The effect of approximating irrigated area on the gross irrigation requirement

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Abstract. *The gross irrigation requirement (GIR) is the estimated irrigation required to maintain the landscape considering evapotranspiration, rainfall, and irrigation system efficiency. Irrigation volume must be converted to depth to compare to the GIR. The objective was to evaluate the variation in irrigation using three methods to determine landscape area: A) irrigated area, B) turfgrass only, and C) parcel information. The irrigated area was defined as the area covered by the existing irrigation system observed during on-site visits. Irrigated areas were overlaid on aerial images to determine turfgrass only areas assuming that established ornamentals required no irrigation. The final method, irrigable area estimated from removing building footprints from total parcel area, is common when on-site visits are unfeasible, but can have significant error when large portions of outdoor space is unirrigated. The evaluation was conducted by determining differences in estimating irrigation application by smart controllers compared to GIR assuming an 80% efficiency factor using the three area methods. Results showed that estimating turfgrass only areas from aerial imagery was just as accurate as on-site area measurements whereas the parcel area estimation was more conservative. From the perspective of a targeted water conservation program, using parcel areas may be the best option due to directing resources concerning water conservation toward proven excessive irrigators for maximum program effectiveness.*

Keywords. Gross irrigation requirement, irrigation, landscape area, smart controllers

Introduction

In 2013, groundwater resources were considered insufficient in Central Florida to sustain projected population growth. Though landscape irrigation is proportionately small in water consumption compared to agriculture, research has shown that utility customers in Central Florida over apply landscape irrigation by 6 to 8 times the amount of irrigation required (Davis and Dukes 2014) and irrigation accounts for over half of total residential water use (Haley et al. 2007). Thus, reducing over-irrigation across the region may reduce the burden on the aquifer.

The total irrigated area is one of the most important factors needed to relate total water volumes to the calculated irrigation requirement. On-site measurements of landscape area are not feasible on a large scale, such as by a utility or water management district. Two different approaches to estimating landscape area include using satellite images to delineate green area and using readily available parcel data obtained through the property appraiser. However, the amount of error in these estimated methods is unknown. The objective of this study is to determine the best methods to estimate irrigated area in effort to identify over-irrigated landscapes for future targeted sustainable programs.

Materials and Methods

Study Description

In 2011, a smart controller study was implemented in Orange County, FL. Smart controllers are technologies that assist in recommended irrigation scheduling when installed and programmed properly. Current smart controllers on the market include evapotranspiration (ET) controllers and soil moisture sensors (SMS). The ET controllers use estimates of ETO to determine theoretical plant water needs. The SMS bypasses scheduled irrigation events when the soil has sufficient moisture.

There were a total of 167 homes chosen across nine locations that were distributed into five treatments per location with a minimum of three replications per treatment. The treatments were as follows: ET controller (ET; 28 households), ET controller with educational programming (ET+Pgm; 38 households), soil moisture sensor (SMS; 28 households), soil moisture sensor with educational programming (SMS+Pgm; 38 households), and monitored only (MO; 35 households). All technologies were installed by a licensed irrigation contractor. The treatments with educational programming received a one-on-one tutorial from the researchers, additional educational materials, and re-programming of their technology to match their specific site conditions. Only results from the MO, ET, and SMS treatments are presented in this paper.

The selected homeowners submitted to an intense screening process to determine applicability of using a smart controller. Initially, homeowners had to fall within 1.5 to 4 times above the gross irrigation requirement (GIR) on a monthly basis (Davis and Dukes 2014). Irrigation application was determined from estimated irrigation volumes using utility billing data and estimated irrigated area using available parcel information. Once selected as a potential participant, each household received an irrigation evaluation by the researchers to verify that excessive irrigation was due to improper irrigation scheduling that could be addressed by the smart technology and not due to faulty irrigation systems or already poor landscape quality.

On-site Area Measurements

During the irrigation evaluations, total irrigated area for each participant was measured using a walking measuring stick. The irrigated area was defined as the total area that the irrigation system was designed to target. Thus, impervious areas within a zone were not removed such as sidewalks and walkways. However, poor adjustments to sprinkler nozzles and other maintenance issues were not considered as irrigated area. Examples would include misaligned sprinklers that irrigate across property lines or into roads or driveways.

Turfgrass Only Area Estimations

When on-site irrigated areas are not available, an alternative method can be to spatially determine the potentially irrigated green space using satellite images imported into ArcGIS. The bird's eye view depicted the house and other building structures, turfgrass areas, and ornamentals. Polygons were formed around the dominant turfgrass areas since turfgrass is a water-intensive plant material (Romero and Dukes 2011). The ornamentals were not used in this estimation because established plants can maintain plant quality under normal rainfall conditions (Scheiber et al. 2008, Gilman et al. 2009).

Parcel Area Estimations

It has been proposed that using parcel level data available through the property appraiser to estimate irrigated area can be used to accurately predict trends of single-family residential irrigation application (Friedman et al. 2013). Each participating household was searched on the Orange County property appraiser site to determine total parcel size and gross parcel area that includes impervious areas such as the house and driveway. The proposed irrigated area was the difference between the total and the gross estimates.

Data Collection and Analysis

Weather data was collected from three installed weather stations and one Florida Automated Weather Network (FAWN) weather station located near the treatment groups across the county. Two additional rain gauges were installed to have more accurate rainfall measurements in locations that did not receive weather stations. Precipitation, air temperature, relative humidity, and wind speed were collected at 15 minute intervals throughout the study period. The data was used to calculate reference evapotranspiration (ETO) for use in the soil water balance equation in order to determine GIR.

Hourly outdoor water volumes were collected from each household using an automatic meter recording (AMR) device installed and maintained by Orange County Utilities. Irrigation application as a depth was calculated from water volumes using estimated irrigated areas. As a result, three estimations of irrigation application were produced for each participant from December 2011 through July 2013. The analysis was separated into four seasons due to significant differences in rainfall throughout the study period.

Statistics were conducted using Statistical Analysis Systems (SAS) software (Cary, NC). Results were modeled using the GLIMMIX procedure with treatment differences determined using least mean square differences for type of area by treatment for each season within the study period. Significance was determined at a 95% confidence level.

Gross Irrigation Requirement

The net irrigation requirement (NIR) is the amount of water required to reach the root zone to maintain plant water needs. It is calculated using a daily soil water balance with inputs of ETO and rainfall. The root zone was estimated as having a depth of eight inches for turfgrass and available water holding capacity was determined from soil survey information based on treatment location.

The gross irrigation requirement (GIR) is the amount of irrigation that must be scheduled to achieve NIR due to inefficiencies in the irrigation system. The preferred achievable efficiency was selected as 80%. Thus, the GIR was calculated using 80% efficiency as a comparison. A detailed description of how the GIR is calculated can be found in Davis and Dukes (2014).

Results

In all seasons and treatments, there was no difference in estimated irrigation application between the measured landscape area and the turfgrass only areas determined using ArcGIS (Figs. 1-4). This resulted in an average error of 3% - 7% in monthly irrigation application estimations across treatments (Fig. 5). This was not surprising considering turfgrass is the dominant plant material in most landscapes within the study.

In all seasons and treatments, the irrigation application determined using the parcel area was not different or was significantly less than the irrigation application estimated using the measured area. More often than not, using parcel area was significantly less than measured area. As a result, average error ranged from -12% to -18% across treatments.

Except in one instance occurring in the wet 2013 season for the comparison treatment (Table 4), the irrigation application estimated using the turfgrass only areas was significantly different than when estimated using the parcel areas. The parcel areas over-estimated the irrigated area resulting in lower estimates of irrigation application.

Except during the wet 2013 season (Table 4), the irrigation application by the MO treatment using all three area estimates resulted in significantly different irrigation application than GIR. This indicates that the participants without technological changes remained excessive irrigators throughout most of the study. Though it is unknown why there was no difference during the wet 2013 season, it is possible that the frequent rainfall resulted in many participants switching their timers to the off position for short periods of time. These potentially missed events may have counteracted the over-irrigation during the events that actually occurred.

The SMS was not significantly different when using the parcel area compared to the GIR during both wet seasons (Table 2, Table 4).

Conclusion

There is a need for a methodology to efficiently target habitual excessive irrigators for intervention in effort to increase water conservation and sustainability. One of the important inputs to accurately determine irrigation application is the irrigated area. Estimating irrigated area by direct measurement on a large scale, such as by a utility, would be too expensive and time consuming to make it a feasible option. Investing in estimating turfgrass area using ArcGIS was just as accurate as on-site area measurements, so it may be a good option if it is economically feasible. Using parcel data was less accurate, typically resulting in under-estimations of irrigation application. However, from a water conservation program perspective, this may be the best option due to its relatively low cost in obtaining the areas and generally errs on the conservative side. This way, resources concerning water conservation can be directed toward proven excessive irrigators for maximum program effectiveness.

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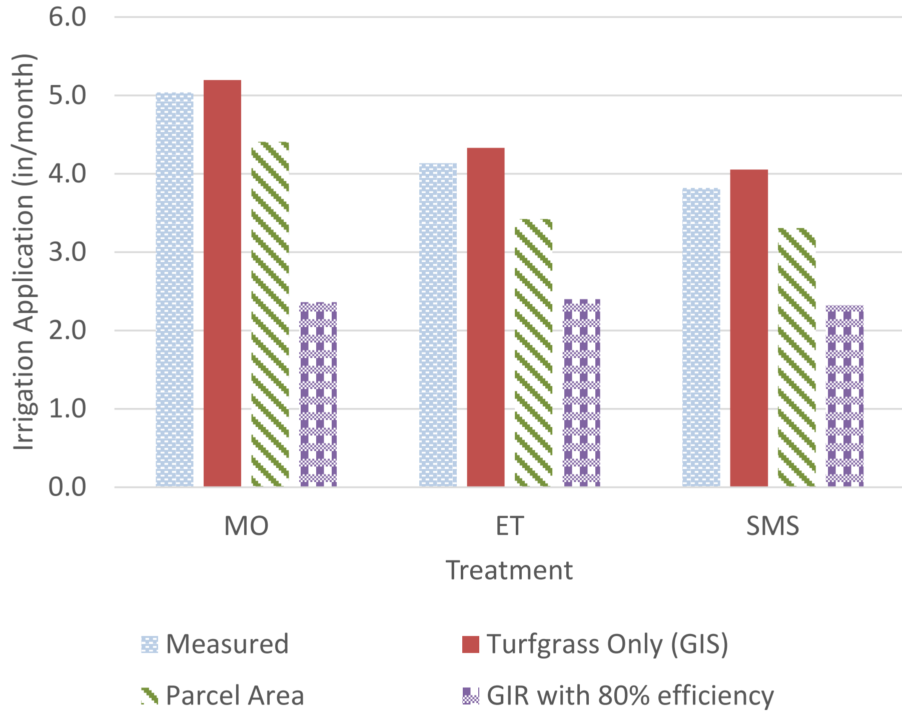

Figure 1. Average irrigation application during the Dry 2012 season using three different landscape areas compared to the gross irrigation requirement.

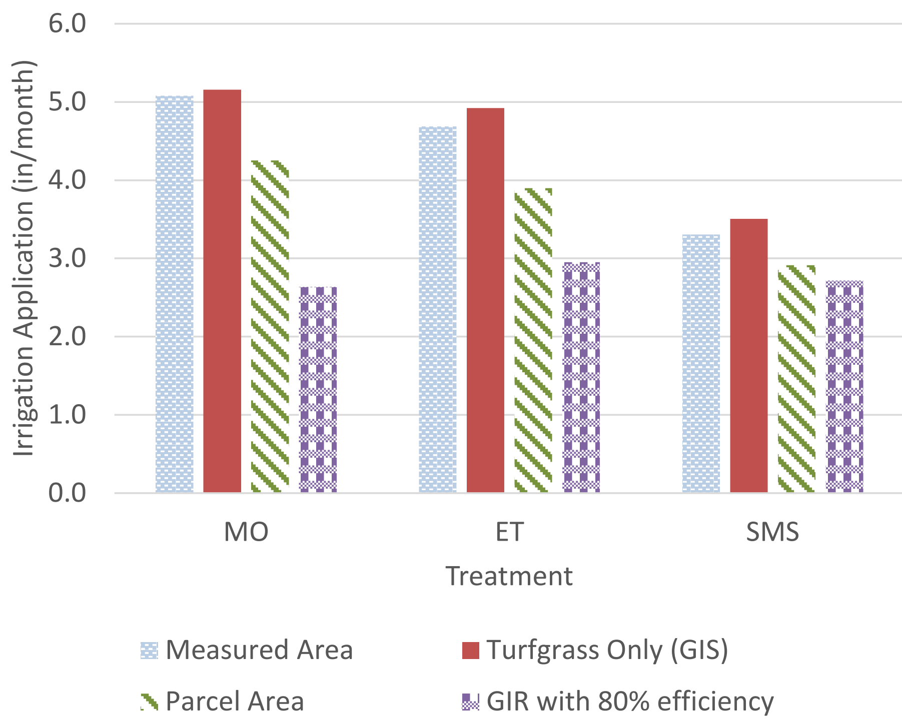

Figure 2. Average irrigation application during the Wet 2012 season using three different landscape areas compared to the gross irrigation requirement.

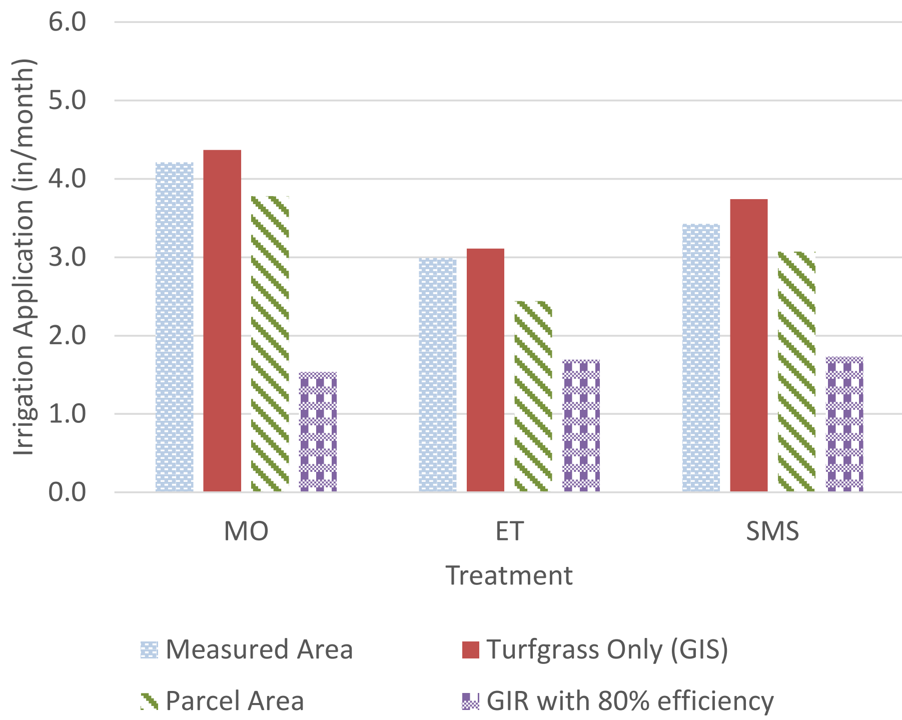

Figure 3. Average irrigation application during the Dry 2013 season using three different landscape areas compared to the gross irrigation requirement.

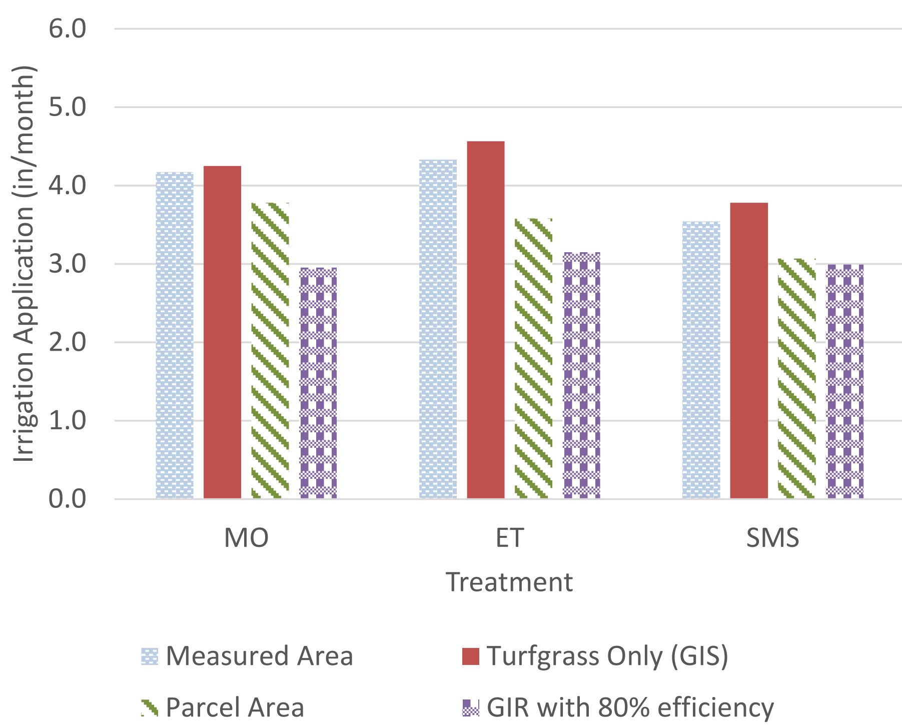

Figure 4. Average irrigation application during the Wet 2013 season using three different landscape areas compared to the gross irrigation requirement.

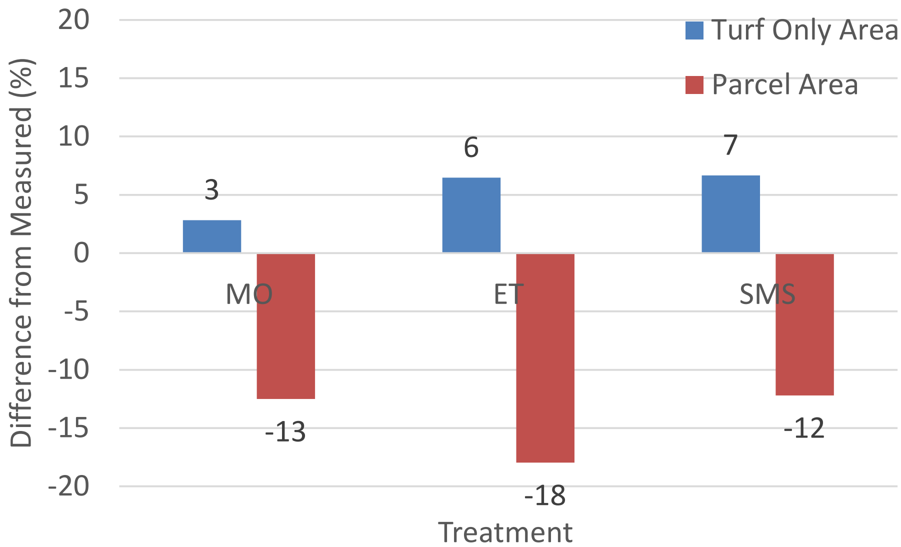

Figure 5. Average error of irrigation application on a monthly basis when determined using the turfgrass only and parcel area estimations, both compared to the measured landscape areas.