**Residential Irrigation Water Application Influenced by Socio-economic Parameters**

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**Abstract**

This paper investigates the relationship between socio-economic parameters and applied irrigation water. Irrigation water use was correlated to property value, property size, aerial estimated irrigated area, and existence of a swimming pool. This project includes 142 homes in Pinellas County irrigating with potable water, from the public water supply, 56 of which are participating in a sensor technology irrigation conservation study. To properly evaluate irrigation water based on utility data, outdoor and indoor water was separated from five years of utility water use data. Winter water consumption was assumed to only be indoor use. The subtraction of the minimum winter use allowed for estimated monthly outdoor use. To determine actual irrigation application amounts, the outdoor usage in gallons was then converted into depth, based on irrigated area estimated by a combination of both property appraisal information and measured areas from GIS aerial images. Increased outdoor water use was positively correlated with property value and negatively correlated with irrigated area. These relationships probably exist because on larger homes the economic effect of increased water use is less important to homeowners and on smaller homes the economic penalty for over-irrigating is minimal.

**Introduction**

Nearly all new homes in Florida are constructed with in-ground automatic irrigation systems. Studies have shown that residential landscape irrigation can account for more than 64% of a home's total water use and recent research in Florida has indicated that homeowners are over irrigating by applying more than the plant water needs (Haley *et al.*, 2007). Irrigation water use conservation efforts are necessary due to the increase in overall water use that is related to increased population. The Southwest Florida Water Management District (SWFWMD), which is one of the five Florida water management districts, accounts for a quarter of the state’s overall population, with more than four million inhabitants. Between 1990 and 2000, the population in this region grew by over 640,000 residents, approximately 19%, and is projected to increase another 1.8 million by 2025. The 2000 population for Pinellas County, the study area, was 921,482 and is forecasted to be 1,078,600 by 2025, increasing 17% by 2025 (SWFWMD, 2005).

Within the SWFWMD, public water use accounts for 42% if the total freshwater use, the second largest water use sector after agriculture. Although there has been considerable population growth, the water use amount has remained fairly constant from 1993-2002. This is a result of an 11% decrease in per capita water use, from 140 to 123 gpd. However, when the per capita water use is normalized for drought or excessively wet seasons; the total public water use shows an

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upward trend. It is expected that as population growth continues, public water use will become the dominant water use sector. According to the SWFWMD 2005 District Management Plan, the projected water demand for the public supply is expected to increase to 223 million gpd (SWFWMD, 2005). More than 80% if this water withdrawn from groundwater sources, most of which comes from the Floridan aquifer, which has increasingly been regarded as a limited resource.

In a study on residential irrigation efficiency with the St. Johns River Water Management District (SJRWMD), setting irrigation controllers according to historical turfgrass water requirements resulted in a 30% reduction of water use (Haley *et al.*, 2007). Rain sensors have been shown to save 34% of irrigation water when set at ¼ inch of rainfall (Cardenas-Lailhacar, 2006). Soil moisture sensor controllers have been shown to reduce irrigation water use up to 92%, under rainy conditions, with no decline in turf quality (Cardenas-Lailhacar *et al.*, 2008).

Although within the SWFWMD, twice weekly irrigation is permitted, Pinellas County has more stringent water use regulations. In accordance with Pinellas County Code 82-2, irrigation is only authorized for one day a week between the hours of 6:00 pm and 8:00 am (PCU, 2007a). Water use, ordinance compliance, and conservation knowledge influence the domestic irrigators' tendency to employ the automatic settings of irrigation controllers, rain sensors, and soil moisture based controllers versus manual adjustment.

Other human factors, such as the inclination to manually override the automatic system, relate to conservation psychology. Research has been conducted proving the effectiveness of technology in reduction of outdoor (lawn and garden) water use. However, these studies have been primarily conducted in controlled settings. When attempting to incorporate the recommendations of the research into the residential arena savings are less apparent than those found in the controlled settings (Geller *et al.*, 1983; Campbell *et al.*, 2004).

Baumann (1990) established three factors which affect the intensity of water use by residential users. The first two are economically driven: the consumer's ability to pay for and the willingness to pay for water at a given price. The non-economic factor is the consumer's conservation behavior. This reflects the motivation to employ effort or technological innovations for water conservation. Campbell et al. (2004) has suggested that when looking at the correlation between water use and socio-economic level alone, lower income homeowners may use more water because of limited resources available to fix leaks and install new water saving devices in the home. However, the common assumption regarding household size is that with a larger house there is greater water consumption. Higher value homes tend to have more features that consume water than homes of lower value. According to Whitcomb (2005), the main concern of homeowners with respect to increased costs is outdoor use. The current rate for potable water from Pinellas County Utilities is $4.04 per 1000 gal as of October 1, 2006, resulting in nearly a 25% increase over the previous two years (PCU, 2007b).

Previous studies have looked at aerial images to determine irrigation area and outdoor water use as a fraction of utility records. However these studies primarily focused on the water needs relative to evapotranspiration, suggesting water savings in relation to plant water needs. Kjelgren et al. (2002) looked at relative water use between residential and commercial properties, but did not look at the correlation between residential irrigated area and property value. Irrigation increased midsummer through early fall due to increased evapotranspiration rates, if there was limited rainfall. Dewees and Woods (2006) also looked at aerial images and evapotranspiration in relation to reduced outdoor water use, focusing on over irrigation in summer months. The aerial photography was used to target the highest residential water users as part of a water conservation program in Austin, TX. The program has been expanded to include commercial costumers with irrigation sub-meters. Because this study focused on excessive water consumption it also neglected the small-yard over-irrigator.

The objectives of this paper are to assess the effect of socio-economic attributes on residential irrigation water use in Southwest Florida. The attributes included are: property value, irrigated area, the presence of a pool, and the participation in irrigation study. Through statistical analysis, conclusions will be drawn regarding socio-economic effects on water use.

**Materials and Methods**

This project included 142 homes in Pinellas County selected as a cluster sample. All homes irrigate with water from the public supply. As part of the total sample, 56 are participating in a sensor technology irrigation conservation study (Haley and Dukes, 2007). The study area is Pinellas County, Florida (Figure 1) which is part of the Pinellas-Anclotte River Basin within the Southwest Florida Water Management District. Pinellas County has a humid subtropical climate, with frost and freezing temperatures occurring at least once annually. The average annual rainfall within the SWFWMD is 53 inches, with 60-65% occurring between in the summer months when evapotranspiration rates are highest. The groundwater supply in southwest Florida comes from the Floridan aquifer. This aquifer is recharged by rainfall which occurs in the district as the sole source of natural replenishment (SWFWMD, 2005).

Property information was gathered from the Pinellas County property appraisal public records (www.pcpao.org) for each home included in the analysis. These records included information on the comparable sales from 2005-2006 (which denotes property value), the property size, total gross living area (i.e. gross structural footprint), and residential extras (e.g. pool, enclosure, patio, shed, etc.). A calculated irrigated area was determined by subtracting the gross structural area and residential extras from the property size. From the Pinellas County public GIS records (www.gis.pinellas.org), the residential parcels are outlined and an aerial layer from Jan/Feb 2006 was overlaid (Figure 2.). Using the GIS layers, the irrigated areas were outlined with a polygon tool (note the red polygons in Figure 2) and the area of each polygon was calculated by GIS to determine the aerial estimated irrigated area. Actual irrigation area from site visits to homes participating in the irrigation conservation program was used to verify assumptions in the aerial estimated irrigation area methodology. The aerial estimated irrigated area was then compared to the calculated irrigated area from the property appraisal information.

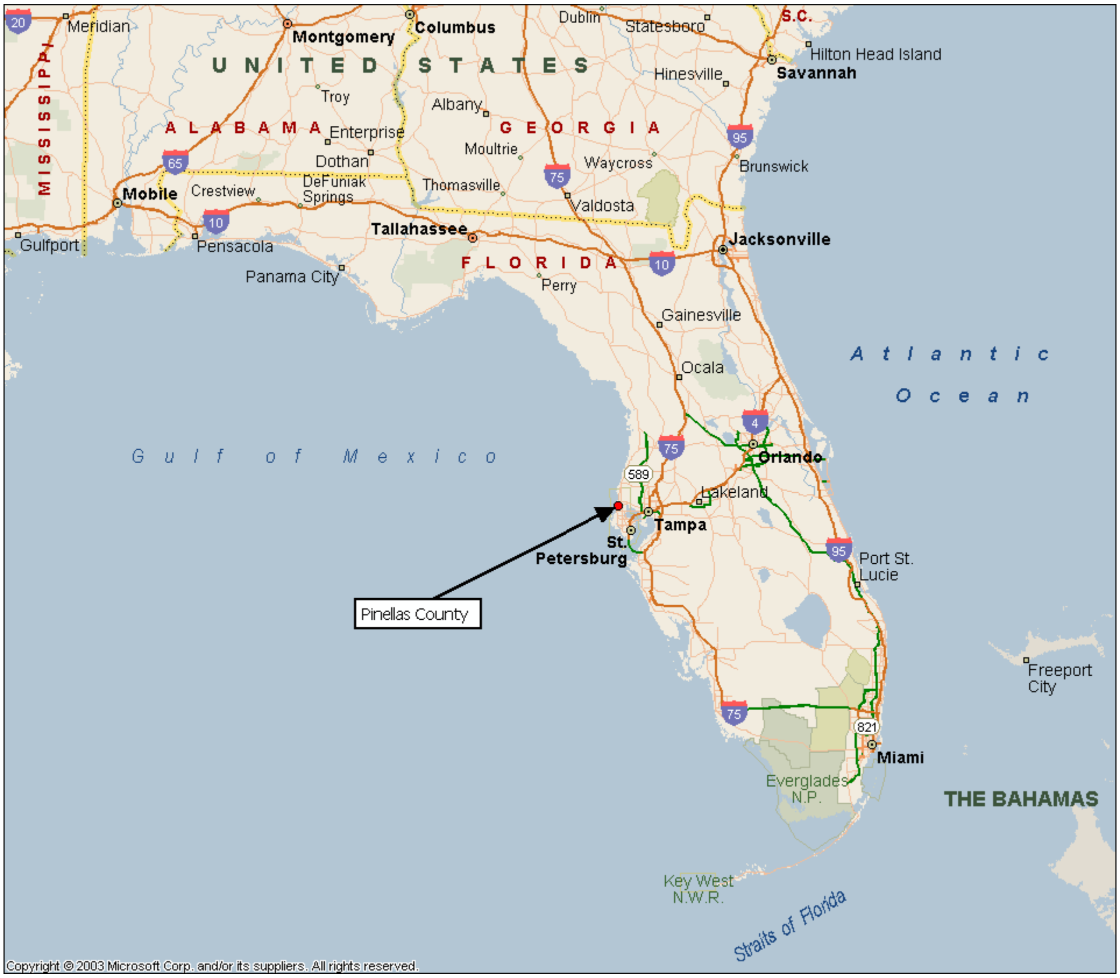


**Figure 1. Map of the Florida, including location of data collection (Pinellas County).**

Monthly water data was obtained from Tampa Bay Water Authority for a period of five years for each residence. Irrigation use was estimated based on the volume of monthly water used outside and the aerial estimated irrigated area. To calculate the monthly outdoor water use, the winter (December, January, and February) water use was analyzed for each parcel to determine the winter minimum usage. The minimum winter water use was assumed to be only indoor use; therefore, any use greater than the winter minimum was assumed to be assumed outdoor use. If a monthly use was less than the winter minimum, the outdoor use was estimated as zero for that month. The homes participating in the sensor based irrigation study have sub-meters for their irrigation water use which were used to verify the winter minimum method.

Data analysis was performed using SAS software. Procedures included measurement of correlation coefficients, ANOVA analysis, and frequency tables with chi-square statistics. Positive and negative correlations were based on Pearson's correlation coefficient. The multivariate analysis enables assessment of the direct and indirect effects for related variables. An analysis of variance was used to determine main effect differences through PROC GLM and means comparisons were performed with Duncan's Multiple Range Test at a 95% confidence level (SAS, 2004).

**Figure 2. Aerial view of residential parcels with red polygons denoting irrigated area and black polygons denoting parcel boundaries.**

## Results

To estimate the monthly outdoor water use, the winter (December, January, and February) water use was analyzed for each parcel to determine the winter usage. For the five years of utility data, winter average, low quartile (lowest 25%), and minimum use were compared. The calculated outdoor use by winter average, low quartile, and minimum for the 2006-2007 billing period was compared to the actual irrigation water use from the participating homes that had sub-meters for irrigation water consumption. The average actual monthly average use for the 2006-2007 time period was 2.0 in/month. Using the average winter use, the monthly average consumption resulted in 0.91 in/month, a 54% error. The low quartile outcome was 1.5 in/month, which is a 25% difference form the actual value. The minimum winter water use over the billing period resulted in 2.2 in/month average use which was the lowest error at 9%.

The GIS aerial images proved to be more accurate estimations of actual irrigated areas than the property appraisal data. To determine the accuracy of the GIS measurement method, the true irrigated area was measured on-site at homes in the participant group, with the average error within 5%, with no over or under-estimation greater than 10%. Although 35% of the calculated irrigated areas where also within 5% of the aerial estimated areas, the error ranged from 49% under-estimation to 180% over-estimation. Sources of error can be found for both methods of determining irrigation area. The property appraisal information may include enclosures, patios, and pools. However, it is not clearly defined whether the pool/patio is housed within the enclosure or additional area. Additionally, the property appraisal information rarely includes driveways, child play grounds, and sheds. When looking at the property size, from the public records, the parcel may consist of two lots or a fenced portion, were there are obviously non-irrigated areas. The parcel lines can also cause discrepancy; within GIS the boundaries do not always coincide with the actual parcel size, sometimes including lakes or natural areas adjacent to the property. Possible irrigated areas beyond the total property size and not included in the recorded parcel area are easements, walkways, and buffer zones. These areas which are irrigated and considered part of the actual irrigated area were included in the aerial estimated irrigated calculations.

From the correlation analysis, there were associations between irrigation application depths with property value, house size, presence of a pool, and aerial estimated irrigated area. Overall, there was a positive correlation between property value and irrigation application depth (r = 0.66) and a negative correlation between irrigated area and water application depth (r = 0.85); note Figures 3 and 4 respectively. This trend is most evident when looking at the homes without pools (Table 1). There was a significant difference ($p<0.001$) between the water use in homes with and without a pool on the property. The homes with pools used on average over 0.5 inches more water per month. Upon further investigation, the presence of a pool can be considered a conditional relationship, where the impact is greater for one group than for another when other factors are included. This could be caused by a combination of two factors. First, the pool may consume a notable fraction of the average monthly consumption, and the monthly use should be offset accordingly. Additionally, external factors may need to be considered. For example, people who reside in homes with pools may tend to spend more time outdoors, consequently having a stronger motivation for increased landscape aesthetics.

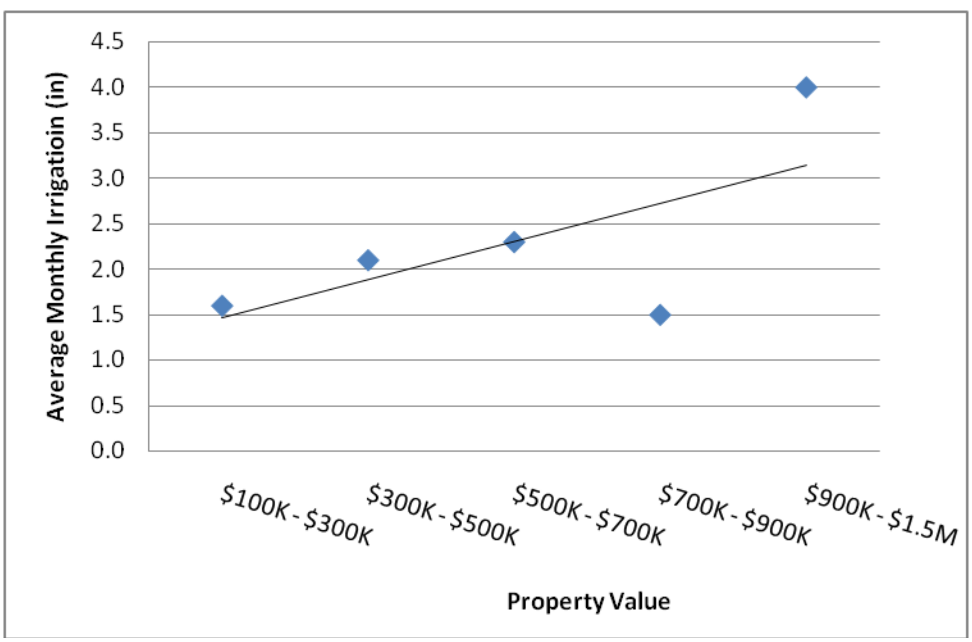


**Figure 3. Effect of property value on average monthly irrigation for all homes.**

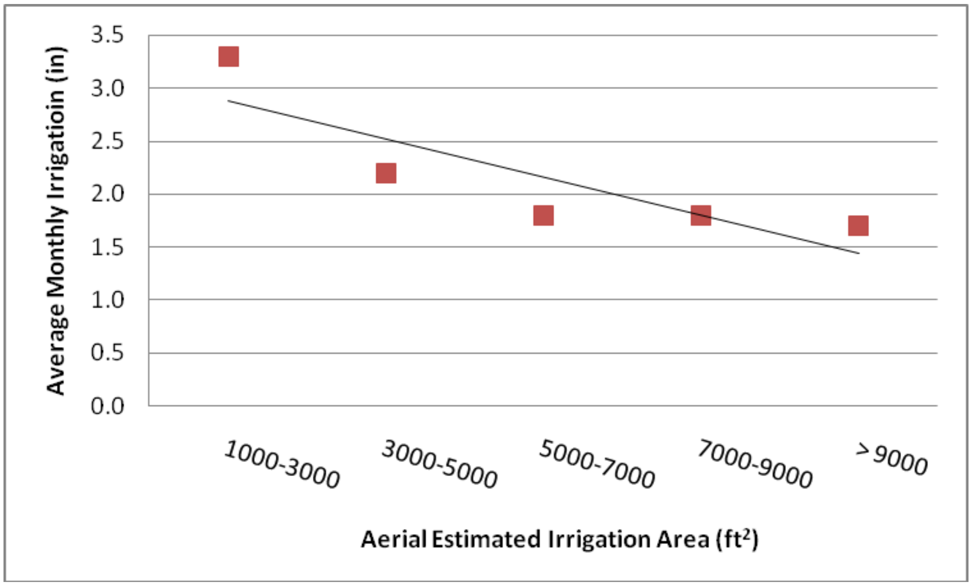


**Figure 4. Correlation between irrigated area and monthly irrigation for all homes included in analysis.**

Property values were categorized in to five profiles: $100,000 to $300,000, $300,000 to $500,000, $500,000 to $700,000, $700,000 to $900,000, and $900,000 to $1,500,000 (Table 1). The interaction of a having pool can also be seen here, nearly all homes valued above $500,000 have a pool. The positive correlation between property value and irrigation application depth suggests socioeconomic level affects conservation behavior, likely because cost is less of a primary motivation. From the analysis of property value and outdoor water application, it can also be observed that the homes ranging from $900,000 to $1,500,000 used the largest amount of water for outdoor use ($p<0.001$). This trend concurs with the literature, suggesting that sensitivity to water cost results in reduction of use (Whitcomb, 2005). For homes participating in the sensor based technology program, the trend between increased water applications with increased property value is most apparent. For the total sample, the same trend exists, aside from the $700,000 to $900,000 range, which has the lowest calculated outdoor water application depth.

Conversely, the smaller the property, the more water was applied, described by the negative correlation in Figure 4. It is also interesting to note that the homes with smaller irrigated areas all have property values ranging from $100,000 to $500,000. The increase in negative correlation between irrigated area and water application could be due to a misunderstanding of irrigation scheduling principles and the over-design of irrigation systems (e.g. too many heads per hydrozone). Moreover, high consumption of outdoor water use is typically flagged by excessive volume use, not taking area into consideration. Therefore, over irrigation in smaller irrigated areas are rarely flagged by local purveyors or felt as an excessive economic stress.

Of the 142 homes included in this analysis, 56 have been part of an irrigation conservation study since 2006. In Table 1, it can be observed that the homes associated with the irrigation study applied more irrigation on average, 2.2 inches per month, versus 1.7 inches per month for the non-participant group ($p<0.001$). The increased outdoor water use for participating homes might be attributed to consistent use of an automatic irrigation system, as it was one of the criteria for participation in the sensor based irrigation water conservation program. However, since the commencement of that study there has been a significant ($p<0.001$) reduction, from 2.5 to 2.1 inches per month of average outdoor water application during 2006-2007 for participating homes due to treatment effects in that study (Haley and Dukes, 2007)

**Table 1. Average outdoor water application depth per month for the time period of 2002-2007.**

| Category | | Overall | | With Pool | | Without Pool | | Participants | |
|---|---|---|---|---|---|---|---|---|---|
| | | $Use_{avg}$ (in) | No. | $Use_{avg}$ (in) | No. | $Use_{avg}$ (in) | No. | $Use_{avg}$ (in) | No. |
| Property Value Range | \$100K - \$300K | 1.6 c* | 66 | 2.1 b | 32 | 1.2 b | 34 | 2.0 c | 25 |
| | \$300K - \$500K | 2.1 b | 54 | 2.2 b | 43 | 1.5 a | 11 | 2.0 c | 21 |
| | \$500K - \$700K | 2.3 b | 7 | 2.3 b | 7 | - | 0 | 2.1 c | 4 |
| | \$700K - \$900K | 1.5 c | 8 | 1.5 c | 7 | - | 1 | 3.2 b | 3 |
| | \$900K - \$1.5M | 4.0 a | 7 | 4.0 a | 6 | - | 1 | 4.7 a | 3 |
| Aerial Est. Irr. Area Range ($ft^2$) | 1000-3000 | 3.3 a | 7 | 3.7 a | 5 | 2.3 a | 2 | 5.4 a | 3 |
| | 3000-5000 | 2.2 b | 31 | 2.6 b | 19 | 1.5 b | 12 | 2.0 bc | 13 |
| | 5000-7000 | 1.8 c | 60 | 2.1 c | 38 | 1.2 bc | 22 | 1.9 c | 22 |
| | 7000-9000 | 1.8 c | 31 | 2.2 c | 21 | 0.9 c | 10 | 2.1 bc | 10 |
| | > 9000 | 1.7 c | 13 | 1.8 d | 12 | 0.3 d | 1 | 2.2 b | 8 |
| | *Average* | *1.9* | | *2.3*¤ | | *1.3*¤ | | *2.2* | |
| | *Total* | | *142* | | *95* | | *47* | | *56* |

* Lower case letters denote significant differences at the 95% confidence level based on Duncan's Multiple Range Test.
¤ Means comparisons between homes with and without pools show these averages to be significantly different.

## Summary and Conclusions

To properly evaluate irrigation water based on utility data, outdoor and indoor water consumption must be separated. Three methods for calculating outdoor water use as a fraction of total water use were compared: winter average, low quartile (lowest 25%), and minimum use. The winter water use was assumed to only be indoor use, and subtracting the winter use provided the estimated monthly outdoor use. The minimum winter water use over the billing period was calculated as 2.2 in/month (6,700 gal) on average. The minimum winter method yielded the lowest error, 9%, compared to the actual irrigation water use collected from participating homes. To determine actual irrigation application amounts, the usage in gallons was then converted into inches, based on irrigated area. To estimate these areas, a combination of both property appraisal information and measured areas from GIS aerial images was used. The property appraisal information alone may vastly over and under estimate the actual property size, which will in turn cause substantial error when calculating the irrigated area. For this sample, to verify the accuracy of the areal estimated irrigated area, the true irrigated areas were measured on homes in the participant group.

A pro-environmental behavior such as water conservation can stem from reluctance to over-use irrigation water based on cost. Two barriers to this conservation behavior, observed in this study were economic level, displayed in the form of property value, and irrigated area. The property value analysis showed that the highest value range (\$900,000-\$1,500,000) used the most water even when normalized for irrigated area. Overall there was a trend of increased water application with increased property value. Conversely, the smaller the irrigated area, the more water was applied. A primary cause for the increased use in both homes of higher property value or smaller irrigated area is likely due to minimal impact water cost for excessive use. The homes with pools used on average over 0.5 inches more water per month. This increase irrigation water use could be due to the pool or some other factor not considered in this analysis but correlated to the presence of a pool.

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