Stewardship Coefficient: Measuring the Impact of Best Practices

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Abstract

With an improved understanding of sprinkler system performance come better decisions regarding optimum parameters such as sprinkler selection, layout, operation and adjustment. Overlapping sprinklers, extended runtimes and unmatched precipitation rates severely increase the amount of water used to irrigate a turf area. By calculating the amount of overwatering done and comparing it to the amount of under-watering, a more complete picture of the sprinkler system performance can be achieved. Catch can data is analyzed and compared to theoretical results, providing a solid basis for using the stewardship coefficient. This added perspective enriches the audit outcome and computes the true impact of current best practices without requiring additional data. By calculating the true cost of best practices, a more complete picture of a sprinkler system performance can be achieved. Only by highlighting areas in need of improvement can changes be made that enable comprehensive landscape stewardship.

Keywords

conformal irrigation, intelligent precipitation, audit, uniformity, catch can, best practices, stewardship coefficient,

Introduction

An ever increasing focus on outdoor water conservation requires continuously improving management of limited water resources. Having a better understanding of how a sprinkler system is performing empowers the turf manager to make better decisions regarding optimum parameters such as sprinkler selection, layout, operation and adjustment. This process of improvement typically begins with a thorough audit of the site to measure the sprinkler systems ability to deliver the correct amount of water in the right places within the bounds of the turf area. This whitepaper outlines an additional perspective in order to enrich the audit outcome as well as computing the true impact of current best practices. No additional audit data is collected, rather two additional performance parameters are defined and demonstrated that can better illustrate the tradeoffs occurring in each hydrozone at a particular site.

Turf health and quality are very important objectives for all landscaped areas. Aside from the environmental benefits (Zoldoske, 2008), the visual appeal of a healthy, lush lawn is the primary reason turf is installed in the vast majority of landscapes. A lush, green, healthy, properly maintained lawn resonates with a large majority of turf owners. At issue is the amount of water required to properly care for a lawn. Currently, irrigation audits are performed to determine both the amount and distribution of water applied to the turf area. Calculating uniformity from catch can data commonly gives insight into the areas of the lawn that are receiving the least amount of water. This is an aid for evaluating the risk to turf health and quality since the driest areas of the lawn are more prone to disease, wilt and browning.

Overcoming these dry areas usually requires running the zone longer in order to apply more water to the driest fraction. Naturally, when runtime is extended, the remaining majority of the turf area is overwatered. Overwatering causes its own set of turf health issues in addition to the obvious impact on the water budget. Thus, in an effort to reduce the effects of under-watering in the driest 25% of the turf area, overwatering the other 75% is a commonly accepted practice. This conflict between health and conservation naturally raises these questions:

> Could an auditor use additional information to better understand the health/conservation tradeoff for all hydrozones?
>
> Could improved visibility of the overwatered areas highlight design issues that should be addressed to maximize water savings?

By calculating the amount of overwatering done and comparing it to the amount of under-watering being done, a more balanced picture of the sprinkler system performance can be achieved.

Method

The Irrigation Association describes Distribution Uniformity (DU) as the evenness with which a sprinkler system deposits water over a hydrozone (IA, 2007). It is a ratio of the average volume of water deposited over the driest areas to the average volume of water over the entire hydrozone. By using catch can data from the driest 25% of the hydrozone, the Lower Quartile Distribution Uniformity (DUlq) can be calculated. Since the lower quartile represent the driest areas of the hydrozone, the wettest areas can be similarly represented by the highest 25% of the same catch can data. Thus the calculation for the Higher Quartile Distribution Uniformity (DUhq) is performed in a similar manner and is defined as:

$$DUhq = \frac{Average\ Catch\ Volume\ in\ Highest\ Quarter}{Average\ Catch\ Volume\ in\ Zone}$$

Notice that the auditor does not require additional catch can data from the site. The calculation of DUhq is derived from the same method as for DUlq. After DUhq has been calculated, the amount of overwatering in the wettest quarter of the turf area is readily apparent since this value will never be less than 1. Now with both DUlq and DUhq calculated, a more balanced picture of overall zone performance can be seen.

The most straightforward method to compare these two uniformity values is to form a ratio. This provides a general indication of the tradeoff between the wettest and driest areas within the zone with very little effort. Because turf health and water use are both strongly related to under-watering and overwatering respectively, this ratio is also an overall indicator of the lawn health to water savings potential for the zone. This ratio, called the stewardship coefficient (Cs), calculates the ratio of under-watering to overwatering in the zone. This coefficient is defined as:

$$Cs = \frac{DUlq}{DUhq}$$

As Cs increases, approaching the limiting value of one, the zone is becoming more balanced between lawn health and water conservation. A zone with Cs less than one indicates a stewardship imbalance, meaning the zone is either severely under-watered, over-watered or both. Now armed with a more complete toolkit to evaluate the overall balance between health and water use, the effect of two well known irrigation best practices can be evaluated.

Today, the majority of gear drive rotors have single leg or stream DUs ranging from 0.50 to 0.80 as reported by manufacturers. When the DU of an individual sprinkler head is less than 1.0, dry fractions in the zone will automatically occur. The common remedy is extending zone run time to sufficiently water the driest fraction. Additional runtime is often calculated from a Run Time Multiplier (RTM). The multiplier is calculated based on the DU values obtained from the catch can data for the zone. The lowest 50% or 25% of the catch can data are commonly used and are referred to as the lower half (lh) and lower quartile (lq) respectively. These represent the driest areas in the hydrozone. A value proportional to the reciprocal of the selected DU value is used to multiply the current zone run time in an effort to provide additional water to the driest fraction in the zone. For example, the RTM when using DUlq is given as:

$$\mathrm{RTM} = \frac{1}{0.4+(0.006 \times DUlq)}$$

According to the Golf Irrigation Auditor handbook, most properly designed irrigation systems have average DUlq's between 0.55 and 0.75. This means the run time multiplier will range between 1.38 and 1.18. A field report by Mecham, et al. (2004) in which 6800 audits revealed an average measured DUlq of 0.58 or less. Thus an RTM of 1.35 accurately represents what is in use in the field today.

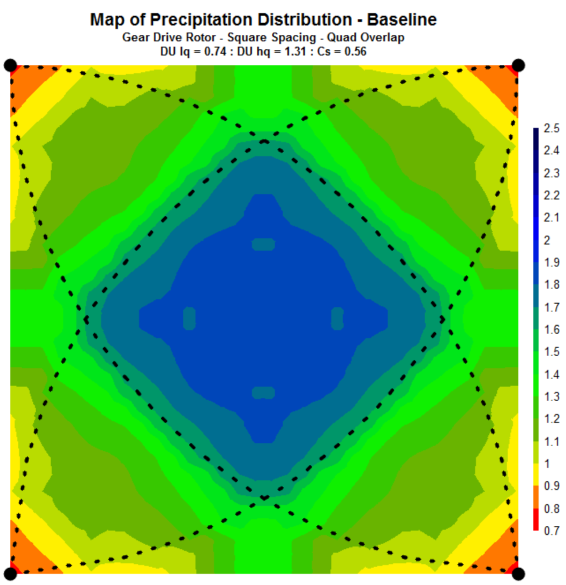
The other best practice is the head to head (H2H) paradigm. This requires that the spacing between sprinkler heads does not exceed the rated throw of the head for a given pressure. This insures that the area close in to the head is sufficiently watered by adjacent heads. This requirement also insures that the individual spray patterns provide overlapping coverage within the zone. The amount of overlap varies from layout to layout but areas with 3X and 4X overlap are common.

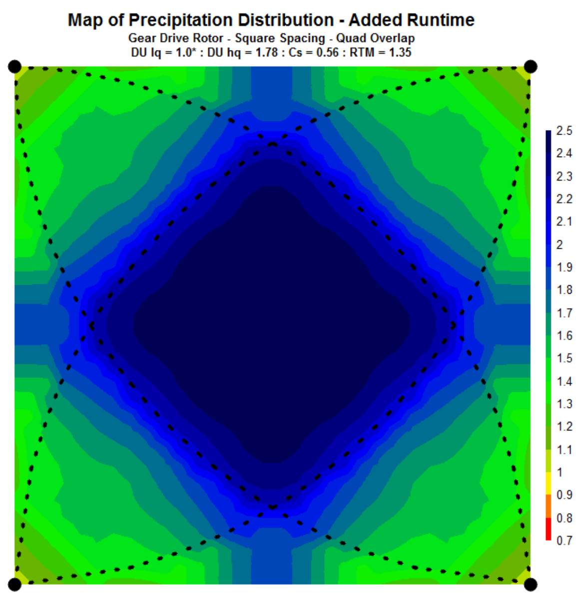
In order to calculate the true cost of these best practices, a virtual turf test area was created that will predict the water use for a given sprinkler layout. For this study, the test area is a 32 ft square turf area with one gear driven rotor in each corner each rotating thru 90° of arc resulting in a square spacing and quadruple overlap. The sprinkler profile data was obtained from the Center for Irrigation Technology (CIT, Fresno, CA) in the form of .prf files. These single leg profile data records were input into Catch3D, a personal computer program from Utah State University designed to visualize sprinkler distribution.

A full 360° pattern was generated for a given rotor. This pattern was sectioned into four equal quadrants and overlaid onto a 32x32 cell grid. The resulting, high density, square grid contains 1,024 cells with the cumulative deposition from each rotor spraying through 90°. The high density grid can be used to plot a high resolution map of the precipitation distribution, or densigram, as well as perform all of the calculations outlined in this paper. The plotting was performed using a commercial plotting package.

Results

Figures 1 and 2 are densigrams for the baseline and added runtime cases, respectively. The rotor locations and radius witness lines are included for clarity. The color gradient scale shows variations in application from 70% to 250% of the required amount over the area.





Figures 1 (l) and 2 (r). Densigrams for Baseline and RTM added cases.

When viewed in high resolution, the effects of head to head overlap are immediately clear. The areas with 3X and 4X overlap are clearly evident. Approximately 90% of the test area receives more water than the required amount. The baseline application ranges from 76% to 180% of the required amount. The lowest quartile is dry enough to warrant the use of a Run Time Multiplier (RTM) to ensure adequate watering of the driest areas. The effect of adding an RTM is evident in Figure 2. The variation is from 104% to 247% of the required amount. This is a significant increase in the volume of water used to irrigate this area. Table 1 shows the calculated results.

Condition	DU lq	DU hq	Cs	DU lh	RTM lq	RTM lh
Baseline	0.74	1.31	0.56	0.81	1.35	1.23
RTM lq	1.00	1.78	0.56	1.10	1.00	0.91
SmartRotor	0.98	1.01	0.97	-	-	-

Table 1 – Virtual Test Area Results

A more detailed way to examine the data is to look at the dryness distribution in the hydrozone. Solomon, et. al. refer to this type of plot as a Destination Diagram (Solomon, 2007). By plotting the relative amount of water deposited into each square foot of the virtual test area from least to greatest, a dryness distribution chart can be produced, as seen in Figure 3. For a given X and Y on the appropriate 'dryness' line, the plot shows that X% of the zone received less than the application amount Y.

Once the data are presented in this format, several things become clear. In the pursuit of watering the driest 25% of turf areas, a significant amount of overwatering is occurring in the remaining 75% of the area. To determine the amount of overwatering as a result of the added runtime, one can simply calculate the area between the baseline curve (blue) and the RTM added curve (red) in Figure 3. This area difference represents a 29% increase in the total water applied from the baseline.

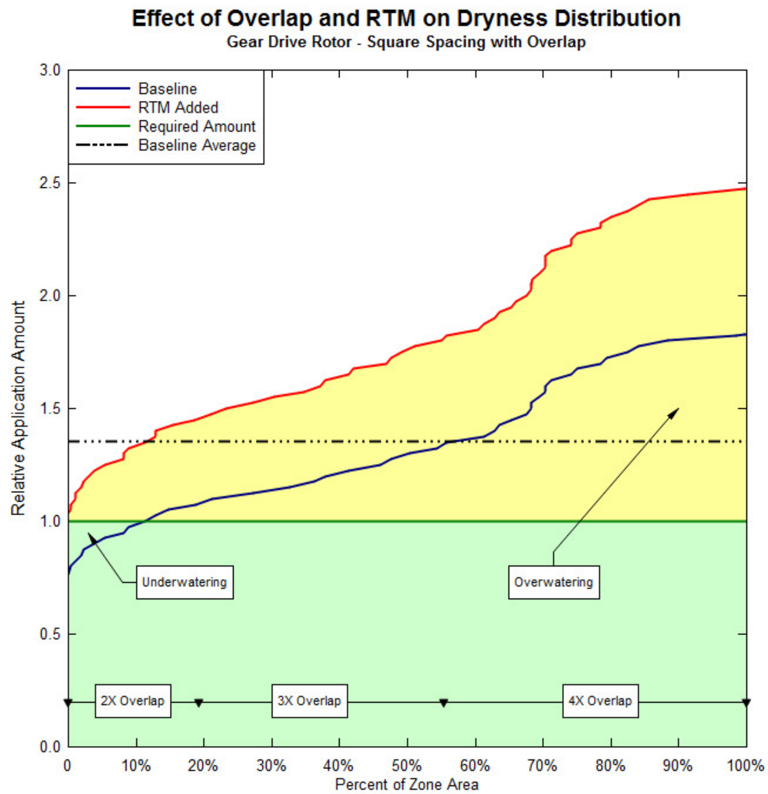


Figure 3. Dryness Distribution Curve.

To determine the amount of excess water arising from the head to head (H2H) paradigm, the area under the required amount line (green) is subtracted from the area under the baseline curve. This represents a 40% increase from the required amount. When the H2H paradigm is referenced to the all too common RTM Added case, the increase is almost double or 80% from the required amount. This is represented by the yellow highlighted area in Figure 3. Undoubtedly, there are measurable water and energy costs associated with the practice of using a Run Time Multiplier and the best practice of head to head overlap. This whitepaper has demonstrated that the overwatering associated with the using an RTM can be as high as 29% while the head to head paradigm can result in overwatering as high as 80%.

While simply relaxing the H2H requirement could easily reduce water use by 50%, today's gear drive rotor sprinklers are incapable of properly watering without the overlap condition. One solution to this predicament is conformal irrigation, which relaxes the head to head requirement, allowing the stewardship coefficient to approach unity. The result would be a significantly more uniform application, closely approximating natural rain. With conformal irrigation, water is applied in concentric bands from the head out to the outermost perimeter. This "banding" can be seen in Figure 4.

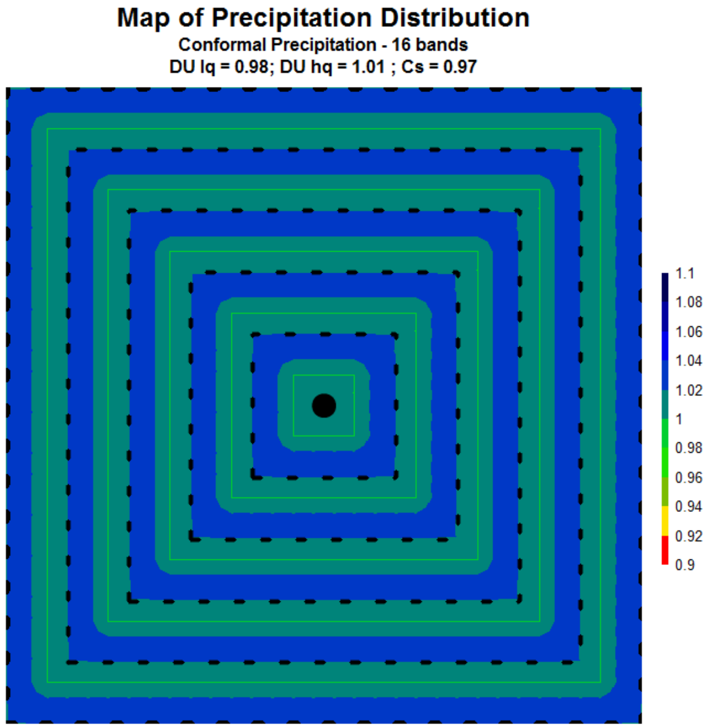


Figure 4 Densigram of Banded Watering

In order to see the variation between bands, the scale has been reduced to ± 10% of the required amount. The accumulated variation within the zone at the end of the watering cycle ranges from 100% to 103% of the required amount. The result is a stewardship coefficient of 0.97, indicating a properly balanced zone. By applying water in bands that are concentric with the outer perimeter, the gross overlap found with traditional H2H layouts can be eliminated. When this method is used, much higher DUlq and lower DUhq values are predicted. This results in a stewardship coefficient that is very close to unity for maximum water conservation and optimum turf health.

Conclusions

While the conformal paradigm can easily be visualized, it has not been realized until recently. New advances in intelligent precipitation technology (IPT) now allow water to be applied in concentric bands from a single sprinkler head. The benefits of this new technology are significant water savings while eliminating dry spots and overspray. Based on the dryness distribution plot in Figure 3, an intelligent system can reduce water use by 40% to 50% in most cases. Combined with zero overspray, water savings approaching 70% may be achieved while reducing structure damage and providing real time water use data.

Only by improving the tools used to evaluate turf watering can progress be made toward the common industry goal of reducing outdoor water use. Both the Higher Quartile Distribution Uniformity (DUhq) and the Stewardship Coefficient (Cs) are effective metrics for characterizing a hydrozone. Only by highlighting areas in need of improvement can changes be made that can enable the landscape irrigation industry to achieve these goals.

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