Research Report on Turfgrass Allowance

Purpose

The purpose of this report is to present and explain data indicating that residential landscapes consisting primarily of turfgrass use considerably more water than landscapes with a mixture of other plants. When the U.S. Environmental Protection Agency's (EPA's) WaterSense® program submitted its draft criteria for water-efficient new homes for public comment, numerous individuals responded that turfgrass should not be restricted in the landscapes of new homes.

Turfgrass indeed offers many benefits such as controlling erosion, filtering stormwater runoff, and decreasing surrounding air temperatures; these points are not in dispute. Within the scope of water efficiency, however, there is a compelling case to design yards with climate-appropriate amounts of turfgrass and a mixture of other landscape plants that provide similar benefits. This report presents the data supporting EPA's position that outdoor water use in single-family new homes must be addressed by the *WaterSense Single-Family New Home Specification* and that limiting turfgrass can result in significant water savings.

1.0 Introduction

WaterSense is a voluntary, national program sponsored by EPA with a goal to preserve water for future generations by helping to transform the market for water-efficient products and services. The WaterSense label is a simple way for consumers to identify products that have been independently certified to meet EPA's criteria for efficiency and performance.

For the past three years, EPA has been developing a specification for water-efficient single-family new homes to encourage the construction of houses that use at least 20 percent less water than a traditional new home, both inside and out. Indoors, the homes will feature WaterSense labeled products, ENERGY STAR qualified appliances when installed, and other water-efficient fixtures and plumbing systems. Outdoors, the homes will feature water-efficient landscaping and efficient irrigation systems, if installed. Homeowners will be provided with a manual that educates them on all aspects of water efficiency in their new home.

The goal of the landscape design criterion in the specification is to encourage home builders to install water-efficient landscapes in new homes, thus minimizing the need for supplemental watering. Builders have the option of designing the landscaped area to use a regionally appropriate amount of water (determined by a landscape water budget) or to design the landscaped area to contain no more than 40 percent turfgrass.

The intent of the turfgrass allowance is to promote practical turf areas that meet specific functional needs, such as play areas for children. An average-sized yard* landscaped in 40 percent turfgrass yields almost 2,500 square feet of functional area. Practical turf areas are just

* Based on an average lot size of 0.35 acres (U.S. Census 2007 American Household Survey, median lot size) minus the footprint of the home and permanent hardscapes.

one component of Xeriscape[**], a seven-step approach for making a landscape more water-efficient. Xeriscaping is a common practice throughout the United States, with programs existing in more than 40 states.[1] Through the *WaterSense Single-Family New Home Specification* and the *Resource Manual for Building WaterSense Labeled New Homes*, WaterSense promotes all aspects of Xeriscaping, including planning and design, soil analysis, appropriate plant selection, practical turf areas, efficient irrigation, use of mulches, and appropriate maintenance.

2.0 Outdoor Water Use

WaterSense has addressed outdoor water usage in the specification because a large portion of publically-supplied water used in homes is applied outdoors. On average, single-family homes in this country use 30 percent of their household water outdoors[2]; however, in many areas of the country, outdoor water use ranges from 50 to 70 percent.[3] For example, 60 percent of residential water is used outdoors in Phoenix, Arizona,[4] and 70 percent of residential water is used outdoors in Las Vegas, Nevada.[5]

Examining outdoor water use and finding ways to be more efficient is important because our demand as a nation is growing faster than our water resources can manage. Between 1950 and 2000, the U.S. population increased nearly 90 percent, while the amount of water used from the public supply increased by 208 percent.[6] For example, in 1965, average daily water use in Georgia was 50 gallons per person. In 2000, the per capita use had risen to approximately 200 gallons per day, a large portion of which was used outdoors.[7]

Once considered a problem only in desert regions, water supply issues have become more common nationwide in less drought-prone regions such as Georgia[8] and the Northeast.[9] Even under non-drought conditions, at least 36 states have predicted water shortages by 2013.[10]

Not only does outdoor water use comprise a significant portion of residential use, it stresses existing water supplies by contributing to peak demand during summer months.[11] During these hot, dry times, utilities must increase capacity to meet residential landscape irrigation requirements, sometimes as much as three to four times the amount used during winter months.[12] For example, rain rarely falls in Austin, Texas, during July and August; as a result, the city's overall water use increases by nearly 100 percent compared to winter use.[13] Even in temperate regions of the country, peak demand occurs during spring and summer months. A study in a region east of the Mississippi River demonstrated that water use increased by one third during the spring to fall growing season.[14]

3.0 Landscape Design Impacts on Water Use

Research suggests that turfgrass receives the highest percentage of the residential irrigation water in traditional landscaping. Several studies indicate that commonly used varieties of turfgrass require more water than many commonly used landscape plants. In addition, homeowners tend to overwater turfgrass. As a result, landscapes with large expanses of turfgrass generally use more water than those planted with a mixture of other plants such as groundcover, shrubs, and trees.

[**] Term coined by Nancy Leavitt of Denver Water in the early 1980s (Sovocool and Rosales)

a. Water Use on Turfgrass-Dominated Landscapes

Many research studies show that turfgrass-dominated landscapes, typical of residential yards in the United States, use more water than those with a mix of regionally appropriate plants such as groundcover, shrubs, and trees. While many of these studies were conducted in the western United States due to the serious water supply issues facing those regions, water savings from switching to regionally appropriate landscapes are still expected elsewhere in the country.

In Marin, California, a study of 548 dwelling units found a strong correlation between the perimeter of turf and water use. Researchers developed a multiple regression model of water applied to the landscape compared to the turf perimeter, turf area, and total landscape area. Results showed a very strong correlation ($R^2 = 0.91$), with turf perimeter identified as the dominant independent variable. When comparing turf-dominated landscapes to those dominated by water-conserving tree, plant, and shrub varieties, the researchers found that the turf-dominated landscapes used 54 percent more water than the mixed landscapes.[15]

A study of 27 residential sites in Las Vegas monitored the water use of mixed landscapes (ranging in percentages of turfgrass area) to quantify savings from newly installed satellite irrigation controllers. The researchers conducted an analysis on turfgrass area and water use. Results showed that 81 percent of the variation in total outdoor water use was described by the total turfgrass area at each site. Based on this finding, the author noted that turf limitations in an arid environment may have merit if the variety being limited is tall fescue.[16]

The Irvine Ranch Water District in Orange County, California, conducted an analysis of irrigation water use for different villages in the City of Irvine. A comparison of acre-feet per acre of water consumption on irrigated areas indicated that plant material, or type of plant, has an impact on water use. One village that consisted of homes landscaped mainly with California native plants used 1.39 acre-feet of water per acre (54 percent) less than another village that consisted of homes with nearly 100 percent turfgrass landscapes.[17]

The Southern Nevada Water Authority conducted a five-year Xeriscape study comparing landscape water use before and after converting turfgrass to water-efficient landscaping. Per unit area, the water-efficient landscaping used 76 percent less water (55.8 gallons per square feet) than turfgrass.[18]

Likewise, an estimate from Arizona stated that a 3,000-square-meter turfgrass lawn in the state uses 9,000 to 15,000 gallons of water per month, whereas the same area covered with plants, shrubs, and trees uses only 800 to 1,300 gallons per month.[19]

b. Turfgrass Water Requirements

Scientists have studied turfgrass water use for many varieties commonly planted in the United States. These varieties are categorized as either cool season or warm season turfgrasses, based on ideal growing conditions such as soil temperatures.[20] Common cool season turfgrasses include tall fescue and Kentucky bluegrass and grow best at soil temperatures between 16 and 24° Celsius (C), commonly in northern or humid regions. Common warm season turfgrasses include bermudagrass and St. Augustinegrass, which grow best in soil temperatures between 27 and 35° C, commonly in southern or arid regions.[21]

Plant water use is commonly explained in terms of a reference evapotranspiration (ET_o) and crop coefficients. Evapotranspiration (ET) is by definition "the loss of water from a vegetated surface through the combined processes of soil evaporation and plant transpiration." Reference evapotranspiration refers to the ET from a 3- to 6-inch-tall cool season grass that completely covers the ground and is supplied with adequate water. Crop coefficients are adjustments made to ET_o regarding specific plant water requirements.[22]

Kneebone et al.[23] stated that cool season turfgrasses use approximately 80 to 100 percent of ET_o, whereas warm season varieties typically use 80 to 90 percent of ET_o.[24] A previous study[25] stated that the appropriate mid-season crop coefficient for bermudagrass ranges from 0.6 to 0.8 and should be applicable to other warm season grasses, including Zoyia and St. Augustinegrass. It was noted that water applied under 60 percent of ET_o may result in unhealthy turfgrass. Specific evapotranspiration rates for a variety of turfgrass species can be located in Table 5.2 of *Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes*.[26]

While studies to quantify the water use of trees and shrubs are much less extensive[27], limited research indicates that landscapes planted with a mixture of shrubs and trees generally results in lower water use than those dominated by common turfgrass species such as Kentucky bluegrass or tall fescue. Kjelgren et al.[28] explained that the limited studies that do exist on water loss rates for temperate-climate woody species vary widely with both plant and environmental factors[29] but that generally, water-loss rates are lower than those for turfgrass. Research on California landscape plants is more extensive than in most other regions of the country and shows that water requirements for vegetation commonly found throughout the state range from 100 percent of ET_O for cool season grasses to 70 percent of ET_O for warm season grasses, 50 percent of ET_O or less for groundcover, and 20 percent of ET_O for shrubs and trees.[30]

Additionally, research suggests that groundcover, shrubs, and trees can maintain an acceptable appearance at lower levels of water application than many common turfgrasses. For example, studies of groundcover in Colorado and California showed that several species performed acceptably well when water was applied at 20 percent or 50 percent of ET_O.[31] Similarly, a study examining the appearance of transplanted young oaks in San Francisco showed that various water applications (0, 25, or 50 percent of ET_O) had no affect on their growth after the one-year establishment period.[32] Another study in Southern California examined six of the most common groundcover species to determine the minimum amount of irrigation required to maintain the species. With proper irrigation and soil maintenance the species were consistently maintained with an acceptable appearance at 33 percent of ET_O.[33] In Colorado, a research study examined the water use of 15 commonly planted shrubs and compared water use to a typical Kentucky bluegrass lawn. The average crop coefficient for the landscapes plants was 0.56. The study stated that a typical bluegrass lawn receiving traditional management practices of watering, mowing, and fertilizing would have a crop coefficient of 0.81. The researcher noted a rule of thumb—"a typical bed of landscape plants will require about two-thirds the amount of water as a Kentucky bluegrass lawn."[34] Research from California agrees with the Colorado study demonstrating that a typical California lawn of cool season turfgrass can require several times more water than one consisting of native plants.[35]

The non-uniformity of landscape plantings also plays a role in the water use of mixed-plant landscapes versus turfgrass. Kjelgren et al.[36] stated that uniform turfgrasses can be considered a benchmark for high water use because of their need for a uniform appearance, as opposed to the non-uniformity of woody and perennial plants. He noted that trees, shrubs, and perennials generally tolerate drought more effectively than turfgrass and maintain an acceptable appearance under water stress, as opposed to turfgrasses, which go dormant. Kjelgren explained that reducing the amount of irrigation water applied to meet plant uniformity needs can moderate irrigation demand, but emphasizes that precision-irrigated turf landscapes still consume large amounts of water.

c. Watering Habits on Turfgrass-Dominated Landscapes

While southern and arid regions of the United States have suitable climates for warm season turfgrass, it is common to see plantings of cool season varieties. Unfortunately, this leads to water requirements that are unsustainable for these regions. In addition, homeowners tend to overwater turfgrasses, often by overwatering the entire lawn to avoid a few dry spots. Overwatering can cause numerous problems for turfgrass health, including a shallow root system; increased disease, weeds, or insect infestation; reduced drought tolerance; increased thatch and excessive growth; and reduced tolerance to other stresses such as shade and soil problems.[37]

Homeowners also prefer to keep yards lush and green, even during the winter months. Many turfgrass varieties can go dormant during certain parts of the year and will turn brown, but are still healthy and will naturally return to a green color when the season changes. Unfortunately, homeowners commonly water throughout the winter to keep their lawns green. To address this issue, many utilities are developing educational campaigns to promote turfgrass dormancy and discourage watering during dormant periods.

4.0 Other Programs

The turfgrass allowance option in the WaterSense specification is consistent with other national and regional green building programs and local water-efficiency programs. Nationally, the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®) for Homes program awards points for the reduction of conventional turfgrass in the landscape. Similarly, the National Association on Homes Builders' National Green Building Standard and Green Building Guidelines award points for limited turfgrass. Additionally, the Sustainable Sites Initiative recommends the use low-water-demand vegetation and notes that if turfgrass is installed, it should be regionally appropriate and minimize post-establishment requirements for irrigation

At the regional level, various green building programs around the country address turfgrass installation in new homes. Build It Green California requires that all installed turf has a water requirement lower than that of tall fescue. In addition, it awards points for limiting turfgrass to 33 percent of the landscape and additional points for limiting turfgrass to 10 percent of the landscape. East Bay Municipal Utility District's WaterSmart program, also in California, limits turf areas to no more than 25 percent of the total irrigated area. In Colorado, Built Green requires the landscape design to follow the Xeriscape principle of practical turf areas. In the Las Vegas metropolitan area, Southern Nevada Water Authority's WaterSmart Home program excludes the use of turfgrass in the front yard and limits the use of turfgrass in the back yard to 50 percent of the landscapable area, not to exceed 1,000 square feet.

Some cities across the country have also begun to limit the amount of turfgrass installed in new homes. For example, in 2002, El Paso, Texas amended its municipal code to restrict turf areas to 50 percent or less of the total outdoor landscaped area.[38] Other utilities and cities are providing incentives to reduce turfgrass in landscapes, including Southern Nevada Water Authority, Albuquerque Bernalillo County Water Utility Authority in New Mexico, the City of Chandler, Arizona, San Antonio Water System in Texas, and Aurora Water in Colorado.[39]

5.0 Benefits of Water-Efficient Landscapes

There are many benefits associated with landscapes that combine a mixture of shrubs, trees, and groundcover with functional areas of turfgrass, including water savings, aesthetics, functionality, and reductions in maintenance and chemical use.

a. Water Savings

Various studies across the country have quantified savings from converting landscapes dominated by turfgrass to those that are water-efficient in nature.

Southern Nevada Water Authority's Xeriscape program demonstrated a water savings of 30 percent in landscapes that converted at least 500 square feet of turfgrass to Xeriscape with a minimum of 50 percent tree canopy coverage. The author acknowledged that other parts of the country may not see such large savings due to the arid climate of Las Vegas, but noted that the 30 percent savings realized per average-sized conversion was consistent with the findings of studies conducted in other localities.[40]

A report by the Pacific Institute described a study in the North Marin Water District that demonstrated how proper choice of plants and landscape design could reduce water use up to 54 percent.[41] The report also showed that turfgrass reductions used 19 to 33 percent less water than traditional turfgrass landscapes.[42] The author noted that the landscape plants that replaced turfgrass were not necessarily low-water-using. He estimated the potential water savings in California from outdoor residential landscape design ranges as follows:

- Turfgrass reduction: 275,000 acre feet/year (AF/yr) to 480,000 AF/yr
- Landscape design: 275,000 AF/yr to 780,000 AF/yr
- Low-water-using plant choice: 435,000 AF/yr to 1,160,000 AF/yr

A study examining the impacts of Xeriscape application in seven cities in the Front Range in Colorado demonstrated that water savings ranged from 18 percent to more than 50 percent compared to control samples. The study suggested that water savings in the 30 percent range could be sustained for a properly designed and maintained Xeriscape. In this study, new property owners achieved water savings with a landscape design using approximately one quarter low-water-using plants, one quarter medium-water-using plants, and up to half the area with traditional turfgrass. The author predicted water savings might increase if the design were shifted to one third each of low-water-using plants, medium-water-using plants, and traditional turfgrass.[43] The report also listed similar studies with associated water savings ranging from 20 to 50 percent.[44]

In addition to overall savings, it is important to note that much of the recorded water savings occurred during summer months, thereby reducing peak water use for utilities. In many parts of the country, utilities face peak demand during the growing season, due to increased irrigation water use. Often, new infrastructure is required to meet peak demand. Reducing outdoor water use decreases the peak in summer months, potentially saving utility infrastructure costs. For example, the Southern Nevada Water Authority reported that the average monthly difference in irrigation application between the Xeriscape and turfgrass groups was 9.62 gallons per square foot in July, demonstrating the lack of a "peak" for the Xeriscape group. The study concluded that per unit area, Xeriscape reduced the winter-to-summer peak use by 48 percent.[45]

While it is true that a portion of the water savings from these studies may be attributed to efficient irrigation, it also true that a portion is due to landscape design.[46]

b. <u>Attractive Landscapes and Functional Turf Areas</u>

As mentioned above, the landscape design option of 40 percent turfgrass allows for an adequate area of functional turf, approximately 2,500 square feet on an average-sized landscape. The remaining landscape should consist of a variety of shrubs, trees, and groundcover resulting in an attractive and functional yard. The mixed-variety landscape provides habitat for wildlife, shaded areas, and outdoor spaces for homeowners to enjoy. Figure 1 represents a landscape with 100 percent turfgrass and Figure 2 represents a sample WaterSense labeled new home landscape.

Figure 1. Sample Landscape with 100 Percent Turfgrass

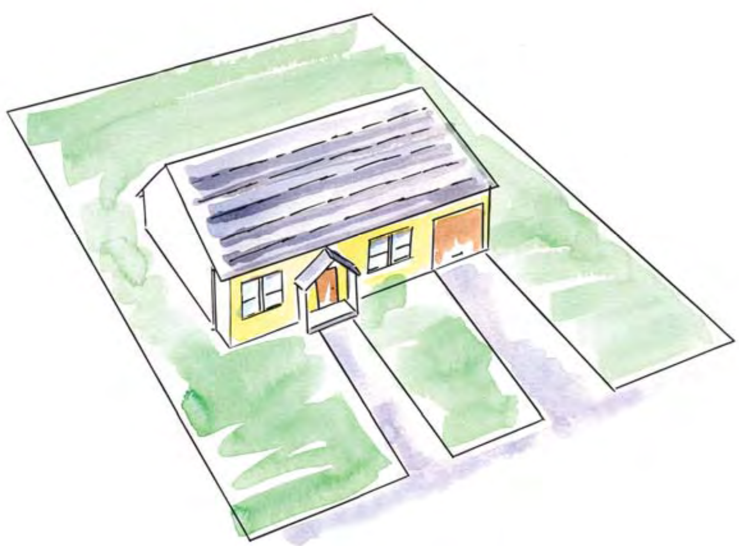

Figure 2. Sample WaterSense Labeled New Home Landscape

c. Other Benefits

Landscapes that combine a mixture of plants with a functional area of turfgrass achieve the same, if not greater, benefits than landscapes dominated by turfgrass. Many landscape plants such as groundcover and native grasses are effective at reducing runoff from the site. Common landscape plants such as trees and shrubs can be more effective than turfgrass at reducing site temperature, controlling erosion, and trapping pollutants from stormwater.[47] Various environmental benefits include:

- In addition to providing the same cooling effect through evapotranspiration to the atmosphere that turf does, trees and tall shrubs provide additional cooling benefits by shading building rooftops, sidewalks, and other impermeable materials that absorb and reradiate solar energy.[48,49]

- During the summer, trees can help shade home exteriors from the summer sun, reducing cooling needs.[50] Reduced energy needs in buildings translate to lower energy bills for residents and lower green house gas emissions.

- With deeper root systems and dense networks of fine roots, trees and shrubs help to stabilize soils, reducing erosion.[51]

- Many landscape plants such as groundcover and native grasses are effective at reducing runoff from a site. Additionally, they require little or no fertilizer, reducing fertilizer runoff into local waterways.[52]

In addition to the benefits listed above, water-efficient landscapes can reduce the maintenance, time, and money homeowners spend on their yards, as well as the need for chemicals to keep lawns green. Well-designed native landscapes can reduce required maintenance as compared to an all-turfgrass landscape.[53] Sovocool et al.[54] reported that study participants with predominantly Xeriscape landscapes reported average annual reductions of 26.4 hours of labor and $206 in direct maintenance costs compared with participants with turfgrass-dominated landscapes. Similarly, Nelson[55] showed that water-efficient landscapes reduced labor needs by 25 percent. Additionally, the study showed a reduction in fertilizer use by 61 percent, fuel use by 44 percent, and herbicide use by 22 percent.[56]

6.0 Conclusion

Limiting turfgrass in water-efficient landscapes is a common practice in green building programs across the country; EPA, however, wanted to strike a balance between design flexibility and water savings. The WaterSense approach to outdoor water efficiency is holistic in nature, promoting both water-efficient landscaping and flexibility in design practices. The *WaterSense Single-Family New Homes Specification* provides two options to meet the landscape criteria, one of which is a landscape water budget, and the other a turfgrass allowance of 40 percent.

Because climates and landscapes vary so much from region to region, the water budget option offers the most flexibility for builders interested in meeting the specification. EPA decided to include a turfgrass allowance because not all builders will opt to use the water budget approach. WaterSense based the percentage of turf allowed on the research described in this report indicating that landscape water use is higher in traditional turf-dominated yards than those with a mixture of landscape plants and smaller areas of turfgrass.

For homeowners seeking to reduce their outdoor water use without giving up their lawns, WaterSense labeled new homes offer a viable alternative. In addition to allowing turfgrass based on a set percentage or local climate conditions, the *WaterSense Single Family New Home Specification* encourages regionally-appropriate plant selection that ensures healthy, beautiful yards that require less maintenance and save water for future generations.

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[1] Wade, Gary L. and James T. Midcap. 2000. *Xeriscape: A guide to developing a water-wise landscape.* Cooperative Extension Service. The University of Georgia College of Agricultural and Environmental Services. Griffin, GA.

[2] Vickers, Amy. 2002 *Handbook of Water Use and Conservation*. Amherst, MA: WaterPlow Press.

[3] Gregg, Tony T., Dan Strub, and Drema Gross. 2007. Water efficiency in Austin, Texas, 1983–2005: An historical perspective. *Journal AWWA*, 99 (2):76–86.

Ferguson, B.K. 1987. Water conservation methods in urban landscape irrigation: An exploratory overview. *Water Resources Bulletin*, 23:147–152.

Mayer, Peter W. and William B. DeOreo.1998. Residential End Uses of Water. Aquacraft, Inc. Water Engineering and Management. American Water Works Association.

Milesi, Cristina. 2005. Mapping and modeling the biogeochemical cycling of turf grasses in the United States. *Environmental Management*, 36 (3):426–438.

Sovocool, K.A. and J.L. Rosales. 2001. A five-year investigation into the potential water and monetary savings of residential xeriscape in the Mojave Desert. 2001 American Water Works Association Annual Conference Proceedings. June. Southern Nevada Water Authority, Nevada (working paper supported by the Southern Nevada Water Authority and the U.S. Bureau of Land Management). <http://www.snwa.com/assets/pdf/xeri_study.pdf>

Vickers, *Op. cit.*

Yabiku, Scott T., David G. Casagrande, and Elizabeth Farley-Metger. 2008. Preferences for landscape choice in a southwestern desert city. *Environment and Behavior*, 40 (3): 382–400.

[4] *Idem.*

[5] Devitt, D. A., K. Carstensen, and R. L. Morris. 2008. Residential water savings associated with satellite-based ET irrigation controllers. *Journal of Irrigation and Drainage Engineering*, 134(1):74–82.

[6] Hutson, Susan S., Nancy L. Barber, Joan F. Kennedy, Kristin S. Linsey, Deborah, S. Lumnia, and Molly A. Maupin. Estimated use of water in the United States in 2000. U.S. Geological Survey Circular 1268. U.S. Department of the Interior. U.S. Geological Survey.

[7] Wade and Midcap 2000, *Op. cit.*

[8] Wade, Gary L. 2005. Water-use demonstration landscape: a case study in water conservation. Paper presented at the 2005 Georgia Water Resources Conference, April 25–26, in Athens, Georgia.

Wade and Midcap, *Op. cit.*

[9] Vickers, Amy. 2006. New directions in lawn and landscape water conservation. *Journal AWWA,* 98 (2):57-61,158.

[10] U.S. Government Accountability Office. 2003. Freshwater Supply: States' Views of How the Federal Government Could Help Them Meet the Challenges of Expected Shortages. GAO-03-514. <http://www.gao.gov/new.items/d03514.pdf>.

[11] Gregg, *Op. cit.*

Pleasance, Glen. 2002. "Quantified reductions in residential irrigation." Paper presented at the American Water Works Association Water Sources Conference Proceedings.

Wade and Midcap, *Op. cit.*

[12] Vickers, Amy. 1991. The emerging demand-side era in water management. *Journal AWWA,* 83:38–43.

[13] Gregg, *Op. cit.*

[14] Kjelgren, Roger, Larry Rupp, and Doug Kilgren. 2000. Water conservation in urban landscapes. *HortScience*, 35 (6):1037–1040.

[15] Nelson, John Olaf. 1987. Water conservation landscapes show impressive savings. *Journal AWWA*, 79 (10):35–42.

[16] Devitt et al., *Op. cit.*

[17] Sanchez, Fiona M. 2006. "Impact of landscape plant palettes and community development planning on irrigation water use." Paper presented at the American Water Works Association Water Sources Conference Proceedings.

[18] Sovocool, Kent A., Mitchell Morgan, and Doug Bennett. 2006. An in-depth investigation of Xeriscape as a water conservation measure. *Journal AWWA,* 98 (2):82–93.

[19] Richard, G. 1993. Pima county's buffers. Planning 59:15–17.

[20] Beard, James B. and Michael P. Kenna. 2006. *Water quality of quantity issues for turfgrasses in urban landscapes*. Ames, Iowa: Council for Agricultural Science and Technology.

[21] *Idem.*

[22] Brown, Paul. 2000. Basics of Evaporation and Evapotranspiration. University of Arizona Cooperative Extension, College of Agriculture and Life Sciences. <http://ag.arizona.edu/pubs/water/az1194.pdf>.

[23] Kneebone, W., D. Kopec, and C. Mancino. 1992. Water requirements and irrigation. Turfgrass. *American Society of Agronomy*, 32:441–472.

[24] *Idem.*

[25] Kneebone, W.R. and I.L. Pepper. 1982. Consumptive use by sub-irrigated turfgrasses under desert conditions. *Agronomy Journal,* 74:419–423.

[26] Beard and Kenna, *Op. cit.*

[27] Kjelgren, *Op. cit.*

[28] *Idem.*

[29] Buwalda, J.G and F. Lenz. 1993. Water use by European pear trees growing in drainage lysimeters. Journal of Horticultural Science 70:53–540.

Kjelgren, R. and T. Montague. 1996. Isolated tree water use in various urban surfaces. Paper presented at the ASAE International Conference on Evapotranspiration and Irrigation Scheduling, November 3–6, in San Antonio, Texas.

Lindsay, P. and N. Bassuk. 1991. Specifying soil volumes to meet the water needs of mature urban street trees and trees in containers. Journal of Arboriculture 17:141–149.

[30] California Department of Water Resources (CDWR). 2000. Estimated Irrigation Water Needs of Landscape Plantings in California. University of California Cooperative Extension. Department of Water Resources, Sacramento, California. <http://www.owue.water.ca.gov/docs/wucols00.pdf>.

[31] Pittenger, D.R, D.A. Shaw, D.R. Hodel, and D.B. Holt. 2001. Responses of landscape groundcovers to minimum irrigation. Journal of Environmental Horticulture 19:78–84.

Staats, D. and J.E. Klett. 1995. Water conservation potential and quality of non-turf groundcovers versus Kentucky bluegrass under increasing levels of drought stress. Journal of Environmental Horticulture 13:181-185.

[32] Costello, L.R., K.S. Jones, and D.D. McCreary. 2005. Irrigation effects on the growth of newly planted oaks (*Quercus* spp.). Journal of Arboriculture 31:83–88.

[33] Pittenger, D.R., D.R. Hodel, D.A. Shaw, and D.B. Holt. 1992. Determination of Minimum Irrigation of Needs Non-Turf Groundcovers in the Landscape. University of California Water Resources Center, Berkeley, California.

[34] Mecham, Brent Q. 2004. Comparison of Turfgrass & Landscape Plants Water Usage to Grass Reference Evapotranspiration.

[35] Hanak, Ellen and Matthew Davis. 2006. Lawns and water demand in California. California Economic Policy 2 (2):1–23.

[36] Kjelgren, *Op cit.*

[37] Trenholm, L.E. and J. Bryan Unruh. 2003. Let Your Lawn Tell You When to Water. University of Florida Institution of Food and Agricultural Sciences Extension, Department of Environmental Horticulture, Gainesville, Florida. <http://edis.ifas.ufl.edu>.

[38] City of El Paso. 1991. Car wash ordinance No. 15106. 10 Nov. 2007. <http://www.elpasotexas.gov/muni_clerk/ordinances.asp>.

[39] Bounds, Gwendolyn. 2009. Turf battle heats up over limits on water-guzzling landscapes. *The Wall Street Journal*. September 18.

[40] Sovocool et al. 2006

[41] Nelson, J.O. 1994. “Water saved by single family Xeriscapes.” Paper presented at the American Water Works Association National Conference, June 22, 1994. New York, New York.

[42] Nelson, *Idem.*

Sovocool and Rosales 2001 in Gleick et al 2003

[43] Medina, Jonnie G. and Julie Gumper. 2004. YARDX: Yield and Reliability Demonstrated in Xeriscape: Final Report. Metro Water Conservation, Incorporated, Littleton, CO, 140 p.

[44] Gregg, Tony, J. Curry, and C. Grigsby. 1994. Xeriscaping: Promises and Pitfalls. Report for the Texas Water Development Board. City of Austin.

Medina and Gumper, *Op. cit.*

Nelson, John. "Water Saved by Single Family Xeriscapes." Preliminary Draft for American Water Works Association National Conference. New York, June 1994.

Sovocool, A. Kent, and J.L. Rosales. 2003. A Five-Year Investigation into the Potential Water and Monetary Savings of Residential Xeriscape in the Mojave Desert. Las Vegas, Nevada: Southern Nevada Water Authority.

Testa, A., and A. Newton. “An Evaluation of a Landscape Rebate Program.” Paper presented at American Water Works Association Conserv ’93, December 1993.

Proceedings. December, 1993.

[45] Sovocool, *Op. cit.* 2006.

[46] Addink, S. 2005. Cash for Grass: A Cost Effective Method to Conserve Landscape Water? University of California, Riverside Turfgrass Research Facility, Riverside.

[47] U.S. Environmental Protection Agency. Office of Water. 2002. *Water-Efficient Landscaping*. EPA832-F-02-002. <www.epa.gov/owm/water-efficiency/index.htm>.

[48] Giridharan, R., Lau, S.S.Y., Ganesan, S., abd Givoni, B. 2008. Lowering the outdoor temperature in high-rise high-density residential developments of coastal Hong Kong: The vegetation influence. *Building and Environment*, 43(10): 1583-1595

[49] Goward, S.N. 1981. Thermal behavior of urban landscapes and the urban heat island. *Physical Geography*, 2(1):19-33

[50] Davis, S., Martien, P., Sampson, N., 1992. Planting and light-colored surfacing for energy conservation in cooling our communities: a guidebook on tree planting and light-colored surfacing. EPA Guidebook 1992, 93–110.

[51] Young, A. 1989. Agroforestry for Soil Conservation. CAB International.

[52] Department of Environmental Protection, Bureau of Watershed Management. Dec 30, 2006. Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species *In* Chapter 5.6.3 Pennsylvania Stormwater Best Management Practices Manual. Document Number 363-0300-002

[53] Martin et al. 2002 in Yabiku et al. 2008

[54] Sovocool, *Op. cit.* 2006.

[55] Nelson, *Op. cit.*

[56] *Idem.*