Comparison of Distribution Uniformities of Soil Moisture and Sprinkler Irrigation in Turfgrass

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Introduction:

A uniform distribution of water by sprinkler systems on turf is essential for good turf quality and efficient use of water. Observations by water managers have raised the issue that the use of lower-quarter distribution uniformity, DU_{LQ} for irrigation scheduling results in over watering of landscapes The Irrigation Association (IA) proposes in their recent water management publications, the use of the lower-half distribution uniformity, $DU_{LH,}$ for landscape irrigation scheduling. A related question is the relationship between DU as determined by a catch can test and the distribution of water in the soil.

Irrigation scheduling is based on irrigation efficiency which is determined by irrigation management efficiency and the distribution uniformity, DU. Catch can uniformity data is used to calculate sprinkler low quarter distribution uniformity, DU_{LQ}, to assess sprinkler system performance and for irrigation scheduling purposes. The applied irrigation water can move laterally as surface flow when the soil surface layer is saturated, and laterally and vertically due to capillary action in the soil. This redistribution of water in the soil may result in a more uniform distribution of water than the catch can DU_{LQ} data would suggest.

Distribution uniformity as measure by the low quarter distribution (DU_{LQ}) is a common measurement to determine performance of installed systems. This distribution uniformity is determined by the following:

$$DU_{LQ} = \frac{V_{LQ}}{V_{avg}}$$

where: V_{LQ} = average of the lowest one fourth of catch cans measurements, ml

V_{avg} = average all catch cans, ml.

One approach to the calculation of runtime for an irrigation schedule is to use a runtime multiplier (RTM) to calculate the irrigation water requirement (IWR). Where:

$$RTM = \frac{100}{DU_{LQ}}$$

and:

$$IWR = RTM \ x \ PWR$$

where:

PWR = Plant water requirement

A study in Colorado (Mecham 2001) compared the DU_{LQ} based on catch cans and a DU_{LQ} for soil moisture at the catch can locations. For example one irrigation zone had a catch can DU_{LQ} of 68% and DU_{LQ} in the soil of 87%. The author suggested use of DU_{LH}, based on the lowest half of the catch can readings, for scheduling. A preliminary California study (Curry 2004) found that the soil DU_{LQ} values were an average of 33% higher than the catch can DU_{LQ}. An additional find was that the soil moisture DU_{LQ} was similar to the catch can DU_{LH} in clay soils with turfgrass. The results appear to be similar in both studies and suggest use of DU_{LH} for turfgrass irrigation scheduling. The Irrigation Association (IA 2005) recommended using a lower half distribution uniformity ($DU_{LH)}$ calculated from the lower half of catch can data.

An extensive study in Florida (Dukes, 2006) in sandy soil concludes that soil moisture uniformity distribution approximates DU_{LH} calculated from catch can measurements.

Based on the early reports and the Irrigation Association recommendations, this 2005 study expanded the previous work of soil moisture distribution with sprinkler irrigation of cool season turfgrass (Curry, 2004). The research objective was to study the relationship of sprinkler distribution uniformity, DU, as measured with catch can tests, with soil moisture distribution in the root zone of turf as measured with a TDR.

<u>Methods and Procedures</u>:
Three cool season turf plots with different soil and turf conditions were setup for this project. At the beginning of the project several procedures to collect catch can sprinkler distribution data and measurements of volumetric soil moisture were explored and evaluated. The procedures selected were to conduct catch can tests twice at each plot, once before the beginning of the series of irrigations where soil moisture was measured with a TDR at each catch can location, and a second time after the irrigations and soil moisture measurements were completed for each plot. The volumetric soil moisture was measured with time-domain reflectometry (Field Scout TDR 300, Spectrum Technologies, Inc.[1]).

Each plot had 49 points uniformly distributed (equidistant from each other) throughout the plots for catch can locations. Catch can data were recorded immediately after the end of each irrigation. For each irrigation event, TDR readings were recorded within one hour before the irrigation, and 1, 2, 6, 24, and 48 hour intervals after the end of irrigation. Total number of TDR soil moisture measurement for each plot was 245 after each irrigation event. Soil moisture was measured within one foot diameter of each catch can location. Since 6 TDR measurements were taken at each location over a 2 day period, the TDR probe locations were rotated in a one foot diameter area to minimize the effect of the probes on the soil. Table 1 gives additional information for each plot.

1. Mention of trade names or other proprietary information is made for convenience of the reader and does not imply endorsement by authors.

Table 1. Summary of turf plot and data collection information.

Plot Number	Soil	Turf	Irrigation System	Catch Can DU_{LQ} (Ave of 2 tests)	TDR Probe Length
1	Clay Loam	Fescue, good condition	Half Circle Rotor Sprinklers, 35 ft spacing, Pr = 0.44 in/hr. Runtime = 68 minutes	0.73, 5 foot square spacing for catch cans, 49 cans	4.8 inch (12 cm)
2	Sandy Clay Loam	Fescue, new planting, medium condition	Quarter Circle Rotor Sprinklers, 50 ft Spacing, Pr = 1.4 in/hr. Runtime = 15 minutes	0.72 7 foot square spacing for catch cans, 49 cans	3 inch (7.5 cm)
3	Sandy Loam	Fescue, good condition, 4 - 6 inch height	Full Circle Rotor Sprinklers, 50 ft Spacing, Pr = 0.36 in/hr. Runtime = 60 minutes	0.65 7 foot square spacing for catch cans, 49 cans	4.8 inch (12 cm)

The irrigation systems were tuned up before the tests to correct sprinkler arc orientation, vertical plumb, and head height. Three inch probes on the TDR were used on plot 2 because the soil was compacted and the 4 inch probes could not be inserted to their full length in this compacted soil. There were about 8 locations out of the 49 locations in this plot where the TDR could not be used with the 3 inch probes. The TDR probe developed problems and had to be rebuilt with new firmware in midsummer; only the data with the rebuilt TDR are included in this report.

Results:

Comparison of the distribution uniformities in Figure 1 show that the soil moisture distribution had a higher DU_{LQ} than the catch can DU_{LQ} for all three sites. The mean TDR DU_{LQ} is the mean volumetric moisture content (VMC) of soil based on 49 measurements with the TDR probe for each time interval of 1, 2 , 6, 24, and 48 hours after the irrigation.

The mean catch can DU_{LQ} is the mean of two catch can tests, one test before the series of irrigations at each plot and one immediately after the last data collection at that site.

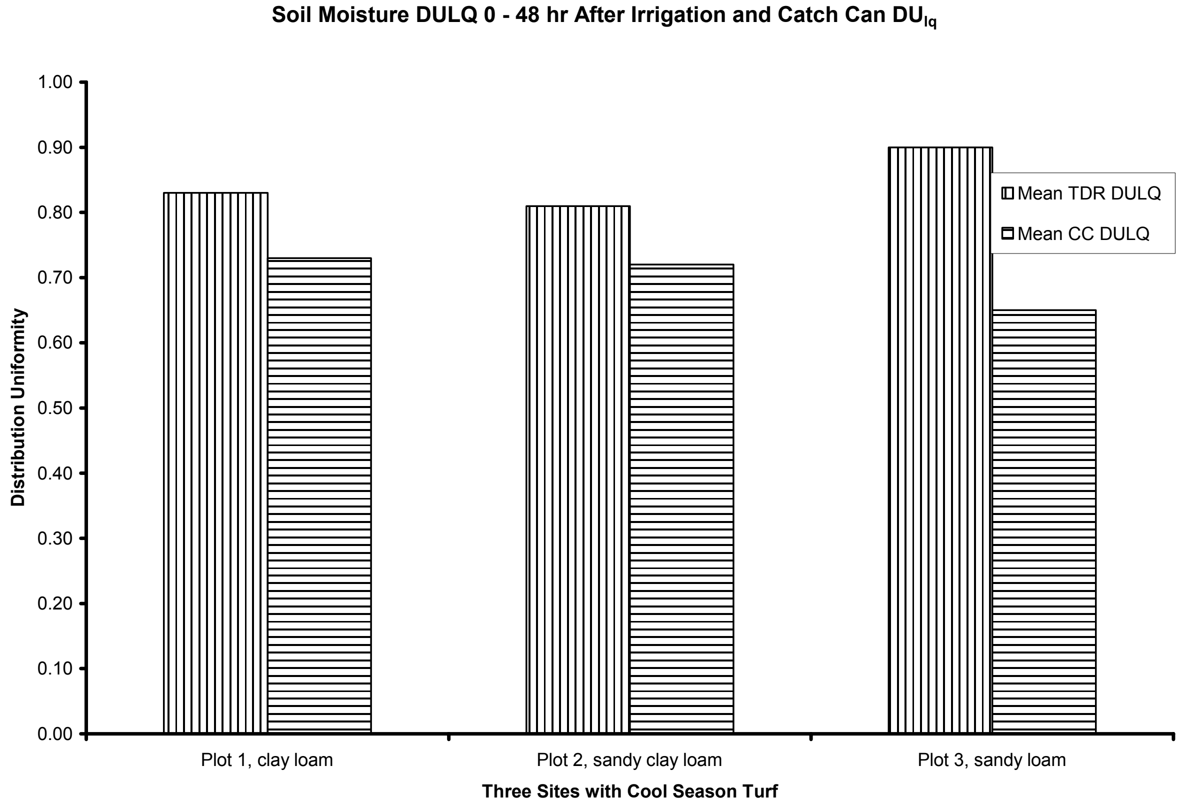

Figure 1. Comparison of distribution uniformity for the soil moisture after irrigation (Mean TDR DU_{LQ}) and sprinkler catch can distribution (Mean CC DULQ).

The largest difference between the catch can and soil moisture DU_{LQ} was at the plot 3 site for 1, 2 and 6 hours after the irrigation (Figure 2). The catch can DU_{LQ} was lower at this site and the turf quality is good, dense turf, maintained at approximately 4 - 6 inch height. The dense turf at this site may contribute to more dispersion of the applied sprinkler water and higher level of irrigation management at this site may contribute to the high soil moisture DU. Mean soil moisture distribution was higher than catch can distribution uniformity for all sites for each time interval. Plot 3 was located on a CIMIS weather station site in a very open area. The second catch can test was conducted on a day with slightly higher winds which may have been a factor in the catch can distribution uniformity DU_{LQ} of 0.55 compared 0.74 for the first measurement. Therefore, the mean differences for plot 3 may be greater due to the low catch can DU_{LQ} for that site.

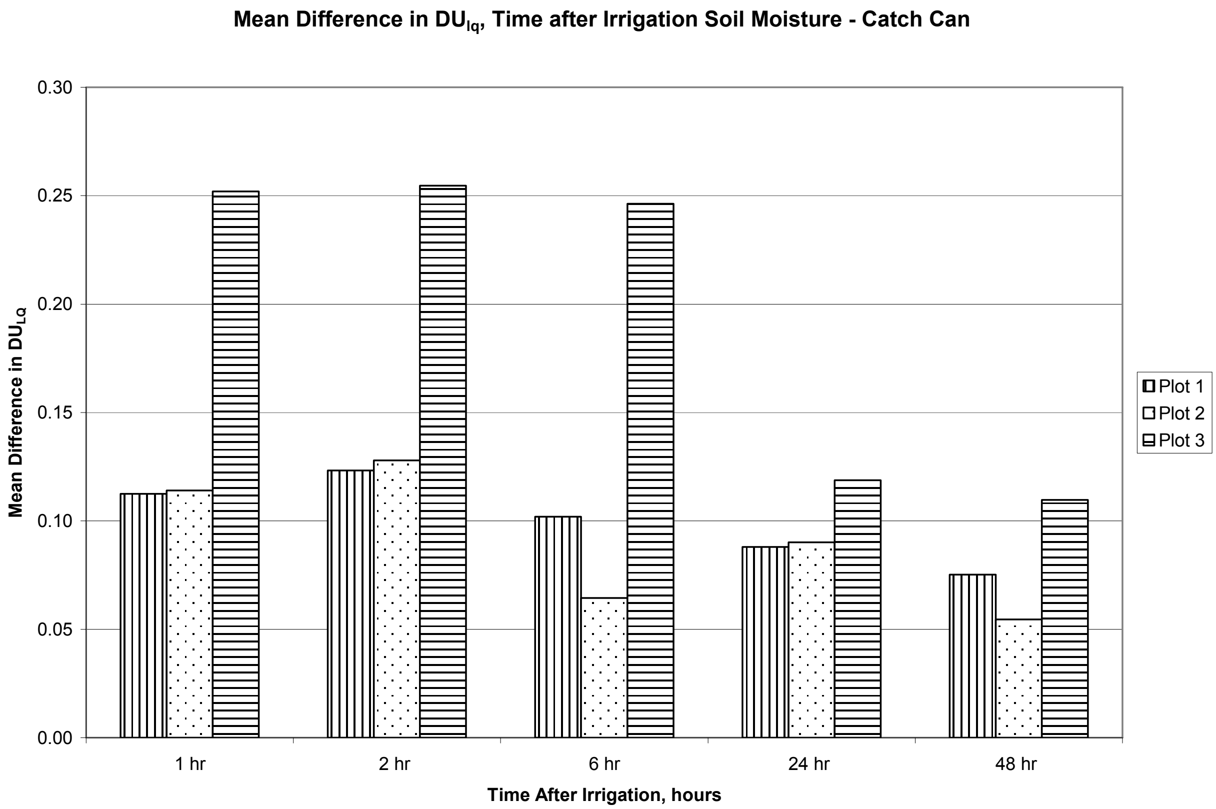

Figure 2. Summary of the differences between the catch can DU_{LQ} and soil moisture DU_{LQ} at the indicated time after irrigation.

Data analysis was performed using the Statistical Analysis System software (SAS Institute, Inc.). Mean differences between the DU for soil moisture and catch can using Duncan multiple range test at the 95% confidence interval.

Table 2 Distribution uniformity of soil moisture based on TDR measurements and sprinkler distribution uniformity based on catch can tests.

Location	Replication	Soil TDR Post Irr. 1 hour DU_{LQ}	Catch Can[1] DU_{LQ}
1	1	0.84	0.69
1	2	0.84	0.71
1	3	0.86	0.71
1	4	0.83	0.75
1	5	0.85	0.77
Mean[2]		0.84a	0.72b
2	1	0.81	0.71
2	2	0.81	0.72
2	3	0.87	0.71
2	4	0.88	0.72
2	5	0.83	0.71
Mean		0.84a	0.71b
3	1	0.93	0.74
3	2	0.93	0.60
3	3	0.85	0.65
3	4	0.93	0.55
3	5	0.89	0.65
Mean		0.91a	0.64b

1. There were two actual catch tests per location, once before the irrigation events and once after the irrigation events. Sprinkler DU_{LQ} for other irrigation events were assumed to vary based on hourly average wind data. Wind speeds for the GR site ranged from 2.7 - 4.9 mph, CIMIS, 2.6 – 6.1 mph, and TS 1.6 - 5.6 mph.

2. Mean values in rows followed by different letters are statistically different at the 95 % level by Duncan's Multiple Range Test.

There was significant differences between the means of DU_{LQ} for catch can and soil moisture measured one hour after the end of irrigation for each of the three sites. In each case the soil moisture was more uniform.

The equation in the IA publication, Landscape Irrigation Scheduling and Water Management, $DU_{LH} = 38.6 + (0.614 * DU_{LQ})$, can be used to calculate the DU_{LH} based on the DU_{LQ}, or the DU_{LH} can be calculated directly from the catch can data. The catch can DU_{LH} is 82% when calculated using the above equation with a 70% mean CC DU_{LQ} (overall mean for the 3 plots). DU_{LH} of 82% is a better indicator of the mean soil moisture DU_{LQ} of 85% than the catch can DU_{LQ} of 70% for this study (Table 3). .

Table 3. Summary of mean volumetric soil DU_{LQ} (TDR), mean catch can DU_{LQ} (CC) and calculated runtime multipliers.

	Soil Mean TDR DU_{LQ}	Soil Runtime Multiplier	Catch Can Mean DU_{LQ}	Catch Can Runtime Multiplier
Plot 1, clay loam	0.83	1.20	0.73	1.40
Plot 2, sandy clay loam	0.81	1.23	0.72	1.39
Plot 3, sandy loam	0.90	1.11	0.65	1.54
Mean of three sites	0.85	1.18	0.70	1.43

As can be seen from Table 3, the runtime multiplier is decreased by 17% when the soil moisture DU_{LQ} is used rather than the catch can DU_{LQ}. Therefore, for irrigation scheduling purposes it may be appropriate to use a catch can DU_{LH} as the indicator of soil moisture distribution.

Distribution uniformities for the two catch can tests at the CIMIS site (Plot 3) were 0.74 with 2.8 MPH and 0.55 at 4.2 MPH wind. This site is an open area and the wind appears to affect the CC DU_{LQ} substantially. The catch can DU_{LQ} for both catch can tests at the plot 2 location were very similar and the hourly wind speed recorded at a nearby CIMIS weather station were nearly the same for both test dates (Table 4). There was a 2.9 MPH difference in wind speeds at Plot 1 area and a small difference in a catch can DU_{LQ}. However, this plot is near tree rows and buildings which may limit the effects of wind on catch can DU_{LQ} at this site.

Table 4. Average hourly wind speed and catch can results.

Date	Hour	Wind Speed (MPH)	Catch Can DU_{LQ}, %	Location
4/18/2005	1100	5.6	0.69	Plot 1
10/21/2005	1000	2.7	0.77	
			Mean = 73	
9/14/2005	1000	3.0	0.71	Plot 2
11/23/2005	800	2.9	0.72	
			Mean = 72	
9/13/2005	1000	2.8	0.74	Plot 3
11/23/2005	900	4.2	0.55	
			Mean = 0.65	

Soil moisture DU_{LQ} did not increase or decrease in any consistent pattern with soil volumetric water content for all three plots. We expected soil moisture uniformity might increase with higher soil moisture volumetric moisture contents.

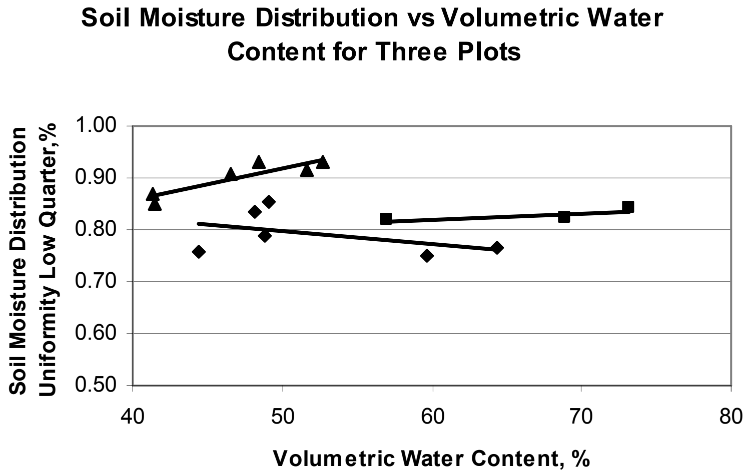

Figure 3. Soil moisture distribution uniformity relationship to the volumetric soil water content as measured with the TDR.

Summary and Conclusions:
Three plots with cool season turf and rotor sprinklers were monitored to compare catch can DU_{LQ} and soil moisture DU_{LQ}. Soil moisture was measured with a TDR with 4 inch probes on two plots and 3 inch probes on one plot at 1, 2, 6, 24, and 48 hours after the irrigation. The series of measurements were analyzed for 6 irrigation events for plots 2 and 3, and 3 irrigation events for plot 1.

1. The mean soil moisture DU_{LQ} was 85% when combining data from the three plots for time after irrigation from 1 to 48 hours. The mean catch can DU_{LQ} was 70%.
2. There was a significant difference in the mean values DU_{LQ} of catch can and soil moisture DU.
3. The catch can DU_{LH} was 82% when calculated from the equation in IA publications.. The soil moisture DU_{LQ} was 85%. This data may suggest that the catch can DU_{LH} may better represent the soil moisture distribution in the 3 – 4 inch root zone.
4. Irrigation scheduling based on the soil moisture DU_{LH} would apply about 17% less water than using the catch can DU_{LQ}. The question of turf quality with irrigation water management based on the DU_{LH} was not addressed in this study
5. The largest differences between soil moisture and catch DU's were at Plot 3 at the 1, 2, and 6 hour measurements. This weather station site has very dense turf maintained at a 4 – 6 inches height which may contribute to a more uniform distribution of the irrigation water in the soil.

References:
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