Benefits of Evaluating Irrigation System Uniformity

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Michiana Irrigation Association Winter Workshop
Irrigated Acres – Michigan and Indiana

Source: USDA NASS
Indiana – Irrigated Acres by Crop Type

Source: USDA NASS
Agricultural Irrigation Water Use in Michigan


• Agricultural water withdrawal in 2019: 106 billion gallons (MDARD, 2020).
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

Ultrasonic Flow meter
Water Pressure Measurement
Catch Can Testing
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.

**Catch Can Testing**

*Most system apply within 85% of the expected application*

<table>
<thead>
<tr>
<th>Farm Name</th>
<th>Sam</th>
</tr>
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<tbody>
<tr>
<td>System Uniformity Coefficient</td>
<td>79</td>
</tr>
<tr>
<td>System Identification</td>
<td>Cornering Arm System on Farm-Behind House</td>
</tr>
<tr>
<td>Deviation from desired application</td>
<td>-0.04</td>
</tr>
<tr>
<td>Wind speed (mph)</td>
<td>4 mph</td>
</tr>
<tr>
<td>Wind Condition (variable or steady)</td>
<td>steady</td>
</tr>
<tr>
<td>Rate of application calculator</td>
<td></td>
</tr>
<tr>
<td>Time from start to end of application at highest rate section of system (min.)</td>
<td>22</td>
</tr>
<tr>
<td>Rate of application for the highest rate section of system (minute /one inch)</td>
<td>40.00</td>
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<tr>
<td>Average Application (cm)</td>
<td>1.104</td>
</tr>
<tr>
<td>Length of evaluation area (ft)</td>
<td>1380</td>
</tr>
<tr>
<td>Average Application (in)</td>
<td>0.46</td>
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<tr>
<td>Catch Can Spacing Distance (ft)</td>
<td>10</td>
</tr>
<tr>
<td>Average catch, collected only (ml)</td>
<td>86.95</td>
</tr>
<tr>
<td>70% average catch can (ml)</td>
<td>59.94</td>
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<tr>
<td>Evaluation area, full circle (acres)</td>
<td>122.82</td>
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<tr>
<td>Catch can opening area (sq in)</td>
<td>7.977</td>
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<tr>
<td>Diameter of catch can (cm)</td>
<td>9.9</td>
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<tr>
<td>Catch can opening area (sq in)</td>
<td>11.767</td>
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</table>

<table>
<thead>
<tr>
<th>catch can number</th>
<th>Distance from center point</th>
<th>catch water in ml</th>
<th>Data adjustment</th>
<th>Comments</th>
<th>Water volume (cm)</th>
<th>Water volume (in)</th>
<th>% applied average</th>
<th>Deviation from average (%)</th>
<th>Area covered per catch can (acres)</th>
<th>Area covered per catch can (% of catch can)</th>
<th>Weighted Deviation</th>
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<tbody>
<tr>
<td>25</td>
<td>10</td>
<td>86.95</td>
<td>1.156</td>
<td>0.455</td>
<td>99.26%</td>
<td>-0.74%</td>
<td>0.01623</td>
<td>0.01%</td>
<td>0.0001</td>
<td></td>
<td></td>
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<tr>
<td>26</td>
<td>20</td>
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<td>1.156</td>
<td>0.455</td>
<td>99.26%</td>
<td>-0.74%</td>
<td>0.01623</td>
<td>0.01%</td>
<td>0.0001</td>
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<td>1.156</td>
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<td>99.26%</td>
<td>-0.74%</td>
<td>0.01623</td>
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<td>0.0001</td>
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<td>0.01623</td>
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<td>0.0001</td>
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<td>0.455</td>
<td>99.26%</td>
<td>-0.74%</td>
<td>0.01623</td>
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<td>60</td>
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<td>0.455</td>
<td>99.26%</td>
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<td>0.01623</td>
<td>0.01%</td>
<td>0.0001</td>
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<tr>
<td>7</td>
<td>70</td>
<td>125</td>
<td>1.624</td>
<td>0.659</td>
<td>139.48%</td>
<td>28.83%</td>
<td>0.01097</td>
<td>0.08%</td>
<td>0.0011</td>
<td></td>
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<tr>
<td>8</td>
<td>80</td>
<td>76</td>
<td>0.974</td>
<td>0.384</td>
<td>83.69%</td>
<td>-16.31%</td>
<td>0.11539</td>
<td>0.09%</td>
<td>0.0028</td>
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<tr>
<td>9</td>
<td>90</td>
<td>115</td>
<td>1.494</td>
<td>0.588</td>
<td>126.32%</td>
<td>28.92%</td>
<td>0.12862</td>
<td>0.11%</td>
<td>0.0014</td>
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</tr>
<tr>
<td>10</td>
<td>100</td>
<td>185</td>
<td>1.964</td>
<td>0.737</td>
<td>117.16%</td>
<td>-17.16%</td>
<td>0.14474</td>
<td>0.12%</td>
<td>0.0014</td>
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</tr>
</tbody>
</table>

Application is 4% under expectation

Irrigation System Evaluation – Case study

Coefficient of Uniformity : 73

Coefficient of Uniformity : 91
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.

\[
DU = \frac{D_{1q}}{D} * 100
\]

\(D_{1q}\) 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: \( B \times C = 1.2 \) 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 \times 100 \text{ acres} \times 1.2 \text{ 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%
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)

IRRIGATION SYSTEM, MICROIRRIGATION

**CODE 441**

**STATES: 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 sprays 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., windscreens).

**CONDITIONS WHERE PRACTICE APPLIES**
This practice applies on sites where soil 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.

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SPRINKLER SYSTEM

**Code 442**

**STATES: 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
- Teaching or retardation 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
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.
Evaluating Irrigation System Uniformity

By Lynden 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 irrigation 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 Standard 436.2 — Available at:
- NPCC Handbook — Available at:

Pivot Extensions (converging arm or 2-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 converging arms or 2-arms. These systems require two separate evaluations if the maximum deviation for 20 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 the irrigation system.
2. Have the producer start the system and establish a setting for his normal operation (avoid weather extremes).
3. Run the system for 10-minutes or more without changes to water supply system.
   - Please catch cars in a line from the center pivot point past the outer edge of the wetted area.
   - Catch cars 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 cars 10 feet apart for system overhead impact sprinklers, and 15 feet apart for all other center pivot application systems.
   - Plow catch cars 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 car opening.

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 containers 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 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 case where 24 emitters are tested, this would be the highest 4).
6. Plot the sums on the monograph (Figure 1). If the same sums, are large, it is the scale of the monograph you can divide both the highest and lowest by a common

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

Dr. R. Tom Fernandez and Thomas A. Dudt

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, do few calculations and reference to a graph. (Fig. 1) The graph is called a uniformity monograph and was developed by Beals and Kerster (1983).

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 (**).
Acknowledgment

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- Hunter Hansen
- Catherine Christenson
- Allison Smith