A Method to Create Precision Irrigation Thresholds Using Soil Moisture Sensing and Mapping Technologies

Chase Straw[1], Joshua Friell[2], Ryan Schwab[3], Shane Evans[3], and Eric Watkins[3]

[1]Department of Soil and Crop Sciences, Texas A&M University, College Station, TX
[2]The Toro Company, Bloomington, MN
[3]Department of Horticultural Science, University of Minnesota, St. Paul, MN

Introduction

The golf course industry is under increasing public pressure to improve environmental impacts by reducing management inputs, particularly irrigation. Precision irrigation is a potential strategy; however, in practice, adoption of soil moisture sensors (SMS) and mapping technologies necessary for implementation has been slow. The purpose of this research is to demonstrate that adoption of currently available SMS and mapping technologies can provide golf course superintendents with appropriate, actionable information that can result in significant water and cost savings relative to evapotranspiration (ET)-based and traditional irrigation scheduling methods.

Objectives

Provide a brief overview of an on-going precision irrigation study and describe the method used to create thresholds for the study's precision irrigation-based treatments.

Materials and Methods

- The study was initiated in July 2019 at Edina Country Club in Edina, MN.
- Two course surveys were conducted 11 and 15 July 2019 using the Toro Precision Sense 6000 (PS6000) to measure and georeference hundreds of volumetric water content (VWC; %) data points (Figure 1). The GPS receiver on the PS6000 also georeferenced all fairway irrigation head locations.

Figure 1. The PS6000 attached to the hitch of a utility vehicle (left) and an example of georeferenced data points from one fairway (right). Each yellow point represents a measurement location.

- All spatial methods and analyses to-date were conducted in ArcMap 10.6 (ESRI, Redlands, CA).
- Ordinary kriging was used to interpolate PS6000 data and produce soil moisture maps, which were raster maps comprised of 1 m^2 pixels.
- Nine fairways (six par 4s and three par 5s) were selected for use in the study and placed into similar groups of three based on size, soil moisture descriptive statistics, and spatial maps of soil moisture variability (Figure 1).
- Three irrigation scheduling treatments were initiated in June 2020 and assigned using a randomized complete block design. The treatments include a SMS-based, ET-based, and traditional irrigation schedule (i.e. when the superintendent felt irrigation was necessary).

Figure 2. Soil moisture maps of the nine fairways selected for use in the study.

Materials and Methods

- Irrigation management zones for fairways receiving the SMS-based treatment were delineated around each irrigation head using Thiessen polygons, and then classified using zonal statistics and Jenks natural breaks to create "high," "moderate," and "low" soil moisture classes (i.e. the wettest, average, and driest areas of a fairway, respectively; Figure 3). Irrigation programs were created for each soil moisture class, so that all irrigation heads within a class on each fairway would irrigate together.
- Toro TurfGuard in-ground SMS were installed 22 Aug. 2019. One sensor was placed in each soil moisture class within each replication, for nine total sensors (Figure 3). Soil moisture is measured from the in-ground SMS every 5 min at 5 and 18 cm depths and can be monitored using Toro SiteVision software.

Figure 3. The irrigation management zone delineation and classification process (left), an in-ground SMS (center), and in-ground SMS locations within each fairway receiving the SMS-based treatment (right). "High," "moderate," and "low" soil moisture classes represent the wettest, average, and driest areas of a fairway, respectively.

- A dry down was conducted on the SMS-based treatment fairways 27 May through 2 June 2020 to identify maximum and minimum soil moisture limits for each in-ground SMS. In addition to VWC data from the in-ground SMS, the PS6000 was used to measure VWC and normalized difference vegetation index (NDVI; i.e. turfgrass quality) periodically during the dry down.
- The dry down began following a 3-day period with a cumulative total of approximately 3.8 cm rainfall. SiteVision was used to monitor VWC for each SMS on each fairway and record the maximum limit after the rainfall and the minimum limit once the golf course superintendent began to feel uncomfortable with turfgrass quality (e.g. wilt, discoloration) (Figure 4 and 5; Table 1).

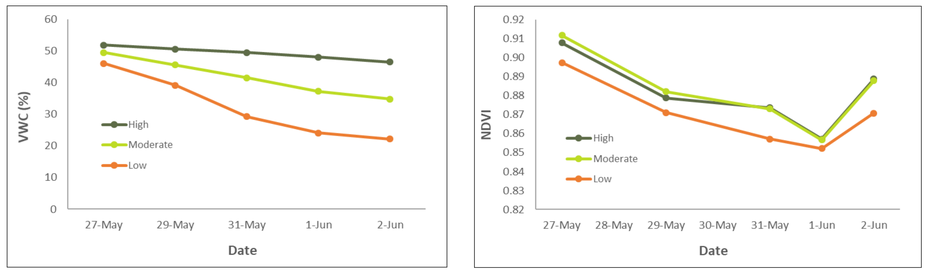

Figure 4. An example of mean VWC (left) and NDVI (right) throughout the dry down on fairway 1, which is receiving the SMS-based treatment. Mean VWC was determined from averaging all VWC data collected by the in-ground SMS midnight-midnight each day that NDVI data were collected with the PS6000. "High," "moderate," and "low" represent the wettest, average, and driest areas of the fairway, respectively, and correspond with the soil moisture classes.

Figure 5. An example of soil moisture maps during the dry down on fairway 1 from georeferenced VWC data collected with the PS6000.

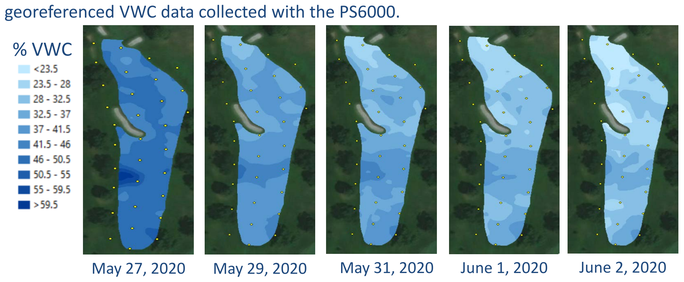

Table 1. Soil moisture limits determined from in-ground SMS during dry down.

Fairway	Soil moisture class	Max/Min	VWC (%)
1	Low	Max	49
		Min	18
	Moderate	Max	53
		Min	30
	High	Max	56
		Min	44
2	Low	Max	46
		Min	19
	Moderate	Max	56
		Min	26
	High	Max	53
		Min	45
3	Low	Max	51
		Min	22
	Moderate	Max	54
		Min	21
	High	Max	57
		Min	22

Treatment Applications

Through the 2020 and 2021 growing seasons:

- Irrigation for SMS-based treatments is allowed within a soil moisture class once VWC has reach the minimal limit for a given sensor (Table 1). Once irrigation is allowed, the applied depth for each irrigation event will be 0.5 cm (adjustments made as necessary).
- 60% of ET is being replaced every three days for ET-based treatments (adjustments made as necessary).
- Traditional treatments have the golf course superintendent irrigating as he typically would.
- Total depth of irrigation applied to each fairway is being recorded for each irrigation scheduling treatment by the Toro Lynx Central Control System software and will be compared on an area basis. NDVI data from the PS6000 will be utilized to evaluate turfgrass quality between treatments, in addition to visual turfgrass quality ratings (1-9 scale) of entire fairways made periodically by the golf course superintendent.

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