TREEE Funded Project FY 2012-2013

Seasonal Runoff Losses of Carbon, Nitrogen and Phosphorus from warm-season turfgrass systems

Investigators: Jacqueline A. Aitkenhead-Peterson and Ben Wherley

Funding: $10,000

Objectives: The objectives of our proposed research were to: 1) Quantify seasonal runoff losses of N, P, and C from warm-season turfgrass systems. 2) Quantify irrigation input and output SAR, dissolved organic carbon and nitrogen and orthophosphate-P weekly over one year. 3) Calculate mass losses of C, N and P per unit area and 4) Develop empirical models for predicting mass losses and C, N and P from soil over time. 5) Determine if fertilization reduces or enhances C, N and P losses.

Summary: We examined three replicate plots receiving zero fertilizer and three replicate plots receiving 4.9 g m^2 urea fertilizer one week after sod was installed and 4.9 g m^2 of Scotts Company Southern Turf Builder in May 2013. Sod was installed on the plots in September 2012. For the first six weeks we applied irrigation water to force runoff to assess losses of C, N and P and sodium retention and cation release from the soil. Thereafter, rain event runoff only was captured and analyzed except for months where there was no rain when we irrigated to produce runoff.

Fertilizer and Seasonal effects on macro and micro-nutrient export

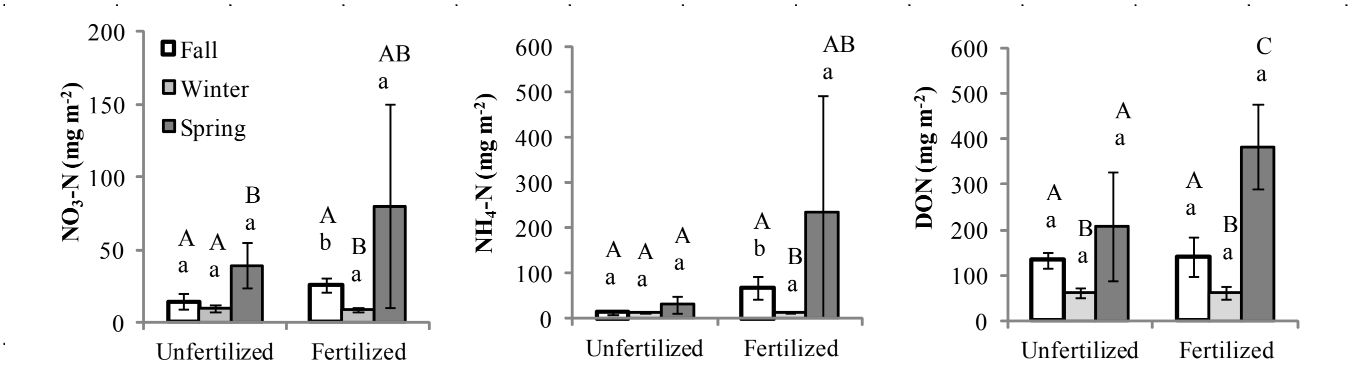

Figure 1. Exports of nitrate-N, ammonium-N and dissolved organic-N from fertilized and unfertilized St. Augustine turfgrass plots by season. Error bars are standard deviation. Different lower-case letters indicate a significant difference between unfertilized and fertilized plots for each season. Different upper-case letters indicate a significant difference in exports within unfertilized or within fertilized plots by season.

Nitrate-N

Season had a greater effect on nitrogen exports within treatments compared to fertilization type among treatments. There was a significantly higher export of nitrate-N during the spring in the unfertilized treatments relative to fall and winter exports. There was a significantly lower export of nitrate-N during the winter relative to the fall in the fertilized treatments (Figure 1). Fertilization resulted in significantly higher exports of nitrate-N in the fall only just after turf was established (Figure 1).

Ammonium-N

Season had a significant effect on ammonium-N exports in the fertilized plots only. Winter exports of ammonium were significantly lower than in the fall for the fertilized plots (Figure 1). Fertilization significantly increased export of ammonium-N in the spring only; there was no effect of fertilization for the winter of spring seasons (Figure 1).

Dissolved organic nitrogen

Season had a significant effect on DON exports in both the unfertilized and fertilized plots. DON export was significantly lower in the winter compared to the fall and spring in the unfertilized plots (Figure 1). DON export was significantly higher in the spring compared to the winter and fall, and DON export was significantly higher in the fall compared to the winter in the fertilized plots (Figure 1). Fertilization had no significant effect on DON exports in any season (Figure 1).

Orthophosphate-P

Season also had a greater effect on phosphate-P exports than fertilization. There were significantly lower phosphate-P exports during the winter compared to the fall and spring, but there was no significant difference in phosphate-P export when comparing fall and spring in both the unfertilized and fertilized treatments (Figure 2). Fertilization had no significant effect on phosphate-P export (Figure 2).

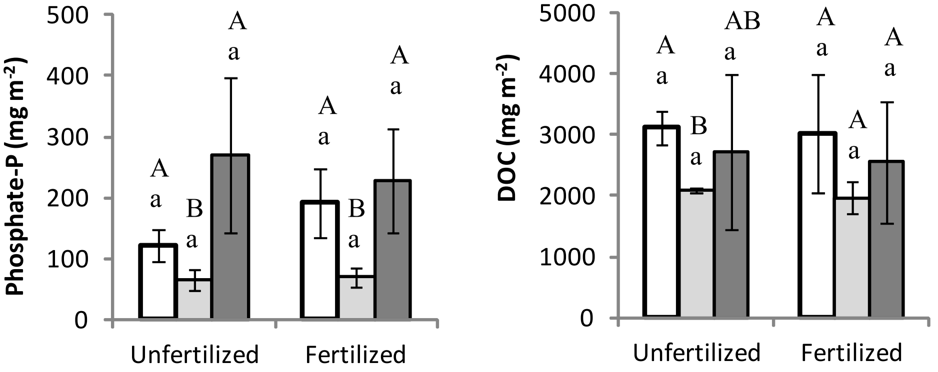

Figure 2. Exports of phosphate-P and dissolved organic carbon (DOC) from fertilized and unfertilized St. Augustine turfgrass plots by season. Error bars are standard deviation. Different lower-case letters indicate a significant difference between unfertilized and fertilized plots for each season. Different upper-case letters indicate a significant difference in exports within unfertilized or within fertilized plots by season.

Dissolved organic carbon

There was no significant effect of season in the fertilized plots but in the unfertilized plots DOC exports were significantly lower in the winter compared to the fall (Figure 2). Fertilization had no significant effect on DOC export (Figure 2).

Sodium
Fertilization had no significant effect on sodium exports but season did. In the unfertilized plots there were significantly higher sodium exports in the fall compared to the winter and spring seasons (Figure 3). In the fertilized plots sodium export was significantly higher in the fall compared to the spring (Figure 3).

Potassium
Neither season or fertilization had a significant effect on potassium exports in the unfertilized plots (Figure 3). In the fertilized plots, fertilization had no effect on potassium export but exports were significantly higher in the spring compared to the fall (Figure 3).

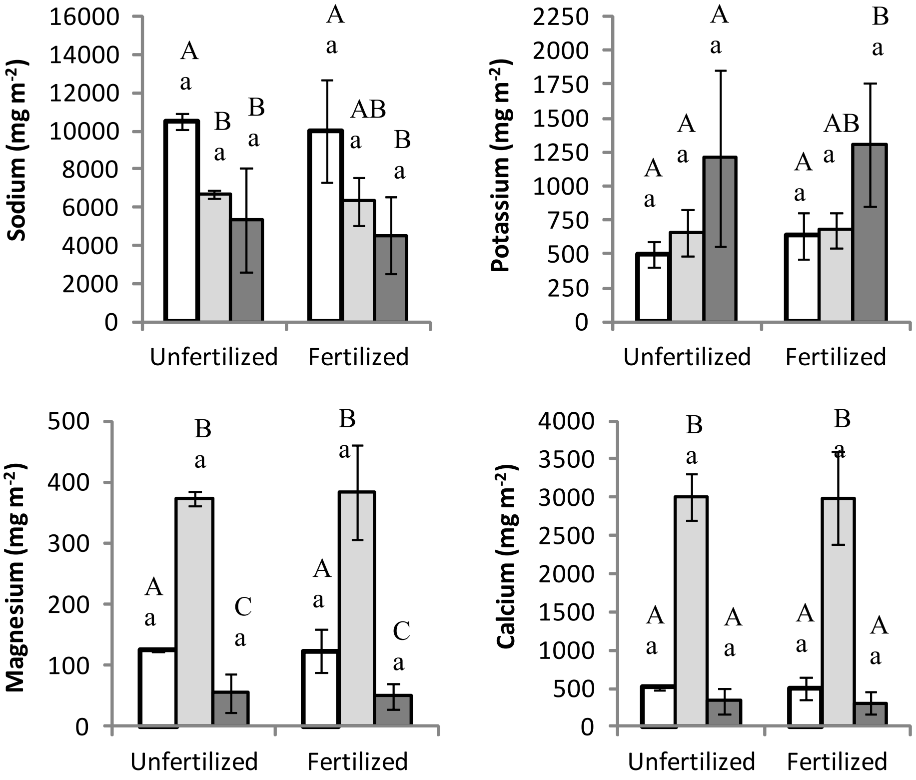

Figure 3. Exports of sodium, potassium, magnesium and calcium from fertilized and unfertilized St. Augustine turfgrass plots by season. Error bars are standard deviation. Different lower-case letters indicate a significant difference between unfertilized and fertilized plots for each season. Different upper-case letters indicate a significant difference in exports within unfertilized or within fertilized plots by season.

Magnesium
Season had an effect on magnesium exports but fertilization did not. Winter had significantly higher magnesium exports compared to fall and spring and spring had significantly lower magnesium exports compared to fall and winter and in both the unfertilized and fertilized plots (Figure 3).

Calcium

Season had an effect on calcium exports but fertilization did not. Winter had significantly higher calcium exports compared to fall and spring in both the unfertilized and fertilized plots (Figure 3).

Season, Fertilization and Irrigation water interactions

Using multivariate analysis with irrigation water (municipal tap water or rain), fertilization (fertilized or unfertilized) and season (fall, winter or spring) as independent variables and run off chemistry as dependent variables showed that season had a significant effect on DOC, sodium, magnesium and calcium exports (p = 0.05-0.001). Irrigation water type had a significant effect on DON, phosphate-P, DOC, sodium, magnesium and calcium exports (p = 0.05-0.001). Fertilization had no significant effect on any nutrient exports measured. There were some interactions; season and irrigation had a significant interaction effect on DOC, magnesium and calcium (p = 0.02-0.001).

Retention and release of base cations

To determine retention or release of cations from the plots we deducted runoff outputs (mg m^{-2}) from rain and irrigation inputs (mg m^{-2}) and divided by inputs and multiplied by 100 for a percentage loss. Negative values indicate that all input cation was lost plus soil stored cations. Sodium whether inputs were from rain or irrigation water was retained in the plots during all seasons (Figure 4). Between 77 and 96% of all input sodium was retained during the course of the study. Potassium showed soil losses throughout the study; between 12 and 115% of input potassium was lost (Figure 4). Magnesium and calcium had extremely high soil losses during the winter season and this was likely caused by high rainfall and gypsum addition.

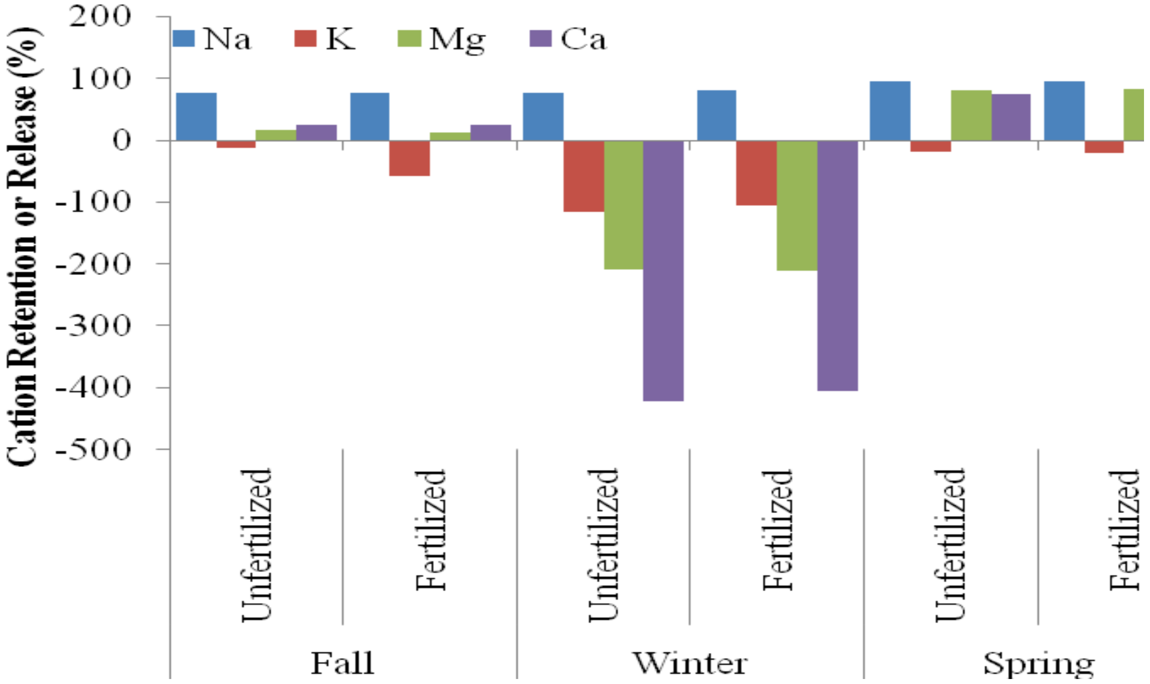

Figure 4. Retention and release of cations in unfertilized and fertilized treatments by season.

Modeling exports of C, N and P

Potassium export explained between 94 and 96% of the variance in nitrate-N exports in the unfertilized plots (Figure 5) and between 77 and 99% of the variance in nitrate-N exports in the fertilized plots (Figure 6). Potassium also explained between 82 and 92% of the variance in phosphate-P in the unfertilized plots and between 56 and 96% of the variance in phosphate-P in the fertilized plots. Variance in DOC and DON exports was also well described by potassium exports (Figures 6 and 6). Between 83 and 84% of the variance in DOC export in unfertilized plots was explained by potassium (Figure 5) and between 61 and 92% of the variance in DOC was explained by potassium in the fertilized plots. Eighty-six to 98% of the variance in DON was explained by potassium in the unfertilized plots (Figure 5) and between 77 and 99% of the variance in DON was explained by potassium in the fertilized plots (Figure 6). Relationships between anion exports and potassium exports were stronger in both unfertilized and fertilized plots irrigated with tap water compared to rain water inputs (Figures 5 and 6).

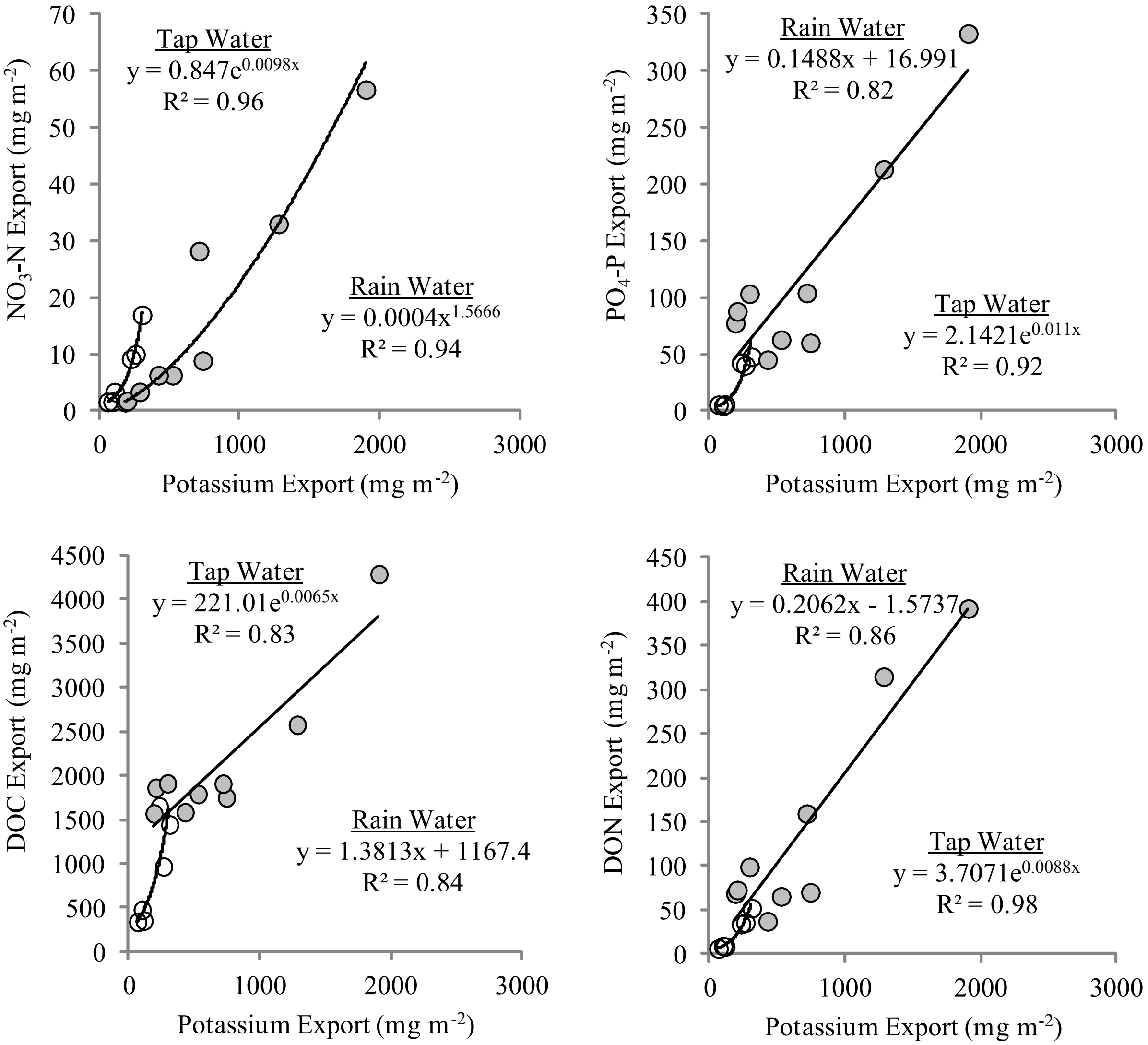

Figure 5. Relationship between anion (NO_3-N, PO_4-P, DOC and DON) exports and potassium exports in unfertilized plots. All seasons are included. Open circles are municipal tap water irrigation and grey circles are rain water.

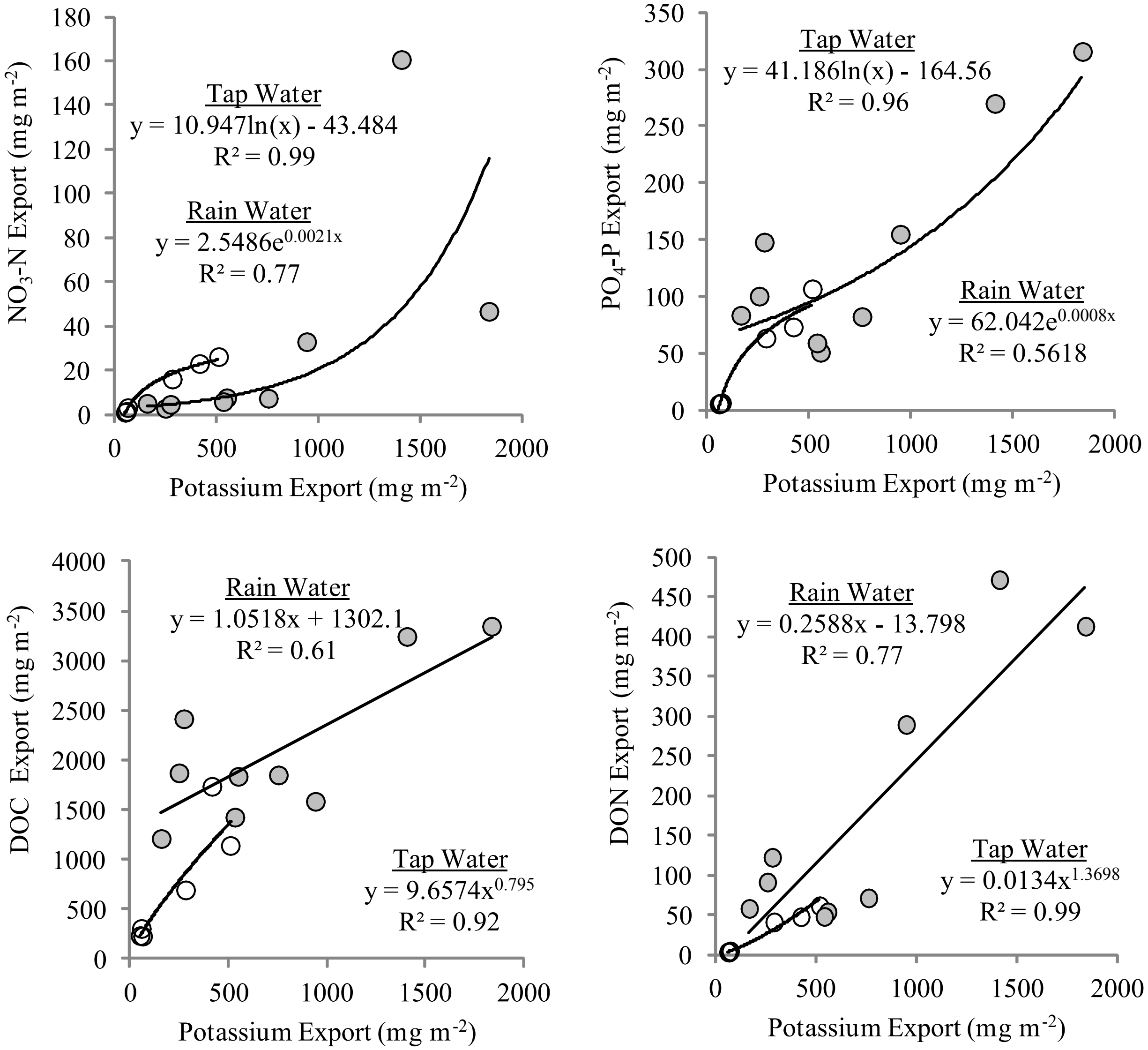

Figure 6. Relationship between anions (NO_3-N, PO_4-P, DOC and DON) and potassium exports in fertilized plots. All seasons are included. Open circles are municipal tap water irrigation and grey circles are rain water.

Conclusion

While runoff exports of N will increase slightly if runoff occurs just after fertilization, overall these exports on a seasonal basis are not significantly different from plots that have received no fertilization. Abiotic functions in soil to maintain electroneutrality of runoff water must be considered when examining anion and cation losses and exports from homeowner lawns. For example, consider the acid rain era when large exports of sulfate were accompanied by exports of aluminum and iron and then when those were depleted by calcium. This study showed that irrigation with sodic municipal tap water resulted in retention of sodium and concomitant release of potassium, magnesium and calcium. This release of base cations required an equivalent release of anions to maintain the electroneutrality of runoff water. The mechanisms involved when irrigating vegetation with high sodium water is the release of protons and replacement of potassium, then magnesium and calcium with sodium. The release of protons will increase the pH of soil solution available to runoff. Fertilization was rarely responsible for increases in C, N and P export; instead season had a greater effect on their exports.

Summary Progress Report for FY 2013 TREEE Awards

Title: Impact of Irrigation Frequency and Volume on Rainfall Capture and Runoff Losses from Turf Lawns

PI: Richard White

Collaborators: Charles Fontanier, Ben Wherley

Objectives: 1) Quantify St. Augustinegrass canopy density with diminishing soil moisture and irrigation treatment, 2) Measure runoff volumes and nutrient loading from St. Augustinegrass lawns as affected by irrigation level, 3) Evaluate the significance of soil water content and lawn canopy status in predicting runoff volumes.

Impact: Municipal water suppliers in drought-stricken regions of Texas often implement restrictions on landscape irrigation. The potential for severe canopy loss due to water deficits could increase post-drought runoff volumes and nutrient loading. Information gathered during the study will help municipalities and stream management entities better understand the hydrological implications of local water restrictions.

Summary: The study is being conducted at the Texas A&M Surface Runoff Facility located at the TAMU Urban Ecology Center. The site was constructed with a 3.5 to 4% slope and was planted with St. Augustinegrass (Figure 1) to be maintained as a residential lawn. At the foot of each plot, guttering systems route water through calibrated flumes where meters monitor flow and water samples are collected. Treatments consist of three irrigation levels (50%, 75%, and 100% of ET_c) applied on two-day per week calendar-based intervals.

Status: The bulk of the experiment remains ongoing. Saturated hydraulic conductivity, soil bulk density, horizon depths, and slope have been measured for each plot. Soil moisture monitoring devices were installed (Figure 2) at multiple locations and soil depths and water infiltration was measured multiple times. Biweekly ratings and digital images have been collected to monitor turf performance. Canopy parameters such as leaf area index, shoot density, and above ground biomass shall be collected at the onset of visible drought stress and canopy loss. When seasonal rains return, runoff volumes and nutrient loading shall be compared among irrigation treatments.

Figure 1. Newly sodded turf being irrigated with auto samplers in background.

Figure 2. Installation of soil moisture sensing probes at multiple depths.

Figure 3. Measurement of infiltration rates using double-ring infiltrometers.

Summary Progress Report for FY 2013 TREEE Awards

Title: Cumulative Effects of Irrigating Turfgrass Lawns with Diminishing Water Volumes Based Upon Historical Evapotranspiration

PI: Richard White

Collaborators: Charles Fontanier, Ben Wherley

Objectives: 1) quantify St. Augustinegrass turf performance under deficit irrigation using historical average ET_o, 2) evaluate interactions between deficit irrigation and fertility, and 3) evaluate the variability in turf performance between multiple years of similar management.

Impact: Results will offer science-based but practical recommendations for management of St. Augustinegrass in Texas. Specifically, managers and policy makers can better understand the minimal irrigation needs for viability of St. Augustinegrass turfs because of this long-term irrigation study.

Summary: The study was conducted at the Texas A&M Agrilife Turfgrass Science facility on F&B Road with 'Raleigh' St. Augustinegrass maintained comparably to a residential lawn. The experimental design was a randomized complete block split-plot arrangement. Whole main plots were sixteen individually irrigated zones having four replicates of four irrigation treatments. Split-plot treatments were fertilizer rates. An audit revealed irrigation application rates to be approximately 1.5" per hour. Irrigation treatments were initiated on July 1 in both 2011 and 2012 to apply the following irrigation amounts three days per week (MWF): 'overwatering' (100% ET_o), 'turf coefficient' or 'Tc' (0.6 x ET_o), 'normal stress' (60% Tc or 0.36 x ETo), 'severe stress' (40% Tc or 0.24 x ET_o). Baseline ET_o volumes were selected from historical monthly averages for College Station. Irrigation treatments continued through September. Any needed irrigation after October 1, 2011 was uniformly applied to the study area (Photograph 1). Three fertilizer rates were evaluated within each irrigation treatment: 0.0, 0.4, and 0.8 lb N 1000 ft^{-2}. Visual quality, digital image analysis (DIA), and volumetric water content were measured weekly through September. Clipping yield was measured monthly, and soil chemistry was analyzed once at the conclusion of the growing season.

Photograph 1. Irrigation was applied as needed beginning October 1, 2011 to allow recovery of St. Augustinegrass prior to the 2012.

Status: Treatment application and data collection concluded during autumn 2012 as described in the summary information. Results of the 2012 growing season experiment were compared to the previous year, and findings presented at the annual ASA-CSSA-SSSA Meetings. Final data analysis, report generation, and manuscript preparation are ongoing. Treatments will be continued in 2013 in order to monitor cumulative effects of long-term irrigation and fertility management.

Photograph 2. Representative areas of severe stress treatment (0.24 x ET_o) St. Augustinegrass in 2011 (left) and 2012 (right).

Preliminary Findings: Averaged over both years, historical ET_o was similar to actual ET_o, although from year to year actual ET_o differed by approximately ± 20%. During a dry year such as 2011 (when conservation is critical), historical ET_o resulted in 20% water savings compared to the water that would have been applied if actual ET_o had been used for scheduling irrigation. Where temporary turf density reductions can be tolerated (Photograph 2), irrigation levels as low as 0.24 x ET_o sustained sufficient survival of crowns to allow full fall/spring recovery under the worst single-year drought in Texas history. During 2012, historical ET-based irrigation over irrigated by 22% compared to real-time ET based irrigation estimates. Turf density was not reduced during 2012 as substantially as during 2011 by deficit irrigation (Photograph 2 and Figure 1) and recovery was much more rapid. In general, recovery of turfgrass density increased with increasing nitrogen after irrigation treatments were terminated.

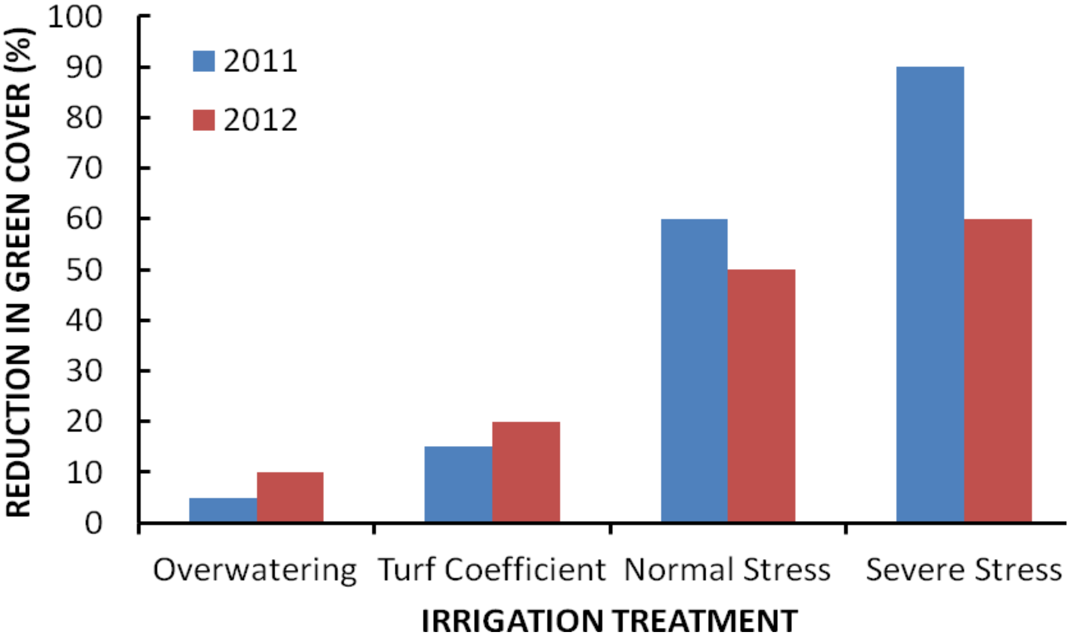

Figure 1. Maximum reduction in green canopy cover of St. Augustinegrass in response to irrigation treatments during 2011 and 2012 at the Texas A&M Agrilife Turfgrass Science facility on F&B Road in College Station, Texas.