Water Conservation Practices on the Reduction of Greenhouse Gas Emissions on Creeping Bentgrass Putting Greens

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Abstract

Soil moisture and temperature are known predictors of greenhouse gas (GHG) losses from highly managed turfgrass. Irrigation management practices that conserve water use have the potential to reduce GHG losses but may adversely affect overall turfgrass quality. A field study was developed to evaluate the impact irrigation regimes (Business as Usual, Supplemental Rainfall, Syringing, and Natural Rainfall), nitrogen (N) source (Urea and Milorganite), and rate (146 kg N ha^{-1} yr^{-1} and 293 kg N ha^{-1} yr^{-1}) has on GHG (carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]) emissions from creeping bentgrass (*Agrostis stolonifera)* greens. Sampling occurred weekly throughout the 2015 growing season. Gas samples were taken using a vented closed gas chamber for 40 minutes following USDA-ARS GRACEnet methods. Soil temperature, soil moisture, canopy temperature, canopy greenness, and turfgrass quality data were also collected. Results indicate that nitrogen sources applied at the high N rate resulted in significantly higher ($p<0.01$) emissions of both CO_2 and N_2O. Irrigation practices exposed to full sunlight (Supplemental Rainfall & Syringing), thus having a higher soil temperature, resulted in significantly higher emissions of both CO_2 and N_2O; the reverse was true for irrigation treatments experiencing shade from nearby trees (Business as Usual, Natural Rainfall). Both turfgrass quality and canopy greenness were significantly ($p<0.05$) impacted by irrigation practices, N source, and rate. Canopy greenness was improved with the higher rate of Milorganite and Urea. Higher turfgrass quality was associated with the use of Milorganite at both the high and low N rates. Canopy temperature was significantly ($p<0.001$) affected my irrigation regime; supplemental rainfall and syringing had elevated canopy temperature due to a lack of shade. Water is a natural resource therefore it is critical to identify irrigation practices that conserve water use and protect our environment through the reduction of greenhouse gas emissions.

Introduction

The concentration of carbon dioxide (CO_2) in the atmosphere is increasing at an unprecedented rate, due primarily to fossil fuel burning and land use change. The increased awareness of this global problem has led to increased pressure by society to minimize the impacts of elevated atmospheric concentrations of greenhouse gases (GHG).

Nutrient cycling on golf courses has the capacity to sequester GHG through the accumulation of soil organic carbon. However, cultural management practices can offset sequestration by mitigating GHG emissions directly (fertilization) or indirectly (maintenance equipment). Fertilizer application, irrigation, and other turfgrass management practices have the potential to contribute to emissions and mitigation of greenhouse gases, leading to uncertainties in the net contribution of turfgrass ecosystems to climate change.

Our previous results have shown that soil moisture and soil temperature are significant predictors of GHG flux. Soil moisture has the potential to be managed on golf courses with the monitoring of soil moisture and the implementation of proper irrigation practices. Therefore, the purpose of this project was to identify fertilizer practices (source/rate of Urea and Milorganite) and irrigation practices (Business As Usual, Supplemental Rainfall, Syringing, and Natural Rainfall) that will decrease GHG (carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]) losses while maintaining adequate soil moisture needed for overall plant health and turfgrass quality.

Materials & Methods

- The first year of this two year field project was initiated in the spring of 2015 at the Lincoln Park Golf Course in Grand Forks, North Dakota. Four different irrigation regimes were implemented (Photo 1). Plot size was 0.61 m x 0.61 m and treatments were replicated four times in a randomized complete block design.
    - **Regime 1** - No irrigation added (natural rainfall only).
    - **Regime 2** - Supplement natural rainfall to provide a total of 1.5 inches of water per week (determined expected rainfall each week and supplement rainfall amounts with irrigation if needed).
    - **Regime 3** - Syringing during the hottest part of the day to wet the turf canopy (light water application).
    - **Regime 4** - Regular irrigation scheduling set by the superintendent (Watering every other night for 15 minutes per station; approximately 0.15 – 0.20 inches of water).
- Plots were fertilized May through October with an annual nitrogen (N) rate of either 147 kg N ha^{-1} yr^{-1} or 294 kg N ha^{-1} yr^{-1}
    - For the 147 kg N ha^{-1} yr^{-1} treatments, fertilizer was applied monthly (May-October) at a rate of 24.5 kg N ha^{-1} and for the 294 kg N ha^{-1} yr^{-1} treatments, fertilizer was applied monthly (May-October) at a rate of 49 kg N to each plot.
    - Two sources of fertilizer were used: Urea (46-0-0 as a fast-release N source), and Milorganite (5-2-0 as a slow-release N source). Milorganite is also a natural organic fertilizer.
    - Monthly applications were applied the second week of each month throughout the growing season (May-October) (Photo 2 & 3).

Photo 1: Four irrigation regimes were used in this study (Business As Usual, Supplemental Rainfall, Syringing, and Natural Rainfall). Photo 2: N fertilizer applications were made monthly throughout the growing season (May-Oct.). Photo 3: Urea and Milorganite fertilizers supplied annual nitrogen (N) rates of either 147 kg N ha^{-1} yr^{-1} or 294 kg N ha^{-1} yr^{-1}.

- GHG sampling was initiated on 6/10/2015 and occurred weekly throughout the growing period until 10/15/2015.
    - At each sampling date, gas samples were taken using a vented closed gas chamber that was placed over the plots for 40 minutes following the United States Department of Agriculture-Agricultural Research Service Greenhouse gas Reduction through Agricultural Carbon Enhancement network (USDA-ARS GRACEnet) methods.
    - Samples were taken from the same location throughout the growing season as the anchors for the gas chambers were tamped into the ground flush with the soil surface at the beginning of the season.
    - To ensure a good seal, the tops of the gas chambers were also tamped in after they were placed over the anchors (Photo 4).
    - Gas samples were taken at 0, 20, and 40 minutes post closure of the chamber (Photo 5). This method allows gas concentrations to build up inside of the chamber, and a flux rate of the gases from the surface to be calculated based on the change in concentration over time.

Materials and Methods

- At each sampling date canopy temperature, soil temperature, soil moisture, canopy greenness, and turfgrass quality data were collected (Photo 6).
    - Canopy temperature was assessed using a IR Temp Meter (Spectrum Technologies).
    - Canopy greenness was assessed using a CM 1000 (NDVI Meter; Spectrum Technologies) chlorophyll meter.
    - Turfgrass quality was on a visual rating of 1 to 9 where 1=bare soil, 6=minimally acceptable, 9=optimum uniformity, density, and greenness.

Photo 4: Prior to sampling for greenhouse gases, the gas chambers were tapped onto the anchors to create a good seal. Photo 5: Gas samples were taken at 0, 20, and 40 minutes post closure of the gas chamber and anchor. Phot0 6: Soil moisture and soil temperature was taken at each sampling date to access soil conditions.

Results to Date

- Results show higher CO_2 emissions in the supplemental rainfall and the syringing treatments. These results also show that soil moisture was significantly different by irrigation treatment, and that the two irrigation treatments located under shade (Business as Usual and Untreated) had significantly lower soil temperatures than the two irrigation treatments not located under shade (Supplemental Rainfall and Syringing). Soil temperature is a likely co-variate for CO_2 flux and this difference is likely influencing our results. The next step in data analysis will be to treat temperature as a co-variate to explain the variation and be able to better determine the differences between irrigation treatments.
- Across irrigation treatments, the fertilizers applied at a higher rate resulted in significantly higher emissions of CO_2 and most frequently the highest emissions was associated with the Urea.
- Nitrous oxide (N_2O) showed similar trends to the CO_2 emissions in that on dates were significant differences occurred, the syringing and the supplemental rainfall had higher emissions than the two other treatments.
- Across irrigation treatments, similar trends were observed for N_2O as was observed for CO_2 in that significantly higher emissions of N_2O were associated with higher rates of urea, but occasionally the higher rate of Milorganite had significantly higher emissions of N_2O.

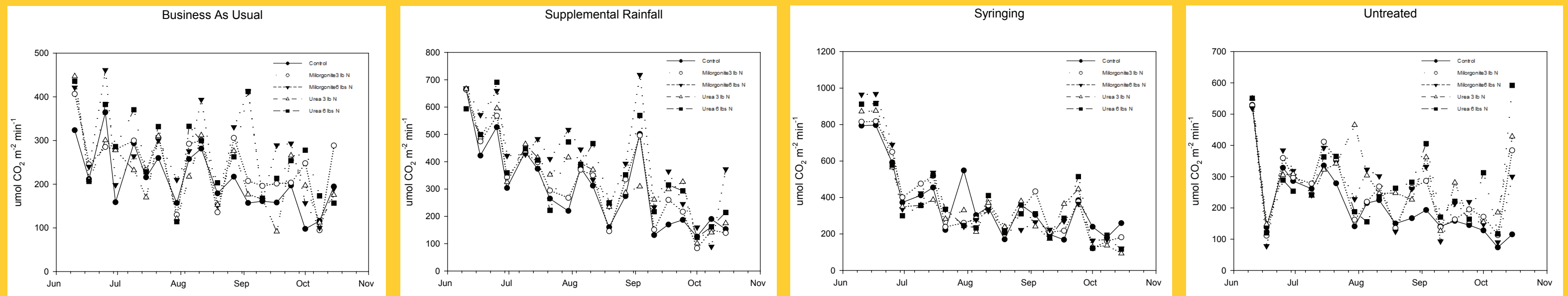

Figure 1. CO_2 flux by fertilizer treatment for the Business As Usual, Supplemental Rainfall, Syringing, and Unirrigated Natural Rainfall treatments for the 2015 growing period.

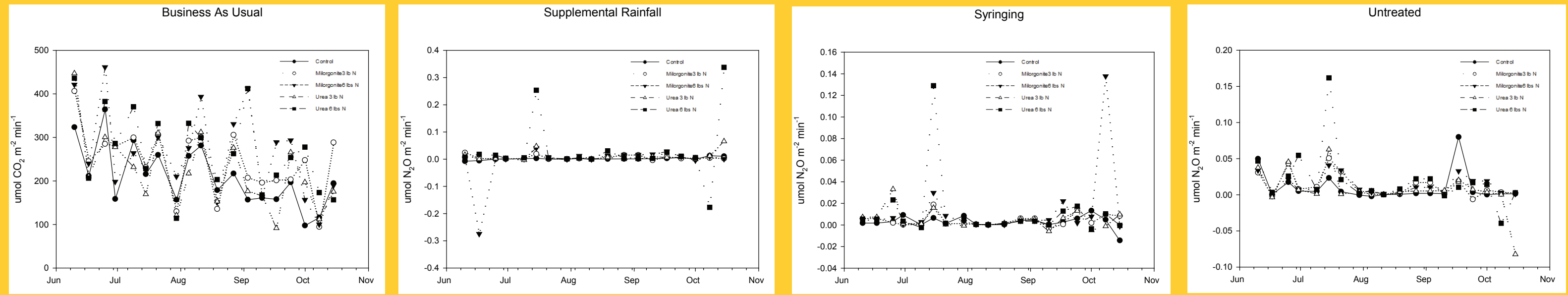

Figure 2. N_2O flux by fertilizer treatment for the Business As Usual, Supplemental Rainfall, Syringing, and Unirrigated Natural Rainfall treatments for the 2015 growing period.

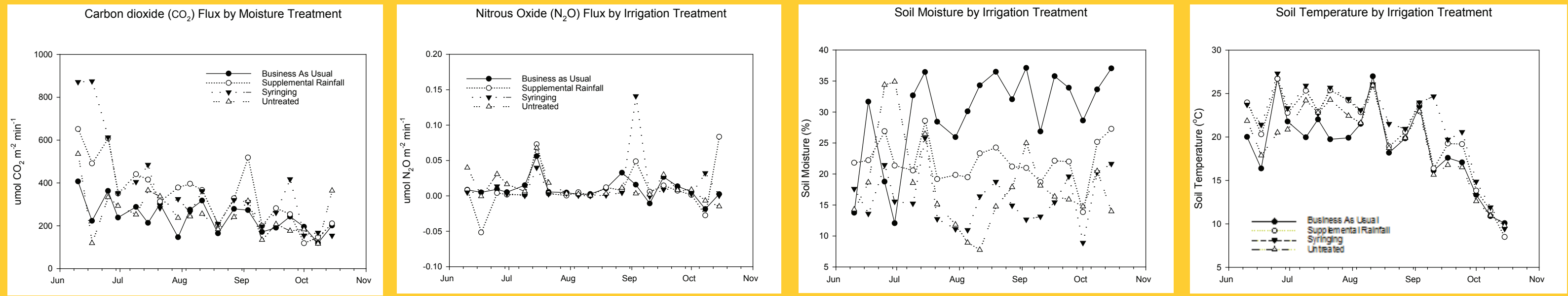

Figure 3. CO_2 flux by moisture (irrigation) treatment; N_2O flux by moisture (irrigation) treatment; soil moisture by moisture (irrigation) treatment; soil temperature by moisture (irrigation) treatment. This data shows that Temperature is mostly likely a co-variate with CO_2 flux and further statistical analysis will need to be done to separate the affects of Irrigation Treatment.

Results to Date

Canopy Greenness (Figure 4; Photos 7-9):

- Irrigation regime was significant on all dates in 2015 except on July 15.
- Fertilizer treatment was significant on 11 of the 17 dates in 2015.
- MILH and UREH (293 kg N ha^{-1} yr^{-1}) consistently produced greener turf whereas the turf response to UREL (146 kg N ha^{-1} yr^{-1}) was similar in color to the UNT treatment.

Turfgrass Quality (Figure 5; Photos 7-9):

- Irrigation regime was significant 8 dates of the 17 dates in 2015.
- Fertilizer treatment was significant on overall turfgrass quality 12 of the 17 dates in 2015.
- Both Milorganite treatments (MILL & MILH) significantly improved turfgrass quality.

Canopy Temperature (Figure 6):

- Irrigation regime was significant on all dates in 2015 except on July 15.

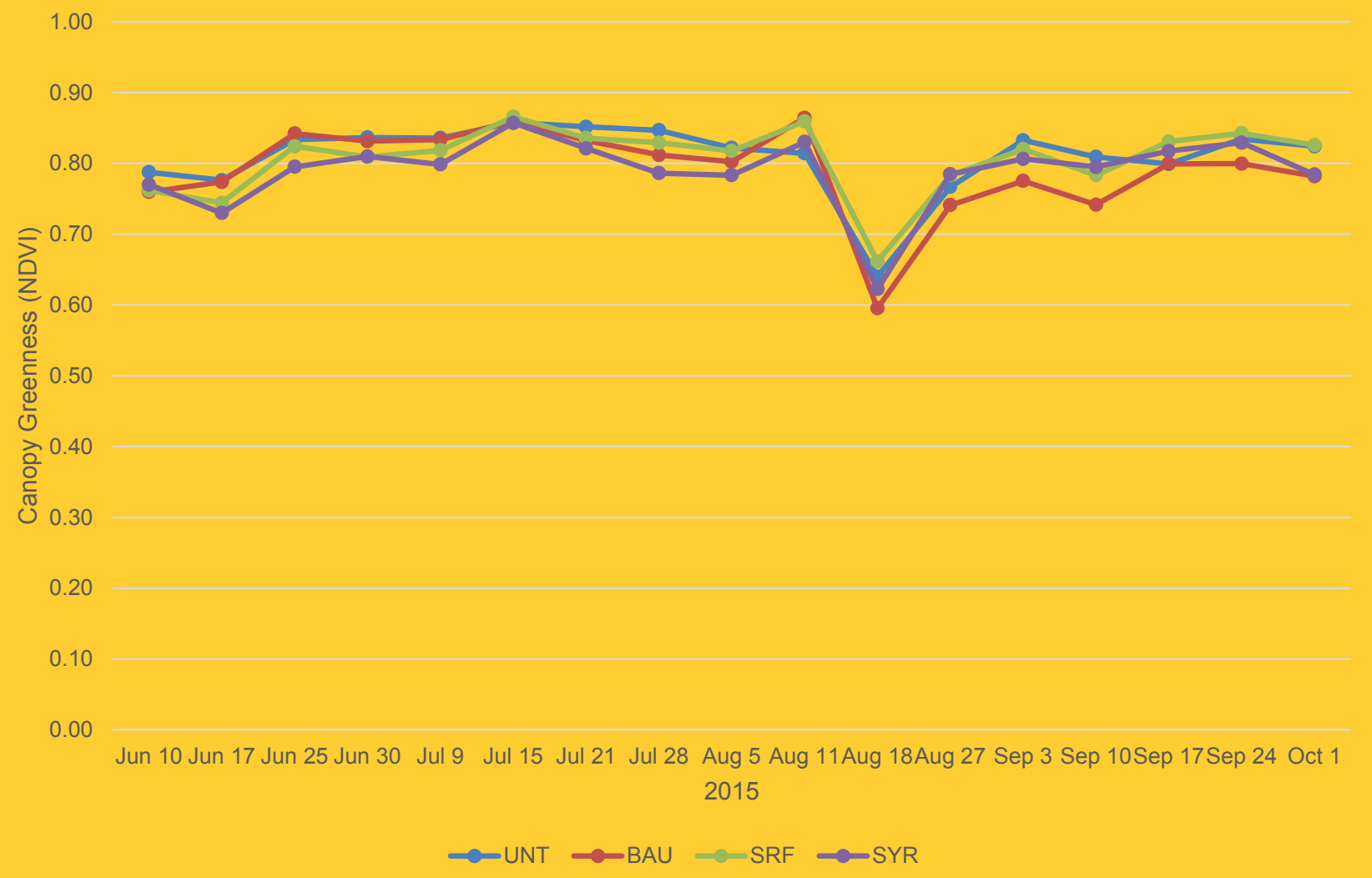

Figure 4: Canopy greenness (NDVI) by turfgrass area (UNT=Unwatered, BAU= Business as Usual, SRF=Supplemental Rainfall, SYR=Syringing) in 2015.

Photo 7: Canopy greenness and turfgrass quality differences on the putting green under the SRF=supplemental Rainfall irrigation regime on June 17th, 2015.

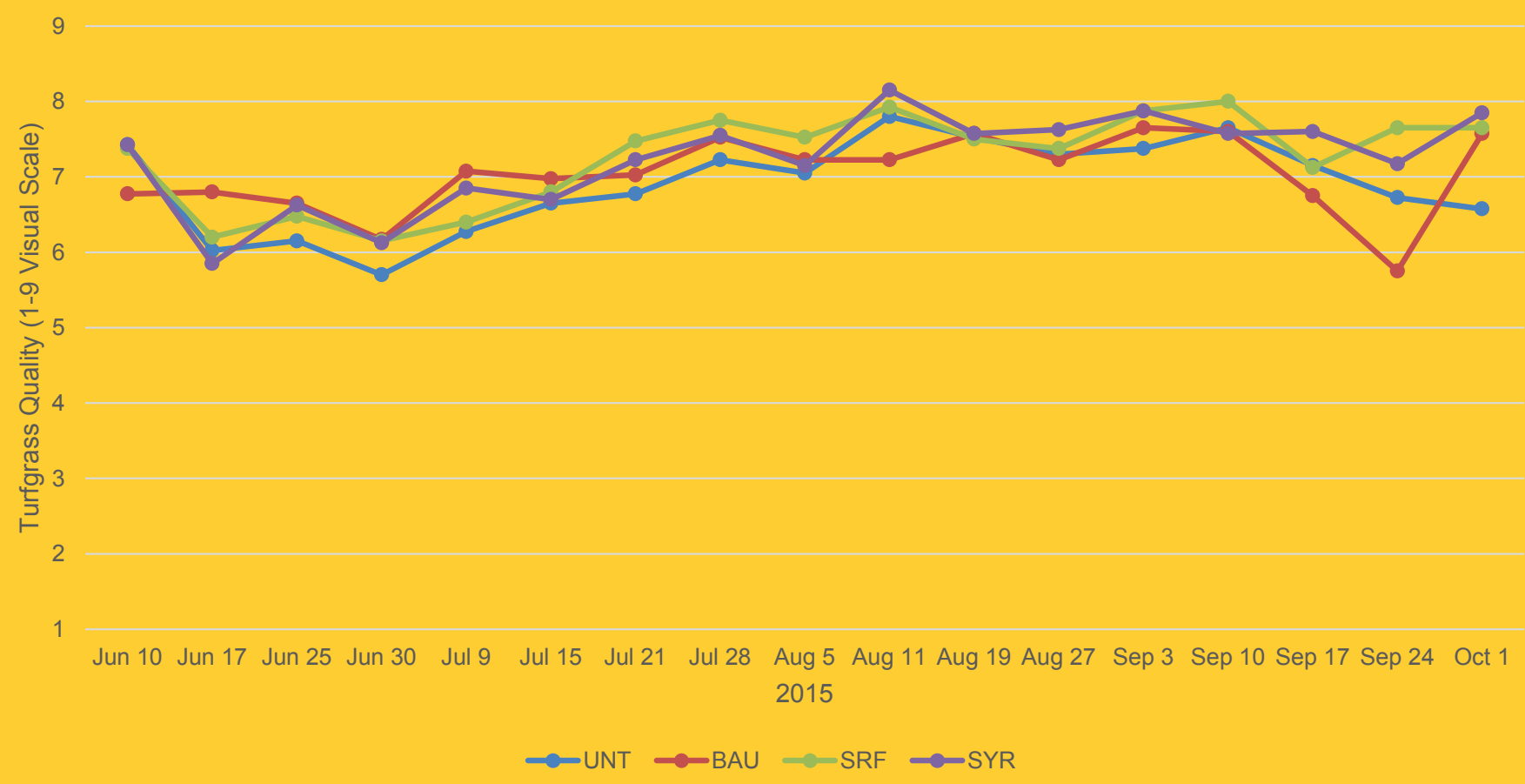

Figure 5: Turfgrass quality (1-9 visual scale; 9=Best, 6=Acceptable, 1=Worst) for all site locations in 2015 (UNT=Unwatered, BAU= Business as Usual, SRF=Supplemental Rainfall, SYR=Syringing).

Photo 8: Canopy greenness and turfgrass quality differences on the putting green under the SYR=Syringing irrigation regime on June 17th, 2015.

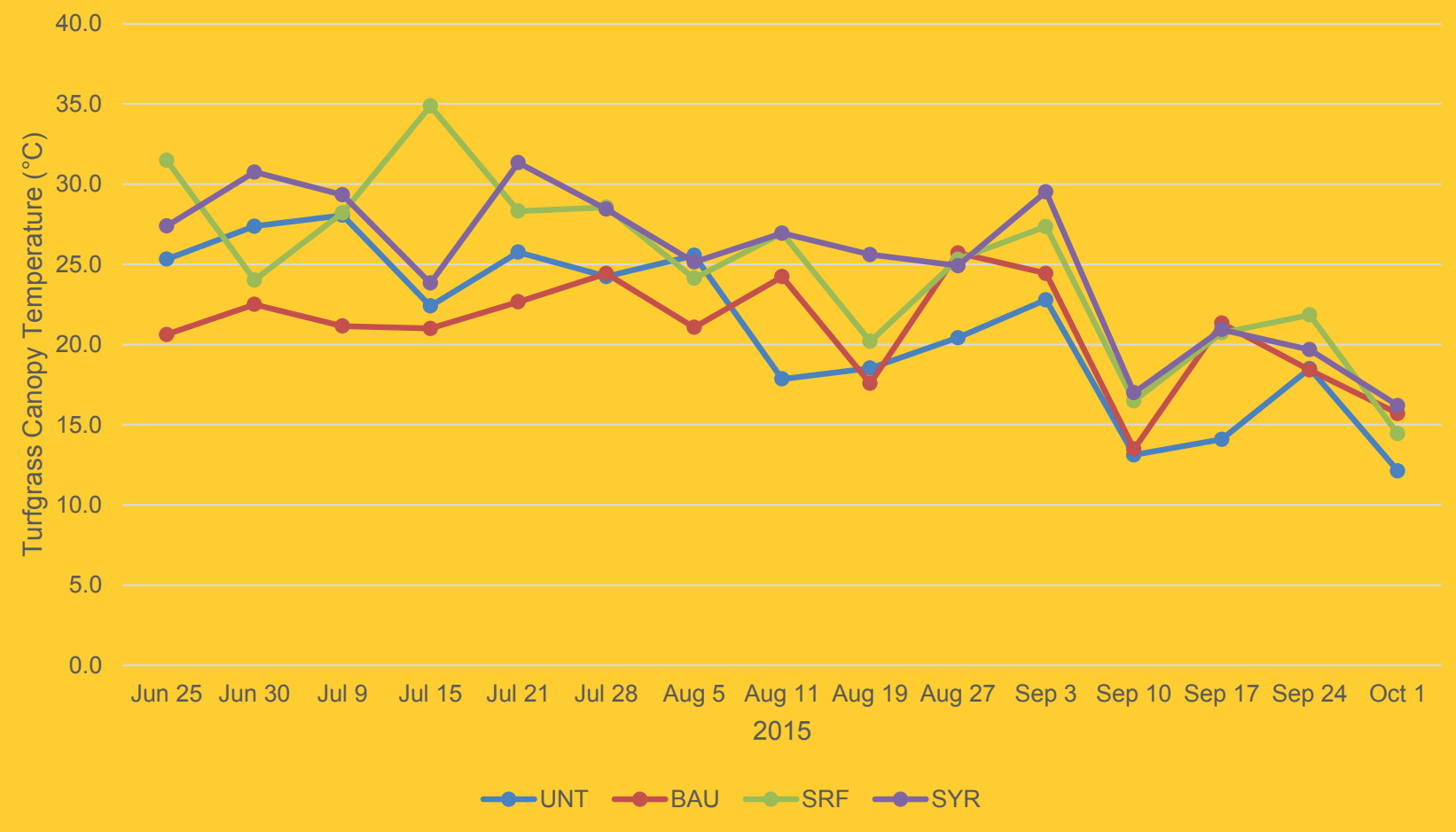

Figure 6: Canopy temperature by turfgrass area (UNT=Unwatered, BAU= Business as Usual, SRF=supplemental Rainfall, SYR=Syringing) in 2015.

Photo 9: Canopy greenness and turfgrass quality differences on the putting green under the SRF=supplemental Rainfall irrigation regime on July 27th, 2016.

Next Steps

In our previous greenhouse gas emissions study, we primarily looked at nitrogen fertilization practices. We found that soil moisture and soil temperature are significant predictors of greenhouse gas losses from highly managed turf. These findings lead us to move our focus to water use by superintendents on golf courses. Shade is known to decrease canopy and soil temperatures. Therefore, turfgrasses grown in shaded environments only require periodic irrigation. Nitrogen fertility requirements are also lower for turfgrasses grown in shaded areas. Shade is known to increase CO_2 levels however, little is known how high cultural intensity putting greens should be managed to reduce greenhouse gas losses while maintaining the highest quality of turf on a golf course.

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