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Alternative Water Sources for Urban Landscape Irrigation in Arid Regions

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Abstract: Whereas irrigated agriculture is the largest water user in many countries, urban landscape irrigation is rapidly approaching that distinction, particularly in highly urbanized regions, including those afflicted by desertification. Texas (in United States) is one geographical region caught in this quandary, with about one-half of its 695,621 km^2 area covered by semi-arid and arid ecosystems like the Chihuahuan Desert. While the urban landscaped area of this state occupies only 1% of its surface, it uses approximately 13% of the total annual water use by all activities, representing about 47% of the total water use within the urban and municipal sectors. Fierce water competition caused by accelerated growth of urban population, industrial and energy-producing activities, along with agricultural production are challenging the sustainability of the current exotic and heavy water user urban landscapes. Along with a change to sensibly designed landscapes using water-conserving native and adaptive plant materials with weather- and sensor-guided irrigation and deficit irrigation practices, the use of alternative irrigation water sources is imperative to minimize their dependence on high-value potable water. Use of alternative water sources, including brackish, reclaimed, condensates and graywater, however, presents challenges to both plants and urban soils. Systematic monitoring and proper management practices are needed when employing these alternative water sources to minimize issues related to salinization and other undesirable effects to the immediate urban and surrounding periurban and natural environments.

Key Words: Graywater, Irrigation, Reclaimed water, Salinity, Water quality

1. Introduction

While irrigated agriculture is the largest world water user, an exponential population growth, primarily in urban areas, is creating a huge demand for water resources, and therefore a serious competition and crisis for good-quality water resources (UN-Water, 2009). In developed countries (*e.g.* USA) urban landscape irrigation has become a major water user, using considerable volumes of potable water, even in a state like Texas, which has a large portion of its vast 695,621 km^2 area covered by semi-arid and arid ecosystems such as the Chihuahuan Desert. Based on the recognized aridity index defined as the ratio of annual precipitation to potential evapotranspiration rates (Maliva and Missimer, 2012), about one half of the Texas territory would be classified as semi-arid or arid.

While the urban landscaped area of Texas occupies only 1% of its surface (6,974 km^2), it uses approximately 13% of the total annual water consumed by all activities (**Fig. 1**), and represents ~47% of the total potable water use within the urban and municipal sectors (Cabrera *et al*., 2013). An increase of 82% (from 25.4 to 46.3 million) in Texas population growth, mostly in urban areas, in the next five decades is projected to also increase municipal water demand by 71.4% over the same period (TWDB, 2012). The 562 water projects recommended

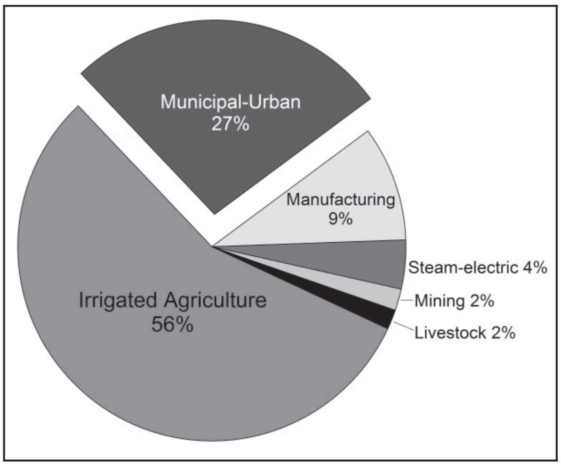

Fig. 1. Relative water demand in 2010 for various activities in Texas. About half of the water used by the municipal-urban sector (~13% of total) was devoted to landscape irrigation. Drawn from data in Cabrera *et al*. (2013) and TWDB (2012).

to supply these increased water needs include municipal and irrigation conservation strategies, along with use and reuse of alternative water sources, new reservoirs and desalination.

2. Water Conservation Strategies

2.1. Selection of plant materials

The use of water-conserving landscape plants and suitable designs for each eco-geographical region (*i.e.* soil and climate) are the main components of urban water conservation.

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Agricultural research/extension agencies, municipal utilities and water districts have preferred/approved listings of native and adaptive, resource-efficient landscape plants and trees suitable for each region, and their use is often promoted with rebates and incentives (Cabrera *et al*., 2013).

Utilization of properly chosen native and adapted plants to each region, with proper design and maintenance (including soil conditioning and mulching) should ensure their survival and ornamental performance within the limits of the expected regional precipitation, with little to no supplemental irrigation.

2.2. Efficient irrigation technology and management

Irrigation management with smart controllers based on evapotranspiration (ET) and soil moisture conditions, compared to traditional timers and calendar-based irrigation, offer the potential for significant landscape water conservation, particularly with the development of more refined equipment and sensors. The incorporation of deficit irrigation and crop coefficients (Kc) into ET-based irrigation is a refinement that increases the potential for more water savings while maintaining the aesthetic quality and function of landscape plants and turfgrasses (Pannkuk *et al*., 2010).

3. Alternative Water Sources for Urban Irrigation

Reserving the use of municipal potable water primarily for direct human uses (drinking, cooking, bathing, laundry, etc.), and employment of alternative water sources for landscape irrigation and other industrial uses is a proposition that should result in enhanced water savings and conservation efforts in the urban sector.

3.1. Rainwater and stormwater

For millennia civilizations have practiced and relied on rainwater harvesting as a source of water for household to agricultural uses. Depending on the collection/storage system this source offers the potential to have the purest, best quality, low-salt content water (*i.e.* suitable water in **Table 1**). Development of affordable, centrally treated and distributed water in urban areas caused rainwater harvesting to be forgotten. A renewed interest has emerged in arid regions like Texas due to drought, scarcity, competition and rising costs, and it is being actively promoted by water purveyors (TWDB, 2005). Rainfall frequency and limitations in storage capacity are two of the conditions that might be restricting a more extensive use of this source in residential landscape irrigation.

Reuse of stormwater can also be seen as an option for urban landscape irrigation and other non-potable uses. With few exceptions, however, stormwater collection, treatment, storage and uses are typically handled by local municipal utilities. Current stormwater management practices are considered to be ahead of research, as there is a lack of technologies designed specifically for stormwater recycling, with more attention being directed to pollution control (Hatt *et al*., 2006). There are some urban design propositions that call for retaining water in the urban landscape through stormwater harvesting and reuse in urban vegetation to reduce heat island effects through enhanced evapotranspiration and surface cooling (Coutts *et al*., 2013).

Table 1. Main chemical quality parameters in suitable irrigation water for ornamental landscape plants, slightly brackish and reclaimed water in Texas (Data from Anderholm and Heywood, 2003; Cabrera *et al*., 2013; Duncan *et al*., 2009; Farnham *et al*., 1985).

PARAMETER	Suitable Water	Slightly Brackish	Reclaimed
pH	6.0 – 8.0	7.3 – 8.3	7.0 – 8.0
EC (ds/m)	<1.0	1.6 – 4.7	1.0 – 2.0
Na (mg/L)	<70	50 – 560	90 – 120
Cl (mg/L)	<110	30 – 510	120 – 160
B (mg/L)	<1.0	---	0.5 – 1.0
HCO_3 (mg/L)	120 - 180	80 –250	180 – 200

3.2. Brackish and saline waters

Brackish groundwater, from naturally saline aquifers or those affected by coastal saltwater intrusion-aquifers are abundant in Texas (TWDB, 2013). While TWDB indicates that brackish water with electrical conductivity (EC) up to 4.7 dS/m could be employed for irrigation, this salinity level exceeds the maximum level of 1.5 dS/m recommended for most landscape plants (Table 1), in addition to having high concentrations of ions like sodium (Na) and chloride (Cl), which are particularly toxic to many plants (Farnham *et al*., 1985). The growth and quality of plants irrigated with saline water suffer significantly, particularly shrubs and trees, expressed in scorched, necrotic and chlorotic leaves, ultimately leading to plant death (Niu and Cabrera, 2010). A higher degree of tolerance to overall salinity and specific ion concentrations can be observed in turfgrasses and some annual plants (Duncan *et al*., 2009). Blending of brackish and saline waters with other high quality water sources, along with suitable irrigation and leaching practices and salt-tolerant species, could be successfully used to grow and maintain aesthetically pleasant urban landscapes.

3.3. Reclaimed water

Municipal reclaimed water has also been considered a viable alternative for landscape irrigation, being extensively used in golf courses, large corporate and municipal parks and landscapes in arid urban areas across the western US, including

Texas. Depending on the degree of treatment, however, reclaimed waters could have similar drawbacks as brackish water, with relatively high levels of total salinity and undesirable specific ions (Duncan *et al*., 2009). It should be noted that the quality of the reclaimed water produced by the San Antonio Water System (SAWS), the largest municipal water treatment facility of its kind in the US, is fairly good, with an average EC of 1.1 dS/m, 180 mg/L of alkalinity (HCO_3^-), 145 mg/L of Cl and 98 mg/L of Na, all levels that were slightly to moderately higher than those recommended for woody ornamental shrubs and trees, but still adequate for most annuals and turfgrasses (Duncan *et al*., 2009; Farnham *et al*., 1985). Availability and supply of reclaimed water is unfortunately limited, as its collection (*i.e.* original raw sewage effluent), treatment and subsequent distribution are strictly regulated, and employ a separate pipeline system accessible to only few large end-users (SAWS, 2006). Depending on the final quality of reclaimed water, use in landscape irrigation could require the use of modified sprinklers or drippers to minimize direct contact with the foliage of plants, to reduce salt scorching. These precautions are also suggested to minimize the risk of human exposure to the recycled water, due to concerns with pathogenic microorganisms and other chemicals that could still be present in undesirable concentrations (Duncan *et al*., 2009). As with brackish water, successful use of reclaimed water calls for use of salt-tolerant plants (Farnham *et al*., 1985; Niu and Cabrera, 2010), suitable irrigation equipment and management, leaching requirements, and short- and long-term management of urban soils and their associated watershed to minimize salt accumulation and undesirable effects on the urban ecosystem (Duncan *et al*., 2009).

3.4. Air conditioning condensates

Another potential source for landscape irrigation is the condensate water from air-conditioning (A/C) systems (Guz, 2005). This is more viable in sites with a relatively large indoor footprint vs. landscape footprint (*i.e.* commercial buildings), offering the possibility to be self-sufficient for their landscape irrigation needs. The quality of condensate water can be very good, and requires minimal treatment for storage or immediate use. Condensate recovery systems in San Antonio (Texas) have worked so well that it became the first US city to require its new commercial buildings to design drain lines to readily capture A/C condensate water (Guz, 2005). There are still design and engineering issues being addressed for the successful and cost-effective implementation, and in the case of landscape irrigation applications, these include storage, treatment (like chlorine injection to prevent bacterial growth) and hook-up to irrigation systems.

3.5. Graywater

Graywater, defined as residential wastewater from laundry, showers and bathtubs, is an additional alternative water source with potential for residential landscape irrigation. Graywater can constitute as much as 60% of the total wastewater from a household, and might yield up to 114 m^3 per year for an average US family (Roesner *et al*., 2006). Graywater from laundry (clothes washing machines) constitutes one-half of the total household graywater, and could potentially provide up to 130 mm of annual irrigation to an average-sized landscape. The routing of the drain hose from washing machines to a simple drip irrigation set-up would be a relatively inexpensive option to reuse this graywater compared to plumbing retrofits to reroute, capture and use graywater effluent from bathtubs and showers. Graywater reuse could represent a substantial saving of potable water supplies if coupled with a well-designed low-pressure drip irrigation system and using native and adaptive (resource-efficient) plant materials (Cabrera *et al*., 2013). A convenient feature of reusing laundry graywater is the ability to reroute or reconnect the washing machine effluents back to the sewer system when not needed due to rainfall or low irrigation demand. Among the issues that discourage an extensive and permitted use of graywater for landscape irrigation is a lack of documented knowledge on the short and long-term effects of graywater on plants and soils. Furthermore, as with reclaimed water, there is the need to identify any and all associated microorganisms and chemicals that are of concern for public health, plus the irrigation equipment considerations and practices needed to successfully manage and apply graywater (Roesner *et al*., 2006).

4. Concluding Remarks

Population and economic growth, competition and climate change (*i.e.* drought) are placing significant pressures in the water balance (demand-availability) across the planet, more evidently in arid regions, and where agriculture “clashes” with urban development. While agriculture is by far the largest user of water, the increased growth and economic development in urban areas across the world are shifting the balance of water use and allocation patterns (UN-Water, 2009). The literature indicates significant advances in water use efficiency achieved by modern irrigated agriculture, *i.e.* crop yields produced per unit of water used (Wagner, 2012). The urban sector is, however, severely criticizing their volumetric water use, but often loses track of its own deficiencies, for instance the significant use of potable water resources devoted to irrigation of exotic ornamental landscapes. The use of alternative irrigation waters, along with smart-irrigation technologies and landscape designs based on water-conserving native and adaptive plants and turfgrasses, could significantly enhance water conservation and use efficiency while sustaining the many societal and environmental benefits of urban landscapes. A remarkable urban water conservation effort is that realized by the San Antonio Water System over the last two decades, basically using about the same amount of water that it used in 1984, despite a 67% increase in population - or dropping the per capita water use by ~40%, from 840 to 515 liters per day (Cabrera *et al*., 2013). The bulk of the water conservation efforts and subsequent accomplishments by this city have revolved around improving landscape water use. It is contended that sound research-based results and outreach education efforts are still very much needed to help urban communities in arid regions to achieve substantial progress in their urban water use efficiency and conservation goals.

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