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

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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 studies 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 two year field project (2015-2016) 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 in May and occurred weekly throughout the growing period until October..
  - 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.

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.

- 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.

Results

- Soil moisture was the highest for the BAU irrigation regime followed by SRF; UNT had the next highest soil moisture but was not significantly different from SYR which had the lowest soil moisture content.
- Soil temperature was highest for the SYR and SRF irrigation regimes which were located in full sun compared to the UNT and BAU irrigation regimes which are located in shaded areas.
- SRF (second highest moisture; highest temperature) had the highest CO_2 flux ($p<0.01$). SYR (highest temperature; lowest moisture) had the next highest CO_2 flux, followed by the UNT (low temperature), and BAU (highest moisture; low temperature).
- Across irrigation regimes, 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 treatment in 2015.
- N_2O showed similar trends to CO_2 emissions in that on dates where significant differences occurred, the SYR and the SRF had higher emissions than the two other treatments in 2015.
- In 2016, the SRF and BAU irrigation regimes had the highest N_2O flux compared to the other two treatments (SYR and UNT).
- In 2015, higher emissions of N_2O was associated with higher rates of urea, but occasionally the higher rate of Milorganite had significantly higher emissions of N_2O.
- As with CO_2, higher emissions of N_2O was associated with higher rates of fertilizer but no significant difference was found in fertilizer source in 2016.
- There were no significant differences in soil CH_4 for any treatment.

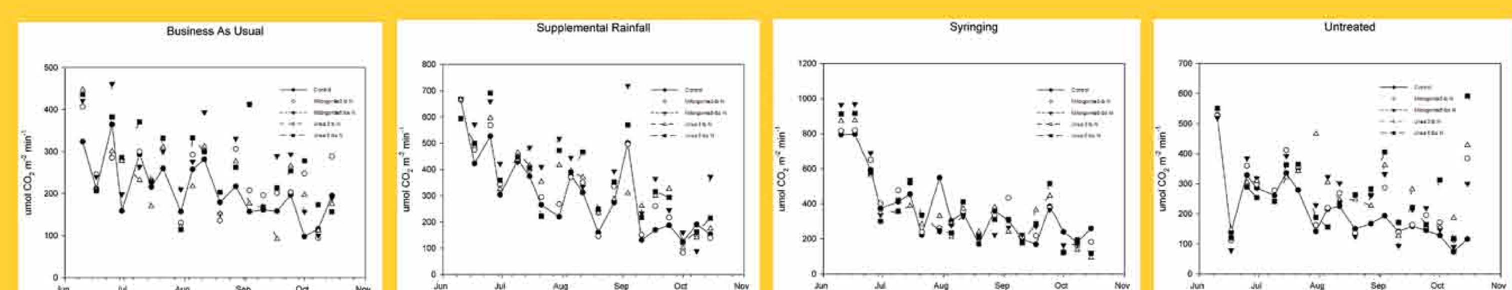

Figure 1. CO_2 flux by fertilizer treatment for the Business As Usual, Supplemental Rainfall, Syringing, and Unirrigated Natural Rainfall treatments for the 2015 growing period.

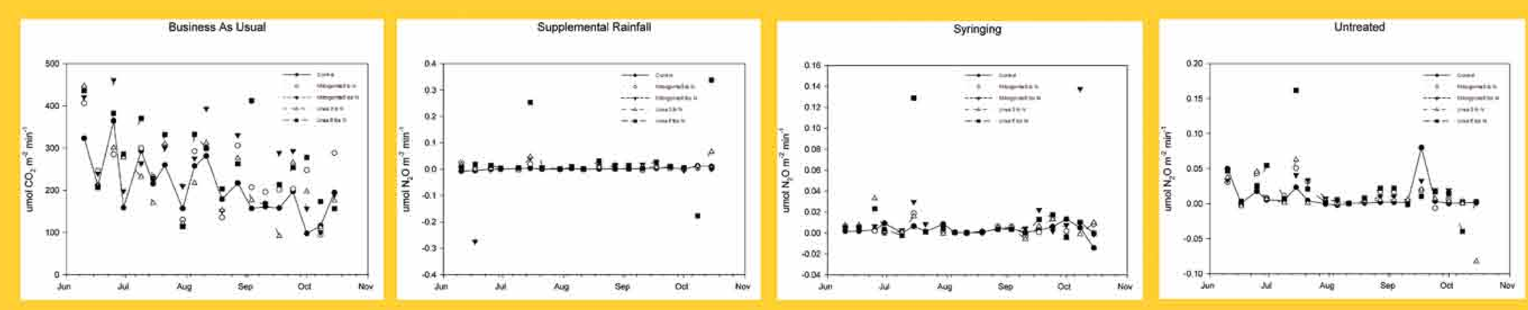

Figure 2. N_2O flux by fertilizer treatment for the Business As Usual, Supplemental Rainfall, Syringing, and Unirrigated Natural Rainfall treatments for the 2015 growing period.

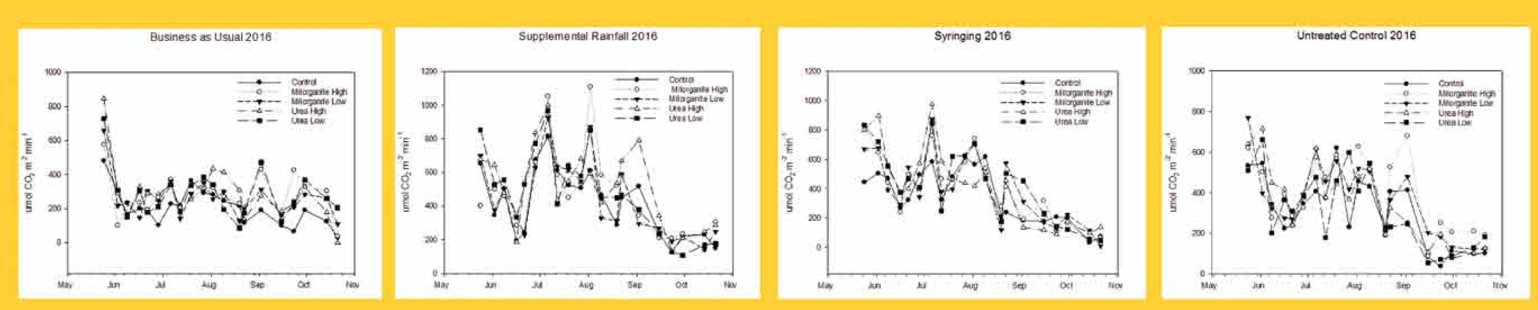

Figure 3. CO_2 flux by fertilizer treatment for the Business As Usual, Supplemental Rainfall, Syringing, and Unirrigated Natural Rainfall treatments for the 2016 growing period.

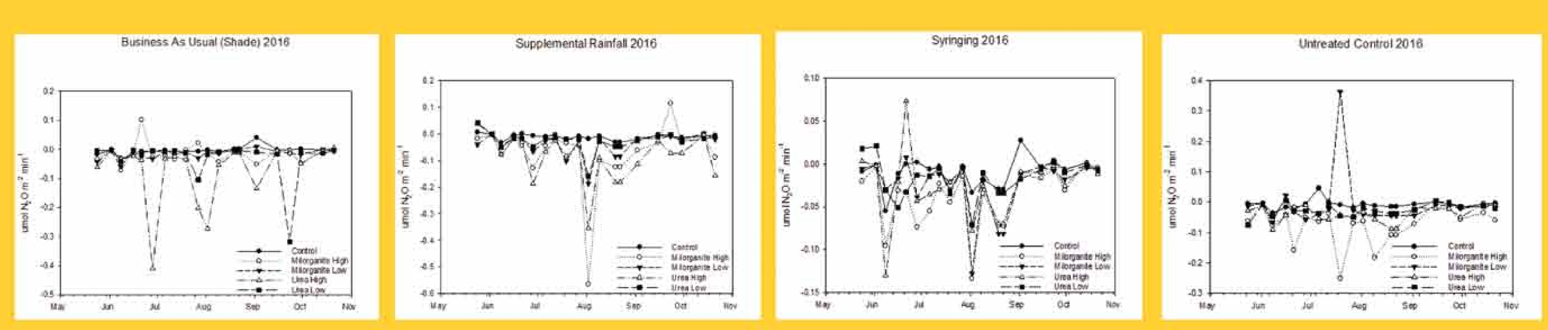

Figure 4. N_2O flux by fertilizer treatment for the Business As Usual, Supplemental Rainfall, Syringing, and Unirrigated Natural Rainfall treatments for the 2016 growing period.

Results

Canopy Greenness (Figure 5 & 6; Photos 7-11):

- Irrigation regime was significant on all dates in 2015 except on July 15. Fertilizer treatment was significant on 11 of the 17 sampling dates in 2015.
- Irrigation regime and fertilizer treatment was significant for 12 of the 18 sampling dates in 2016. Irrigation regime was significant on canopy greenness consistently during the hottest part of the growing season (June 21, 2016 – August 9, 2016).
- 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 7 & 8; Photos 7-11):

- Irrigation regime was significant 8 of the 17 dates in 2015 and 9 of the 20 dates in 2016.
- Fertilizer treatment was significant on overall turfgrass quality 12 of the 17 dates in 2015 and 11 of the 20 dates in 2016.
- Both Milorganite treatments (MILL & MILH) significantly improved turfgrass quality. Urea applications decreased overall turfgrass quality due to speckling (Photos 7 & 8).

Canopy Temperature (Figure 9 & 10):

- Irrigation regime was significant on all dates in 2015 except on July 15, 2015 and all dates in 2016 ($p<.001$).
- SYR and SRF had higher canopy temperatures than the BAU and UNT irrigation regimes.

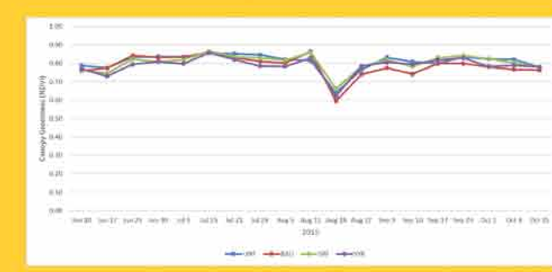

Figure 5: Canopy greenness (NDVI) by turfgrass area (UNT=Unwatered, BAU= Business as Usual, SRF=Supplemental Rainfall, SYR=Syringing) in 2015.

Figure 6: Canopy greenness (NDVI) by turfgrass area (UNT=Unwatered, BAU= Business as Usual, SRF=Supplemental Rainfall, SYR=Syringing) in 2016.

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

Figure 7: 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).

Figure 8: Turfgrass quality (1-9 visual scale; 9=Best, 6=Acceptable, 1=Worst) for all site locations in 2016 (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 9: Canopy temperature by turfgrass area (UNT=Unwatered, BAU= Business as Usual, SRF=supplemental Rainfall, SYR=Syringing) in 2015.

Figure 10: Canopy temperature by turfgrass area (UNT=Unwatered, BAU= Business as Usual, SRF=supplemental Rainfall, SYR=Syringing) in 2016.

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

Photo 10: Canopy greenness and turfgrass quality differences on the practice putting green under the BAU= business as usual irrigation regime from the September fertilizer application. Photo taken October 28th, 2016.

Photo 11: Last fertilizer applications of the year as well as soil sampling. Canopy greenness and turfgrass quality differences can be seen on the practice putting green under the SRF=supplemental rainfall irrigation regime on October 28th, 2016.

Next Steps

In our previous greenhouse gas emissions study, 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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