A CASE FOR TARGETED WATER CONSERVATION OUTREACH

[1]David W. Smith, Extension Program Specialist
Texas A&M AgriLife Extension Service, Biological & Agricultural Engineering, College Station, Texas
[2]Charles Swanson, Extension Program Specialist
Texas A&M AgriLife Extension Service, Biological & Agricultural Engineering, College Station, Texas
[3]Jennifer Nations, Water Resource Coordinator
City of College Station, Texas

Abstract. Many cities and water utilities employ public awareness and education efforts for commercial and residential customers to promote water conservation and irrigation efficiency. These campaigns are usually intended for a wide audience and present brief, general messages to build awareness. This approach however may have limited impact on reducing water waste from landscape irrigation and at a high cost. An alternative strategy is to target education and provide assistance in a manner that achieves maximum water savings more economically by examining seasonal water use trends among different segments of the community. Since 2010 College Station, Texas Water Utilities performed more than 500 residential landscape irrigation 'checkups'. Using data collected from the 'checkups' and monthly water records, an analysis showed that small properties (<5,000 sqft) consistently applied more irrigation than large properties (>10,000 sqft) when normalized by landscape area. The difference was significant in four out of eight years examined. Newer properties (<10 years) consistently showed higher irrigation use compared to all other age groups. In fact, average irrigation applied from newer properties was significantly greater ($p<0.05$) than properties older than 30 years in four of eight years. These results can be useful for generating maximum impact when constrained by limited resources.

Keywords. Landscape, residential, conservation, education, irrigation efficiency, irrigation scheduling

INTRODUCTION

Landscape irrigation for residential and commercial properties, golf courses, athletic fields, and other types of recreation areas is estimated to be the third-largest user of water in Texas, behind only agriculture and municipal uses (Cabrera et al., 2013). With a growing population and competing interests for limited water supply, local communities employ various strategies to reduce potable water consumption including tiered water rates, prescriptive irrigation days, citations for water waste, and education campaigns. The greatest potential for municipal water conservation is in landscape irrigation. A study of monthly water use of 800 residences from 2000 through 2002 in College Station, Texas indicated that the average peak water consumption during the summer increased as much as 3.3 times the winter water use (White et al., 2004) as plant water requirements typically exceed precipitation. With in-ground, automated irrigation systems much of this water is wasted due to poorly-designed systems, improper scheduling (over-irrigation), and failure of system integrity. Furthermore, residential water customers find programming and operation of their controller difficult and confusing. This presents a real challenge for municipal and water utility driven water conservation efforts that encourage strategies such as potential evapotranspiration-based (ETo) scheduling, multi-cycling irrigation events to prevent runoff, and prescriptive, address-based weekly operation schedules. These strategies assume that customers are proficient in programming their controllers. In fact, failure to properly implement these recommendations can be counter-productive and actually increase overall irrigation use.

In 2010, College Station Water Utilities began providing free landscape irrigation 'checkups' to residential customers. To date, the City has performed more than 500 irrigation checkups, primarily for customers identified as having above average seasonal water use (Coleman, 2014). The checkup includes a general inspection of system components to identify damaged or broken hardware, documentation and evaluation of existing controller programming, and education on how to reduce runoff and install rain shut off sensors. Following the checkup a written report is delivered to the customer detailing significant findings along with recommendations for reducing irrigation use. Beginning in May 2012, College Station Water Utilities, in collaboration with the Texas A&M Department of Recreation, Parks, and Tourism provided additional resources to perform irrigation system checkups to meet increasing demand for this service. A licensed irrigator was hired to conduct irrigation inspections during the peak irrigation season.

The objective of this study was to identify any discernable difference or trend in irrigation applied (normalized by landscape area) among residential properties due to the size of the landscape and age of property. If such differences are found, this data can be used to strategically plan outdoor water conservation efforts and direct limited funding and personnel to that segment of the customer base where water savings is more promising.

METHODOLOGY

Landscape Irrigation Checkup

College Station Water Utilities publicizes the free irrigation checkup service by distributing a letter to approximately 5,000 residential customers whose historical water consumption substantially exceeded their estimated water budget. The City also hosts a series of summer 'sprinkler system workshops' in the summer season for approximately 200 residents per year. Interested residents contact City staff either by email or telephone to schedule an appointment with the irrigation inspector. In 2012, 2013, 2014, and 2015 irrigation checkups were conducted for 211 residential customers (205 unique customers). Irrigation checkups were performed in 44 subdivisions within the city of College Station. Fifty-eight percent of all inspections were conducted in four subdivisions: Pebble Creek (58), Castlegate (34), Emerald Forest (20), and Edelweiss Estates (11).

Data collected during the checkup included the number and type of application devices, brand and model of controllers, irrigation start times, run times, presence of rain shut-off sensors, and inventory of hardware deficiencies and operational problems.

Data Collected

- Controller brand
- Current controller time/date
- Irrigation start times
- Irrigation programs being utilized ('A', 'B', 'C', etc.)
- Individual station run times
- Seasonal adjust or water budget setting

- Presence of controller backup battery
- Presence and functionality of rain shut-off sensor
- Type(s) of sprinkler heads (per station)
- Dominant plant type (turfgrass, shrubs, flowers, etc. per station)
- Description of area being irrigated per station
- Extent of sun exposure per station (full sun, part sun, shade)
- Integrity of system devices (backflow prevention device, solenoid valves, sprinkle heads)

Though not included in this report, data was compiled and analyzed to determine commonalities in system equipment and design, general tendencies in controller programming, and occurrence of hardware and system performance problems. This information too can be instrumental in prioritizing specific topics for future water conservation education, outreach, and training for residential customers.

Irrigation Use Analysis

All residences in this study were served by a single water meter that registered combined indoor and outdoor water consumption. College Station Water Utilities provided monthly water consumption data for the seven year period from 2008 through 2015. Irrigation use was calculated by subtracting average indoor water use from total metered water consumption on a monthly basis. For the purpose of this study irrigation use was investigated and compared for the typical growing season in College Station – April through September. Indoor water use was estimated to be the average monthly consumption for December, January, and February over the period from 2008 to 2015 or over the period of reliable record during this seven year period.

Landscape water use (irrigation) in ‘gallons’ was normalized for landscape size and converted to inches of water applied using the following equation.

Irrigation (inches) = irrigation (gallons) / [area of landscape (sqft) x 0.6234]

Estimate of residential landscape area was calculated as the total property size (in square feet) minus the residential footprint, space occupied by garages, out-buildings, patios, sidewalks, and driveways. Total property, garage, and patio area was acquired from the Brazos County Appraisal District, http://www.brazoscad.org/. Further deductions for sidewalks, driveways, and other non-pervious area were estimated using Google Earth satellite maps and area/distance calculator tools.

Area of landscape (sqft) = total property area (sqft) – non-pervious area (sqft) (including house, garage, patio, sidewalk, and driveway footprint)

Net Plant Water Requirement (Net-PWR) Estimation

Net plant water requirement was computed using a daily water balance approach utilizing measured evapotranspiration (ETo) and precipitation data, crop coefficients for warm season turfgrass, and soil water storage constraints assuming a 6-inch root zone depth and clay soil type. ETo data was acquired from two automated weather station locations – the Texas A&M University Golf Course and Texas A&M Turf Lab. Net plant water requirement (Net PWR) was calculated using the following relationship:

Net PWR (inches) = (ETo (inches) x Kc x Af) – Reff (inches)

Where:

Kc = monthly crop coefficient (dimensionless)
Af = allowable stress factor (dimensionless)
Reff = effective rainfall (inches)

Long term average monthly crop coefficients for College Station are referenced in the Texas Landscape Irrigation Auditing and Management Short Course Manual – Version 3 (Fipps et. al., 2009). For this analysis, a stress adjustment factor of 1 (no stress) was used.

Methodology for estimating effective rainfall followed that used for similar analyses performed by the Texas A&M School of Irrigation (Swanson, 2015).

IF R < 0.1, THEN Reff = '0'
IF 0.1 < R ≤ 1, THEN Reff = 'R'
IF 1 < R ≤ 2, THEN Reff = 'R x 0.67'
IF R > 2, THEN Reff = '2'

Where:

R = actual daily rainfall (inches)

Daily Net-PWR was further constrained by assuming that plant-available water could be stored within a 6-inch root zone and a clay soil. Total Net-PWR for irrigation season each year was calculated by summing daily Net-PWR from April through September.

Landscape Irrigation Ratio (LIR)

The LIR is one approach to quantifying landscape water use (or irrigation) efficiency (Glenn et. al., 2015). The LIR metric provides a means to evaluate and compare landscape water conservation potential for properties regardless of property size. It is calculated by dividing the volume or normalized equivalent depth of outdoor water use divided by the landscape water requirement over a certain time interval.

LIR = irrigation (inches) / Net-PWR (inches)

This study examined the LIR over the typical landscape irrigation season (April through September).

Glenn et al. (2015) used the LIR approach to assess landscape water use efficiency in single-family residences in Logan, Utah in 2004 and 2005. Category benchmarks, defined by LIR ranges, were specified as 'justifiable' and 'unjustifiable' water use and further classified as 'efficient', 'acceptable', 'inefficient', and 'excessive'. This classification system was used in this study to compare water use efficiency for residences over the typical irrigation season from 2008 to 2015.

Justifiable water use
- Efficient LIR ≤ 1
- Acceptable 1 < LIR ≤ 2

Unjustifiable water use

Inefficient $2 < LIR \leq 3$

Excessive $3 < LIR$

RESULTS

Characterization of Irrigation System Hardware and Controller Programming

Controllers and rain shut-off sensors – Of the 211 residential customers Toro®, Hunter®, and RainBird® model controllers were used by 78% (165) of residents. These controllers are similar in basic operation and feature multiple program options (‘A’, ‘B’, ‘C’, etc. programs) and multiple start times per program. Almost all controllers provided for a 9-volt backup battery intended to retain program settings in case of power loss. If a functional backup battery were not present, these controllers reverted to a default irrigation schedule of watering every day, 10 minutes per station, at 5:00 AM start time once power was restored after an outage. Only 18% (38) of irrigation systems inspected were equipped with a rain shut-off sensor. Of those, 63% (24) were wireless and 37% (14) were hard-wired.

Irrigation Stations – A total of 1,204 stations were inspected. The average number of stations per residence is 5.8. Seventy-three percent (154) of residents had 6 or fewer stations. Of these, pop-up fixed spray heads and rotor-type sprinkler heads were the most common representing 52% and 37% of all sprinkler head types. Other sprinkler devices noted include ‘mixed’ (a combination of multiple sprinkler head types), drip irrigation, and multi-stream application devices designed for slow-application rate.

Irrigation Schedules – A critical part of the irrigation checkup was to educate the resident on the capability and use of their irrigation controller in facilitating efficient irrigation practices such as adjusting individual station runtimes, utilizing multiple programs to compensate for different irrigation frequency needs, and setting multiple start times (multi-cycling) to prevent water runoff. Existing controller settings were documented and immediately brought to the attention of the resident. In most cases, residents were not familiar with their current controller settings and did not realize the implications for inefficient water use.

> <u>Station run times:</u> An analysis of all residents suggests that, in general, stations with relatively high application rates were set with lower run times. For example, the average run time for pop-up spray sprinkler heads was 12 minutes while the average run time for rotor sprinkler heads was 17 minutes. Drip irrigation (characterized by relatively low water application rate) was usually set to run much longer. At a minimum, this illustrates that an attempt was being made to adjust individual station run times for different sprinkler types.
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> <u>Irrigation days:</u> Irrigation days were fairly well dispersed throughout the week with Mondays, Wednesdays, and Fridays being the most common. The calendar day option was obviously the most common selection for setting irrigation day, with less than 4% (23) of residents using the ‘odd/ even day’, or ‘interval day’ feature.
>
> <u>Program start times:</u> Eighty-eight percent (347) of all program start times documented occurred between midnight and 8:00 AM. The most common start time was 5:00 AM. This was not surprising given that the default start time for most major controller brands was also 5:00 AM. Though irrigating in the early morning is strongly encouraged and essential for reducing

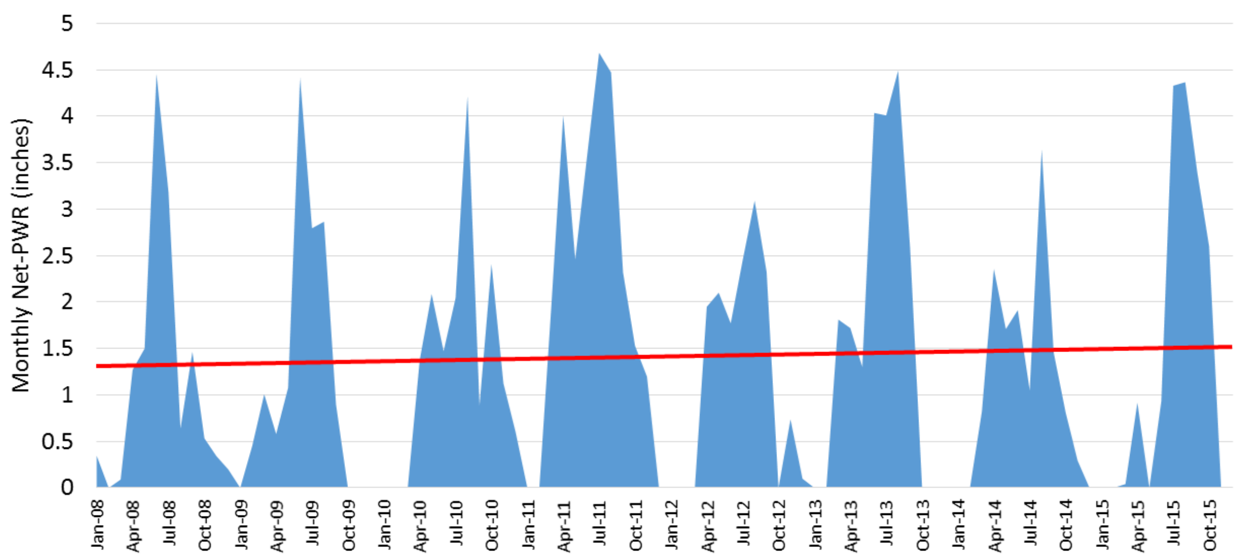
evaporative losses, there may be a need in some locations or subdivisions to minimize peak morning demand to limit pressure drop.

Multiple programs: When properly used, multiple controller programs (‘A’, ‘B’, ‘C’, etc.) and multi-cycling on irrigation days can minimize over-irrigation and help prevent water runoff. A survey of residents showed that only 16% (34) used more than one program, and 32% (67) practiced multi-cycling.

Net-PWR (2008 – 2015)

Net plant water requirement was calculated using a daily water balance approach using measured evapotranspiration and precipitation, and constrained by an assumed root depth and soil type using the methodology previous defined. This approach was selected to limit the water contribution from heavy or intense rainfall events. During intense rainfall water is more likely to run off the landscape and/or water moves beyond the typical plant root zone thereby becoming unavailable to the plant. Figure 1 shows the normal pattern and overall trend of Net-PWR over the eight-year period. Residential water customers typically begin irrigating in April and continue through September or longer depending on weather trends and early fall tropical storm development in the Gulf of Mexico. Peak Net-PWR usually ranges between 4.0 and 4.5 inches per month in June, July, or August. Overall, Net-PWR trended upward over the study period, most likely a result of the extreme drought conditions in 2011 and 2013.

Figure 1 – Monthly Net-PWR from 2008 to 2015



Irrigation Comparison of Landscape Size and Age of Property

Landscape size for each property was calculated and placed into categories (<5,000 sqft, 5,001 to 10,000 sqft, and >10,001 sqft). The mean and range of average irrigation applied from April through September in each year (normalized on a sqft basis) are listed in Table 1 according to size category. Interestingly, for all years irrigation use (expressed in inches applied) was greatest for small landscapes (less than 5,000 square feet). There was also a significant difference ($p<0.05$) between the smallest and largest landscapes for half of the years studied (2008, 2009, 2010, and 2012). General observations were that the smaller landscapes (and properties) were also those located in relatively new subdivisions where plants were less mature and subject to more frequent watering to establish plants.

Table 1. Comparison of irrigation applied (in inches) by landscape size.

Year	<5,0000 sqft			5,001 – 10,000 sqft			> 10,001 sqft		
	[1]M	[2]R	[3]N	M	R	N	M	R	N
2008	**26.4**	3.3 – 122.5	35	**22.6**	3.0 – 50.9	93	**16.4**	2.6 – 29.2	39
2009	**23.9**	1.1 – 80.4	36	**21.9**	4.0 – 55.0	97	**16.2**	1.9 – 30.1	38
2010	**22.3**	1.8 – 98.2	37	**18.4**	1.5 – 35.1	97	**14.3**	2.1 – 33.3	39
2011	**31.0**	2.1 – 187.1	40	**28.0**	4.2 – 75.6	100	**23.0**	8.3 – 41.0	39
2012	**20.6**	1.6 – 55.5	42	**19.3**	3.8 – 54.3	102	**16.0**	0.9 – 25.9	39
2013	**21.2**	3.3 – 73.5	41	**20.0**	3.0 – 46.7	99	**16.5**	1.9 – 38.6	39
2014	**16.1**	0.9 – 40.2	24	**15.9**	0.2 – 32.9	71	**12.3**	0.2 – 25.0	24
2015	**15.4**	0.4 – 36.8	48	**16.1**	0 – 37.4	103	**15.6**	0 – 45.8	41

[1]Average irrigation applied (in inches) from April through September.
[2]Lowest to highest irrigation applied (in inches).
[3]Number of residents.

A similar comparison is shown in Table 2 with delineation by age of property. Younger properties (10 years and younger) showed consistently higher irrigation use (per square foot landscape area) when compared to all other age groups. In fact, average irrigation applied was significantly greater ($p<0.05$) than properties older than 30 years in 2008, 2011, 2013, (relatively dry years), as well as 2014 and 2015. This may be due to the higher irrigation frequency required (and thus a greater chance for water loss) during the establishment phase of new landscape plants. This difference may also be a function of more shade (provided by mature trees and shrubs), and relatively deeper root systems in established turfgrass that characterize older properties.

Table 2. Comparison of irrigation applied on properties by age delineation.

Year	1 – 10 years		11 – 20 years		21 – 30 years		>30 years	
	[1]Mean (in.)	[2]N	Mean (in.)	N	Mean (in.)	N	Mean (in.)	N
2008	**29.7**	14	**22.2**	93	**22.2**	36	**16.7**	23
2009	**26.0**	19	**20.9**	93	**21.0**	36	**18.8**	33
2010	**20.2**	21	**18.5**	93	**18.5**	36	**15.5**	23
2011	**28.8**	26	**29.1**	93	**26.6**	36	**22.5**	23
2012	**19.5**	29	**19.5**	95	**18.9**	36	**15.6**	23
2013	**21.5**	30	**19.6**	91	**20.2**	36	**15.5**	22
2014	**18.5**	16	**14.5**	67	**17.1**	21	**12.2**	15
2015	**18.0**	39	**17.4**	95	**15.0**	36	**13.0**	23

[1]Average irrigation applied (in inches).
[2]Number of residents counted in this category.

Landscape Irrigation Ratio (LIR)

Water use efficiency describes how closely irrigation applied matches plant water requirement. The LIR metric (used by Glenn et. al, 2015) (defined as the ratio of landscape water use divided by landscape water requirement) is one measure of water use efficiency. Although the choice of LIR classification is somewhat subjective, this methodology does provide a means to gauge the effectiveness of water conservation outreach, education, and awareness efforts among a large population.

LIR was computed for all properties, landscape size classifications, and age categories. Figure 2 illustrates that water use efficiency for these properties is typically a function of landscape size, with the smaller properties having lower water use efficiency compared to larger properties. Figure 2 also shows and overall increasing trend in water use efficiency (lower LIR) over the 8-year study period, with water use efficiency increasing more sharply for landscapes less than 5,000 square feet.

Figure 2. LIR comparison and trend for various landscape sizes.

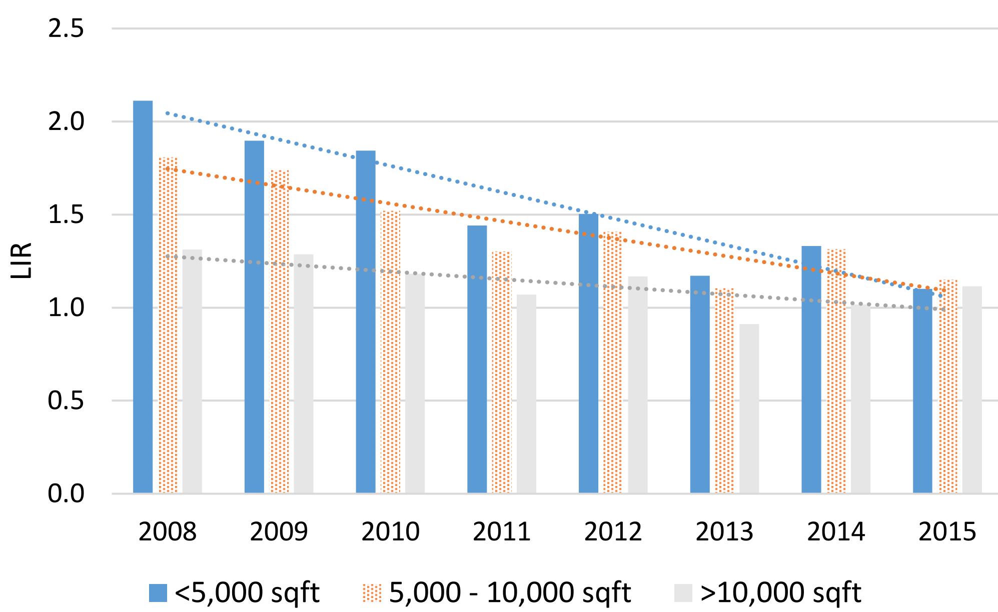
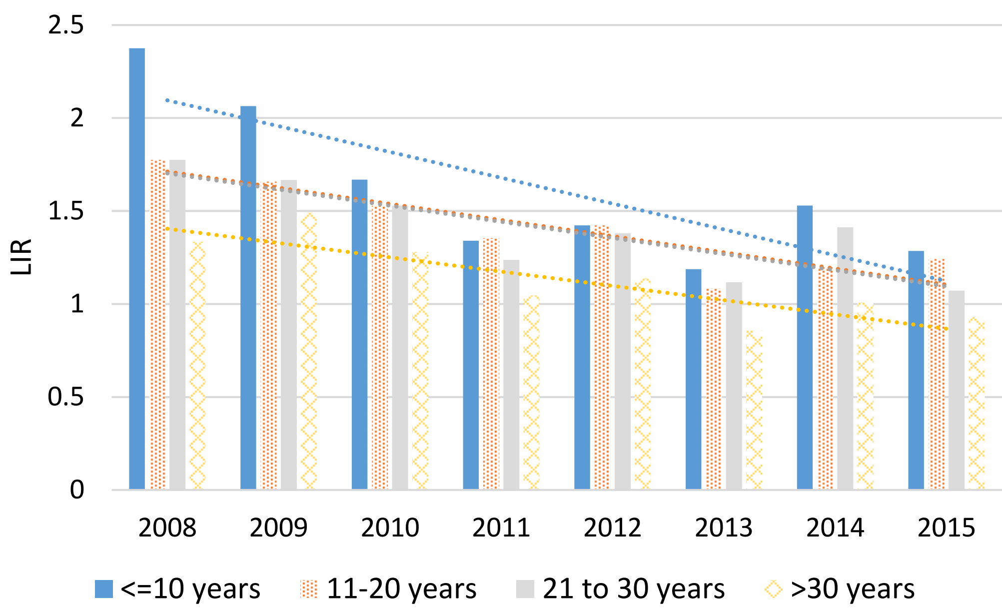


Figure 3 shows a similar trend with increasing water use efficiency over time for all properties independent of age. However, properties less than or equal to 10 years of age are consistently less water efficient compared to older properties, particularly compared to the oldest age group (30 years and older). Water use efficiency appears to be increasing most dramatically (decreasing LIR) over the 8-year study period for those properties of the youngest age group.

Figure 3. LIR comparison and trend with age of property.



LIR for all residents included in this study were calculated and categorized using the classification system defined by Glenn et al. (2015). Overall, the percentage of residents classified as either 'efficient' or 'acceptable' increased from 70 percent to 91 percent from 2008 to 2015, with the highest percentages in these two categories occurring in 2011 (93 percent) and 2013 (95 percent), both extremely dry growing seasons. Furthermore, the number of properties classified as either 'inefficient' or 'excessive' dropped dramatically over the study period with less than 10 percent of residents falling into these categories.

Table 3. Distribution of residents by LIR category.

[1]LIR Category	Percentage of residents by LIR category							
	2008	2009	2010	2011	2012	2013	2014	2015
Justifiable water use								
Efficient LIR ≤ 1	19	19	26	31	26	51	35	41
Acceptable 1 < LIR ≤ 2	51	50	51	62	63	44	50	50
Unjustifiable water use								
Inefficient 2 < LIR ≤ 3	22	25	21	6	9	4	14	8
Excessive 3 < LIR	8	5	2	1	2	1	1	1
Total (%)	100	100	100	100	100	100	100	100
[2]N	167	170	173	178	183	179	119	193

[1]LIR is defined as the ratio of landscape water used divided by landscape water required (Net-PWR). Category designations defined by Glenn et al. (2015).
[2]Number of residents.

DISCUSSION

In 2012, 2013, 2014, and 2015 211 irrigation inspections for 205 unique customers were conducted as part of the College Station Water Utility's free residential irrigation checkup program. The objective of this study was to identify any discernable difference or trend in irrigation applied (normalized by landscape area) among residential properties due to the size of the landscape and age of property. Landscape size appears to play a significant role in the amount of irrigation applied. Average irrigation applied during the growing season was significantly higher for the smallest landscapes compared to the largest landscapes in 2008, 2009, 2010, and 2012 (relatively wet years). Younger properties (10 years and younger) showed consistently higher irrigation use when compared to all other age groups. In fact, average irrigation applied was significantly greater ($p<0.05$) than properties older than 30 years in 2008, 2011, 2013, (relatively dry years), as well as 2014 and 2015. Water use efficiency, as measured by the Landscape Irrigation Ratio metric, showed an overall increase over the study period. Trends also show a decrease in the portion of residents classified as 'inefficient' or 'excessive' suggesting that the irrigation checkup service may have long term impact in reducing over-irrigation.

CONCLUSIONS

Results of this study reveal that although current education and the landscape irrigation checkup service appear to be effective in increasing water use efficiency, future efforts should focus on younger and smaller properties to achieve greatest savings on a per unit area basis and to maximize limited financial and personnel resources. Younger properties are often characterized by new plants with limited root zones and usable water storage capacity, as well as limited shade which increases overall evaporative losses. Use of automated irrigation systems designed and managed for established landscapes on establishing landscapes can lead to significant water waste (water that is not utilized by new plants). Irrigation applied to younger landscapes is necessarily increased to accommodate these special needs and consequently increases the potential for water loss due to evaporation, runoff, and wind drift. The increasing presence of smaller properties being built in new subdivisions in College Station, Texas helps to explain why the smaller properties in this study also had the highest water use when normalized on a square foot basis. This study supports the need to target newer properties for outdoor water conservation, and to educate homeowners on methods to minimize water loss while their landscapes are becoming established and increasing soil water storage capacity over time.

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