Precision Irrigation for Golf Courses Using Sensor and Mapping Technologies

Chase Straw[1], Josh Friell[2], and Brian Horgan[3]

[1]Department of Horticultural Science, University of Minnesota, St. Paul, MN

[2]The Toro Company, Bloomington, MN

[3]Department of Plant, Soil and Microbial Sciences, Michigan State University, East Lansing, MI

Introduction

The golf course industry is under increasing public pressure to improve environmental impacts by reducing management inputs, particularly irrigation. Precision irrigation is a viable 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

1. Quantify response of turfgrass conditions to changes in plant available water.
2. Quantify changes in water consumption between SMS-based, ET-based, and traditional irrigation scheduling.

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 using the Toro Precision Sense 6000 (PS6000) to measure and georeference hundreds of volumetric water content (VWC; %) data points (Figure 1). A GPS receiver on the PS6000 was used to also georeference 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 (Table 1; Figure 1).
- Three irrigation scheduling treatments will be initiated in 2020 and were assigned using a randomized complete block design. The treatments include a SMS-based, ET-based, and traditional irrigation schedule.

Table 1. Descriptive statistics and lower quarter distribution uniformity (DU) of volumetric water content (VWC) at each survey date on the fairways used in the study.

Fairway[z]	# of samples	Min	Max	Mean	SD	DU_{lq}[y]
		%				
July 11, 2019						
3	477	34.9	69.7	51.0	6.0	87.1
5	546	32.8	63.8	49.6	4.1	89.5
6	564	32.2	69.4	51.8	5.2	87.5
8	751	35.0	67.0	49.1	4.6	88.4
9	N/A	N/A	N/A	N/A	N/A	N/A
10	848	21.8	61.6	47.3	4.9	86.3
13	657	33.9	65.3	52.2	4.8	88.3
14	503	25.5	61.3	50.2	4.8	87.3
15	437	27.8	64.1	53.3	4.1	89.7
July 15, 2019						
3	523	19.3	53.1	35.8	6.1	81.2
5	715	18.5	50.8	38.1	5.4	80.6
6	561	25.1	53.2	41.3	5.3	82.6
8	724	32.0	56.3	45.8	5.0	85.4
9	324	19.8	53.6	39.3	5.7	81.2
10	963	25.1	56.4	41.8	5.1	83.7
13	736	25.4	58.4	44.2	4.7	85.2
14	449	28.2	56.7	45.3	4.7	85.7
15	394	26.9	57.9	46.4	4.3	87.1

[z] Area of each fairway: 3 = 5,125 m^2, 5 = 6,582 m^2, 6 = 6,530 m^2, 8 = 8,435 m^2, 9 = 3,755 m^2, 10 = 9,932 m^2, 13 = 8,268 m^2, 14 = 5,448 m^2, 15 = 5,038 m^2.

[y] DU_{lq} = (mean of lowest quarter of the data ÷ mean of all the data) × 100.

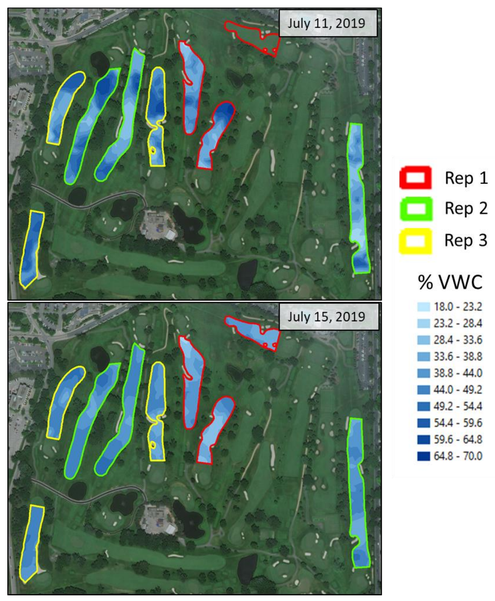

Figure 2. Soil moisture maps of the nine fairways selected for use in the study.

Materials and Methods

- Irrigation management zones for the fairways receiving the SMS-based treatment were delineated around each irrigation head using Thiessen polygons, and then classified using the "zonal statistics" tool and Jenks natural breaks (Figure 3).
- Toro TurfGuard in-ground SMS were installed 22 Aug. One sensor was placed in each soil moisture class within each replication, for a total of nine 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 at any time 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).

- One catch can irrigation audit was conducted on all fairways included in the study to quantitatively define the relationship between the programmed water application and the true depth of irrigation applied (Table 2).
- Irrigation depth data were interpolated for visual assessment of irrigation distribution uniformity (Figure 4).
- Correlation coefficients were determined between catch can amount data from the one irrigation audit and VWC data from the two surveys using the ''modified.ttest'' function in the SpatialPack package of RStudio. There were no significant relationships on any fairways (data not presented).

Table 2. Descriptive statistics and lower quarter distribution uniformity (DU_{lq}) of catch can amount on each fairway used in the study.[z]

Fairway[y]	Area (m^2)	# of samples[x]	Min	Max	Mean	SD	DU_{lq} (%)[w]
			mm				
3	5,125	101	0.3	2.8	1.5	0.6	51.7
5	6,582	134	0.0	7.4	1.5	0.8	46.7
6	6,530	126	0.6	14.0	1.6	1.5	62.5
8	8,435	173	0.0	2.8	1.3	0.6	45.4
9	3,755	78	0.4	5.1	1.5	0.7	47.3
10	9,932	204	0.4	2.8	1.6	0.5	62.5
13	8,268	168	0.0	2.9	1.3	0.6	50.0
14	5,448	112	0.4	5.1	1.5	0.7	61.3
15	5,038	101	0.5	2.8	1.4	0.5	60.0

[z] Runtime for all heads were 4 min and 10 s, which was equivalent to approximately one full rotation.

[y] Catch can audits were conducted on 16 (rep 1 fairways: 3, 5, and 9), 19 (rep 3 fairways: 6, 14, and 15), and 23 (rep 2 fairways: 8, 10, and 13) Sept. 2019.

[x] Catch cans on each fairway were laid out using a georeferenced 7 m^2 sampling grid.

[w] DU_{lq} = (mean of lowest quarter of the data ÷ mean of all the data) × 100.

Figure 4. Irrigation distribution maps of the nine fairways selected for use in the study.

- Canopy temperature was measured during the two course surveys in July using an unmanned aerial vehicle (UAV). Normalized difference vegetation index (NDVI) was also measured with the UAV, as well as with the PS6000 (data not presented).

Next Steps

- In spring 2020, dry downs will be conducted to determine upper and lower soil moisture limits in order to calculate plant available water (PAW) for each in-ground SMS within the SMS-based treatment fairways. Valve-in-head sprinkler control will then be utilized to schedule individual heads in each soil moisture class within each fairway to run together. Irrigation will only be allowed within a soil moisture class once the PAW has been reduced by 50%. When irrigation is allowed, the applied depth will be the lesser of the total forecasted ET before the next forecasted rain event or the amount required to return the VWC to 75% of total PAW (adjustments made as necessary).
- The fairways receiving the ET-based treatments will take a deficit irrigation approach, where 70% of reference ET will be applied every three days (adjustments made as necessary).
- The fairways receiving the traditional treatment will be irrigated by the superintendent as he usually would, taking into account any information typically used.
- Total water consumption will be recorded for each treatment by the irrigation system software (Toro Lynx Central Control). Totals will be quantified and compared on an area basis.
- Once irrigation treatments are initiated, canopy temperature and NDVI will be measured regularly by a UAV. To a lesser extent, the PS6000 will be used to measure and monitor VWC and NDVI.

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