Introduction:

Rapid population growth, economic development, and climate change are all contributing to increased demands on global water resources. Water stress is already apparent in arid and densely populated regions world-wide and projections show that water scarcity shows a pattern of pandemic increase in the years to come. The areas at most risk are urban areas, which are projected to be the location of much of the world’s population increase1,2. Because agriculture is estimated to be responsible for nearly 90% of groundwater consumption globally3, it stands to reason that water conservation has been emphasized in agricultural systems. However, locally available water in urban locations is at risk. One area in which water use could be significantly decreased in urban ecosystems, particularly in arid and semi-arid environments, is in landscaping4.

Urban water protection efforts have identified residential and commercial landscapes as one of the largest sources of conservation potential. These landscapes are estimated to consume 40-70% of all municipal water.5 Covering approximately 50 million acres in the US, turfgrass is the most common landscape feature in most urban landscapes and consumes the majority of this water6. Endter-Wada, et al., performed research on urban landscape water consumption in Utah, where they determined that lawns were typically overwatered. The most common reason for overwatering is automatic, timer-run sprinkler systems. These water lawns at designated times regardless of actual water needs. Due to this and other factors, 31.3% of residential and 64.8% of corporate research sites were practicing wasteful landscape watering7. Although community resource management strategies have been shown to be effective in reducing urban water consumption2,7, more can be done as growers have a better understanding of optimizing water application.

The importance of nutrient management and its relationship to turf water use and drought tolerance is often overlooked. For example, application of excessive nitrogen fertilizer is common in landscape turf settings. Excess nitrogen increases rates of growth and water use and simultaneously reduces root development8, both of which make turf more vulnerable to drought. However, nutrient deficiencies can also be problematic when drought occurs because plants are already experiencing abiotic stress and are less able to tolerate drought conditions. It is important for growers to find optimal nitrogen amounts in order to optimize water use. This can be done by carefully regulating plant health. Use of sensors can automate this process and make both fertilization and watering more efficient.

Remote sensing technologies have been available for decades, but have not been applied to turfgrass on a large scale. They have proven to be incredibly valuable in other cropping systems. The first infrared thermometer devices were developed in the 1960s. They work well for assessing water stress, because canopy temperature increase as plant available water declines. This is because transpiration has a cooling affect, so a decline in transpiration leads to an increase in temperature. A method developed in the 1980s compares measured canopy temperatures with well-watered and non-transpiring baselines to produce a measurement called the Crop Water Stress Index (CWSI)9.

One problem with use of CWSI alone to optimize water application is that some nutrient deficiencies may have a confounding affect. This was demonstrated by Carroll, et al., in maize9. However, some of these can be accounted for by including spectral reflectance sensors. These measure the Normalized Difference Vegetation Index (NDVI) of plant canopies and can be used to assess green biomass or nitrogen content10.

The Brigham Young University Turfgrass research program is seeking to optimize water and nitrogen supply. As part of this goal, they would like to evaluate the potential application of soil water sensors and remote canopy sensors to improve irrigation and fertilization decisions. Construction of a turf irrigation research facility was initiated outside of the BYU research greenhouse in the fall of 2016 and Kentucky blue grass (species) was established in the summer of 2017. The facility consists of 27 individual research plots (3.4 m x 3.4 m), divided in a randomized, complete block design among three irrigation zone treatments. Irrigation treatments are deficient, optimum, and excessive. Within each irrigation treatment, there are three nitrogen levels, each replicated three times. Nitrogen fertilizer treatments are deficient, optimum, and excessive. In collaboration with Decagon Devices, water content sensors, water potential sensors, spectral reflectance sensors, and infrared radiometers monitor the plots and report to dataloggers in the field. During a three-week period from 9-23-17 to 10-16-17, the nitrogen and fertilizer treatments were implemented and sensor activity logged. Our objective is to combine all sensor data from this period, visualize soil and plant conditions over time, identify periods where stress occurred, and generate descriptive statistics to compare experimental treatments. Additionally, we will provide a Docker container that will make it possible to recreate our analysis on future datalogger datasets.

(Maybe try to describe previous studies more effectively)

Methods:

* Use docker container
* Tidy data with Python
* Design figures in R

Figures:

1. Generate line charts for soil sensors in plots 403, 503, and 603 (time vs VWC; time vs kPa). Make separate charts for each depth and sensor type, and each chart with three lines, one for each turf plot (403, 503, and 603).
2. Generate time vs treatment average VWC line charts. These will use treatment averages from the VWC sensors found in all 27 plots. The lines will each represent a irrigation treatment average VWC. Make separate charts for each nitrogen treatment level.
3. In there are days where variation in AWC is apparent in #3, generate an analysis of variance for average daily AWC on specific days of interest.
4. Generate time vs NDVI line charts. Each line will represent one of the 9 instrumented plots. Line plots that compare nitrogen treatments with separate charts for each irrigation treatment level.
5. Generate time vs canopy temperature line charts. Each line will represent one of the 9 instrumented plots. Line plots that compare average of irrigation treatments.
6. Schematic

(which two will we use to show our progress?)

Works Cited:

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(Might need at least one more source from 2016-2018)