Outdoor Water Use Conservation through Native Plants

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Abstract

The front lawn with the white picket fence is one of the iconic images of the American suburb. But in California, the front lawn is one of the greatest consumers of outdoor water use. Because of population growth, water is becoming scarcer every year and thus it is important to find ways to change our water consumption so that there is enough for all sections of society. This report focuses on the city of Davis and investigates whether water and money can be saved by changing residents' front lawns into a landscape of native plants. Five different city blocks in Davis were digitized to calculate average lawn size, which was then extrapolated to represent all lawns in the city. A series of calculations were done to gain estimates of the total water use for regular turfgrass and buffalo grass (developed by UC Davis as a water efficient alternative to turfgrass) using the Crop Coefficient Method. We also calculated the total water use for native plants using the Landscape Coefficient Method, the cost of water for both grass and native species, and the economic viability of making the change from turfgrass to a native plant landscape. Our results show that native plants use an estimated total water use of 422 acre feet/year while turfgrass requires 1407 acre feet/year- a 60% reduction in water use. While this reduction is significant, our calculations of water cost show that there is only a $46 difference per year for the different landscapes. Furthermore, our economic analysis illustrates that in order to make the switch from turfgrass to native plants, residents would have to pay a cost of $3960 and they would not get a return on their investment until 23 years later. Therefore, a large amount of water can be saved in Davis by converting lawns to native plant landscapes but due to the cheap price of water, residents lack an incentive to make the change.

Introduction

Our project is about outdoor water use, specifically, a landscape's water requirement. The major factors affecting a landscape's water requirement are the present climate, the average evapotranspiration, the area of the landscape, and the water consumption of the plants. A landscape's water requirement is important because according to the EPA, landscape irrigation is estimated to account for one-third of all residential water use. Our project will go in depth on water conservation; we wanted to further examine if it is possible to save water by using native plants instead of turfgrass, and by how much it will benefit a homeowner. Given that lawn water requirements are a rather significant amount of total water use, it is important to find alternatives to better manage the allocation of water towards this specific use.

Objective

The main objective of this project was to estimate whether or not converting residential yards with non-native grasses into those with native plants would be cost-effective and decrease water consumption for the city of Davis. This project was divided into three main tasks. The first was the estimation of average lawn size per residence and summation of total lawn area for Davis. There was not enough time and resources to conduct ground measurements for each individual lawn in Davis, therefore we had to choose a few city blocks and measure the average lawn size by digitization. The second task was the analysis of water consumption rates of conventional lawns and native plants by comparing evapotranspiration rates and the necessary amount of water the different types of plants consume. Using equations found in WUCLOS, we were able to estimate the water consumption and our end product was an approximation of how much water the entire city would need per year to sustain each of these landscapes. The third task was a cost benefit analysis that would determine if it would be worthwhile for a homeowner to remove turfgrass and install the native plants instead. For this analysis we used an interest rate formula and our results showed us how many years it would take for a resident to see a return on his or her initial investment on converting a lawn over to native plants.

Hypothesis

It is possible to estimate outdoor landscape water use in the city of Davis by knowing evapotranspiration rates, plant type, and landscape area. We further hypothesize that by converting lawns in Davis to native plants landscapes water consumption and costs will be reduced significantly compared to current usage and costs.

Data Sources

Crop Coefficient and Landscape Coefficient equations and variables from WUCOLS (2000)

Buffalograss Information from Takao Nursery

Evapotranspiration rate for Davis from CIMIS website

Herbicide information on RoundUp from Scotts Micracle-Gro Company

NAIP 2010 Imagery from Cal-Atlas

Native plants species suggestions from the Arboretum All-Stars

Native plants species suggestions from the Redwood Barn Nursery

Native plants species suggestions from Kelly’s Color Nursery

Native Plant Price Information from Annie’s Annuals

Parcel Data and Water Rate data from the City of Davis 2010 Water Management Plan

Methods and Assumption

Methods: Calculating Lawn Area

To calculate lawn area we used 2010 NAIP aerial imagery downloaded from the Cal Atlas website. We then proceeded to digitize lawns from different blocks in Davis. We chose 5 different blocks in different parts of the city: North, South, East, West, and Central. The aerial imagery had a resolution of 1 meter, but this proved insufficient for delineating lawn area. Thus, we used Google Earth alongside the NAIP image to help with the digitization. After creating polygons of all the lawns, we calculated the area of each shape in square feet. We found many pros and cons to measuring lawn area with this method. The pros are that we can measure many more lawns in a shorter amount of time by using aerial imagery. We also have a view of the front and back lawn of a house. This method also allows a single person to map all the lawn areas. If we had measured lawn area in person we would have needed a team of people with us. The cons of using this method were that we didn't have as high as accuracy compared to on the ground measurements. Additionally, on the ground measurements would have allowed me to better differentiate between lawn and other vegetation such as trees and grass.

Assumptions: **Lawn Area**

Because we are only using a few blocks of houses and then extrapolating to the entire city, we are assuming that everyone in Davis has a lawn. Of course this is not true so our method overestimates the amount of lawn area in Davis.

Methods: **Estimating Total Water Use for Lawns**

To calculate total water use for turfgrass, we used The Crop Coefficient Method as described in WUCOLS III:

Crop Evapotranspiration = Crop Coefficient x Reference Evapotranspiration

ETc = Kc x ETo

Kc was given to us in WUCOLS, we chose to use the crop coefficient for cool season grasses.

The ETo for Davis was retrieved from the CIMIS website.

We also chose to calculate water use for a special type of turfgrass: UC Verde Buffalograss. This grass was developed by scientists at UC Davis and UC Riverside to be water efficient in the Central Valley climate. According to the Takao Nursery, this species of grass only needs a half an inch of water per week once it is established.

Assumptions: Estimating Total Water Use for Lawns

By using the Crop Coefficient Method we are assuming that everyone in Davis grows the same species of grass on their yard. Thus our equation may be overestimating or underestimating water use depending if people choose to grow cool season turfgrasses or warm season turfgrasses.

Methods: Estimating Total Water Use for Native Plants

To estimate the total water use for a native plant landscape we referred to the Landscape Coefficient Method:

Landscape Coefficient = species factor x density factor x microclimate factor

$K_L = k_s \times k_d \times k_{mc}$

Landscape Evapotranspiration = Landscape Coefficient x Reference Evapotranspiration

$ET_L = K_L \times ETo$

Different equations were needed for the native plants because landscape plants are usually composed of more than one species. They can also be planted in a variety of different densities and these landscapes will include a range of microclimates depending on where the plants are placed.

Assumptions: Estimating Total Water Use for Native Plants

Because the Landscape Coefficient Method has so many variables, there is not one combination that will accurately reflect the water use of every house in Davis. Different homeowners will plant different species in differing ranges of density. Whether plants are placed on the North or South side of a house or whether they are in a windy or protected area will greatly affect how much water a plant will lose. Since we can't calculate all these different combinations, we tried to use a number for each variable that fell in the middle range.

Methods: Estimating the Cost of Water

In order to calculate the cost of water we took the estimated water requirement of both native plants and convention grasses and converted the units from gallons/year to cubic hundred feet (ccf) because Davis calculates their water bill using ccf as their units. Afterwards, this number was multiplied by the Tier 1 water rate at $1.50 per ccf. The number produced was the cost of water per year that each type of grass required.

Assumptions: Estimating the Cost of Water

The Tier 1 water rate was chosen for this calculation because the majority of households do not reach Tier 2, or only pass Tier 2 slightly. Since Tiers are calculated based on cumulative water usage of the entire household, lawns may not be the only cause high water bills. Also, we assume that there are no irregularities during the year that would cause the water requirement of the grass to rise and push the household into the Tier 2, costing $1.90 per ccf. In reality, grass, as well as households, would demand more water in the summer months than in the winter months. Therefore, it could be very likely that our estimate was low because lawns may be responsible for households reaching the Tier 2 rate during peak water demand periods.

Methods: Estimating Cost of Lawn Removal

The cost of lawn removal would include labor and materials necessary to eliminate the existing lawn. The amount of herbicide needed would correspond to the 4 treatments during a 3-4 week time period. The cost of herbicide is determined by the average cost ($30 per container) of 1.33 gallon container of the herbicide, Roundup Weed & Grass Killer Plus Weed Preventer Pump 'N Go, and this number is multiplied to meet the appropriate lawn area.

Assumptions: Estimating Cost of Lawn Removal

We are assuming that the homeowner is willing to remove the lawn him/herself because this is the most cost effective method. Also, we assume that the homeowner has access to the necessary tools, except herbicide, to remove the lawn. In addition, water is needed in the process of removing the lawn, but we neglected this cost because water needs varies. The amount of water needed varies because this depends on existing weather conditions, as well as time of year the homeowner plans to remove the native plants. Water costs would be higher in the summer or drier conditions, and lower in the spring or wetter conditions. Also, Roundup product was arbitrarily chosen as the herbicide of choice because it suggested by the UC Verde Buffalograss website. In addition, the amount of herbicide required also varies because there is variability in the resiliency of grasses and weeds from lawn to lawn.

Methods: Cost of Installing Native Plants

The cost of installing native plants would include the labor and the materials needed start the plants. We took three native plants with low water needs and got the price for each and the diameter that they eventually grew to be, then added both those things together to determine the total price and amount of plants needed to fill the median Davis yard area.

Assumptions: Cost of Installing Native Plants

Again, we assume the homeowner is absorbing the labor and material costs, so the only monetary cost to them would be purchasing the native plants. Extra water may be needed in the process of removing the old grass and weeds, as well as in helping the native plants getting established, but the amount of water needed can vary depending weather and time of planting, so we neglected this cost as well as the extra water cost from removing the existing grass.

Methods: Cost-Benefit Analysis for Converting to Native Plants

We used equation 3.1 from the interest rate formulas and plugged in the annual water cost difference between homeowners who have lawns and homeowners who have native plants, a savings of $46. We also included the initial investment ($3600) and the herbicide purchased in order to do lawn removal ($360) . Knowing these two amounts, we can determine the amount of time it takes for the homeowner to get a full return from their internal investment (in years). We also chose 4 percent for our interest rate.

Assumptions: Cost-Benefit Analysis for Converting to Native Plants

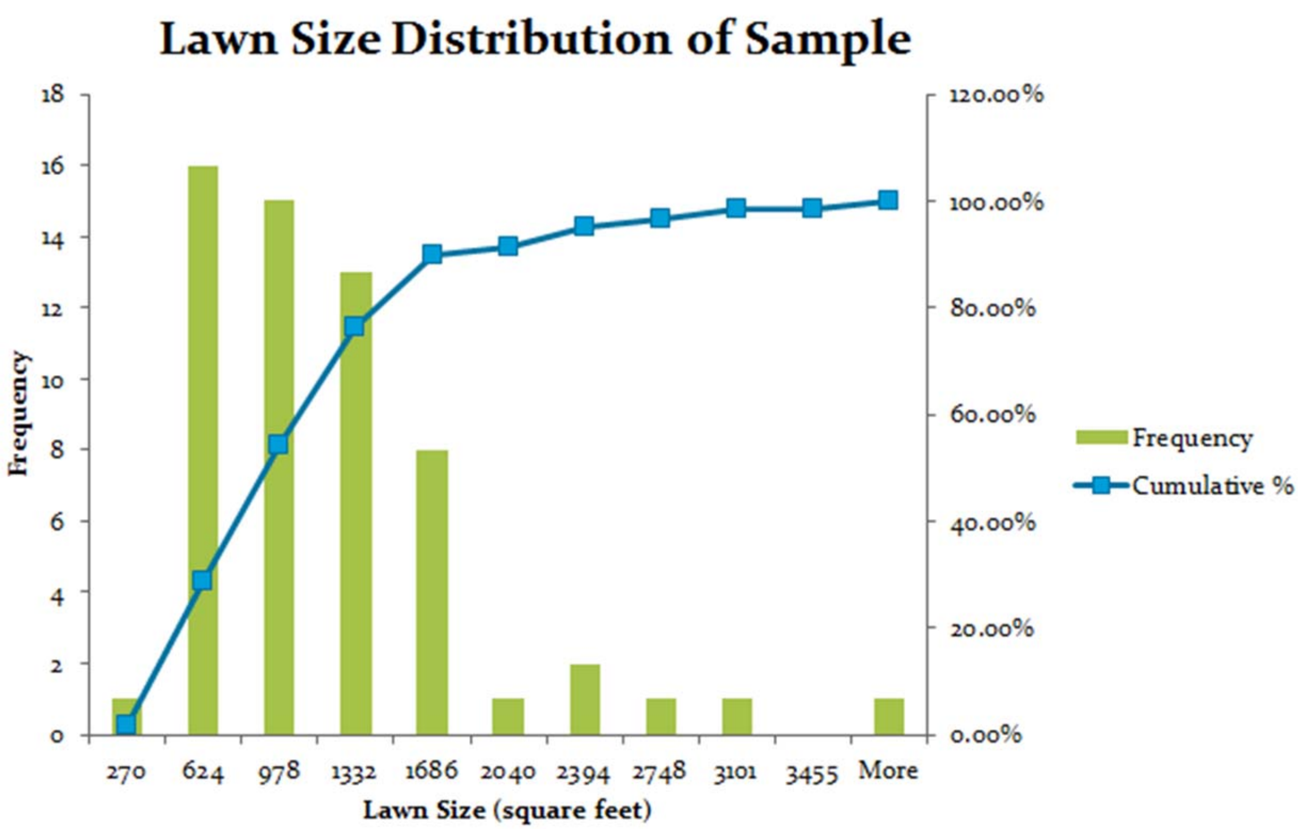
Our initial investment is probably too high. The price of the plants was calculated using the individual cost of each plant, but in reality, a homeowner is likely to pay less money for buying the plants in bulk. Additionally, we used an interest rate of 4%; since interest rates are always fluctuating, a homeowner may get his initial investment back sooner or later depending on the state of the economy.

Calculation/Results

Lawn Area:

Once we had the area of all of polygons that we had digitized on the aerial image, we did some simple statistics to get the spread of our data:

Count:	59
Minimum:	270 ft^2
Maximum:	3809 ft^2
Mean:	1073 ft^2
Median:	897 ft^2
Standard Deviation:	670 ft^2
Total Parcels in Davis	14,725



When we viewed the spread of the data graphically, we saw that we had a number of outliers in the upper range. This greatly skewed the mean and thus we chose to use t*he median lawn size of 897 square feet for our calculations.*

Turfgrass:

As stated above, we use the Crop Coefficient Method to calculate water use for turfgrass. Once we had this number, we used the median lawn area, an irrigation efficiency of 0.75, and the number of homeowner parcels in Davis to calculate the water use for the city and per household.

Estimating Water Needes for Turfgrass			
ET 0	52.5		
Kc	0.8		
ET Landscape	42	inches	
ET Landscpae	42		
Area (sq ft)	897.06207		
Conversion (ft to gallons)	0.62		
Water ET	23359.496	gallons/year	
Water ET	23359.496		
Irrigation Efficiency	0.75		
Applied Water	31145.995	gallons/year	
Applied Water per house	31145.995		
Total homeowner parcles	14725		
Total Water Use of City	458624777	gallons/year	
	1407.4659	acre feet/year	

For the Buffalograss we did a similar calculation:

Buffalo Grass			
0.5	inches per week		
52	Weeks/ year		
26	inches per year		
Water Need/year	26	inches	
Area (sq ft)	897.0621		
Conversion (ft to gallons)	0.62		
Applied Water per house	14460.64	gallons/year	
	0.044378	acre-ft/year	
Total homeowner parcels	14725		
	0.044378	acre-ft/year	
Irrigation Efficiency	0.75		
Total Water Use of City	871.2884	acre feet/year	

As we can see regular turfgrass requires 1407 acre feet/ year for the city, but buffalo grass only needs 871 acre feet/ year

Native Plants

For our native plant landscape our calculations are laid out here:

Estimating Water Needs for Landscape Plantings		
Species Factor ks	0.2	low
density factor kd	1	average
microclimate factor kmc	1.2	
Landscacpe Coefficient KL	0.24	
Landscacpe Coefficient KL	0.24	
Reference Evap Eto	52.5	
Landscape Evapo Et L	12.6	inches
Landscape Evapo Et L	12.6	
Irrigation Efficiency	0.75	
Total Water Applied	16.8	inches/year
Total Water Applied	16.8	inches/year
Area	897.06207	
Conversion (ft to gallons)	0.62	
	9343.7985	gallons/year
Applied Water per house	9343.7985	
Total parcles	14725	
Total Water Use of City	137587433	gallons/year
	422.23977	acre-ft/year

We can see that compared to turfgrass, native plants would use only 422 acre-feet/ year for the entire city. This is a 60% decrease in water use!

Water Cost

We simply took the average water used annually to water turfgrass and native plants and converted them to ccf and multiplied by Tier 1 rate to get the annual cost of each.

Tuffgrass: 33,086 gal per year * 1ccf/748 gal *$1.50 per ccf= *$66*

Native Plants: 9,925 gal per year * 1ccf/748gal *$1.50 per ccf= *$20*

This results in annual savings of $46 dollars, if lawns were converted to native plants.

Lawn Removal

The cost of the Roundup product is $30 and covers ~300 sq. feet. The Roundup needs about 3-4 treatments over the course of a month to kill all existing vegetation.

897sq ft/300sq. ft.= 3 Bottles of Roundup per treatment

3 Bottles * $30 per bottle * 4 treatments=*$360 would be spent on herbicide needed to remove lawn*

Native Plant Installation

The total price for our three native plants was $30, and this covered 7.25 square feet. The median lawn area (897 sqft) was divided by 7.25 in order to determine how many bundles of native plants needed to be purchased. Afterwards, we just multiplied this number with $30 to get the cost of replanting the lawn.

897 sq. ft. /7.25 sq. ft. = *123 units needed to cover entire lawn.*

123 units * $30 per unit = *$3600 is the cost for 123 units of native plants*

Cost-Benefit Analysis: Return on Initial Investment

After adding up the cost of lawn removal and native plant planting, we use interest rate formula 3.1. t is time in years. The cost of the native plants plus the herbicide to kill the lawn comes out to $3960.

46=3960([.04*(1+.04)^t]/[(1+.04)^t]-1)=> *t=23 years is the time it would take to make up the initial investment through water savings.*

Conclusions

Through our research, we found that our hypothesis was partly correct. We were able to estimate outdoor landscape water use for the city of Davis and our calculations showed that converting lawns to native plant landscapes would significantly reduce water usage cost. However, based on our water cost calculations, we found that there was only a $46 per year difference between people who have lawns and people who have native plants. Thus, costs would not be significantly reduced by switching landscapes because water is so cheap in Davis. However, if residents were willing to pay an upfront cost of $3960 to remove their lawns and replace them with native plants, their investment would start to show profit in water cost savings after 23 years. On a larger scale, people in other parts of the world may be able to use our data as a model for their own water conservation landscape plans, but it is important to remember that our calculations rely on very specific information from our area. If someone from another city wanted to do a similar analysis, they would have to adjust the variables to account for the climate and the native plants in their area. What we've gotten from the project is that the price of water is so low that there is not much of an economic incentive for residents to give up their green lawns and put in native plants.

Recommendation/Limitations

Our limitations have be enumerated throughout the report. There are limitations in the aerial imagery we used to estimate lawn area, as well the variables we used to calculate water use and water cost. Because there are so many factors that went into the calculations we cannot claim complete accuracy or specification for our water estimates for Davis. For further study, we would recommend that more lawns be measured throughout Davis to increase the quality of our sample. Additionally, we recommend that the landscape coefficient method be run multiple times with a range of variables in order to get a better representation of the different landscapes that exist in Davis.

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