Landscape Coefficients for Single- and Mixed-species Landscapes

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Abstract. Urban landscape irrigation is becoming increasingly important from a resource management point of view. Significant water use savings may be achieved if landscape irrigation is based on reference evapotranspiration (ETo). This study measured landscape crop coefficients (Kc) for landscapes that are comprised of different vegetation types and irrigation water quality differences affecting Kc. The Kc was determined from the ratio of actual evapotranspiration to the ETc, calculated from the modified Penman-Monteith equation. Irrigation quantity was based on 100% replacement of ETc. The Kc values were determined for the following landscape vegetation on a fine sandy loam: St. Augustinegrass [Stenotaphrum secundatum (Walt.) Kuntze.], a single shumard red oak (Quercus shumardii Buckl.), St. Augustinegrass plus red oak, native grasses [Muhlenbergia capillaries (Lam.) Trin. and Schizachyrium scoparium (Michx.) Nash], and native grasses plus Red Oak in both College Station (CS) and San Antonio (SA), TX. Soil was systematically placed into lysimeters containing a drainage system and soil moisture probes. Lysimeters (1136 L) were placed in-ground in a randomized complete block design with three blocks. Soil moisture measurements were made at 0- to 20-, 20- to 40-, and 40- to 60-cm depths. The Kc was determined after a rainfall or irrigation event for periods of 2 to 5 days. During the combined growing seasons of 2007 and 2008, Kc in SA increased from early, to mid, to late season. In CS, the Kc was unaffected by plant treatment or season. The St. Augustinegrass treatment Kc seasonally ranged from 0.45 to 0.62 in SA. In CS, soil sodium accumulation caused decreased Kc. These results of Kc demonstrated that both grasses could be grown with a differential response in bermudagrass and native grasses, native grass species, tree species, and mixed species landscapes under different climates. An understanding of this relationship is critical to providing accurate recommendations for landscape irrigation based on ETc. A variety of state-of-the-art technologies are available for reducing irrigation water use in amenity landscapes. One of these “smart irrigation” technologies is an ET-based controller. McCready et al. (2009) compared the effectiveness of an ET-based controller technology treatment with a time-based system with 2 d of irrigation per week without any type of sensing mechanism. Compared with the time-based system, the ET-based treatments used 25% to 62% less water without compromising turf quality. This demonstrates the benefit of using ET-based controllers in landscape irrigation, but there is a gap in the knowledge of what fraction (e.g., 0.7, 0.8) of the ETc is needed in the mixed-species landscape. Coupling ET-based plant water use with ET-based irrigation controllers can provide a means of accurately applying water to the landscape. It is well documented that sodic and saline soil conditions can alter soil water use and transpiration in landscape plant materials (Eom et al., 2007; Munn, 2002; Wang and Nii, 2000). Dean et al. (1996) demonstrated a differential response in bermudagrass and tall fescue growth in arid climates where excess salt and water-induced stress were factors. The Dean et al. study also demonstrated that both grasses could be grown with moderately saline water if irrigation water volume was above a species-specific threshold value. Carrow and Duncan (1998) documented how excess soil sodium (Na) levels can lead to soil structural deterioration and to specific ion toxicity in shoot and root tissue. Sodic soil conditions may develop in amenity landscapes if high Na irrigation waters are used. Therefore, the actual ET/ETc relationship of plants may vary between sodic landscape sites and non-sodic landscape sites. As sources of potable fresh water are depleted, lower-quality water increasingly becomes used for irrigation of turf and woody plants.

Additional index words: evapotranspiration, Stenotaphrum secundatum, Quercus shumardii, landscape coefficient, turf

Landscape plants provide an aesthetic appeal to urban landscapes, prevent erosion of the soil that impairs surface water supplies, sequester carbon, add oxygen to the atmosphere, and improve recharge of groundwater (Beard and Green, 1994). Irrigated areas within the built landscape can also increase property values. Yet, end-user lack of understanding of best management practices for landscape water management will routinely contribute to excess water use. In a study of 800 home consumers in College Station, TX, it was estimated that more than 24 to 34 million gallons of excess water, that is water in excess of an irrigation coefficient of 1.0 of the yearly reference evapotranspiration, were used annually for landscape irrigation during 2001 through 2003 (White et al., 2004). Appropriate landscape design and planning has been heralded for decades as a step toward water conservation (Welsh et al., 2000), yet water consumer irrigation practices have not changed with landscapes designed for water conservation (Peterson et al., 1999).

Evapotranspiration (ET) is the amount of water lost through evaporation from the soil and plant surface plus that lost through plant transpiration. Reference evapotranspiration (ETc) water loss rate is based on environmental demands for a cool-season turf completely covering the ground. Landscape irrigation based on ETc is an emerging area of water conservation that links plant water use to irrigation water replacement rates and schedules. There is evidence that ETc weather station data can be used in irrigating landscape plants (Shaw and Pittenger, 2004; White et al., 2004), yet there is a lack of information on the fundamental seasonal relationships between ETc and actual evapotranspiration of turfgrasses, native grass species, tree species, and mixed species landscapes under different climates. An understanding of this relationship is critical to providing accurate recommendations for landscape irrigation based on ETc.

Urban landscape irrigation is becoming increasingly important from a resource management point of view. Significant water use savings may be achieved if landscape irrigation is based on reference evapotranspiration (ETc). This study measured landscape crop coefficients (Kc) for landscapes that are comprised of different vegetation types and irrigation water quality differences affecting Kc. The Kc was determined from the ratio of actual evapotranspiration to the ETc, calculated from the modified Penman-Monteith equation. Irrigation quantity was based on 100% replacement of ETc. The Kc values were determined for the following landscape vegetation on a fine sandy loam: St. Augustinegrass [Stenotaphrum secundatum (Walt.) Kuntze.], a single shumard red oak (Quercus shumardii Buckl.), St. Augustinegrass plus red oak, native grasses [Muhlenbergia capillaries (Lam.) Trin. and Schizachyrium scoparium (Michx.) Nash], and native grasses plus Red Oak in both College Station (CS) and San Antonio (SA), TX. Soil was systematically placed into lysimeters containing a drainage system and soil moisture probes. Lysimeters (1136 L) were placed in-ground in a randomized complete block design with three blocks. Soil moisture measurements were made at 0- to 20-, 20- to 40-, and 40- to 60-cm depths. The Kc was determined after a rainfall or irrigation event for periods of 2 to 5 days. During the combined growing seasons of 2007 and 2008, Kc in SA increased from early, to mid, to late season. In CS, the Kc was unaffected by plant treatment or season. The St. Augustinegrass treatment Kc seasonally ranged from 0.45 to 0.62 in SA. In CS, soil sodium accumulation caused decreased Kc. These results of Kc demonstrated that both grasses could be grown with a differential response in bermudagrass and native grasses, native grass species, tree species, and mixed species landscapes under different climates. An understanding of this relationship is critical to providing accurate recommendations for landscape irrigation based on ETc. A variety of state-of-the-art technologies are available for reducing irrigation water use in amenity landscapes. One of these “smart irrigation” technologies is an ET-based controller. McCready et al. (2009) compared the effectiveness of an ET-based controller technology treatment with a time-based system with 2 d of irrigation per week without any type of sensing mechanism. Compared with the time-based system, the ET-based treatments used 25% to 62% less water without compromising turf quality. This demonstrates the benefit of using ET-based controllers in landscape irrigation, but there is a gap in the knowledge of what fraction (e.g., 0.7, 0.8) of the ETc is needed in the mixed-species landscape. Coupling ET-based plant water use with ET-based irrigation controllers can provide a means of accurately applying water to the landscape. It is well documented that sodic and saline soil conditions can alter soil water use and transpiration in landscape plant materials (Eom et al., 2007; Munn, 2002; Wang and Nii, 2000). Dean et al. (1996) demonstrated a differential response in bermudagrass and tall fescue growth in arid climates where excess salt and water-induced stress were factors. The Dean et al. study also demonstrated that both grasses could be grown with moderately saline water if irrigation water volume was above a species-specific threshold value. Carrow and Duncan (1998) documented how excess soil sodium (Na) levels can lead to soil structural deterioration and to specific ion toxicity in shoot and root tissue. Sodic soil conditions may develop in amenity landscapes if high Na irrigation waters are used. Therefore, the actual ET/ETc relationship of plants may vary between sodic landscape sites and non-sodic landscape sites. As sources of potable fresh water are depleted, lower-quality water increasingly becomes used for irrigation of turf and woody plants.

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Water is one of our most valuable natural resources and water conservation continues to be a major national priority [Vickers, 2001; Texas Water Development Board (TWDB), 2007]. As a result of population growth, current potable water supplies will be insufficient by the year 2050 in Texas (TWDB, 2003). Currently, 7.8 billion gallons, or ≈6.3% of all potable water, is used outdoors (U.S. Geologic Survey, 2006) primarily for landscape irrigation (Kjelgren et al., 2000; Vickers, 2001; White et al., 2004).
The objectives of this study were to 1) compare landscape crop coefficients ($K_t$; actual ET to ET$_{o}$) by landscape plant treatment; and 2) determine if seasonal differences in $K_t$ occur within sites.

Materials and Methods

Site description. The experiment was conducted at two sites: the Texas A&M University Turfgrass Field Laboratory in College Station, TX, and at a site adjacent to the San Antonio Water System Leon Creek Waste Water Treatment Facility in San Antonio, TX. These two sites will be referred to as the College Station (CS) region and the San Antonio (SA) region. College Station on average has 1000 mm rainfall, 47.8% humidity, and an ET$_{o}$ of 1430 mm. San Antonio on average has 764 mm rainfall, 42.9% humidity, and an ET$_{o}$ of 1522 mm. Table 1 presents average seasonal rainfall and actual seasonal rainfall by site.

Irrigation water analysis. Irrigation water for each site was from the local potable water supply. Irrigation water samples from both sites were analyzed in July 2008. The pH, calcium (Ca), magnesium (Mg), HCO$_3$, Na, and sodium adsorption ratio (SAR) were 9.1, 2, 0.5, 393, 232, and 38, respectively, for irrigation water at CS versus 7.9, 24, 16, 190, 12, and 0.5 for irrigation water in SA. Electrical conductivity of irrigation water was 0.089 and 0.057 S·m$^{-1}$ in CS and SA, respectively.

Lysimeter construction and sensing. Individual waterproof lysimeter containers were 1136-L oval stock tanks (R.G. Applegate Steel Co., Saratoga, IN) 2.43 m long × 1.02 m wide × 0.68 m deep. The distance between the individual lysimeters was 30.5 cm. Tank bottoms were constructed from 1.0 mm galvanized steel and sides were made from 0.85 mm galvanized steel. Tanks were placed in-ground on a smooth level surface and sides were made from 0.85 mm galvanized steel. Tanks were placed in-ground on a smooth level surface and sides were made from 0.85 mm galvanized steel. Tanks were placed in-ground on a smooth level surface and sides were made from 0.85 mm galvanized steel. 

Six soil moisture sensors (ECH2O Probes, Model EC-20; Decagon Devices, Pullman, WA) were placed in two locations (60 cm from each end) in each lysimeter (three sensors per location). Sensors monitored volumetric water content at 0- to 20-, 20- to 40-, and 40- to 60-cm depths (soil surface down to the gravel layer). Cables from the sensors were routed along the inside wall of the lysimeters. All wires were taped to the inside of the lysimeter walls (Fig. 1). From the lysimeters, the cables were enclosed in a 10-cm diameter perforated corrugated drainage pipe and routed to a nearby data collection station. Volumetric soil moisture content measurements were collected using a data logger (model 10X; Campbell Scientific Inc., Logan, UT) coupled with Model AM 16/32 multiplexers. Measurements were taken every 15 min and averaged for every 30 min. At the CS location, a handheld PDA (Palm; Model 500m) and appropriate software (P Connect, Version 2.0; Campbell Scientific Inc.) was used to manually download data weekly. At the SA location, data collection was accomplished using a Com 210 modem and analog telephone line (Com 210; Campbell Scientific Inc.). This allowed daily transfer of data to a central computer in CS.

Lysimeters at each location were irrigated with a two-zone in-ground automatic system. Irrigation spray heads (Hunter PGJ Series, San Marcos, CA) were installed at 3.65-m triangulated spacing. A water meter was installed in each zone to allow measurement of total applied water.

A weather station was located within 250 m of the lysimeters at CS and SA. Environmental data included precipitation, radiant energy, wind speed, humidity, and temperature. Data from these stations were used to calculate reference evapotranspiration using the modified Penman-Monteith equation (FAO Irrigation and Drainage Papers-56, 1998). Irrigation was adjusted every 2 to 3 weeks to replace 100% of calculated reference evapotranspiration minus precipitation. During periods when irrigation water was required, water was applied 1 or 2 d per week.

Plant treatments. Treatments were arranged in a randomized complete block design with three replications. The plant treatments were randomly assigned to the lysimeters within each block and included: St. Augustinegrass [Stenotaphrum secundatum (Walt.) Kuntze] 100% cover, Shumard red oak (Quercus shumardii Buckl.) tree alone with bare soil, native grasses little bluestem [Schizachyrium scoparium (Michx.) Nash] and pink muhlygrass [Muhlenbergia capillaris (Lam.) Trin.], St. Augustinegrass plus one shumard red oak, and native grasses plus one shumard red oak.

Plant installation occurred on 19 Dec. 2006 and 20 Dec. 2006 for the SA and CS locations, respectively. To avoid disturbing sensors and sensor cables, container-grown (11.4 L) shumard red oak trees were planted in the center of the lysimeters. Treatments receiving St. Augustinegrass (All Seasons Turfgrass Inc., Brookshire, TX) were planted with sod grown on a Katy fine-sandy loam series (fine-loamy, siliceous, thermic Aquic Paleudalf). Native grass treatments received nine field-grown (3-L root ball) individual

Table 1. Average seasonal rainfall, actual seasonal rainfall, and percent variation from average rainfall during 2007 and 2008 in College Station and San Antonio, TX.

| Site        | Season | Avg (mm) 2007 | Avg (mm) 2008 |
|-------------|--------|--------------|--------------|
| College Station | Early | 248          | 223 (10%)    |
|              | Mid    | 270          | 311 (+15%)   |
|              | Late   | 225          | 202 (10%)    |
| San Antonio  | Early | 187          | 167 (11%)    |
|              | Mid    | 245          | 557 (+127%)  |
|              | Late   | 179          | 36 (80%)     |

1A total of 34 mm (50% of season) in 3 weeks of August.
2A total of 104 mm (43% of season) in 2 weeks of August.

Fig. 1. Schematic drawing of the lysimeter design.
little bluestem and two container-grown (5.7-L root ball) individual pink muhlygrass. The native grass plus red oak treatment received eight little bluestems and two pink muhlygrass. Native grasses were spaced equidistant across the lysimeter.

**Site management.** St. Augustinegrass was maintained at 5- to 7.6-cm cutting height with a mowing frequency of every 2 to 4 weeks. Clippings were returned to the plots. The bluestem and muhlygrass (native grass treatment) were trimmed to 15 to 18 cm each December. The soil in the St. Augustinegrass alone treatment was used as a reference for fertility decisions. The soil in the St. Augustinegrass alone treatment was sampled (0- to 15-cm depth) for laboratory analysis two to three times each year (Soil, Water, and Forage Testing Laboratory, College Station, TX). Phosphorus, potassium, Ca, Mg, Na, and sulfur were extracted using the Mehlich III extractant (Mehlich, 1978) and were determined by the inductively coupled plasma method. Based on soil analysis, a balanced fertilizer was added to all treatments during 2007 and 2008. Nitrogen at a rate of 48.8 kg·ha⁻¹ was applied in three separate events each year. Plant tissue analysis was conducted in July 2008 for the St. Augustinegrass treatment only to evaluate plant health and potential negative effects of soil salts. Lysimeters were evacuated every 2 to 4 weeks to avoid prolonged saturation of the gravel layer.

**Landscape coefficient determination.** Landscape coefficients were determined from changes in volumetric water content during 2 to 5 d of soil drying and from ET₀, amounts during the same period. Soil drying periods occurred as a result of lack of precipitation and during intervals between irrigations. Soil drying periods began at 0001 h after an irrigation or precipitation event and continued until 0001 h before an irrigation or precipitation event ended the drying period. Changes in soil water volume during soil drying periods provided actual evapotranspiration data for each treatment. Actual evapotranspiration and ET₀ data were used to calculate landscape coefficients by:

\[ K_L = \text{actual ET} \div \text{reference ET in which:} \]

\[ K_L = \text{landscape coefficient} \]

Table 2. Calendar dates used for landscape coefficient calculations.

| College Station | San Antonio |
|-----------------|-------------|
| **Early season** | **2007**    |
| 21–25 Mar., 27–28 Apr., 4–5 May, 1–2 June | 21–25, 28–29 Mar., 26–27 Apr., 3–4, 28–29 May |
| 11–12 June, 9–13 July, 28 July to 1 Aug., 6–9 Aug., 11–16 Sept. | 13–15 June, 26–31 July, 13–15, 27–30 Aug., 6–11 Sept. |
| **Late season** | **2008**    |
| 8–11, 17–21, 23–24 Oct., 1–4 Nov. | 9–12, 17–19 Oct., 30 Oct. to 4 Nov., 13–16 Nov. |
| **Early season** | **2007**    |
| 21–25 Mar., 7–11 Apr., 8–9, 18–22, 24–28 May | 19–21 Mar., 1–3, 27–30 Apr., 5–8, 20–23 May |
| 2–5, 9–12, 16–19, 23–26 June, 21–22, 28–31 July | 3–6, 10–13, 17–20, 24–27 June, 15–18 July, 29 July to 1 Aug., 6–9 Aug. |
| **Late season** | **2008**    |
| 23–26 Sept., 30 Sept. to 3 Oct., 12–14, 20–23 Oct. | 16–18, 22–25 Sept., 6–9, 20–22 Oct. |
accumulation in CS limited gas exchange and water use in the tree. However, the mean tree \( g_s \) was greater in CS than SA when grown with native grasses (Table 4). The mean tree alone \( K_L \) during the entire study was 0.43 for SA and 0.21 for CS.

The \( g_s \) of the St. Augustine grass was the same regardless of the region or the presence of a tree. Mean \( g_s \) of the St. Augustine grass during the entire study ranged from 0.056 ± 0.037 to 0.067 ± 0.047 mol·m\(^{-2}·\)s\(^{-1} \). Mean \( g_s \) of the native grass is not presented as a result of lack of confidence in the data of the pink muhlygrass.

**Grass biomass accumulation.** Grass biomass accumulation was determined by random placement of grids in lysimeters with St. Augustine grass and native grasses. Because of the low-growing dense nature of the St. Augustine grass, each sample completely filled the 100-cm\(^2\) grid. As a result of the upright growth pattern of the native grasses, most grid samples were only partially occupied with leafy tissue. Therefore, in the native grass treatment, the bluestem mass was added to the *Muhlenbergia* mass for one composite native grass biomass.

The grass biomass accumulation data for 2007 were similar among grassy plant treatments within site (data not shown). In 2008, the overall grass biomass accumulation for SA was greater than for CS (41.9 and 25.5 Mg·ha\(^{-1}\), respectively). This is similar to the differences observed for \( K_L \) by region. The mean overall \( K_L \) by region for this study was 0.61 and 0.34 for SA and CS, respectively.

**Discussion**

Water use of turfgrass increases in the fall typically displaying seasonality. Brown et al. (2001) reported that bermudagrass water use increased from June to September. Carrow (1995) also found that after averaging the water consumption from two growing seasons that ‘Raleigh’ St. Augustine grass had greater water use in September and October than in July and August. In our study, St. Augustine grass \( K_L \) increased seasonally in SA. The untrimmed native grasses increased in height and girth from spring until the first frost in November, whereas the mowed St. Augustine grass had a relatively constant plant height and density during this time period. The native grasses with a more three-dimensional canopy thus have higher boundary layer resistance and therefore higher conductance. Plant canopy dimensions may have contributed to the seasonal differences in \( K_L \) in SA between the low-growing turfgrass and the upright bunchgrass-type growth of the native grass. However, during the study, the mean \( K_L \) for native grass was not statistically different from the \( K_L \) of St. Augustine grass with or without a tree. This would imply that a seasonal \( K_L \) could be used in irrigation recommendations for amenity landscapes with mixed species.

Irrigation of turfgrass with water high in Na may be inducing sodic soil conditions (e.g., Aitkenhead-Peterson et al., 2009). Irrigation water, rather than precipitation, became a larger component of \( E_{\text{To}} \) replacement in late spring and summer (Table 1). Irrigation water quality may have influenced \( K_L \). CS irrigation water (SAR = 38) was high in Na and bicarbonate and is assessed as a Na-HCO\(_3\) water, whereas SA irrigation water (SAR = 0.5) was high in Ca and carbonate and is assessed as Mg-HCO\(_3\) water. The effects of soil Na on landscape plant performance in CS are evidenced in the greater \( K_L \) and biomass accumulation in the SA region. Na accumulation in CS likely altered soil water potential and may have caused reduced evapotranspiration compared with SA. Leaf margin necrosis in the Shumard red oak trees in CS was observed initially in early July 2008, and this condition continued into October (data not presented). This marginal leaf necrosis appeared symmetrical, indicating a visual symptom of salt stress (Hammerschlag et al., 1986).

The decreasing \( K_L \) values with season in CS may be the result of the effects of Na in the soil and plant tissue. Tissue analysis from the St. Augustine grass treatment was 11,362 ppm Na in CS compared with 7,882 ppm Na in SA. Soil and plant tissue Na content may have affected the plant’s ability to take up water for transpiration and other metabolic processes (Ben-gal and Shani, 2002; Munn, 2002). Furthermore, the average leachate volume per treatment was 85.8 L in SA and 131.1 L in CS representing 53% more leachate from the CS site although the overall grass biomass accumulation for SA was greater than for CS (41.9 and 25.5 Mg·ha\(^{-1}\), respectively). This is similar to the differences observed for \( K_L \) by region. The

**Table 3.** The \( K_L \) for single- and mixed-species plantings by season and location.

|                | San Antonio | College Station |
|----------------|-------------|-----------------|
| St. Augustine  | 0.52 ab c   | 0.34 ns         |
| St. Augustine + tree | 0.61 a    | 0.34            |
| Tree           | 0.43 b      | 0.21            |
| Native grass   | 0.61 a      | 0.30            |
| Native + tree  | 0.61 a      | 0.33            |

| Region         | Early | Mid | Late | Early | Mid | Late |
|----------------|-------|-----|------|-------|-----|------|
| St. Augustine  | 0.52 ab c | 0.62 ns | 0.51 ns | 0.27 ns | 0.24 ns |
| St. Augustine + tree | 0.56 ns | 0.56 | 0.47 | 0.32 | 0.23 |
| Tree           | 0.31 | 0.37 | 0.66 | 0.24 | 0.19 | 0.20 |
| Native grass   | 0.40 | 0.68 | 0.80 | 0.37 | 0.30 | 0.23 |
| Native + tree  | 0.48 | 0.62 | 0.75 | 0.40 | 0.29 | 0.31 |

*Means with the same lower case letter within column are not significantly different under Scheffe’s mean separation test at \( P = 0.05 \).

*Means with the same upper case letter within row are not significantly different under Scheffe’s mean separation test.

ns = nonsignificant.

**Table 4.** The average stomatal conductance (mol·m\(^{-2}·\)s\(^{-1} \)) and \( s_o \) of tree alone and tree when combined with native grasses and St. Augustine by region.

| Region | Tree | Tree with native grasses | Tree with St. Augustine |
|--------|------|-------------------------|------------------------|
| CS     | 0.225 ± 0.119 B c | 0.240 ± 0.114 A | 0.156 ± 0.069 B |
| SA     | 0.272 ± 0.114 A | 0.198 ± 0.105 B | 0.195 ± 0.103 A |

*Stomatal conductance means with the same letter within column are not significantly different based on Scheffe’s mean separation test.

Fig. 2. Historical monthly difference of evapotranspiration (\( E_{\text{To}} \)) and rainfall (mm) in College Station and San Antonio, TX.

Table 4. The average stomatal conductance (mol·m\(^{-2}·\)s\(^{-1} \)) and \( s_o \) of tree alone and tree when combined with native grasses and St. Augustine by region.
The increase in K_L from early to midseason in CS reduced the use of ETo data as a predictor of seasonal water use were much larger in SA than the K_L in CS. Augustinegrass is widely used in the southern non-sodic mixed-species landscape sites. St. (early, mid, and late season, respectively) in irrigation coefficients of 0.5, 0.6, and 0.7 for mixed-species landscapes. The actual water use. There is a lack of science-did not include field data measurements of few examples for mixed-species plantings. et al., 1995; Maupin and Struve, 1997) but very did not include field data measurements of crop coefficients for turfgrass as a single spe-
stomatal conductance values were not necessarily reflective of seasonal or regional water use. Most of the species-to-species g_s comparisons were generally larger in SA. Potentially this was caused by a greater ET_o in SA and/or a soil Na-induced osmotic factor in water potential in CS. It is possible that the soil Na concentration in CS reduced the g_s as well as the water use. Seasonal differences in plant treatment K_s were much larger in SA than the K_s in CS. The increase in K_s, from early to midseason in the plant treatments in SA followed a corresponding increase in evaporative demand during this time period. Evidence now exists to use ET_o data as a predictor of seasonal water demand in mixed-species landscapes. Also, the negative influence of soil Na accumulation on plant water use is demonstrated. The literature includes several examples of crop coefficients for turfgrass as a single species (Brown et al., 2001; Carrow, 1995; Ervin and Koski, 1998; Kim and Beard, 1988) and for woody plants as a single species (Levitt et al., 1995; Maupin and Struve, 1997) but very few examples for mixed-species plantings. White et al. (2004) described the potential for water savings in mixed-species landscapes by using a coefficient of 0.7. However, that study did not include field data measurements of actual water use. There is a lack of science-based information on seasonal irrigation co-
efficients for mixed-species landscapes. The results of this study trend toward acceptable irrigation coefficients of 0.5, 0.6, and 0.7 (early, mid, and late season, respectively) in non-sodic mixed-species landscape sites. St. Augustinegrass is widely used in the southern United States in mixed-species landscapes (Saha et al., 2007). This same seasonal K_s recommendation of 0.5, 0.6, and 0.7 may also be acceptable at landscape sites irrigated with sodic water to promote leaching of Na. This of course should be coupled with other remediation techniques such as gyspum applications. More work in landscape coefficients is needed. New studies should include other climatic regions and use of other woody plant species combinations. Corresponding work should also determine the aesthetic acceptability of the landscape plants grown under a landscape co-efficient less than 1.0.

Municipalities and water planning agencies use several methods to promote water conservation among users (Barta, 2004; Desena, 1998; Vickers, 2001; Water Information, 2006). The use of a landscape coefficient for irrigating mixed-species land-
scapes has potential to be used in planning local irrigation needs. Seasonal landscape water demand could be closely predicted with a landscape coefficient, weather station data, and number of irrigated acres in the region. The native grasses potentially have higher landscape coefficients than the turfgrass or tree alone. It appears the native grasses are opportunistic plants in regard to water use. Further study on the native grasses water use might determine if lower seasonal K_s (e.g., 0.5) are acceptable for growth and mainte-
nance that meets a specific aesthetic level in the landscape.

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