Factors Leading to Temporal and Spatial Heterogeneity of Soil Moisture Dynamics in Sand-Capped Fairway Systems

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Background

- In-ground soil moisture sensor (SMS) technologies have been largely underutilized as a tool for irrigation management of larger areas, like golf course fairways, due to high variability in native soil systems.
- Sand-capping fairways is becoming an increasingly popular agronomic practice in areas with poor water quality and could offer an opportunity for utilization of SMS due to expected increased uniformity in root zone depth and texture.
- However, field observations by turfgrass managers suggest variability in turfgrass performance due to differences in soil water relations still occurring in sand-capped systems.

Objectives

- Investigate factors that could contribute to variation in soil moisture and turfgrass performance within sand-capped fairways.

Methods

- This research is being conducted at the Texas A&M University Campus Course in College Station, TX on sand-capped 'Celebration' bermudagrass (*Cynodon dactylon*) fairways originally constructed to a targeted 12.7 cm depth. Capping sand was a locally sourced, coarse-textured concrete sand.
- Two fairways were selected based on previously observed performance by the course superintendent, noted as either offering 'consistent' or 'inconsistent' performance during periods of low rainfall and high temperatures, where fairway 4 was consistent and fairway 16 was inconsistent.
- Sampling grids for each fairway were generated in ArcMap 10.4.1 using the fishnet tool at a specified grid spacing of 6.1 m x 6.1 m corresponding to 124 sampling locations for fairway 4 and 128 for fairway 16.
- Sand-capping depth (depth to subgrade interface) was measured at each grid intersection within fairways 4 and 16 by extracting a soil sample using a 5 cm diameter soil probe.
- Soil volumetric water content (VWC) data for the 0-7.6 cm upper sand-cap depth were collected 3 and 5 days after rainfall on August 4, 2020 and August 6, 2020 and 1 and 5 days after irrigation on October 8, 2020 and October 13, 2020 at each grid intersection of Fairway 4 and 16 using a Fieldscout TDR 350 Soil Moisture Meter (Spectrum Technologies, Aurora, IL).
- Turfgrass vigor (normalized difference vegetation index, NDVI) was also collected using a RapidScan CS-45 NDVI meter (Holland Scientific, Lincoln, NE) at the dates and manner described above. Soil compaction (penetration resistance) was collected using a Fieldscout SC 900 Soil Compaction Meter (Spectrum Technologies, Aurora, IL) only at dates following the rainfall event.
- Spatial interpolation of point data was achieved using ordinary kriging in ArcGIS. Kriged maps were generated to demonstrate spatial variability of sand-capping depth, as well as VWC on the four separate dates, for fairways 4 and 16.
- Correlation coefficients were calculated using the 'modified.ttest' function in the 'SpatialPack' package of RStudio to assess the strength and direction of relationship between both fairways.

Table 1. Descriptive statistics of Capping Depth for Fairways 4 & 16.

	Min	Max	Range	Mean	SD
	cm				
Fairway 4	1.27	24.7	23.5	15.1	4.6
Fairway 16	0	21.6	21.59	9.7	4.0

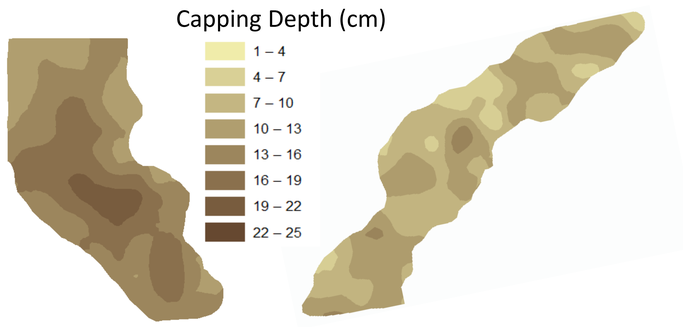

Figure 1. Spatial maps of capping depth (cm) across Fairways 4 (left) and 16 (right).

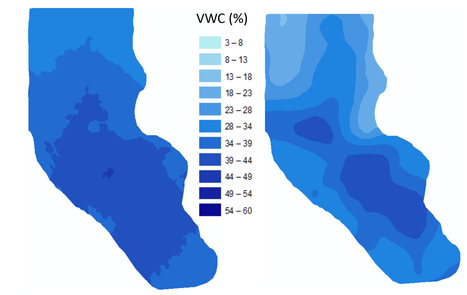

Figure 2. Spatial maps of VWC (%) 3 days (left) and 5 days (right) after rainfall for fairway 4.

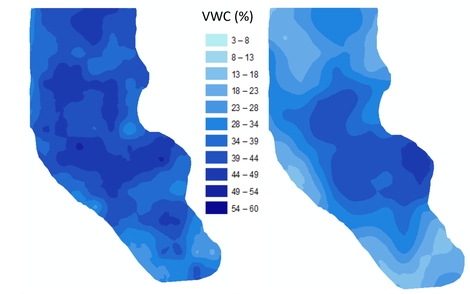

Figure 3. Spatial maps of VWC (%) 1 day (left) and 5 days (right) after irrigation for fairway 4.

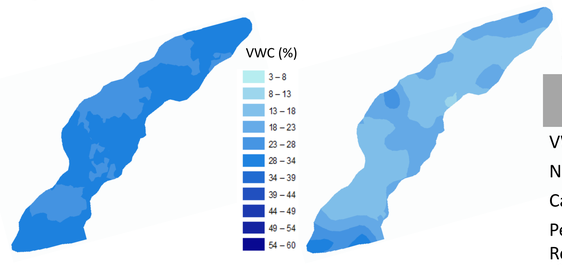

Figure 4. Spatial maps of VWC (%) 3 days (left) and 5 days (right) after rainfall for fairway 16.

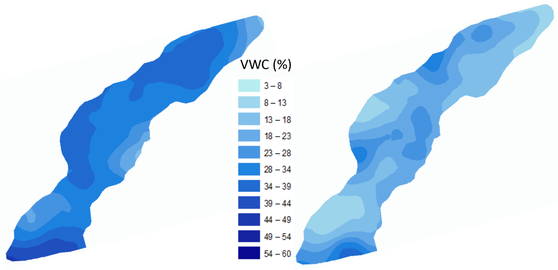

Figure 5. Spatial maps of VWC (%) 1 day (left) and 5 days (right) after irrigation for fairway 16.

Table 2. Correlation coefficient matrix showing relationship between VWC, NDVI, capping depth, and penetration resistance 3 and 5 days (in parentheses) after rainfall for fairway 4.

	VWC	NDVI	Capping Depth	Penetration Resistance
VWC	1	-0.11 (-0.24)	0.38*** (0.49***)	0.03 (-0.17)
NDVI		1	-0.3* (-0.27*)	0.08 (0.15)
Capping Depth			1	0.04 (-0.21*)
Penetration Resistance				1

*Significant at $P < .5$. **Significant at $P < .01$. ***Significant at $P < .001$.

Table 3. Correlation coefficient matrix showing relationship between VWC, NDVI, and capping depth 1 and 5 days (in parentheses) after irrigation for fairway 4.

	VWC	NDVI	Capping Depth
VWC	1	0.06 (-0.04)	0.26* (0.33*)
NDVI		1	-0.23 (-0.02)
Capping Depth			1

*Significant at $P < .5$. **Significant at $P < .01$. ***Significant at $P < .001$.

Table 4. Correlation coefficient matrix showing relationship between VWC, NDVI, capping depth, and penetration resistance 3 and 5 days (in parentheses) after rainfall for fairway 16.

	VWC	NDVI	Capping Depth	Penetration Resistance
VWC	1	0.04 (0.06)	0.10 (0.08)	0.22** (0.09)
NDVI		1	-0.09 (-0.05)	0.13 (-0.02)
Capping Depth			1	0.05 (-0.08)
Penetration Resistance				1

*Significant at $P < .5$. **Significant at $P < .01$. ***Significant at $P < .001$.

Table 5. Correlation coefficient matrix showing relationship between VWC, NDVI, and capping depth 1 and 5 days (in parentheses) after irrigation for fairway 16.

	VWC	NDVI	Capping Depth
VWC	1	0.20 (0.33*)	0.08 (0.20*)
NDVI		1	0.02 (0.06)
Capping Depth			1

*Significant at $P < .5$. **Significant at $P < .01$. ***Significant at $P < .001$.

Results & Findings

•Despite a targeted 12.7 cm capping depth during the 2013 renovation, considerable spatial variability was noted regarding sand-capping depth for both fairways sampled **(Table 1) (Figure 1)** . Variation in capping depth of fairway 16 appeared throughout the entirety of the fairway, while fairway 4 seemed to possess deeper capping depth near the center, tapering off near the edges **(Figure 1)**.

•Capping depth appears to play a more significant role in soil-water relations in fairway 4, since there was a significant positive relationship between VWC and capping depth before and after both rainfall and irrigation (**Table 2 & 3**). This could be explained by differences in mean capping depths between fairway 4 and fairway 16. Other factors could be contributing greater to VWC variability in fairway 16 such as thatch accumulation and elevation/slope (data to be collected).

•Negative correlations (only significant following rainfall) were found in fairway 4 comparing turfgrass vigor (NDVI) and capping depth (**Table 2 & 3**), while a positive correlation was found in fairway 16 for turfgrass vigor after irrigation (only significant 5 days after irrigation) (**Table 5**).

Conclusions and Future Direction

•Other factors that could also contribute to variation in soil moisture and turfgrass performance are currently being evaluated such as elevation/slope, thatch accumulation, and irrigation uniformity.

•By unraveling the factors causing inconsistencies in sand-capped fairway performance and soil moisture dynamics, this research aims to provide golf course superintendents with information that leads to improved water management while maintaining performance and quality standards.