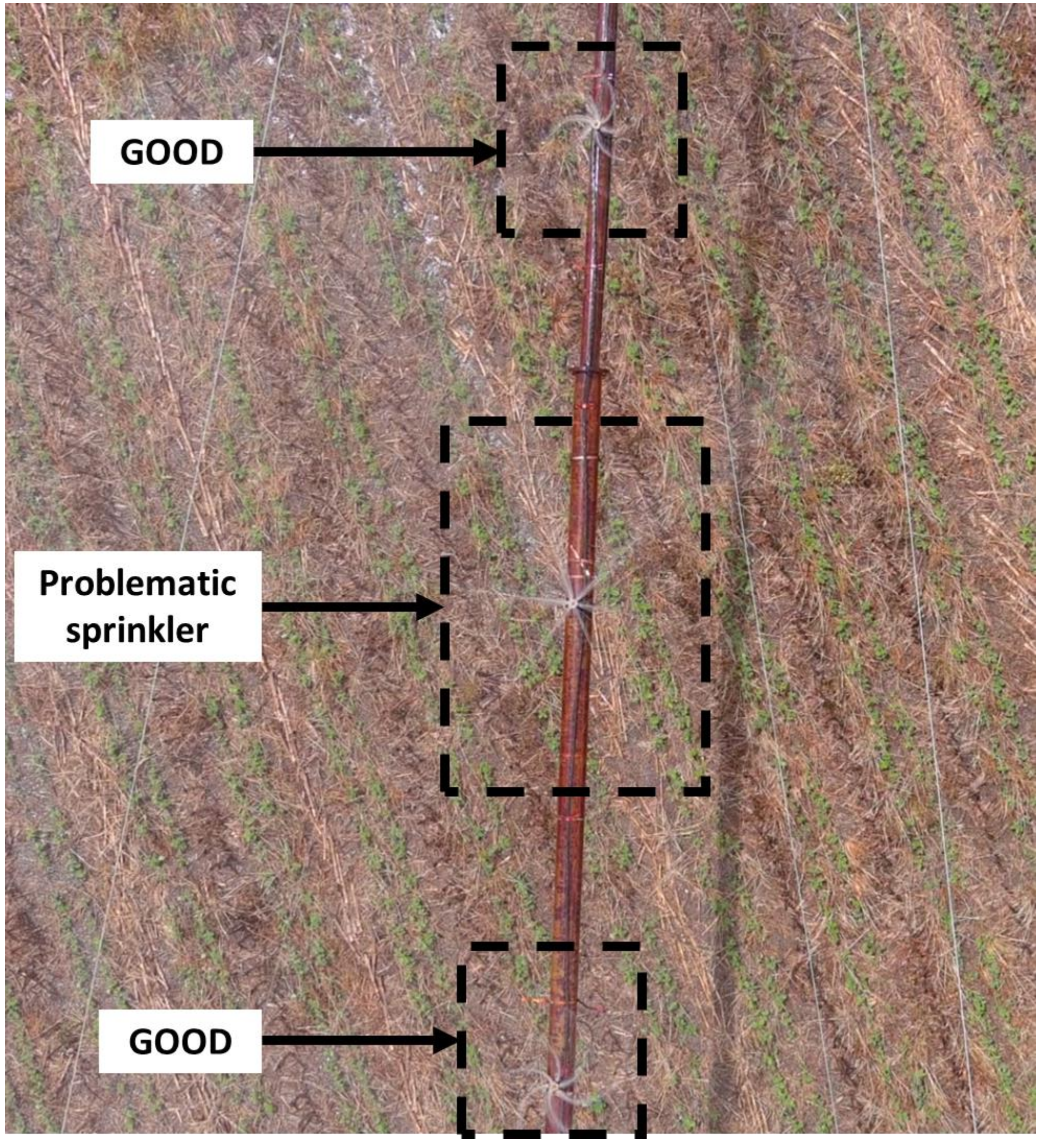
- Drip emitter orifices and sprinkler nozzles wear over time.
- Pressure regulators can fail.
- Keep all the records of systems inspections and repairs.
- For a center pivot irrigation system, consider replacing the whole sprinkler package if there is a growing number of malfunctioning sprinklers.

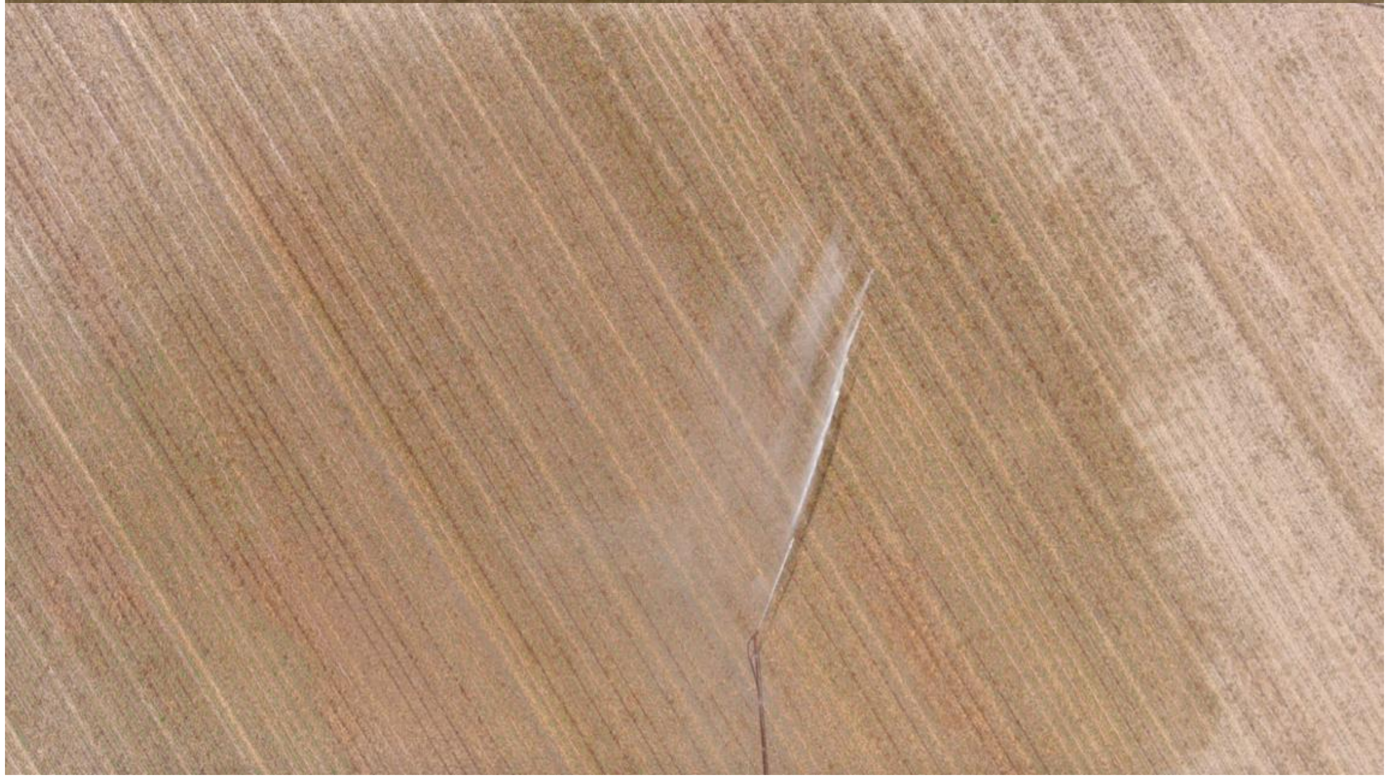
If the uniformity of your irrigation system is poor,

Check for leaks.

Pipe joints, missing sprinklers, between fittings, and holes on your drip tapes.

Unmanned Aerial Vehicle





USDA NRCS EQIP (Environmental Quality Incentives Program)

USDA
United States Department of Agriculture

441-CPS-1

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

IRRIGATION SYSTEM, MICROIRRIGATION

CODE 441

(Ac.)

DEFINITION

An irrigation system for frequent application of small quantities of water on or below the soil surface: as drops, tiny streams, or miniature spray through emitters or applicators placed along a water delivery line.

PURPOSE

This practice is applied to achieve the following purpose:

- Efficiently and uniformly apply irrigation water and maintain soil moisture for plant growth.
- Prevent contamination of ground and surface water by efficiently and uniformly applying chemicals.
- Establish desired vegetation (e.g., windbreaks).

CONDITIONS WHERE PRACTICE APPLIES

This practice applies on sites where soils and topography are suitable for irrigation of crops or other desirable vegetation and an adequate supply of suitable quality water is available for the intended purpose(s).

Microirrigation is suited to virtually all agricultural crops, and residential and commercial landscape systems. Microirrigation is also suited to steep slopes where other methods would cause excessive erosion, and areas where other application devices interfere with cultural operations.

Microirrigation is suited for use in providing irrigation water in limited amounts to establish desired vegetation such as windbreaks, living snow fences, riparian forest buffers, and wildlife plantings.

This practice standard applies to systems that wet only a specific area (e.g., an individual plant or tree) and typically have design discharge rates less than 60 gal/hr at individual application discharge points.

Use NRCS Conservation Practice Standard (CPS) Code 442, Sprinkler System, for systems that uniformly wet the entire field and typically have design discharge rates of 60 gal/hr or greater at individual application discharge points.

USDA
United States Department of Agriculture

442-CPS-1

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

SPRINKLER SYSTEM

Code 442

(Ac.)

DEFINITION

A distribution system that applies water by means of nozzles operated under pressure.

PURPOSE

This practice is applied as part of a conservation management system to accomplish one or more of the following:

- Efficient and uniform application of water on irrigated lands
- Improve plant condition, productivity, health and vigor
- Prevent the entry of excessive nutrients, organics, and other chemicals in surface and groundwater
- Improve condition of soil contaminated with salts and other chemicals
- Reduce particulate matter emissions to improve air quality
- Reduce energy use

CONDITIONS WHERE PRACTICE APPLIES

This standard applies to the planning and functional design of all sprinkler system components (e.g., laterals, risers, nozzles, heads, and pressure regulators).

Individual sprinkler design discharge rates covered by this standard typically have design nozzle discharge rates exceeding 1 gallon per minute and wet the entire field surface uniformly.

Areas must be suitable for sprinkler water application, and have a water supply of adequate quantity and quality for intended purpose(s).

This standard applies to planning and design of sprinkler application systems for:

- meeting crop water demands
- crop cooling, frost protection, or bloom delay
- leaching or reclamation of saline or sodic soils, or soils contaminated by other chemicals that can be controlled by leaching
- application of chemicals, nutrients, and/or waste water

Water Use Advisory Council

Water Conservation and Efficiency Committee DRAFT 2022 Recommendation

Pilot Program: Michigan Agricultural Irrigation Water and Energy Efficiency Program

Synopsis: Irrigation plays an important role in Michigan agriculture, supporting various crops such as corn, soybean, potato, fruits, vegetables, and orchards. High-value crops including potatoes, vegetables, fruits, and seed crops, are almost 100 percent produced under irrigation and require an irrigation system upon contract (MSUE, 2014). Large buyers require these crops to be grown on irrigated land as part of their risk management process to ensure that the crop will not be compromised due to drought. In 2019, Michigan produced $579M in fruit, nut, and vegetable crops (Fruit Growers News, 2021). Agricultural irrigation accounted for 39% of Michigan's consumptive water use (EGLE, 2017), with 125 billion gallons of water withdrawn in 2020 (Eaton, 2021).

There are over 8,000 center pivot irrigation systems in Michigan, and at least one-third of the center pivots are more than 20 years old (calculation based on USDA survey from 2000 and 2018). About 10% of irrigation systems still use high-pressure sprinkler packages, which are not as energy efficient as low-pressure sprinkler packages (USDA, 2018). A preliminary study conducted in 2022 by MSU Irrigation group, shows replacing older sprinkler packages (7-year-old) with new sprinkler package saved an average of 0.2 inch for each inch applied due to improved uniformity. Assuming annual average irrigation application in corn and soybean production is 6 inches, it means that it can save approximately 1.2 inches of water per year in corn and soybean fields. Therefore, 3.2 MG could be saved on 100 acre-size irrigated field per year.

There is a need to increase education and awareness among producers and irrigation suppliers of the needs for repair, maintenance, and replacement of the center pivot irrigation system as well as, irrigation scheduling for uniformity. There is also a need for increased capacity and dedicated technical staff to do the literature review, conduct system evaluation and retrofit, analyze the results to improve agricultural irrigation efficiency and make potential recommendations for the irrigation industry including improvements in distribution uniformity and detailed recommendations for distribution and maintenance of center pivot irrigation system.

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Evaluating Irrigation System Uniformity

By Lyndon Kelley

Evaluation Goals of Irrigation System Uniformity

Irrigation System Uniformity is the concept that all areas within an irrigated field receive the same amount of water. In simple terms, if the producer's goal is to apply one inch of irrigation water, the system will apply one inch of irrigation water in each area. Areas of the field that receive under or over the goal will receive under or over the goal for all applications, multiplying the error.

Areas that are under or over the average by 40 percent and will receive 0.6 inches (if under) or 1.4 inches (if over) of irrigation water each time the producer intends to apply one inch of water. By the end of the season, areas requiring eight inches of irrigation water will receive 4.8 inches (if under) or 11.2 inches (if over) of irrigation water.

Standards and Methods for Evaluation of Irrigation System Uniformity

Two commonly accepted standards or methods are available as guidelines for performing evaluations of Irrigation System Uniformity.

- ASAE Standards (436.1) — Available at: http://msue.anr.msu.edu/uploads/236/43605/ASAE_S436.1.pdf
- NRCS Handbook — Available at your local Natural Resource Conservation Service office or http://msue.anr.msu.edu/uploads/236/43605/USDA-NRCS-IrrigationGuide-Chapter15.pdf

Pivot Extensions (cornering arm or Z-arm)

Some center pivot irrigation systems are designed to expand the wetted area to allow coverage of corner or odd-shaped fields, often referred to as cornering arms or Z-arm. These systems require two separate evaluations if the extension accounts for 30 percent or more of the irrigated portion of the field. One evaluation will evaluate the system while extended, and a second when the arm is not deployed.

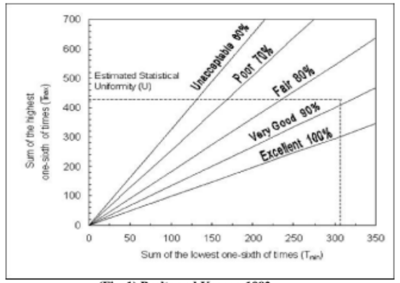
Overview of Evaluation of Irrigation System Uniformity Guidelines (center pivot)

1. Have the producer walk the system length and note any application problems while the system is applying water. All known application problems need to be corrected before doing an evaluation of Irrigation System Uniformity.
2. Have the producer start the system and establish a setting for his normal application (avoid weather extremes).
3. Run the system for 10 minutes or more without changes to water supply system.
   - Place catch cans in a line from the center pivot point past the outer edge of the wetted area.
   - Catch cans should be placed to form a straight line from the pivot point to a point on the outer edge of the wetted area.
   - Space catch cans 20 feet apart for system overhead impact sprinklers, and 10 feet apart for all other center pivot application systems.
   - Place catch cans with opening at a height above the crop, or in a field opening width four times greater than the height difference between the crop and catch can opening.

Conducting a Water Application Uniformity Evaluation for a Micro Irrigation System in the Nursery

Dr. R. Tom Fernandez and Thomas A. Dudek*

More container nurseries in Michigan are utilizing micro-irrigation to water plants. Testing micro irrigation system uniformity should be periodically done and is easy to test as well. All you need to do is determine the amount of time it takes to fill a container from at least 18 emitters in the irrigation zone being tested, a few calculations and reference to a graph. **(Fig. 1)** The graph is called a uniformity nomograph and was developed by Bralts and Kesner (1983).



(Fig. 1) Bralts and Kesner, 1983

Steps to conduct Distribution Uniformity check for microirrigation system.

1. Have a small container capable of holding, 8 to 12 ounces, and a stopwatch or watch with a second hand.
2. Randomly select at least 18 emitters within an irrigation zone. If you decide to use more than 18, do so in multiples of six (see step 4).
3. Time how long it takes to fill the container from each emitter.
4. Add together the lowest 1/6 of the times it takes to fill the bottle (in the case where 24 emitters are tested, this would be the lowest 4).
5. Add together the highest 1/6 of the times it takes to fill the bottle (in the case where 24 emitters are tested, this would be the lowest 4).
6. Plot the sums on the nomograph (Figure 1). If the sums are, too large to fit the scale of the nomograph you can divide both the highest and lowest by a common

Examples to Help You Understand the Process

For example, **(Table 1.)** shows the time it took to fill the same sized bottle from 24 emitters for two systems. In **System 1**, the lowest 4 (1/6 of 24) of the times are labeled with one (*) and the highest 4 (1/6 of 24) of the times are labeled with two (**).

Distribution Uniformity for two Individual Plant Emitter Systems
(Table 1.)

System 1		**System 2**	
Emitter Number	Time to Collect 250 ml (seconds)	Emitter Number	Time to Collect 250 ml (seconds)
1	147 *	1	212
2	456*	2	226
3	211	3	204
4	153*	4	218
5	447*	5	197*
6	215	6	231**
7	202	7	215
8	228	8	203*
9	250	9	199*
10	199	10	224
11	206	11	216
12	233	12	227*
13	151*	13	206
14	455*	14	208
15	149*	15	222
16	211	16	185*
17	222	17	218
18	230	18	229**
19	147*	19	207
20	213	20	215
21	217	21	219
22	214	22	221
23	200	23	232**
24	430**	24	216
Avg. time	241.0833333	Avg. time	214.5833333
Avg. ml/sec	1.036985828	Avg. ml/sec	1.165048544
Avg. ml/min	62.21914967	Avg. ml/min	69.90291262
Avg. GPM	0.016425856	Avg. GPM	0.018454369
Avg. GPH	0.985551331	Avg. GPH	1.107262136

Biosystems and Agricultural Engineering – Irrigation
https://www.egr.msu.edu/bae/water/irrigation/

MSU Extension – Irrigation
https://www.canr.msu.edu/irrigation

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Acknowledgment

- Brenden Kelley
- Hunter Hansen
- Catherine Christenson
- Allison Smith

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