Calculation of Uniformity in Landscape Irrigation Auditing

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Abstract

This paper presents a comparison of methods for calculating uniformity in landscape irrigation auditing. The focus of the paper is a the difference between the Christiansen Coefficient of Uniformity (CU) and the Distribution Uniformity of the Low Quarter (DU_{LQ}). For this analysis 236 individual station in 35 sports athletic fields were analyzed. For comparison purposes, the calculations from these same stations are presented using the Distribution Uniformity of the Lower Half (DU_{LH}) and the Coefficient of Variation (CV). For most landscapes, the CU method was found to produce higher efficiency values than the DU_{LQ} method. In some cases, the difference in efficiency between the two methods was as high as 20%.

Background

In 1992-1994, in collaboration with the Irrigation Training and Research Center (ITRC) the irrigation auditing program developed at Cal Poly was adopted to Texas by the Texas AgriLife Extension Service (then Texas Cooperative Extension Service). This program has since evolved into the Texas Landscape Irrigation Auditing and Management (LIAM) Program which includes a two-day, 16-hour training class, training manual, and the Texas Irrigation Auditing and Scheduling Software package. The LIAM program is also supported by the TexasET Network and Website (http://TexasET.tamu.edu). The goal of the LIAM program is to help conserve water through the development and implementation of appropriate irrigation schedules in landscapes, particularly in turf. Since 1995, over 2500 students have completed the auditing program.

Landscape Irrigation Auditing

An irrigation system audit is comprised of performing a catch can test to determine irrigation systems performance and precipitation rate. A catch can test is conducted by placing catch can “devices” in a grid like pattern within an irrigation systems station. Multiple cans are utilized per station but the number will vary based on the sprinkler spacing and the number of heads in the station. Once the cans are in place, the irrigation system is turned on. After a brief amount of time, usually between 8 and 15 minutes or until there is a readable volume in each can, the system is turned off. The volumes collected are then recorded (either in milliliters or inches). In auditing, this data is then analyzed to assist in determining seasonal irrigation schedules, runtimes for individual stations, and distribution uniformity estimates of the system.

Texas Landscape Irrigation Auditing and Scheduling Software package continues to evolve based on input from users and changes in auditing procedures. The software allows auditors to enter their catch can volumes per station into the software, along with site specific data such as root zone depth, soil and plant type, adjustment factor, MAD, etc. The software includes historical ETo from 19 cities which is used along with the audit data to produce the irrigation schedules. Once all data is entered, a station statistical report can be generated. This report displays the stations precipitation rate, distribution uniformity (low quarter method, DU_{LQ}) and the coefficient of uniformity (Christensens, CU). The base irrigation schedule can then be generated. The software allows users the option of including average rainfall in the schedule. While the software allows users to adjust the runtimes based on either DU or CU, our recommendations are to not do this which is the default setting of the software.

SAFE Program

The LIAM program is an important component of the SAFE (Sports Athletic Field Education Program) which is conducted by the Texas AgriLife Extension Service. The purpose of the SAFE program is to educate managers of sports fields on proper turf, nutrient, and chemical, and water management in order to promote quality facilities while conserving water and protecting the environment. Over 100 facility managers have participated in this program which includes an audit of their fields. Types of fields used in this study include but are not limited to Football, Soccer, Baseball and Softball Fields (McAfee, 2009). Thirty-five (35) of these sites with a total of 236 stations from the SAFE program are used in this paper to examine DU calculations.

Uniformity Methods

The Distribution Uniformity (DU) varies in landscape irrigation systems based on several factors, including the design of the system, the type of sprinkler equipment used, and installation and maintenance practices. Baum, et al. (2005) used DU as an indicator in a comparison of rotor and spray residential irrigation systems. In this University of Florida study, 25 residential systems were audited. In comparing the CU and DU_{LQ} values for residential systems, the averages were 59% and 45% for rotors and sprays, respectively , and that the CU method consistently produced higher DU efficiencies . While rotors had higher DU_{LQ} than spray heads, the authors reported that all the DU_{LQ} results were lower than what should be expected. (Baum, et al., 2005).

Lower Quarter Distribution Uniformity

Various methods exist to determine the DU of an irrigation system. The method widely used in irrigation auditing is the Low Quarter Distribution Uniformity Method (DU_{LQ}). This method can be calculated as follows:

$$DU_{LQ} = \frac{\bar{V}_{LQ}}{\bar{V}} \quad \text{(Eq. 1)}$$

Where $\bar{V}_{LQ}$ is the average volume of the lowest quarter of the cans and $\bar{V}$ is the average of all the cans. This method places more emphasis on the adequacy of irrigation among the low quarter of catch cans. In ranking the irrigation volumes from lowest to highest, this method neglects the overall location of the irrigation water applied and not taking into account any beneficial (high volumes) that may have been applied near the low volumes (Zoldoske and Solomon, 1988).

Christiansen's Coefficient of Uniformity

While not widely used landscape irrigation, CU is the most widely accepted and used method for calculating the uniformity efficiency of irrigation systems. Christiansen's Coefficient of Uniformity (CU) takes a different approach to evaluating system performance. By taking the absolute value of the irrigation volume from the mean (the standard deviation), the method treats over irrigating and under irrigating equally:

$$CU = 1 - \frac{\sum_{i=1}^{n} |V_i - \bar{V}|}{\sum_{i=1}^{n} V_i} \quad \text{(Eq. 2)}$$

Where V_i is an individual catch cans volume and $\bar{V}$ is the mean (average) catch can volume. In comparing the standard deviation to the mean, you calculate on average how uniform the irrigation is being applied (Zoldoske and Solomon, 1988).

Low Half Distribution Uniformity Method

In recent years, another method to calculate uniformity of the irrigation system has been proposed, the Low Half Distribution Uniformity Method (DU_{LH}). In order to calculate the DU_{LH}, the DU_{LQ} is required (IA, 2005). This method is calculated using the following equation:

$$DU_{LH} = 38.6 + (0.614 \times DU_{LQ}\%) \quad \text{(Eq. 3)}$$

Coefficient of Variation

The Coefficient of Variation (CV) is a uniformity measure that has been used to characterize the uniformity of drip irrigation products. This method can be calculated by dividing the standard deviation of the catch cans by the overall mean catch can volume (Dukes 2006). The formula is shown below:

$$CV = \frac{\sqrt{\frac{(V_i-\bar{V})^2+(V_{i+1}-\bar{V})^2+\cdots+(V_N-\bar{V})^2}{N}}}{\bar{V}} \qquad \text{(Eq. 4)}$$

Typically CV is a unit less value expressed as a decimal. CV values that are closer to zero indicate less variation between data values whereas values closer to one show a greater variance in the data. For the purposes of this study, CV shows how similar one catch cans volume is to another's in the station.

Analysis and Discussion

The audit data from 236 stations from the SAFE Program was input into a spreadsheet (Microsoft Excel) to calculate the uniformity values from Equations 1-4. The results are summarized in Tables 1-3 and Figures 1-3 below. CV values were subtracted from 1 (100%) to depict data on the same standard as other methods (normally low CV value indicate less variation-greater uniformity).

DULQ Rating Scale

The Irrigation Association has developed a rating scale for evaluating low quarter distribution uniformity (IA, 2005). Table 1 shows this rating scale for rotors. Table 2 shows the number of stations with DU which fell within each rating scale class. For the irrigation stations analyzed in this study, the largest percentage (48%) of the low quarter distribution uniformities would fall in the "Very Poor" (< 40%) category whereas less than 15% of the CU values calculated for the same stations would be classified as "Very Poor".

Table 1. Rating of Lower Quarter Distribution Uniformity for Sprinkler Zones (IA, 2005)

Sprinkler	Excellent %	Very Good %	Good %	Fair %	Poor %
Rotor	80	70	65	60	50

Table 2. Number of Stations Per Rating and Uniformity Method				
Rating	DU_{LQ}	DU_{LH}	CU	1-CV
Excellent > 80%	3	29	12	7
Very Good 70-79%	18	89	46	21
Good 65-69%	10	42	42	20
Fair 60-64%	24	40	42	27
Poor 50-59%	67	35	59	71
Very Poor < 49%	114	1	35	90

Figure 1 shows the DU calculations for all stations. A linear distribution was calculated for the different methods and the R Squared Value reported in Table 3. Figure 2 and Figure 3 show the DU for same stations at a Football and Baseball Field.

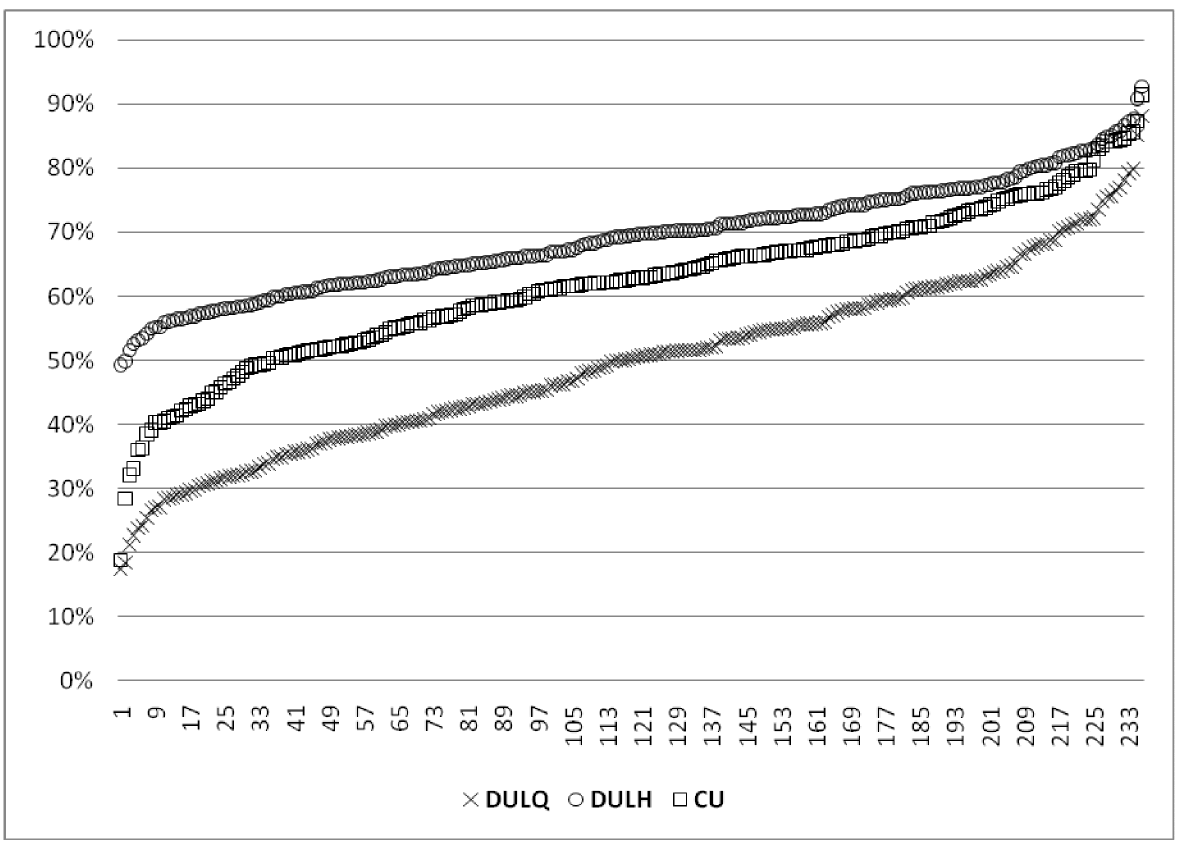

Figure 1. Comparison of Uniformity Values

Table 3 shows the mean, standard deviation and other common statistical analysis of the average DU calculated by each method. The DULQ method produced the lowest uniformity values of all methods. Statistically the DULH method produced the highest uniformity values of the methods.

Table 3. Uniformity Analysis of Different Methods, 236 Stations				
Method	**DU_{LQ}**	**DU_{LH}**	**CU**	**1-CV**
Mean	50%	69%	62%	52%
Standard Deviation	14.2%	8.7%	12.2%	16.6%
Median	50.3%	69.5%	62.7%	45.6%
Max	88%	93%	91%	91%
Min	17%	49%	19%	1%
R Squared*	.9606	.9606	.9303	.9199
Average Cans Per Station: 17				

*R Square Calculated Using a Linear Distribution

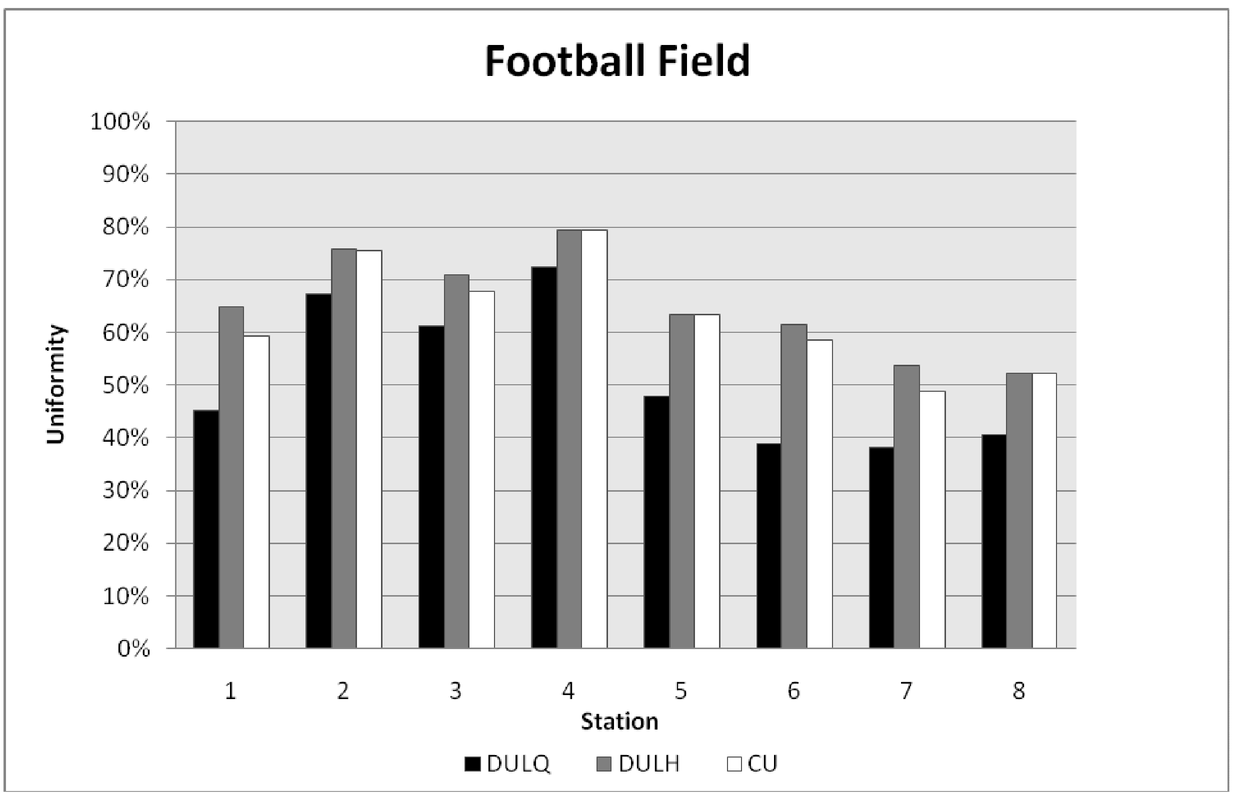

Figure 2. Comparison of Uniformity Values for a Football Field

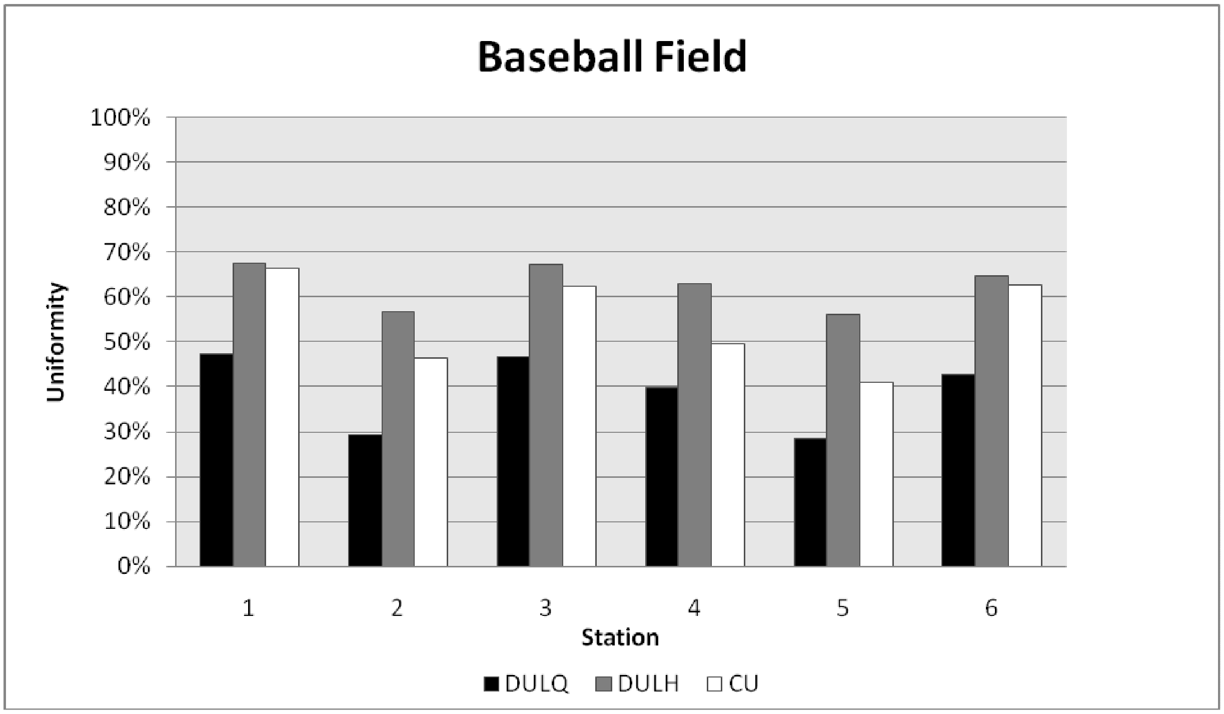

Figure 3. Comparison of Uniformity Values for a Baseball Field

Summary and Conclusion

The DU_{LQ} method, on average, produced the lowest measure of uniformity per station. The DU_{LH} Method produced uniformity values that, on average were higher than the CU method. Overall, the analysis showed that for the same station, the CU method produced on average higher uniformity values than DULQ. These results indicate that similarities exist between the DU_{LH} and the CU methods, but further statistical analysis is needed to show which method produces the more representative uniformity value.

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