Water conservation in Oklahoma urban and suburban watersheds through modification of irrigation practices.

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Number of Students Supported:

Student Status	Number	Disciplines
Undergraduate	3	Horticulture, Agricultural Economics
M.S.	3	Horticulture, Agricultural Economics
Ph.D.	0	NA
Post Doc	1	Horticulture
Total	7	

Publications:

1. Articles in Refereed Scientific Journals

None

2. Book Chapter

None

3. Dissertations & Theses

Haase, John. 2011. Simple Irrigation Audits for Homeowners. “MS Thesis”. Department of Horticulture and Landscape Architecture, Environmental Science Graduate Program, College of Agricultural Sciences and Natural Resources, Oklahoma State University, Stillwater, OK. (in preparation/to be submitted Summer 2011).

Schmidt, JoDee. 2011. Economics and Perception of Turfgrass and Landscape Water Use and Conservation. “MS Thesis”. Department of Agricultural Economics, College of Agricultural Sciences and Natural Resources, Oklahoma State University, Stillwater, OK. (in preparation/to be submitted Summer 2011).

Sidwell, Courtney. 2012. Landscape Irrigation in Oklahoma: Perceptions, Practices, and Best Management Practices. “MS Thesis”. Department of Horticulture and Landscape Architecture, College of Agricultural Sciences and Natural Resources, Oklahoma State University, Stillwater, OK. (in preparation/to be submitted Spring 2012).

4. Water Resources Research Institute Reports

Moss, Justin, Tracy Boyer, Dennis Martin, Kemin Su, Michael Smolen, and Damian Adams. 2011. Oklahoma Water Resources Research Institute Final Technical Report. Oklahoma State University, Stillwater, OK.

5. Conference Proceedings

Martin, Dennis, Santanu Thapa, Steve Batten, Justin Moss, Greg Bell, Jeff Anderson, Yanqi Wu, and Kemin Su. 2010. Evapotranspiration rates of Riviera and U-3 bermudagrasses under non-limiting soil moisture conditions. In: 2010 Agronomy abstracts. ASA, Madison, WI.

Moss, Justin, Dennis Martin, Yanqi Wu, Kemin Su, and Bishow Poudel. 2010. Development and selection of bermudagrasses for water conservation in urban landscapes. In: Proceedings of the 2010 USDA National Water Conference, Hilton Head, SC.

6. Other Publications

Reilley, Michael, Tracy Boyer, Damian Adams. 2010. Using best-worst scaling to understand public perception of municipal water conservation tools. Poster presentation. 2010 Oklahoma Governor’s Water Conference, Norman, OK.

Water Conservation in Oklahoma Urban and Suburban Watersheds Through Modification of Irrigation Practices

Problem and Research Objectives:

Water conservation is important for municipalities throughout Oklahoma. As urban and suburban sprawl increases in Oklahoma, large areas of previously non-irrigated pasture and/or croplands are being converted to irrigated homeowner and commercial landscapes. The consequential increase in irrigated turfgrass areas across Oklahoma will result in increased landscape water use. There is a need to assess current landscape irrigation watering practices in Oklahoma. Furthermore, there is a need to assess the willingness to adopt and pay for irrigation systems and management practices that conserve Oklahoma's water resources.

The goal of this project is to understand and promote more conservation oriented landscape water use in Oklahoma.

The following objectives are proposed for the first year of a potential two-year project.

The objectives of this project are as follows:

1. Assess current landscape water use and irrigation practices in Oklahoma urban and suburban areas through conjoint choice surveys.
    a. Survey homeowners and lawn care companies about perceptions and preferences concerning landscape/turfgrass aesthetics and accompanying irrigation practices, how they make landscape irrigation decisions, and economic factors including willingness to pay for water based on plant health and aesthetics versus associated economic water factors.

2. Determine the accuracy and reliability of remote sensing reference evapotranspiration (ET) data with established crop coefficients compared to actual landscape plant water use in Oklahoma.
    a. Calculate historical growing season reference ET from 1993 to present day using Oklahoma Mesonet remote sensing climate data using the Penman-Monteith method.
    b. Estimate actual plant water use by conducting field lysimeter and atmometer studies and measuring actual weekly water applied to adequately maintain bermudagrass over the growing season compared to Penman-Monteith reference ET.

3. Educate Oklahoma stakeholders and citizens of landscape irrigation practices to conserve Oklahoma water resources.
    a. Hands-on irrigation training and demonstration workshops conducted through the OSU Cooperative Extension Service.
    b. Fact sheets and interactive Oklahoma landscape irrigation website.

This project addressed the following <u>two OWRRI high priority research</u> areas:

- Assess the economic value of current and potential future agricultural water conservation methods in Oklahoma (Objective 1).
- Develop/improve methods for accurately estimating evapotranspiration using remote sensing data that are of practical value to local resource managers (Objective 2).

This work allowed us to gather important and current data to determine the present situation of landscape irrigation in Oklahoma. Critical future work would allow us to collect post-survey and post-implementation data to assess the effectiveness of our water conservation research and extension efforts.

OBJECTIVE 1 – Assess current landscape water use and irrigation practices in Oklahoma urban and suburban areas through conjoint choice surveys.

Objective 1 was split between two separate studies. For easier reading, each study will be discussed separately below.

Study 1: Using best worst scaling to understand public perception of municipal water conservation tools.

Methodology:

Best worst scaling was first introduced by Finn and Louviere in 1992. The concept is widely used in marketing, medical, and more recently food research. Best Worst Scaling is a relatively simple concept whereby respondents are shown a set of characteristics and asked to choose one as being most important and one as being least important. Consumers are shown a set of choices, varied in the number of choices, and asked to rank one of the choices as most preferred (best) and least preferred (worst). An example of a choice set is provided in Figure 1.

Figure 1. Example of Best - Worst Scaling Question

Please check your most preferred and least preferred water conservation tool out of the following choices.

Most Preferred	*(Check only **one** that is most preferred and **one** that is least preferred)*	Least Preferred
☐	**Smart Meter** (Meter that allows homeowners to monitor real time water use)	☐
☐	**Public Information** (Information about water use, and appeals by city officials to voluntarily reduce water use during drought)	☐
☐	**Rebates for Drought Tolerant Landscapes** (Financial assistance for homeowners to install drought tolerant plants)	☐

After making repeated choices among sets, the responses give a relative position of that attribute to each other attribute, i.e., a ranking. Finn and Louviere stated that “Best Worst scaling models the cognitive process by which respondents repeatedly choose the two objects in varying sets of three or more objects they feel exhibit the largest perceptual difference on an underlying continuum of interest.” According to Louviere the advantages of this method is that it attributes and levels are not confounded as in a traditional discrete choice experiment since the utility of just the attribute is calculated.

Unlike ranking, forcing tradeoffs in best worst scaling means avoids the issue of perception of what a particular number represents across individuals.   Table 1 shows the 7 policy tools of interest.

Table 1. Water Conservation Methods and Descriptions

Method	Descriptions
Smart Meter	Meter that allows homeowners to monitor real time water use
Restricted Watering	Ordinances to restrict outdoor watering days and/or times
Increasing Block Rates	Increased charge per gallon for water use above the needs of the average household
Public Information	Information about water use, and appeals by city officials to voluntarily reduces water use during drought
Rebates for Drought Tolerant Landscapes	Financial Assistance for homeowners to install drought tolerant plants
Rebates for Low Flow Appliances	Rebates for low-flow faucets, toilets, appliances, etc.
Home Audits	Help for homeowners to evaluate waste of water and/or set individualized water rates

A 2^8 design was used to assign each of the 7 values to an orthogonal experimental design. The final design was made up of 8 choice sets, 7 contained 3 values, and 1 contained all 7 values. Each survey respondent saw the same choice sets in random order to eliminate any bias from the order in which they were presented. Household members were asked to choose which of the tools was least important/least effective or most important/most effective depending on the design treatment they were shown by random assignment.

The choice of the best and worst (most and least preferred) option in a choice set may be conceptualized as choosing the items that maximize the difference in utility. A choice set has J items, then the result is *J* (*J*-1) tools or possible combinations. Following the techniques of Lusk and Briggeman, let λ_j be the location of the value j on the underlying scale of importance and the true level of importance be $\mathrm{I_{ij}} = \lambda_j + \varepsilon_{ij}$; where ε_{ij} is an error term with an extreme value distribution. The probability that consumer chooses to maximize the distance between item *i* and *k*, that is as the best and worst out of J tools is the probability that the difference in $\mathrm{I_{ij}}$ and $\mathrm{I_{ik}}$ is greater than all other *J* (*J*-1)-1 possible differences in that choice set. Thus the conditional logit may be used:

(1) = Prob (j is most preferred and k is least preferred) $= \frac{e^{\lambda_j - \lambda_k}}{\sum_{l=1}^{J}\sum_{m=1}^{J} e^{\lambda_l - \lambda_m}} - J$

Where l, m are the policy tools seen, but not chosen as the maximizing pair. Each best-worst possible pair is coded in SAS as a 1 if chosen. One value, drought tolerant landscapes is dropped to avoid the dummy variable trap, thus other values are interpreted relative to it and each other.

Participation in an internet survey was solicited via an insert in the City of Stillwater, OK utility bill statements from June-July, 2010, one billing cycle. A total of 310 responses were received by our survey instrument programmed in Survey Monkey from 19,608 mailed utility bills for a response rate of 1.6%.[1] Respondents were randomly assigned one of three survey versions to test for social desirability bias, i.e. whether participants would answer to save their own costs and whether they understood which tools were most effective at reducing water demand. One third of the sample was asked which water conservation technique they most prefer and least prefer. One third of the sample was asked which water conservation technique the average homeowner would most prefer and least prefer (Table 2).

Table 2. Version, Description and Sample Size

Version	Description	Sample Size
SHH	What you most/least prefer	101 Respondents
AHH	What would the average homeowner most/least prefer	105 Respondents
EHH	What is most/least effective	104 Respondents

Lastly, one third of the sample was asked which water conservation technique would be most effective and which technique would be least effective. A total of 310 people provided usable survey responses of which 101 answered the survey soliciting the homeowners preferences for his or her household, 105 answered the survey asking "What would the average homeowner most/least prefer?", and 104 answered the version which asked which techniques the homeowner felt would be the most/least effective.

[1] While survey response will suffer from bias toward citizens with greater internet access and civic participation, an option to complete a mail survey was also included. This survey vehicle was chosen because of its extremely low cost, the willingness of city utility directors to participate, and the ability to reach all customers of the municipality.

Descriptive statistics for the survey respondents are given in Table 3.

Table 3. Characteristics of Survey Respondents (n=310)

Variable	Definition	Mean	Std. Deviation
Gender	1 if male, 0 if female	0.528	0.5
Age	Age in years	51.232	16.297
Ownership	1 if own dwelling, 0 if rent dwelling	0.846	0.362
House	1 if resides in house; 0 otherwise	0.885	0.362
Apartment	1 if resides in apartment, 0 otherwise	0.0553	0.229
Mobile Home	1 if resides in mobile home; 0 otherwise	0.019	0.139
Duplex	1 if resides in duplex; 0 otherwise	0.039	0.195
Child (1)	1 if child under age 2 living in household; 0 otherwise	0.069	0.254
Child (2)	1 if child between ages 2 and 18 living in household; 0 otherwise	0.295	0.733
Environmental Organization	1 if active member of environmental organization; 0 otherwise	0.094	0.362
Maintenance	1 if primarily responsible for lawn maintenance; 0 otherwise	0.764	0.425
Connection	1 if city water connection; 0 otherwise	0.984	0.125

Slightly over half of the respondents were male (52%) and the average age was 51 years. As expected, the 85% of the respondents owned their residence, 88% were single family residences, and 98% used city water. The majority of homeowners (76%) did not use a lawn service and only 9% were active members of an environmental organization. All respondents saw the same choices of drought policy tools and the same information about their average efficacy in reducing demand (Table 4).

Table 4. Efficacy data shown to respondents.

CONSERVATION TOOL	Average Gallons Water Saved per Month per Household	Total Monthly Cost Savings per Household
Smart Meter	700	$4.19
Rebates for Drought-Tolerant Landscapes	600	$3.59
Increasing Block Rates[1]	450	$2.69
Rebates for water efficient items		
Indoor Faucet	413	$2.47
Toilets	400	$2.39
Clothes washers	426	$2.55
Audits/budgets	1,500	$8.97
Public Information	210	$1.26
Restricted Watering[2]	300	$1.79

[1] Projected 30% drop in water use, [2] Projected 30% drop in water use.

Principal Findings and Significance:

The results are depicted graphically in Figure 2 and coefficient estimates for the three scenarios are shown in Table 5. In Figure 2, the parameter estimate within each scenario (vertical colored bar) gives a relative ranking of the preference for a policy tool. The policy tools are grouped from left to right in terms of their efficacy. For example, although increasing block rates are the second most effective tool for reducing water demand, households ranked them last when choosing for themselves or the average neighbor. However, when asked to rank efficacy, respondents understood that the technique was in the top three most effective tools. A likelihood ratio test confirmed statistically significant differences between the three versions of the survey at the (5% confidence level).

Figure 2. Best-Worst Scaling Ranking Results

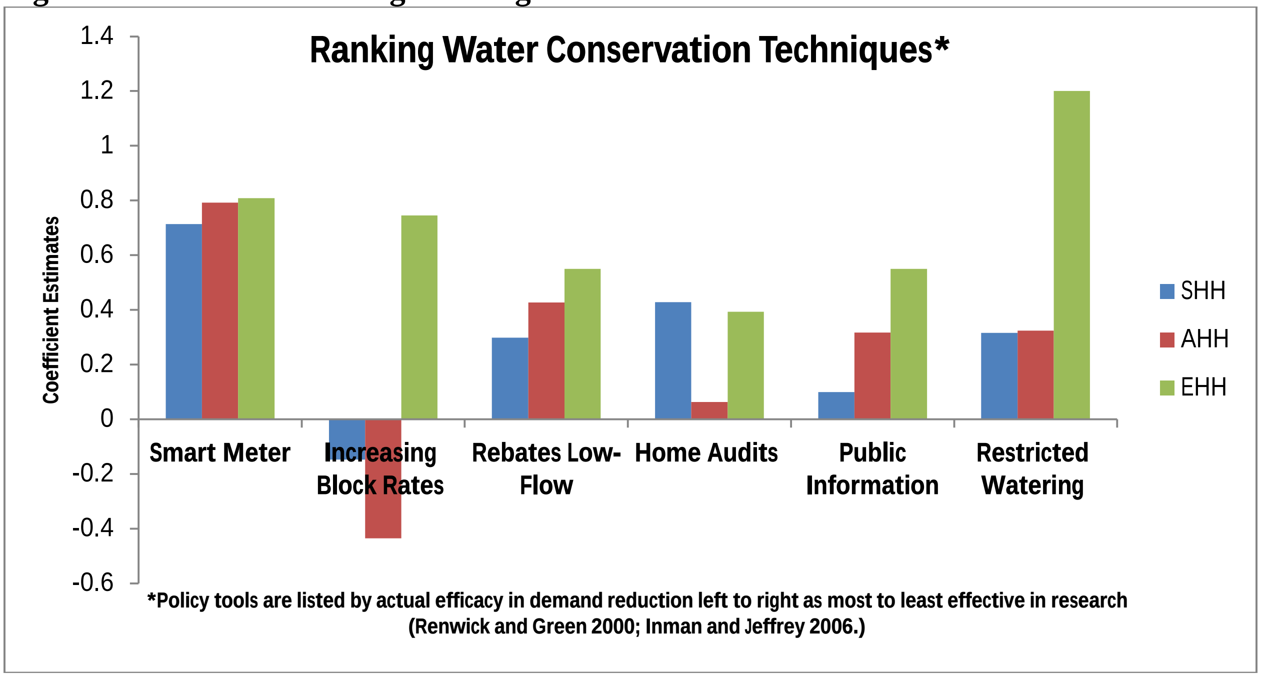


Table 5. Relative Preferences for Water Conservation Tools

	Coefficient Estimate (Standard Error)		
Value	**SHH**	**AHH**	**EHH**
Smart Meter	0.7132*	0.7916*	0.8089*
	(0.102)	(0.1053)	(0.107)
Increasing Block Rates	-0.1479	-0.4347	0.7449*
	(0.1001)	(0.1044)	(0.1012)
Rebates Low-Flow	0.298*	0.4275*	0.5494*
	(0.0984)	0.1013	0.1024
Home Audits	0.428*	0.0637	0.3933*
	(0.0986)	(0.1003)	(0.0996)
Public Information	0.1	0.3176*	0.5494
	(0.0977)	(0.101)	(0.1006)
Restricted Watering	0.316*	0.324*	1.200*
	(0.0986)	(0.1007)	(0.1014)
N individuals	101	105	104
Log Likelihood	101.14	165.20	218.01

*Indicates significance at 99% confidence level

Smart Meters were most popular with homeowners (AHH and SHH), and correctly ranked as highly effective (EHH) suggesting they might be least controversial. Although consumers understood increasing block rate pricing to be effective, households would not choose to levy higher prices on themselves to conserve water. Restrictive Watering, Smart Meter and Increasing Block Rates were ranked as most effective among Oklahomans. Respondents favored Smart Meters, Home Audits and Restricted Watering Schedules as water conservation tools in their own homes. Differences between SHH and AHH results from social desirability bias therefore, AHH may be more accurate than SHH. Although restricted watering is believed (EHH) to be most effective, research has shown it least effective in reducing demand. This result may indicate users did not understand the efficacy chart given or the numbers were too many to remember as they continued through the survey. Results show that policy makers and utility managers should clearly outline efficacy of drought conservation tools and their costs and benefits when seeking to respond to drought. Homeowners will be opposed to tools that will raise costs.

Increasing attention on the efficacy of water conservation tools and the associated household specific data showing the effects on demand for municipal water are direly needed in areas of shortage. In the meantime, however, much of the debate over which tools to adopt to meet seasonal and sustained droughts remain political decisions. Based on the literature on likely tools for reducing demand for water under short term conditions was compiled and the relative preference and understanding of the efficacy of these tools was measured.

We found that people were more likely to say they would adopt voluntary restrictions although these were not presented as the most effective. Household consumers were less likely to adopt methods such as increasing block rates that imposed higher costs on the household. Furthermore, the results between the consumer's statement of his or her own household's preferences were significantly different from the results when reporting preferences believed to be of the "average" household, suggesting that preference surveys do suffer from social desirability bias. Using the results from this study may aide utility managers in designing conservation programs, soliciting support for conservation, and avoiding conflict over the implementation.

Study Two: Determinants of water conservation among Oklahoma golf and recreational turfgrass managers.

<u>Methodology:</u>

On November 16 and 17, 2010, willing participants of the 65th Annual Turf Conference Trade Show held in Stillwater, Oklahoma completed a survey entitled, "Survey of Water Use in Recreational Turfgrass Management." The survey was designed to determine what current water conservation practices are being utilized in turfgrass management practices on Oklahoma's golf courses, recreational fields, and parks and how individual characteristics of the facility and the facility's management influence their adoption. Participants were given two opportunities to complete our survey, one while in attendance at the conference and another a couple weeks later via either online at Surveymonkey.com or through the U.S. mail. In an attempt to increase the response rate, a financial incentive was presented in the form of 6 random drawings for $100. Of the 219 attendees on the conference's participant list, 72 completed the survey. Five of these 219 attendees were excluded due to their employment affiliation with Oklahoma State University, giving us a response rate of 33.64 %. Additional conference guests provided 52 more completed surveys. In the second opportunity, 119 emails and 37 mailers were sent out using a mailing list of turfgrass managers provided by conference leaders out of which 21 surveys were completed via Surveymonkey.com and 4 completed surveys were returned via the mail. The final response rate for the second contact was 17.6% for Surveymonkey.com and 10.8% for the U.S. mail. Including all attempts to contact Oklahoma professional turfgrass managers, a total of 149 responses were collected.

The survey consisted of several questions relating to not only a facility's turfgrass management, but also characteristics of the facility's workers and managers. The survey inquired about: the type of facility, facility location, the annual budget for maintenance, watering methods currently being utilized, type of water source used for irrigation water, motivation and barriers to adopting water conservation methods, education, certifications, age, and the water conservation practices which have been adopted. Ranking was utilized to determine the most important motivations and barriers to adopting water conservation methods. Respondents were asked to rank five motivations for adopting water conservation strategies in order of importance. These motivations included: lowering costs of water used, environmental conservation, reducing labor costs in irrigation, response to price increases by municipal water supply, and reducing mowing or weeding costs. In a separate question, respondents were asked to rank three barriers to adopting water conservation strategies in order of importance. Barriers included: need for knowledge of strategies to reduce water use, concern over performance and appearance of turf for users, and funding for implementing strategies.

After collecting the data from the completed 149 surveys, general statistics were generated and included: the percentages of how many respondents chose a multiple choice answer in a particular question, means, modes, and standard deviations.

Cross tabulations were developed for all completed surveys to demonstrate which of a respondent's/facility's characteristics were mostly associated with either choosing to adopt a particular water conservation practice or choosing not to adopt. These characteristics included: facility type, watering methods currently being used, education level of the respondent, type of college degree held by the respondent, respondent's certifications, number of acres of turfgrass at the facility, ZIP code of the facility, and age of the respondent. For the top 5 most used conservation practices, every characteristic selected by a respondent was categorized as either "conservation method adopted" or "conservation method not adopted," depending on whether or not the individual had adopted the water conservation practice. After all chosen characteristics were categorized, they were then summed or averaged across all responses for each group.

Since our dependent variables have a discrete outcome, either have adopted or have not adopted, the probit procedure was chosen for the regression analysis of the data to predict the likelihood of adoption of users on average, given the facility and individual's characteristics. The probit model is as follows:

$$\text{Prob}(Y=1) = F(\beta' x) \quad \Rightarrow \text{ have adopted}$$
$$\text{Prob}(Y=0) = 1 - F(\beta x) \quad \Rightarrow \text{ have not adopted}$$

The set of parameters (β) reflect the impact changes in x on the probability (Greene, 1992).

Probit models were generated using the SAS 9.2 Program (2011 SAS Institute Inc) to analyze the effects of certain respondent/facility characteristics, such as facility type, current watering methods, education and certifications, and facility location, on the adoption of a certain water conservation technique. Five probit models were estimated, one for each of the top 5 most used conservation practices. In these models, the probability that a respondent/facility will accept a certain water conservation technique is dependent on certain characteristics of the respondent or facility. The water conservation techniques chosen to be analyzed in this study include: reduced watering, reduced percentage of area irrigated, limited irrigation, zoned irrigation, irrigation scheduling, reuse water, irrigation audit, improved cultivars, greens modified, higher mowing heights, switch to alternative, adoption of xeriscaping, and adoption of conservation indoors.

For this study, the following conceptual model was created:

(1) Probability of adopting water conservation technique = ¦ (type of facility, current watering methods, current source for irrigation water, respondent's education level, certification of respondent, acres of turfgrass at facility, age of respondent, regional location of facility)

A linear probability model would not be efficient in analyzing the data because of the discrete nature of the dependent variables. Since $\beta x + \varepsilon$ must equal either zero or one, the variance of the errors depends on β which would result in a problem with heteroscedasticity. Therefore, the empirical model for this study is:

(2) $Y^* = \beta' x + \varepsilon$

Where: $Y^* = 1$ if the practice is chosen, 0 if not chosen, $\varepsilon \sim N(0,1)$, a random error term

For this model all estimated β coefficients are for the x variables. All x variables are dummy variables (1 => characteristic chosen, 0 => characteristic not chosen), except turfgrass acres and age. Y* is the dependent variable or conservation technique, which is either one if adopted or zero if not. Regional information was not directly asked in the survey. Instead, respondents were asked to indicate the ZIP code in which their facility is located. Using GSI software, these ZIP codes were plotted in four Oklahoma regions in which Interstate 35 and Interstate 40 served as boundary lines dividing the state into Southeast, Northwest, Southwest, and Northeast regions. The model in less formal terms is as follows:

The model in less formal terms is as follows:

(3) $Y^* = \beta_1 + \beta_2 Golf + \beta_3 Rec + \beta_4 Sports + \beta_5 Sod + \beta_6 OF + \beta_7 MS + \beta_8 AS + \beta_9 ZS + \beta_{10} MCS + \beta_{11} DI + \beta_{12} SH + \beta_{13} SBH + \beta_{14} OWM + \beta_{15} NoIrr + \beta_{16} City + \beta_{17} Private + \beta_{18} Reten + \beta_{19} OWS + \beta_{20} College + \beta_{21} BS + \beta_{22} Cert + \beta_{23} Acres + \beta_{24} Age + \beta_{25} SE + \beta_{26} NW + \beta_{27} SW + \beta_{28} OS + \varepsilon$

Table 6 provides variable definitions and Table 7, below, provides explanations of the dependent variables used for the different models.

Table 6

Probit Model Independent Variables					
Golf	Golf Course	**DI**	Drip Irrigation	**College**	Some College
Rec	Recreational Park	**SH**	Soaker Hose	**BS**	B.S./B.A.
Sports	Sports Field	**SBH**	Spray by Hand	**Cert**	Certified
Sod	Sod Farm	**OWM**	Other Watering Method	**Acres**	Turfgrass Acres
OF	Other Facility	**NoIrr**	Do Not Irrigate	**Age**	Age
MS	Manual Sprinkler	**City**	City Water Connection	**SE**	Southeast
AS	Automated Sprinkler	**Private**	Private Well Water	**NW**	Northwest
ZS	Zoned Sprinkler	**Reten**	On Site Water Retention	**SW**	Southwest
MCS	Manual Connection Sprinkler	**OWS**	Other Water Source	**NE**	Northeast
		HS	<12th Grade, H.S. Diploma	**OS**	Out of State

Table 7

	Probit Model Dependent Variables
Reduced watering	Reduced watering
Reduced % of area irr	Reduce percentage of area irrigated alone
Limited irr	Limited or nonexistent irrigation
Zoned irr	Zoned irrigation systems
Irrigation scheduling	Irrigation scheduling based on plant water requirements as estimated by site-specific weather data
Reuse water	Reuse or gray water for irrigation
Irr audit	Irrigation audit
Improved cultivars	Selection of improved turfgrass cultivars for drought tolerance
Greens modified	Greens or high use areas modified to improve water percolation and deeper rooting, avoidance of excessive slopes
Higher mowing heights	Higher mowing heights of grass
Switch to alt	Switch to alternative, non-municipal supply
Adopt of xeriscaping	Adoption of xeriscaping or drought tolerant plants where turfgrass is not necessary
Adopt of cons indoors	Adoption of conservation indoors in clubhouse, park structures, etc

Principal Findings and Significance:

Table 8 presents simple statistics of some of the determinants of water conservation adoption. Top responses are highlighted below as follows:

- For facility type, golf courses comprised 47% of responses
- For current watering methods, automated above ground automatic sprinklers comprised 75% of responses
- For water source, city water connection was used for 58% of respondents
- For education level, B.S./B.A. or higher graduate was the highest degree obtained by 46% of respondents
- For facility location, the Northeast region received 46% of responses

In addition, 87% of respondents indicated being certified in the turfgrass management field. On average respondents were about 43 years old and their facilities had an average of 138 acres in turfgrass.

The following are additional findings by the majority of respondents:

- 63% of respondents indicated being lead managers
- 60% of facilities were designated as public, while 40% were private
- Average annual operating budget for maintenance was $469,000
- 80% of respondents apply pesticides to facility turfgrass acres and 82% of respondents apply fertilizers
- 97% were male
- 91% indicated Caucasian decent, 1% African American, and 7% Native American
- 39% ranked “lowering cost of water used” as the most important motivation for adopting water conservation strategies, while 39% ranked “response to price

increase by municipal water supply" as having the least affect on their motivation for adopting water conservation strategies

52% ranked "concern over performance and appearance of turf for users" as the pinnacle barrier to adopting water conservation strategies, while 43% ranked "the need for knowledge of strategies to reduce water use" as having the least effect on prohibiting the adoption of water conservation strategies.

Table 8

Determinants of Conservation Adoption - Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
Golf	149	0.46980	0.50077	70.00000	0	1.00000
Rec	149	0.14765	0.35595	22.00000	0	1.00000
Sports	149	0.14094	0.34913	21.00000	0	1.00000
Sod	149	0.02013	0.14093	3.00000	0	1.00000
OF	149	0.31544	0.46626	47.00000	0	1.00000
MS	149	0.23490	0.42537	35.00000	0	1.00000
AS	149	0.75168	0.43350	112.00000	0	1.00000
ZS	149	0.38926	0.48923	58.00000	0	1.00000
MCS	149	0.25503	0.43735	38.00000	0	1.00000
DI	149	0.25503	0.43735	38.00000	0	1.00000
SH	149	0.12752	0.33468	19.00000	0	1.00000
SBH	149	0.50336	0.50168	75.00000	0	1.00000
OWM	149	0.07383	0.26237	11.00000	0	1.00000
NoIrr	149	0.05369	0.22617	8.00000	0	1.00000
City	149	0.58389	0.49457	87.00000	0	1.00000
Private	149	0.26174	0.44107	39.00000	0	1.00000
Reten	149	0.19463	0.39725	29.00000	0	1.00000
OWS	149	0.15436	0.36251	23.00000	0	1.00000
College	149	0.38255	0.48765	57.00000	0	1.00000
BS	149	0.46309	0.50032	69.00000	0	1.00000
Cert	149	0.86577	0.34205	129.00000	0	1.00000
Acres	149	138.27692	255.28471	20603	0	3000
Age	149	42.92414	11.54023	6396	20.00000	76.00000
SE	149	0.18121	0.38649	27.00000	0	1.00000
NW	149	0.22819	0.42108	34.00000	0	1.00000
SW	149	0.06040	0.23903	9.00000	0	1.00000
OS	149	0.05369	0.22617	8.00000	0	1.00000

Figure 3 illustrates which water conservation practices have been utilized and what percent of respondents are implementing them. The data collected shows the top five most used water conservation practices to be: reduced watering (64%), higher mowing heights of grass (64%), zoned irrigation systems (54%), selection of improved cultivars for drought tolerance (47%), and irrigation scheduling based on plant water requirements as estimated by site-specific weather data (43%). Options in facility types included: golf course, recreational park, sports field, and sod farm. In Figure 4, we see golf course (47%) was the most common facility type followed by other facility type (32%), recreational park (15%), sports field (14%), and sod farm (2%). A majority of the other facility types specified by respondents included lawn care services and educational institutes. A majority of respondents chose automated above ground automatic sprinkler systems as the facility's current watering method (75%), followed by spraying the turfgrass area by hand as needed (50%). Only 5% indicated not utilizing any irrigation methods at their facility (Figure 5). Figure 6 exhibits the division of water source usage. The large majority obtain water for irrigation from city water connections (58%) and private wells (26%). A majority of other water sources specified by respondents included lakes and rivers. The distribution of regional location can be observed in Figure 7. Most facilities (46%) reside in the Northeast region of Oklahoma. With only 6%, the Southwest has considerably fewer turfgrass facilities than the other three Oklahoma regions. This uneven distribution of turfgrass facilities may be due to differences in the amount of precipitation received or population. Having less rainfall than the other regions, may prohibit the Southwest region's ability to sustain turfgrass acres.

Figure 3

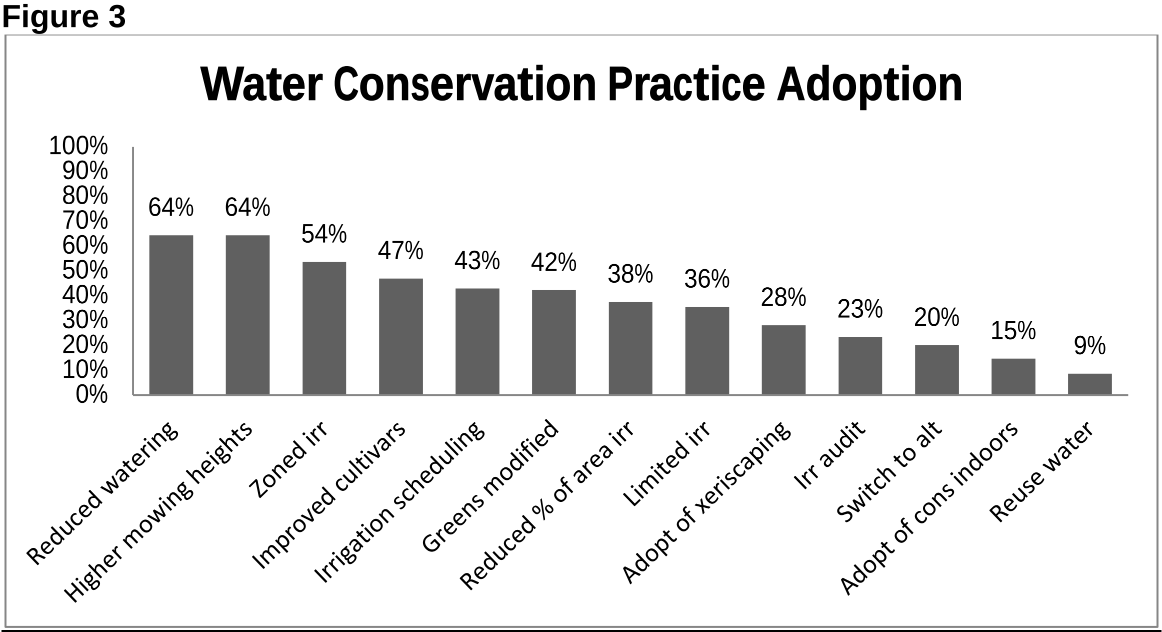


Figure 4

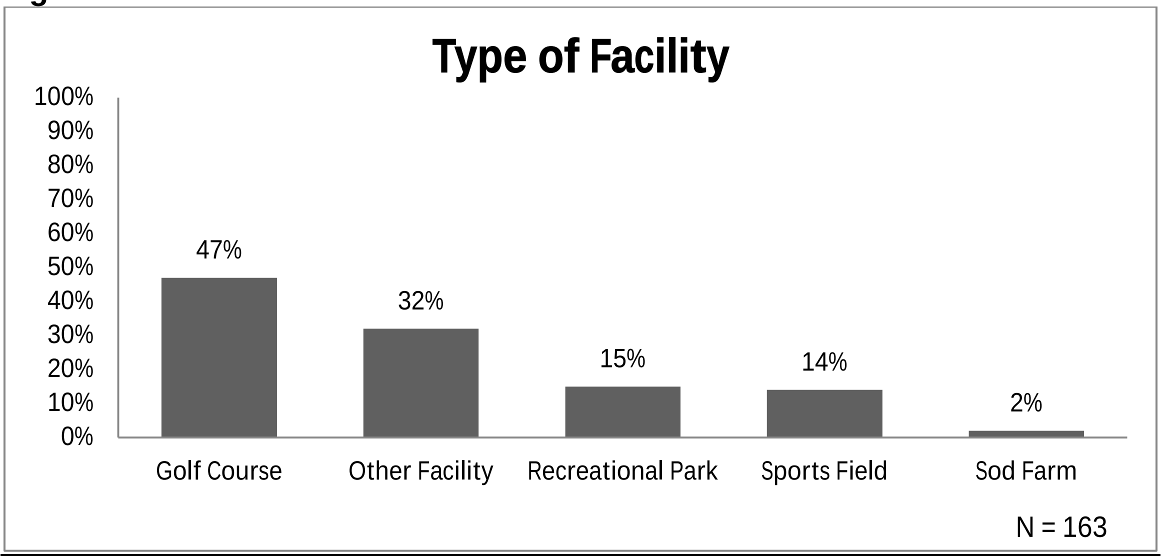


Figure 5

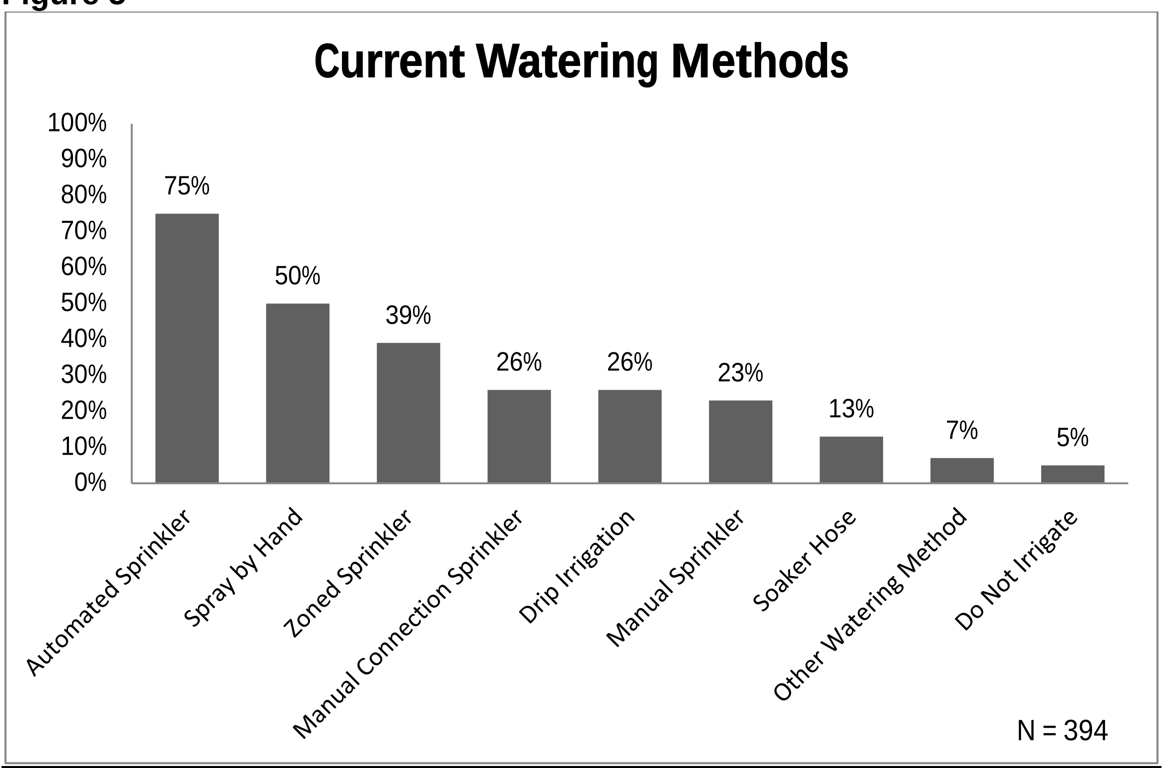


Figure 6

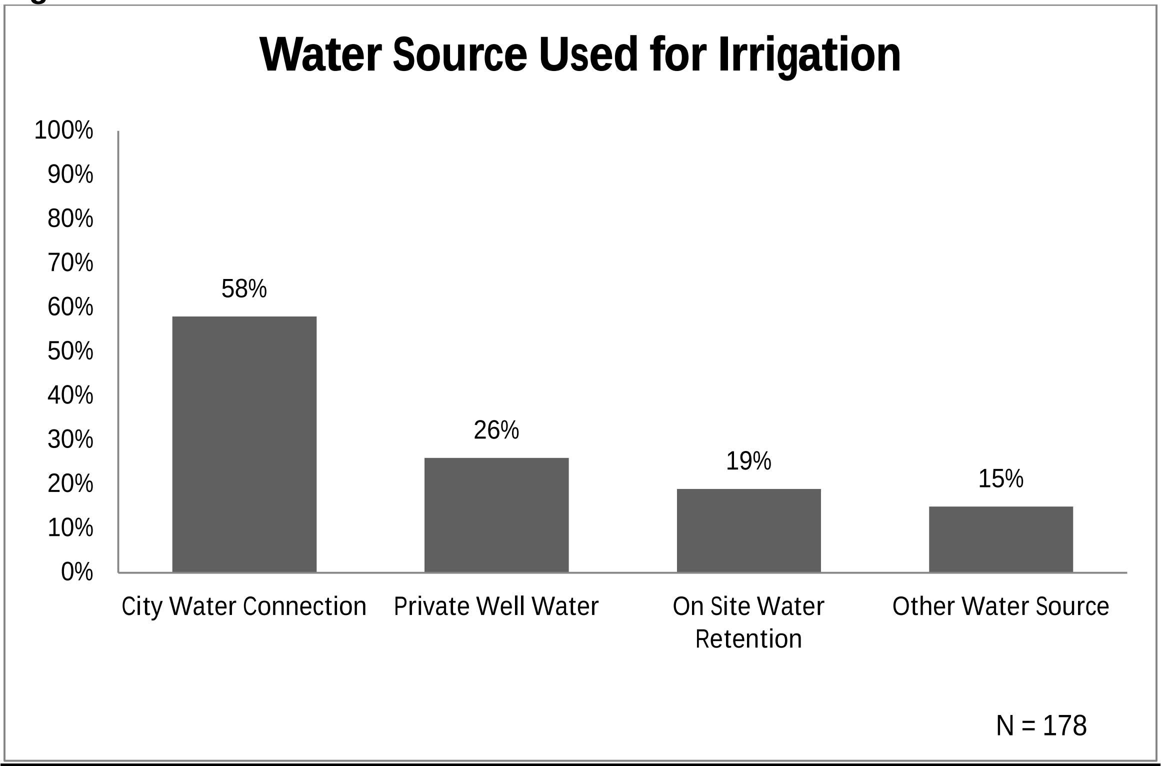
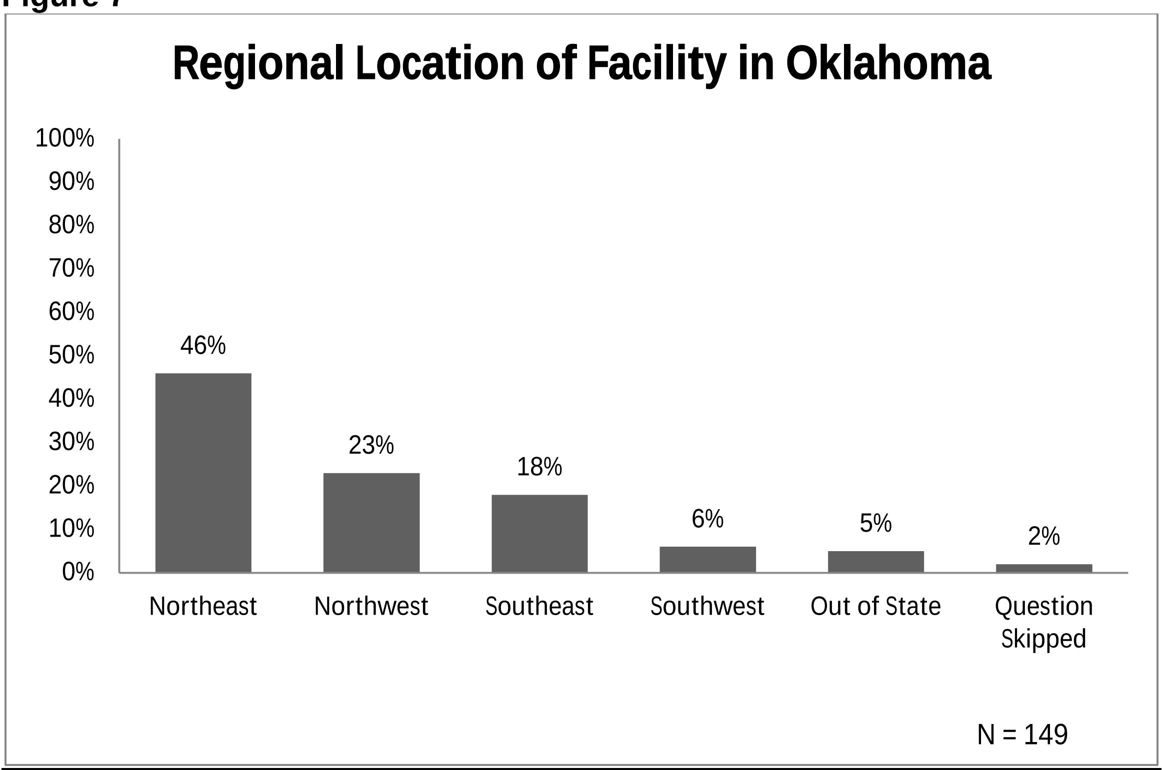


Figure 7



For the most part, survey participants have attained some college education. Approximately 38% have obtained some college education, while 46% have received a college degree, leaving only around 16% that have no college education (Figure 8). As seen in Figure 9, for those who have obtained a college degree, the majority received degrees in Turfgrass Management (32%). Nearly all survey participants (87%) have received certifications relating to turfgrass management. The two prevailing certifications acquired by respondents are the certified pesticide applicator and the licensed pesticide applicator, both state requirements (Figure 10).

Figure 8

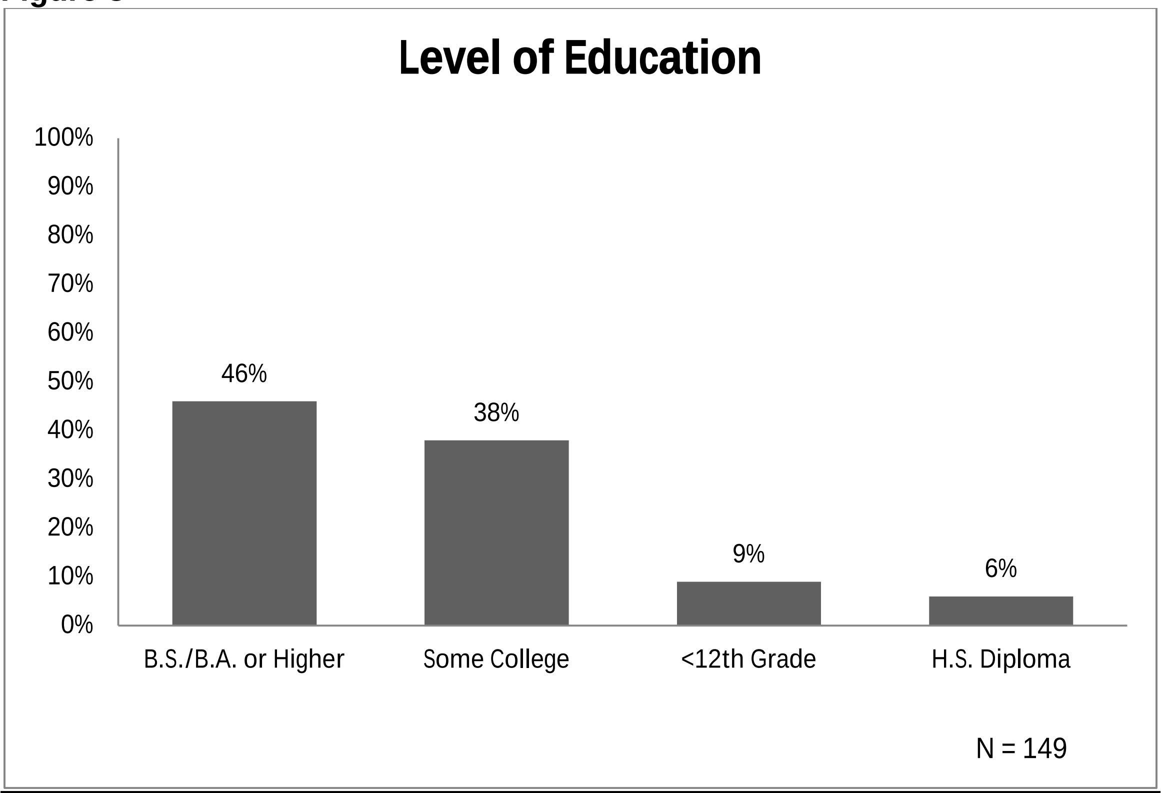


Figure 9

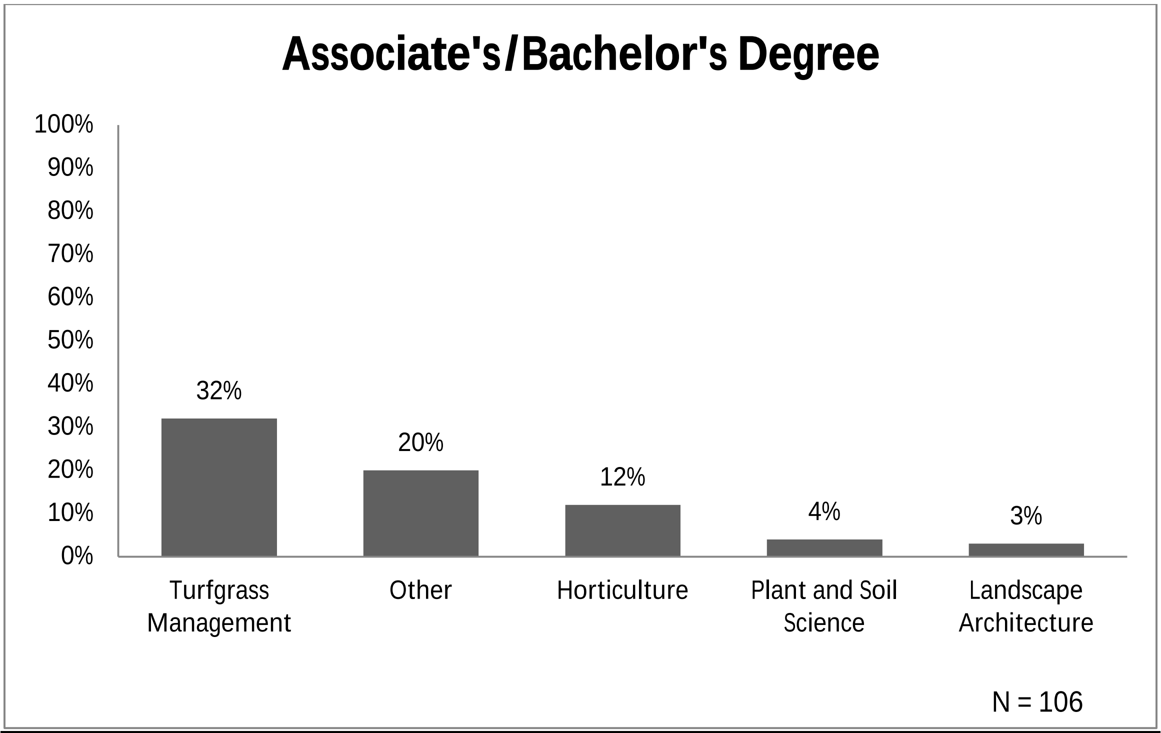
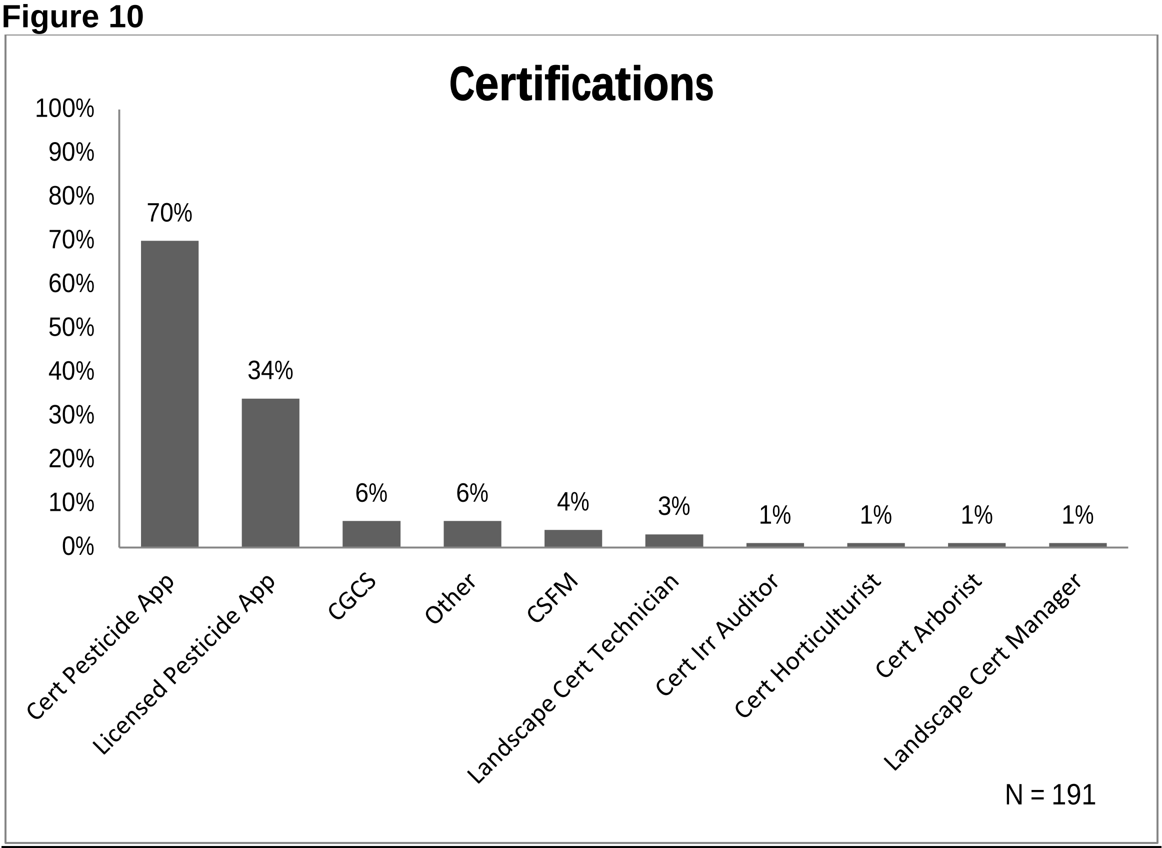


Figure 10



Tables 9 through 13 present the findings of the cross tabulations for the most used water conservation methods. The determinants of water conservation adoption examined in this section of the study are: facility type, watering methods, water source, education, certification, turfgrass acres, facility location, and age. The dominant determinants found upon examination of the data include: golf course, automated above ground automatic sprinkler systems, city water connection, B.S./B.A. or higher graduate, turfgrass management degree, and certified pesticide applicator.

For the reduced watering conservation method (Table 9), all dominant determinants yielded higher percentages of respondents adopting the water conservation strategy than not adopting. Of all the golf course facilities, 74% have adopted reduced watering as a strategy, while 26% have not. For facilities using automated sprinklers as current watering methods, 71% have adopted reduced watering. A majority 62% of respondents who use city water connections for irrigation water have also chosen to utilize this method to conserve water. 67% of college graduates partake in reducing water as do 66% of turfgrass management degree holders. Of the 105 certified pesticide applicators, 69% have reduced watering at their facilities. For respondents using reduced watering, facility size averages 147 acres whereas non-adopters average only 123 acres.

For the higher mowing heights of grass strategy (Table 10), again all dominant determinants produced greater percentages of respondents adopting the water conservation strategy than not adopting. Of golf course facilities, 73% have adopted the strategy. For facilities using automated sprinklers, 69% have adopted higher mowing heights. A majority 66% of respondents who use city water connections for irrigation water have also chosen to utilize this method to conserve water. Approximately 70% of managers who are college graduates partake in higher mowing heights, as do 68% of turfgrass management degree holders. Of the certified pesticide applicators, 70% implement higher mowing heights at their facilities. On average adopters have 144 acres of turfgrass whereas, non-adopters average 127 acres.

For the zoned irrigation strategy (Table 11), all dominant determinants, with the exception of golf course facilities, produced greater percentages of respondents adopting the water conservation strategy than not adopting. Of golf course facilities, only 50% have adopted the strategy. For facilities using automated sprinklers, 57% have adopted zoned irrigation. A majority 64% of respondents who use city water connections for irrigation water have also chosen to utilize this method to conserve water. For zoned irrigation, 55% of college graduates and 55% of turfgrass management degree holders have adopted. Of the 105 certified pesticide applicators, 56% implement zoned irrigation at their facilities. On average adopters have 150 acres of turfgrass whereas, non-adopters average 125 acres.

For the selection of improved cultivars for drought tolerance strategy (Table 12), most of the dominant determinants were associated with producing greater percentages of respondents not adopting the water conservation strategy. Of golf course facilities, only 44% have adopted the strategy, while 56% have not. For facilities using automated sprinklers, 51% have adopted selection of improved cultivars for drought tolerance. A majority 54% of respondents who use city water connections for irrigation water have not chosen to utilize this method to conserve water. Of college graduates, 52% participate in selection of improved cultivars for drought tolerance, but 53% of turfgrass management degree holders do not. Of the 105 certified pesticide applicators, only 45% implement selection of improved cultivars for drought tolerance at their facilities. For respondents using improved cultivars, facility size averages 170 acres whereas non-adopters average only 110 acres.

For the irrigation scheduling strategy (Table 13), all dominant determinants, with the exception of city water connection, produced greater percentages of respondents not adopting the water conservation strategy. Of golf course facilities, 61% have not adopted the strategy while only 39% have. For facilities using automated sprinklers, 54% have not adopted an irrigation scheduling strategy. A majority 53% of respondents who use city water connections for irrigation water have chosen to utilize this method to conserve water. Only 45% of college graduates participate in irrigation scheduling as do only 40% of turfgrass management degree holders. Of the certified pesticide applicators, 58% do not implement irrigation scheduling at their facilities. On average adopters have 174 acres of turfgrass whereas, non-adopters average 111 acres. The cross tabulation results show that with the decrease in the number of facilities who have adopted a particular water conservation practice, the average number of turfgrass acres being managed using the conservation technique generally increase.

Table 9.

Determinants of Conservation Adoption - Cross Tabulations					
Reduced Watering	**Never Used**	**%**	**Used**	**%**	**Total**
Golf Course	18	26%	52	74%	70
Recreational Park	10	45%	12	55%	22
Sports Field	11	52%	10	48%	21
Sod Farm	0	0%	3	100%	3
Other	21	45%	26	55%	47
Manual Sprinkler	11	31%	24	69%	35
Automated Sprinkler	33	29%	79	71%	112
Zoned Sprinkler	20	34%	38	66%	58
Manual Connection Sprinkler	18	47%	20	53%	38
Drip Irrigation	14	37%	24	63%	38
Soaker Hose	7	37%	12	63%	19
Spray by Hand	24	32%	51	68%	75
Other Watering Method	5	45%	6	55%	11
We do not irrigate	8	100%	0	0%	8
City	33	38%	54	62%	87
Private Well	10	26%	29	74%	39
Water Retention	7	24%	22	76%	29
Other	9	39%	14	61%	23
<12th Grade	6	43%	8	57%	14
H.S. Diploma	4	44%	5	56%	9
Some College	20	35%	37	65%	57
B.S./B.A.	23	33%	46	67%	69
Turfgrass Management	16	34%	31	66%	47
Landscape Architecture	3	60%	2	40%	5
Plant & Soil Science	4	67%	2	33%	6
Horticulture	7	39%	11	61%	18
Other	10	33%	20	67%	30
Certified Golf Course Superintendent (CGCS)	3	33%	6	67%	9
Certified Irrigation Auditor	1	50%	1	50%	2
Certified Sports Field Manager (CSFM)	4	67%	2	33%	6
Certified Pesticide Applicator	33	31%	72	69%	105
Licensed Pesticide Applicator	19	37%	32	63%	51
Certified Horticulturist	0	0%	1	100%	1
Certified Arborist	1	50%	1	50%	2
Landscape Industry Certified Manager	0	0%	1	100%	1
Landscape Industry Certified Technician	2	40%	3	60%	5
Other	4	44%	5	56%	9
Turfgrass Acres	123		147		
ZIP	73801		73401		
Age	42		43		

Table 10.

Determinants of Conservation Adoption - Cross Tabulations					
Higher Mowing Heights	**Never Used**	**%**	**Used**	**%**	**Total**
Golf Course	19	27%	51	73%	70
Recreational Park	10	45%	12	55%	22
Sports Field	11	52%	10	48%	21
Sod Farm	2	67%	1	33%	3
Other	18	38%	29	62%	47
Manual Sprinkler	13	37%	22	63%	35
Automated Sprinkler	35	31%	77	69%	112
Zoned Sprinkler	18	31%	40	69%	58
Manual Connection Sprinkler	13	34%	25	66%	38
Drip Irrigation	15	39%	23	61%	38
Soaker Hose	10	53%	9	47%	19
Spray by Hand	23	31%	52	69%	75
Other Watering Method	5	45%	6	55%	11
We do not irrigate	7	88%	1	13%	8
City	30	34%	57	66%	87
Private Well	12	31%	27	69%	39
Water Retention	9	31%	20	69%	29
Other	7	30%	16	70%	23
<12th Grade	8	57%	6	43%	14
H.S. Diploma	4	44%	5	56%	9
Some College	20	35%	37	65%	57
B.S./B.A.	21	30%	48	70%	69
Turfgrass Management	15	32%	32	68%	47
Landscape Architecture	3	60%	2	40%	5
Plant & Soil Science	3	50%	3	50%	6
Horticulture	5	28%	13	72%	18
Other	10	33%	20	67%	30
Certified Golf Course Superintendent (CGCS)	4	44%	5	56%	9
Certified Irrigation Auditor	1	50%	1	50%	2
Certified Sports Field Manager (CSFM)	2	33%	4	67%	6
Certified Pesticide Applicator	32	30%	73	70%	105
Licensed Pesticide Applicator	23	45%	28	55%	51
Certified Horticulturist	0	0%	1	100%	1
Certified Arborist	1	50%	1	50%	2
Landscape Industry Certified Manager	0	0%	1	100%	1
Landscape Industry Certified Technician	2	40%	3	60%	5
Other	4	44%	5	56%	9
Turfgrass Acres	127		144		
ZIP	73801		73401		
Age	43		43		

Table 11.

Determinants of Conservation Adoption - Cross Tabulations					
Zoned Irrigation	**Never Used**	**%**	**Used**	**%**	**Total**
Golf Course	35	50%	35	50%	70
Recreational Park	7	32%	15	68%	22
Sports Field	7	33%	14	67%	21
Sod Farm	2	67%	1	33%	3
Other	22	47%	25	53%	47
Manual Sprinkler	14	40%	21	60%	35
Automated Sprinkler	48	43%	64	57%	112
Zoned Sprinkler	18	31%	40	69%	58
Manual Connection Sprinkler	14	37%	24	63%	38
Drip Irrigation	15	39%	23	61%	38
Soaker Hose	9	47%	10	53%	19
Spray by Hand	32	43%	43	57%	75
Other Watering Method	7	64%	4	36%	11
We do not irrigate	7	88%	1	13%	8
City	31	36%	56	64%	87
Private Well	21	54%	18	46%	39
Water Retention	13	45%	16	55%	29
Other	15	65%	8	35%	23
<12th Grade	7	50%	7	50%	14
H.S. Diploma	3	33%	6	67%	9
Some College	28	49%	29	51%	57
B.S./B.A.	31	45%	38	55%	69
Turfgrass Management	21	45%	26	55%	47
Landscape Architecture	5	100%	0	0%	5
Plant & Soil Science	3	50%	3	50%	6
Horticulture	9	50%	9	50%	18
Other	10	33%	20	67%	30
Certified Golf Course Superintendent (CGCS)	6	67%	3	33%	9
Certified Irrigation Auditor	0	0%	2	100%	2
Certified Sports Field Manager (CSFM)	6	100%	0	0%	6
Certified Pesticide Applicator	46	44%	59	56%	105
Licensed Pesticide Applicator	24	47%	27	53%	51
Certified Horticulturist	1	100%	0	0%	1
Certified Arborist	1	50%	1	50%	2
Landscape Industry Certified Manager	1	100%	0	0%	1
Landscape Industry Certified Technician	1	20%	4	80%	5
Other	4	44%	5	56%	9
Turfgrass Acres	125		150		
ZIP	73801		74012		
Age	43		43		

Table 12.

Determinants of Conservation Adoption - Cross Tabulations					
Improved Cultivars	**Never Used**	**%**	**Used**	**%**	**Total**
Golf Course	39	56%	31	44%	70
Recreational Park	13	59%	9	41%	22
Sports Field	9	43%	12	57%	21
Sod Farm	2	67%	1	33%	3
Other	24	51%	23	49%	47
Manual Sprinkler	20	57%	15	43%	35
Automated Sprinkler	55	49%	57	51%	112
Zoned Sprinkler	31	53%	27	47%	58
Manual Connection Sprinkler	19	50%	19	50%	38
Drip Irrigation	16	42%	22	58%	38
Soaker Hose	9	47%	10	53%	19
Spray by Hand	40	53%	35	47%	75
Other Watering Method	4	36%	7	64%	11
We do not irrigate	7	88%	1	13%	8
City	47	54%	40	46%	87
Private Well	16	41%	23	59%	39
Water Retention	19	66%	10	34%	29
Other	11	48%	12	52%	23
<12th Grade	10	71%	4	29%	14
H.S. Diploma	5	56%	4	44%	9
Some College	31	54%	26	46%	57
B.S./B.A.	33	48%	36	52%	69
Turfgrass Management	25	53%	22	47%	47
Landscape Architecture	4	80%	1	20%	5
Plant & Soil Science	1	17%	5	83%	6
Horticulture	13	72%	5	28%	18
Other	10	33%	20	67%	30
Certified Golf Course Superintendent (CGCS)	5	56%	4	44%	9
Certified Irrigation Auditor	0	0%	2	100%	2
Certified Sports Field Manager (CSFM)	4	67%	2	33%	6
Certified Pesticide Applicator	58	55%	47	45%	105
Licensed Pesticide Applicator	27	53%	24	47%	51
Certified Horticulturist	1	100%	0	0%	1
Certified Arborist	1	50%	1	50%	2
Landscape Industry Certified Manager	0	0%	1	100%	1
Landscape Industry Certified Technician	4	80%	1	20%	5
Other	2	22%	7	78%	9
Turfgrass Acres	110		170		
ZIP	73801		74012		
Age	43		42		

Table 13.

Determinants of Conservation Adoption - Cross Tabulations					
Irrigation Scheduling	**Never Used**	**%**	**Used**	**%**	**Total**
Golf Course	43	61%	27	39%	70
Recreational Park	11	50%	11	50%	22
Sports Field	7	33%	14	67%	21
Sod Farm	2	67%	1	33%	3
Other	28	60%	19	40%	47
Manual Sprinkler	22	63%	13	37%	35
Automated Sprinkler	61	54%	51	46%	112
Zoned Sprinkler	32	55%	26	45%	58
Manual Connection Sprinkler	23	61%	15	39%	38
Drip Irrigation	21	55%	17	45%	38
Soaker Hose	11	58%	8	42%	19
Spray by Hand	47	63%	28	37%	75
Other Watering Method	5	45%	6	55%	11
We do not irrigate	8	100%	0	0%	8
City	41	47%	46	53%	87
Private Well	21	54%	18	46%	39
Water Retention	18	62%	11	38%	29
Other	17	74%	6	26%	23
<12th Grade	10	71%	4	29%	14
H.S. Diploma	6	67%	3	33%	9
Some College	31	54%	26	46%	57
B.S./B.A.	38	55%	31	45%	69
Turfgrass Management	28	60%	19	40%	47
Landscape Architecture	4	80%	1	20%	5
Plant & Soil Science	3	50%	3	50%	6
Horticulture	10	56%	8	44%	18
Other	13	43%	17	57%	30
Certified Golf Course Superintendent (CGCS)	6	67%	3	33%	9
Certified Irrigation Auditor	0	0%	2	100%	2
Certified Sports Field Manager (CSFM)	4	67%	2	33%	6
Certified Pesticide Applicator	61	58%	44	42%	105
Licensed Pesticide Applicator	27	53%	24	47%	51
Certified Horticulturist	1	100%	0	0%	1
Certified Arborist	0	0%	2	100%	2
Landscape Industry Certified Manager	0	0%	1	100%	1
Landscape Industry Certified Technician	2	40%	3	60%	5
Other	5	56%	4	44%	9
Turfgrass Acres	111		174		
ZIP	73801		74008		
Age	43		43		

Table 14 summarizes the probit model information for the five most used water conservation methods: Model 1 - reduced watering, Model 2 - higher mowing heights of grass, Model 3 - zoned irrigation systems, Model 4 - selection of improved cultivars for drought tolerance, and Model 5 - irrigation scheduling based on plant water requirements as estimated by site-specific weather data.

Model 1 produced a log likelihood of -75.7418 and fourteen coefficients significant at a 95% confidence level. Both sports field facilities and other facilities positively affect the probability of adopting reduced watering as a water conservation strategy. Manual sprinklers, automated sprinklers, soaker hose, and spraying by hand as needed are all current watering methods which have a negative impact on the probability of adopting reduced watering. Of these watering methods, use of soaker hoses for irrigation has the greatest negative impact. Manual connection sprinklers however, increase the likelihood of adoption. Three of the water sources have a significantly negative affect on probability of adoption with private well water having the greatest negative affect followed by on site water retention and city water connection. An increase in the number of turfgrass acres at a facility decreases the probability of reducing water. Regionally, facilities in Oklahoma's Northwest are more likely to adopt this conservation method than ones in the Northeast. Having a reverse affect, both out of state and Southwest facilities reduce the likelihood of adopting reduced watering when compared to facilities in the Northeast.

Model 2 produced a log likelihood of -81.10395 and fifteen coefficients significant at a 95% confidence level. Both sports field and sod farm facilities increase the probability of adopting higher mowing heights of grass as a water conservation strategy. All of the watering methods except other watering methods have a significant affect on adoption. Manual sprinklers, drip irrigation, soaker hoses, and having no irrigation practices all increase the likelihood of implementing higher mowing heights of grass while automated sprinklers, zoned sprinklers, manual connection sprinklers, and spraying by hand have the opposite affect and decrease the probability of adoption. Facilities which acquire their irrigation water from city water connections, private wells, and other water sources reduce the probability of using higher mowing heights to conserve water. Individuals who have obtained a college degree are less likely to adopt this water conservation technique than individuals who have no college education. The only region which has a significant impact on the possibility of adoption is the Northwest. Facilities in the Northwest are more likely to utilize higher mowing heights than facilities in the Northeast.

Model 3 produced a log likelihood of -86.0693 and thirteen significant coefficients, including the intercept, at a 95% confidence level. In this model, both recreational park and sod farm facilities have a significant affect on the probability of adopting zoned irrigation. Recreational park facilities reduce the likelihood of adoption while sod farm facilities increase the likelihood of using zoned irrigation systems. Use of manual sprinklers, drip irrigation, soaker hoses, and having no current irrigation practices all increase the likelihood of using zoned irrigation systems. Facilities that use automated sprinklers, zoned sprinklers, and spraying by hand as needed for irrigation are less likely to use this water conservation method. The only water source to have a significant impact on adoption, city water connection, is expected to decrease the probability of using zoned irrigation systems. Having a college degree increases the likelihood of adoption compared to not having any college education. Facilities located in the Southeast are less likely to adopt this water conservation technique than facilities in the Northeast.

Model 4 produced a log likelihood of -83.1073 and seventeen coefficients significant at a 95% confidence level. Golf courses, recreational parks, sod farms, and other facilities all have a positive affect on the probability of adopting the selection of improved turfgrass cultivars for drought tolerance as a water conservation strategy. Of these facilities sod farms have the greatest positive impact while recreational parks have the least. Use of manual sprinklers and having no current irrigation practices both have a positive influence on probability of adoption while the use of automated sprinklers, zoned sprinklers, and other watering methods have a negative influence. Two of the four water sources, city water connection and on site water retention, increase the likelihood of using improved cultivars whereas use of private wells and other watering sources decrease the probability. For every acre increase in turfgrass at a facility the likelihood of adopting selection of improved cultivars is decreased slightly. Facilities located in the Northwest and Southwest regions are more likely to adopt this conservation practice than facilities in the Northeast. Out of state facilities are less likely to conserve water using the selection of improved cultivars than facilities in Northeast Oklahoma.

Model 5 produced a log likelihood of -78.8713 and nineteen significant coefficients, including the intercept, at a 95% confidence level. In this model, four of the five facility types have a significant impact of the probability of adopting irrigation scheduling based on plant water requirements. Golf courses, sod farms, and other facilities increase the probability of adoption while sports fields carry the opposite effect. Use of manual sprinklers, manual connection sprinklers, drip irrigation, and spraying by hand for irrigation all increase the likelihood of adoption whereas probability of adoption of irrigation scheduling is decreased by use of automated sprinklers, soaker hoses, and other watering methods. Facilities which rely on city water connections and private wells for irrigation water are less likely to adopt this water conservation technique. Individuals who either have some college education of received a degree are less likely to adopt irrigation scheduling than individuals who do not have any college education. For every acre increase in turfgrass the probability of utilizing irrigation scheduling decreases slightly. Facilities located in the Northwest region of Oklahoma are more likely to adopt irrigation scheduling than facilities in the Northeast. Out of state facilities are less likely to adopt this conservation measure than facilities located in Northeast Oklahoma.

Table 14

Determinants of Conservation Adoption – Models 1-5
The Probit Procedure

	Model 1 - Reduced	Model 2 - Higher Mowing	Model 3 - Zoned Irrigation	Model 4 - Improved Cultivars	Model 5 - Irrigation Scheduling
Log Likelihood	-75.7418	-81.10395	-86.0693	-83.1073	-78.8713
N	149	149	149	149	149
Intercept	0.5140	0.4840	0.7253 *	-0.0994	1.3633 *
	(0.9876)	(0.9326)	(0.9432)	(0.9841)	(1.0329)
Golf	0.0597	0.0759	0.1597	0.9035 *	0.4403 *
	(0.5804)	(0.5372)	(0.5515)	(0.5861)	(0.5901)
Rec	0.1316	0.1264	-0.3603 *	0.4592 *	-0.1326
	(0.4639)	(0.4318)	(0.4685)	(0.4639)	(0.4605)
Sports	0.4880 *	0.5152 *	-0.0264	0.1182	-0.3771 *
	(0.4833)	(0.4614)	(0.4809)	(0.4938)	(0.5002)
Sod	-5.4121	0.9013 *	0.7798 *	1.8283 *	1.4914 *
	(26814.15)	(1.0938)	(1.1148)	(1.1952)	(1.1804)
OF	0.3893 *	0.0067	0.1525	0.5340 *	0.3936 *
	(0.5333)	(0.5037)	(0.5267)	(0.5412)	(0.5482)
MS	-0.2533 *	0.2985 *	0.2735 *	0.5079 *	0.2987 *
	(0.3387)	(0.3287)	(0.3236)	(0.3303)	(0.3430)
AS	-0.3319 *	-0.3598 *	-0.4285 *	-0.5745 *	-0.5997 *
	(0.3524)	(0.3348)	(0.3414)	(0.3553)	(0.3931)
ZS	0.0470	-0.5620 *	-0.9313 *	-0.2416 *	-0.0696
	(0.3292)	(0.3319)	(0.3252)	(0.3243)	(0.3392)
MCS	0.9705 *	-0.3979 *	-0.1853	-0.1975	0.5192 *
	(0.3778)	(0.3743)	(0.3462)	(0.3473)	(0.3645)
DI	0.0350	0.3520 *	0.5000 *	-0.1376	0.4778 *
	(0.3807)	(0.3634)	(0.3640)	(0.3608)	(0.3765)
SH	-0.8402 *	1.0111 *	0.4248 *	-0.0705	-0.6441 *
	(0.5211)	(0.4667)	(0.4535)	(0.4437)	(0.4647)
SBH	-0.4091 *	-0.2170 *	-0.2623 *	0.0036	0.2653 *
	(0.3191)	(0.2977)	(0.2919)	(0.2966)	(0.3081)
OWM	-0.2079	-0.1923	-0.0036	-1.5288 *	-0.9330 *
	(0.5851)	(0.5456)	(0.5454)	(0.6055)	(0.6147)
NoIrr	8.6630	1.6372 *	1.0410 *	1.8633 *	7.9680
	(14094.51)	(0.6923)	(0.7051)	(0.8606)	(14107.63)
City	-0.4148 *	-0.4380 *	-0.5323 *	0.3308 *	-0.9524 *
	(0.4046)	(0.3826)	(0.3629)	(0.3631)	(0.3983)
Private	-0.7406 *	-0.4703 *	-0.0984	-0.5746 *	-0.8147 *
	(0.3949)	(0.3802)	(0.3469)	(0.3633)	(0.3810)
Reten	-0.4285 *	0.0926	0.2156	0.8640 *	-0.0396
	(0.4280)	(0.3978)	(0.3697)	(0.3889)	(0.3840)
OWS	-0.1936	-0.6545 *	0.1659	-0.3302 *	-0.1880
	(0.4619)	(0.4576)	(0.4202)	(0.4189)	(0.4457)
College	-0.1375	-0.1602	0.4102 *	-0.0858	-0.6843 *
	(0.4025)	(0.3813)	(0.3930)	(0.3917)	(0.4112)
BS	0.0941	-0.4448 *	-0.0029	-0.1012	-0.8179 *
	(0.4348)	(0.4104)	(0.4185)	(0.4245)	(0.4474)
Cert	0.0010	-0.0777	-0.1618	-0.2417	0.2134
	(0.4339)	(0.4133)	(0.3979)	(0.4154)	(0.4209)
Acres	-0.0005 *	-0.0000	-0.0003	-0.0012 *	-0.0011 *
	(0.0005)	(0.0005)	(0.0007)	(0.0014)	(0.0007)
Age	-0.0061	-0.0011	0.0001	0.0074	-0.0021
	(0.0114)	(0.0112)	(0.0110)	(0.0110)	(0.0118)
SE	-0.2343	0.1198	-0.3416 *	-0.2268	0.0928
	(0.3731)	(0.3546)	(0.3441)	(0.3417)	(0.3459)
NW	0.4444 *	0.4573 *	0.2138	0.2351 *	0.8006 *
	(0.3521)	(0.3403)	(0.3303)	(0.3327)	(0.3566)
SW	-0.4554 *	0.0972	-0.1934	0.6109 *	0.2233
	(0.6384)	(0.5349)	(0.5030)	(0.6311)	(0.5762)
OS	-0.9047 *	0.0361	-0.3011	-1.6630 *	-0.5080 *
	(0.6976)	(0.6008)	(0.5543)	(0.7384)	(0.6550)

* Denotes significance at a 95% confidence level

Because adoption exceeded 50% of respondents for only three types of water conservation strategies, higher mowing heights, reduced watering, and zoned irrigation systems, there appears to be a lack of motivation or incentive on the part of Oklahoma turfgrass managers to participate in water conservation. Even though respondents consider lowering cost of water used to be an important motivation for adopting water conservation strategies, concern for maintaining performance and appearance of turfgrass for users overshadows those concerns as the most cited barrier to adoption. Thus, no one technique is likely to meet managers' needs given the concerns of appearance and performance.

Dominant determinants which generally increased probability of adoption of the top five most used water conservation strategies included: facilities located in the Northwest region, Sod Farm facilities, and facilities which utilize manual sprinkler systems or do not irrigate at all. Dominant determinants that most often decreased the likelihood of adopting the top five most used water conservation techniques included: utilization of automated and zoned sprinklers for irrigation, facilities which rely on city water connections and private wells for irrigation water, and increases in turfgrass acres at a facility. Quite simply, these conditions of non-adoption are not random, facilities with automated sprinklers are more likely to have invested in them to ensure turf aesthetics, city water connections indicate likelihood of higher returns to use and/or turf managers have already switched to private wells to avoid higher costs of treated water.

Results suggest extension efforts should be directed at aiding managers in the Southern regions first, continuation of sprinkler auditing training programs, and targeting facilities with greater number of acres first and then smaller facilities second. An additional approach, such as that taken in Georgia, would involve aiding golf and parks managers in development of best management plans for water conservation as a long term conservation tool, rather than a short term emergency response to seasonal or prolonged drought.

OBJECTIVE 2 – Determine the accuracy and reliability of remote sensing reference evapotranspiration (ET) data with established crop coefficients compared to actual landscape plant water use in Oklahoma.

Objective 2 was split between two separate studies. For easier reading, each study will be discussed separately below.

Study 1: Calculation of historical growing season reference ET from 1994 to present day using Oklahoma Mesonet data.

Methodology:

The Oklahoma Mesonet ET Model is a weather-based tool for the estimation of daily water loss from a plant canopy through the combined processes of evaporation and transpiration. Using weather data from the Oklahoma Mesonet, the model calculates daily grass reference evapotranspiration (ET_0G) for each Mesonet site, and, based on those values, estimates daily values for alfalfa reference ET, cool-season grass ET (e.g., a fescue lawn), warm-season grass ET (e.g., a bermudagrass lawn), and pan evaporation.

The model uses the FAO-recommended Penman-Monteith equation. The ET is calculated for a hypothetical well-watered grass surface of 12 cm height with a bulk surface resistance equal to 70 s/m. Using 5-minute Mesonet data to calculate the various parameters, the model uses the 24-hour calculation approach. Soil heat flux, G, is assumed equal to zero (consistent with the recommendation). The 5-minute average weather variables from Mesonet that are used in the calculation are:

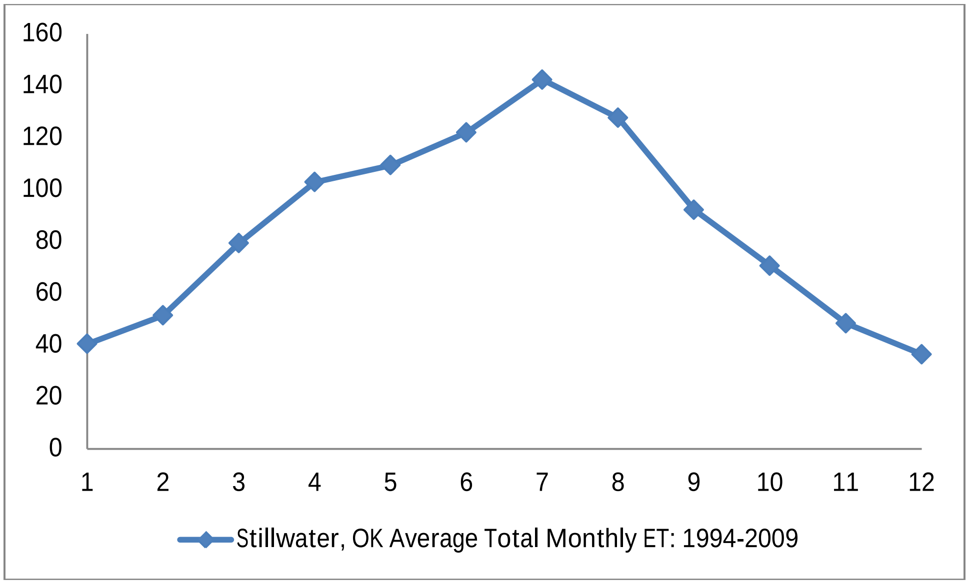
- Solar Radiation (W/m2)
- 2-m Wind Speed (m/s)
- 1.5 m Air Temperature (C)
- 1.5 m Relative Humidity (%)
- Station Pressure (kPa)

Dew point, when needed, is calculated from the air temperature and relative humidity. At station sites not measuring 2-m wind speed, an objective analysis scheme is used to interpolate a value.

Principal Findings and Significance:

Average total monthly ET was calculated from 1994 – 2009 for the Oklahoma Mesonet site at Stillwater, OK (Figure 11). As expected, July and August were the months with the highest total ET at 8.9 and 8.0 inches, respectively. June had the third highest total monthly ET at 7.6 inches.

Figure 11. Average total monthly ET (inches) from 1994-2009 at the Stillwater, OK Mesonet Site.



Study 2: Estimate actual plant water use by conducting field lysimeter and atmometer studies compared to Oklahoma Mesonet ET data.

Methodology:

In addition to the Oklahoma Mesonet reference ET estimates, we also calculated on-site ET at Stillwater, OK using two techniques: 1) modified Bellani plate atmometer (ET Gage, Spectrum Technologies, Plainfield, IL) and 2) weighing micro-lysimeters.

Principal Findings and Significance:

The Bellani plate atmometer method estimated a total monthly ET of 6.5 inches while the Oklahoma Mesonet site recorded a reference ET of 6.8 for August 2010 (Table 11). During September 2010, the atmometer method estimated a total monthly ET of 4.8 inches while the Oklahoma Mesonet site recorded a reference ET of 5.1 (Table 11). Based on the bermudagrass lysimeters during the same two months, total monthly ET of bermudagrass plants was 6.7 inches in August 2010 and was 4.2 in September 2010 (Table 15).

Table 15. Estimated and actual bermudagrass evapotranspiration (ET) in inches during August and September 2010 in Stillwater, OK. Means followed by different letters are different at the 0.05 significance level according to the least significant difference test.

Method	**August 2010**	**September 2010**
	ET (inches)	
Oklahoma Mesonet	6.8 a	5.1 a
Atmometer	6.5 b	4.8 b
Bermudagrass Lysimeter	6.7 ab	4.2 c

Based on these findings, the Oklahoma Mesonet gives a reliable estimate of bermudagrass ET during August 2010, but may overestimate ET during cooler periods such as during September 2010. Similarly, the atmometer data gave a reliable estimate of bermudagrass ET during August 2010, but overestimated bermudagrass ET during September 2010. These results indicate that there is a need to refine crop coefficients for turf areas in Oklahoma, especially during the fall and possibly spring growing periods.

OBJECTIVE 3 – Educate Oklahoma stakeholders and citizens of landscape irrigation practices to conserve Oklahoma water resources.

Methodology:

Three “hands-on”, “train-the-trainer” workshops were conducted during 2010 to educate Oklahomans of proper turf and landscape irrigation practices to conserve water resources. The target audience was Oklahoma Master Gardeners in three Oklahoma counties: Rogers, Tulsa, and Oklahoma. Master Gardeners were chosen as the target audience because each Master Gardener is required to volunteer at least 40 hours per year through their local OSU Cooperative Extension Service county office. Once properly trained, the Master Gardeners have the potential to extend the turf and landscape water conservation information to hundreds of Oklahomans in and near Claremore, Tulsa, and Oklahoma City. The workshops were delivered by Mr. John Haase, OSU CES County Educator in Rogers County, and by PI Justin Moss during 2010.

Principal Findings and Significance:

Seventy-six Master Gardeners attended the training workshops. There were 27 attendees in Rogers County, 27 attendees in Tulsa County, and 22 attendees in Oklahoma County. Each participant completed a pre- and post-survey to assess the effectiveness of the training workshop. In the pre-survey, each participant was asked if they watered their lawns, and if they responded “yes”, they were asked if they knew the quantity of water in inches that they applied to their lawn on a given basis. Of those that responded yes, 83% of participants did not know how many inches they watered their lawn on a given basis. The simple irrigation audit workshop was then delivered to the participants. After participating in the workshop, the participants were asked to conduct a simple irrigation audit at their home and to report the results to Mr. Haase. All participants conducted the simple irrigation audit at their homes and reported their audit results to Mr. Haase. Therefore, 100% of the participants stated in the post-workshop survey that they know how many inches of water were delivered on a given basis for their home irrigation sprinklers. The Master Gardener participants were then instructed to “extend” this information to the general public through their volunteer hours at their local OSU County Extension office. Critical future work should focus on tracking participant outreach and dissemination of simple irrigation audit procedures and practices to conserve water resources to the general public.

As of the writing of this OWRRI report, Mr. Haase is in the process of finishing his M.S. thesis with further results of this project which were not stated as objectives in this OWRRI research grant proposal. Mr. Haase has an expected M.S. thesis completion and graduation date of Summer 2011. Therefore, the research team will orally present further results of this work at the Summer 2011 OWRRI research meeting.