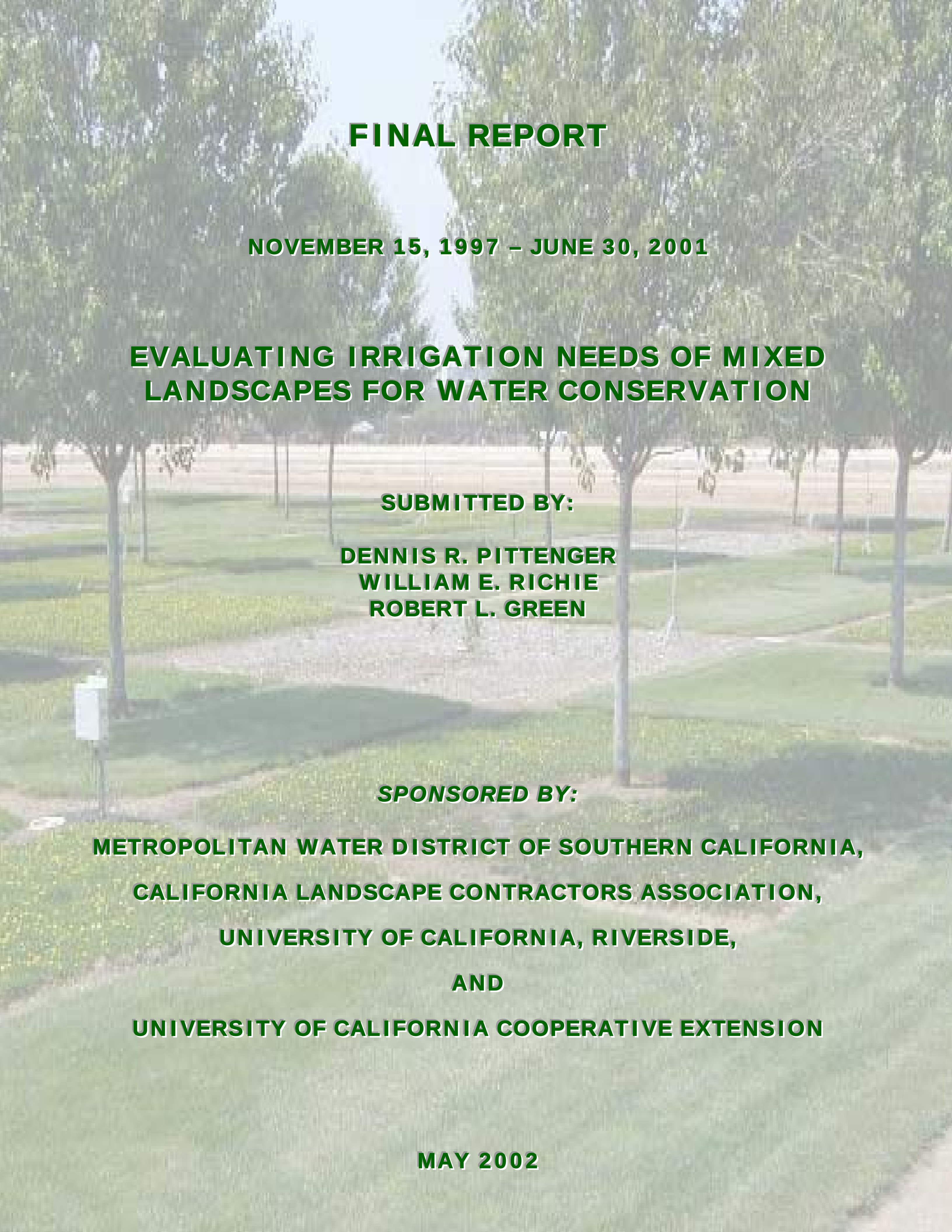

FINAL REPORT

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EVALUATING IRRIGATION NEEDS OF MIXED LANDSCAPES FOR WATER CONSERVATION

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EXECUTIVE SUMMARY

Landscape water conservation strategies center on setting and following a water budget based on the estimated water needs of an entire landscaped area. The standard approach to obtain this estimate for a mixed landscape planting relies on knowing the water needs of individual plant species, but such research-based information is scarce for the hundreds of plant species typically used in southern California landscapes. If and how water needs of mixed landscapes vary from those of the individual species comprising it is unknown. Calculation of a "landscape coefficient" (K_L) has been used in some instances to "quantify" the water need of a mixed landscape area so that a water budget can be assigned. The K_L method is not based on research findings, and it has not been scientifically validated. It is possible that a K_L does not accurately estimate the actual water needs of mixed landscape plantings.

Thus, there is a need to scientifically determine: (a) if the water needs of landscape plant species are influenced by adjacent plant materials, (b) how a mixed landscape's water need might be accurately estimated or quantified, and (c) whether or not the "landscape coefficient method" accurately estimates a mixed landscape's water need. Examples of practical questions we attempted to answer in this study include:

- *Does mixing species in a planting area impact their performance?*
- *Do mixed planting and irrigation amount interact to impact a species' performance?*
- *Is it possible to measure whether or not planting combinations influence a landscape's micro-ET_o?*
- *How do individual species perform at the different irrigation treatments? Did their performances follow what previous research had reported?*
- *Would additional water improve performance of individual species in a mixed planting?*
- *How well does the landscape coefficient method estimate water needs of a mixed landscape?*

Study Design

A 3.5-year field research study was conducted from 1997 through 2000 at the University of California, Riverside that incorporated three landscape plant materials and two levels of irrigation. The plant species selected were: (1) tree, Bradford pear (*Pyrus calleryana* 'Bradford'); (2) groundcover, spring cinquefoil (*Potentilla tabernaemontanii*); tall fescue turfgrass, (*Festuca arundinacea* 'Shortcut'). These plants were chosen to represent a typical mixed landscape planting in southern California and, based on previous research findings, to provide species with similar

individual water requirements. The two irrigation treatments chosen for the study were ≅80% and ≅56% real-time ET_o, which corresponded to 100% and 70% ET_{crop} using monthly crop coefficients (K_c) for cool-season turf. Irrigation treatments were divided by irrigation system distribution uniformity (DU; average of 0.81 in the research plots) according to standard industry practice. These treatments were selected because they represented the water requirements (crop coefficients) for optimum and minimum acceptable performance, respectively, of cool-season turfgrass, and they are widely used to set overall landscape water budgets in many areas of California. The plant materials were arranged in 7 planting combinations as follows:

1. *tree alone*
2. *groundcover alone*
3. *turfgrass alone*
4. *tree in center of groundcover*
5. *tree in center of turfgrass*
6. *½ groundcover and ½ turf*
7. *tree in center with ½ groundcover, ½ turfgrass*

The experiment was designed with four replications of the 7 combinations of plant species at the 2 levels of irrigation. Plant combination plots measured 20 ft × 20 ft with a 2 ft border. When trees were called for, they were located in the center of plots. In plots containing groundcover and turfgrass, the groundcover always occupied the eastern half of the plot and the turf always the western half. After planting, the plant material plots were maintained under well-watered conditions for 20 months to establish plants before the irrigation treatments were begun.

The amount of water applied weekly for each irrigation treatment was calculated from the previous 7-day cumulative ET_o obtained from a CIMIS ET_o station (CIMIS Station #44) adjacent to the research plot. The weekly irrigation amount was divided by individual plot precipitation rates to determine irrigation run times per week, then divided by two (fall, winter, spring months) or three (summer months) to calculate run time per irrigation day.

Performance of the plant materials (visual quality, growth, and physiological water status data) was measured at regular intervals to determine the plant species' responses to the planting combination schemes, irrigation amount, and any interactions of planting scheme with irrigation. Visual performance ratings were recorded monthly for groundcover and turfgrass plantings, while growth measurements of turfgrass and trees were taken seasonally. Measures of physiological water status were taken periodically in groundcover and trees. Visual turfgrass and groundcover performance was measured on a 1 to 9 scale with 9 = best visual quality. A rating of 5 for turfgrass and 6 for groundcover was considered minimally acceptable visual quality. In addition, tree canopy temperatures were recorded during 2000 using an infrared thermometer.

Soil water content was measured using a time domain reflectometry (TDR) system (between 4 and 16 inches deep) and a series of neutron probe access tubes that allowed measurement of soil water to 4 ft deep. Reference evapotranspiration (ET_o) was recorded or calculated from the following three sources for comparison during the study:

1. U.C. Riverside CIMIS ET_o station (station #44) located approximately 160 ft from the research plot, which served as the basis for comparing weather and ET data from other sources;
2. four Bellani plate-type atmometers (C&M Meteorological Supply, Inc.); and
3. meteorological sensors, placed either in all sub-plots within one irrigation block or in all tree and tree + turfgrass sub-plots, multiplexed into a data logger to record micro-environmental factors of soil temperature, air temperature, relative humidity, and solar radiation.

Soil temperatures, relative humidity, air temperatures and solar radiation were measured by the meteorological sensors and used in a modified Penman-Monteith equation (Allen et.al., 1994) to calculate cool-season grass reference ET in the various plots.

Landscape coefficient values (K_L) were calculated for each of the 7 planting combinations. Evaluation of the accuracy of the values was then made by assessing whether plant performance measured in each planting combination under the irrigation regimes in this study would likely have been the same or better if the K_L method was used to determine the irrigation amount.

The plant performance ratings, plant water status, and soil water content data were subjected to analysis of variance (ANOVA) and the general linear models procedure of Statistical Analysis Systems (SAS Institute, 1982).

Results

Tall fescue performed well at 80% ET_o/DU and poorly at 56% ET_o/DU in any planting combination. The presence of a tree or groundcover *did not* consistently affect turfgrass visual quality or color, but in 3 of 4 years its total annual growth (accumulative clipping yield) was reduced when it was planted with a tree or adjacent groundcover. Thus, performance of tall fescue is affected primarily by the irrigation amount and not the planting combination. Combining groundcover and/or trees with tall fescue will not significantly impact the landscape or turf water requirements, providing there is not continuous shading of the turf.

Spring cinquefoil performed well when irrigated at 80% ET_0/DU, but its visual quality was usually unacceptable at 56% ET_0/DU. Unlike tall fescue, spring cinquefoil's visual quality ratings were consistently reduced *whenever it was planted in combination with a tree*, especially at the 56% ET_0/DU treatment. However, the effect of a tree was usually not so great as to cause spring cinquefoil's visual quality to be unacceptable. Consequently, a tree within a planting of groundcover can significantly decrease its quality and increase its drought stress, but since its quality remained acceptable, irrigation greater than 80% ET_0/DU should not be necessary in mixed landscape situations.

Bradford pear trees remained attractive and healthy in all irrigation and planting combination treatments throughout the study. Bradford pear growth was not affected by irrigation amount, but tree growth was reduced when spring cinquefoil or tall fescue were growing around them. Therefore, tree growth is affected more by the presence of turfgrass or groundcover than irrigation amount within the range of irrigation treatments applied in this study. Extrapolating the findings from other research with data from this study, it is reasonable to infer that the minimum irrigation required for acceptable landscape performance of Bradford pear (and many other tree species) ranges from 35% to 56% ET_0/DU.

The results of attempts to calculate meaningful ET_0 values for the individual mixed landscape plantings were disappointing. Even with meticulous refinement in the collection of meteorological data and its use in the CIMIS Penman-Monteith equation, we were unable to see any consistent relationship among the calculated ET_0 values from the plant combinations or between calculated ET_0 and CIMIS ET_0. The makeup of a mixed landscape often violates major assumptions of the Penman-Monteith equation used to calculate ET_0. Thus, CIMIS calculations and ET_0 calculated form mixed landscapes are two different items that are based on different assumptions and principles. Each may be accurate for its context, but they are not analogous. The Penman-Monteith equation does not accurately reflect the relationship among the variables that determine the ET of a mixed landscape, and it may be impossible to derive one that is accurate.

Calculated landscape coefficients (K_L) values were compared to the irrigation treatments in this study. Based on plant performance measured in this study and assuming that the desired level of visual quality for a species is minimally acceptable or better, substituting the K_L values for the irrigation treatments used in the study would:

1. provide an appropriate amount of water to groundcover and groundcover + tree plantings;
2. slightly over-water turfgrass+groundcover and turfgrass+tree plantings;

3. significantly over-water turfgrass and turfgrass + groundcover + tree plantings;
4. over-water trees growing alone; and
5. fail to recognize the unique plant species/irrigation treatment interactions like those identified between tree and groundcover.

<u>Conclusions and Practicum</u>

Plant species combination and irrigation amounts can interact in complicated ways to determine how mixed landscapes perform. Even if the optimum amount of water is provided for a plant species, other plant material growing with it might create interactions that cause the species to perform less than optimally yet remain visually aceptable, and it may experience increased water stress. It is difficult to specifically characterize or quantify the factors that determine a mixed landscape's water requirement. The mechanisms of the species' interactions are unclear, but harmful interactions among species are most obvious when irrigation is reduced (56% ET_0/DU in this study). It seems that the species with highest individual water requirement is the dominant component. Second in importance are the unique biological interactions between particular plant species. These interactions can be observed and measured but they can not be readily predicted or inferred because of the large number of possible plant species mixes that exist.

The meteorological variables affecting plant water use can be measured (i. e. sunlight or shade, temperature, relative humidity, wind), but a suitable mathematical expression to use them in a mixed landscape context does not exist. Attempts in this study to employ the CIMIS equation were unsuccessful because its assumptions are not valid for mixed landscape settings. The landscape coefficient method (K_L) of estimating a mixed landscape's water need does not effectively account for interactions of plant species and irrigation amount described above. It can serve as a tool for establishing rough estimates of a landscape's water needs, but the accuracy one can expect of the K_L estimate for any given landscape mix is unpredictable. Because of the inherent inaccuracy of this method and the imprecise level of plant performance one can expect when using it, the K_L method should not be used to determine specific landscape water budgets.

Thus, the most effective means of estimating a mixed landscape's irrigation need is to use the minimum amount of water required by the most water demanding species in the mix as the basis. This amount can be adjusted up or down in small increments of 5% to 10% ET_0 until significant performance affects (gains or losses) are observed in the landscape. Additional research is needed to determine the minimum water needs of the most widely used landscape plant species so that this technique can be successfully implemented in a wide variety of mixed landscapes.

Findings from the study also provide specific information for effectively conserving water in mixed landscapes, and they reinforce findings of previous research on water needs of cool-season turfgrass, groundcovers, and landscape trees. For instance, there was no evidence that any species, alone or in combination with other species, would have performed significantly better if the planting was irrigated above 80% ET_0/DU (division by DU being an adjustment to account for the uniformity of the irrigation system).

In tall fescue, an adjacent planting of groundcover or a tree can reduce turfgrass growth, but they have limited effect on its visual quality. Tall fescue visual quality and growth in a mixed landscape are primarily affected by irrigation amount, and irrigation above 80% ET_0/DU is not warranted for it to maintain acceptable quality in a mixed landscape (see table below).

Groundcover performance can be affected by both irrigation amount and the plant species growing with it in a landscape (see table below). From a landscape water conservation perspective, irrigation greater than 80% ET_0/DU should not be necessary to maintain minimally acceptable visual quality of a groundcover in mixed landscape situations. Although trees planted in spring cinquefoil reduced its visual quality and increased its water stress, the effect of a tree itself did not cause spring cinquefoil to perform unacceptably. It maintained at least acceptable visual quality at 80% ET_0/DU regardless of the plant species combined with it.

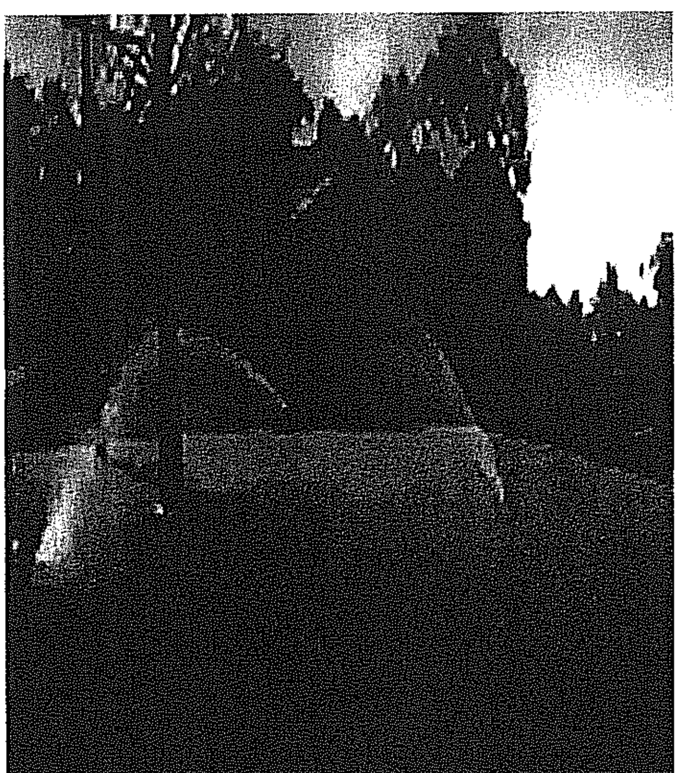
The Bradford pear growth and water stress data document that trees are able to adapt to reduced irrigation and grow normally. Many established tree species may only need irrigation of 56% ET_0/DU or less to provide acceptable growth and aesthetic value in a mixed landscape. However, tree growth my be reduced when a groundcover or turfgrass is growing around it (see table below).

Although plant species combinations and irrigation amount interact in complicated ways, applying additional water will not necessarily overcome adverse species interactions. There is no need to apply more than the optimum amount of irrigation for the most demanding species. Under this management scheme, all species should continue to perform at least acceptably.

What We Know About Landscape Water Requirements

by Dennis Pittenger

Reliable research-based data on landscape plants' water needs is extremely limited. Few sources offer quantitative estimates of landscape plants' water requirements, and most of them, including the widely known publication *Water Use Classification of Landscape Plants* (or *WUCOLS)*, are *not* based on scientific field research. Field research on non-turf landscape plants' minimum water requirements is limited to several of the most commonly used groundcover, tree, and shrub species. There is virtually no water requirement data for California native plants.



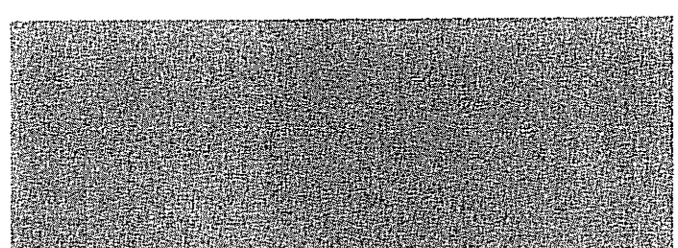
Why is so little scientific information available on landscape water needs? Primarily because there are hundreds of plant species to evaluate and the scientific process requires a great deal of resources to identify water requirements of an individual species. A brief look at how plant water requirements are scientifically determined helps explain.

First, a reference point or standard for comparison is established, which is known as *reference evapotranspiration*, *reference ET*, or most simply ET_o. By definition, it is the amount of water used via transpiration and evaporation by a large planting of tall fescue turfgrass (cool-season turfgrass) when it is unclipped (growing three to six inches tall) and given unlimited water. It is *not* the amount of water a tall fescue lawn requires for good growth. Most landscape species, including turfgrass, require an amount of water that is less than ET_o during most of the year.

Reference ET provides an estimate of the local climate's impact on plant water use. Local climatic factors — sunlight energy, temperature, wind speed, relative humidity, and other variables — are entered in a complex mathematical equation to derive an ET_o value for a given period of time, usually a day. Generally, as sunlight, temperature, and wind increase and as relative humidity decreases, the value of ET_o increases. Although ET_o varies from one climate zone to another the percentage of it used (or the crop coefficient) for a given species does not change. To establish an estimate of a plant's water requirement, it is supplied with known quantities of irrigation and its performance is evaluated. The minimum amount of water at which the desired level of performance is achieved is then compared to ET_o during the same period and expressed as a percentage of ET_o using a term known as a *crop coefficient* or K_c. A simple equation is used to express the plant's water requirement as $ET_{plant} = ET_o \times K_c$.

The concept of using the ET_o standard to estimate a crop's water needs through a crop coefficient was initially derived by agricultural crop scientists to estimate the water requirements of large tracts of field and orchard crops. Thus, the scientific application of ET_o to calculate crop coefficients assumes the plant materials of interest are:

- Well-watered with soil moisture unlimited at all times.
- Growing vigorously.
- Forming a nearly continuous canopy that functions as a single big leaf.
- Grown with the goal of optimum growth and development.
- Using water in direct proportion to the rate of ET_o.



Lawns and other turfgrass plantings closely match the ET_o assumptions, so crop coefficients have been scientifically determined that represent the water needed by common turfgrass species to perform optimally (see table at right). The annual averages are more commonly used, but monthly values generate irrigation schedules that more precisely match turfgrass needs.

Many landscape settings, however, violate the above assumptions. Mixed plantings of groundcover, shrub and tree species create variations in the plant canopy and shading that prevent the overall planting from functioning as a single big leaf, soil water content is not always at optimum levels, and the plants are not usually grown with optimum growth and development as the goal. Expectations of landscape plant performance are simply acceptable appearance and function, which are much less stringent than optimum growth and development. Also, research in plant physiology has revealed that water use of some woody landscape plants does not always continue to increase proportionally as ET_o increases throughout the day, especially when site conditions are harsh, such as when trees are planted within paved parking lots. Altogether, these conditions severely limit the ability of the ET_o equation to accurately reflect a landscape's water requirement and make it impossible to determine a precise crop coefficient for each landscape plant species.

Since landscape plants do not conform to the scientifically accepted assumptions of calculating crop coefficients, the ET_o standard has been used to determine ranges in percentage of ET_o for several species in which they will provide minimally acceptable performance and function, not necessarily optimum growth. The findings show that many universally used species maintain their aesthetic and functional value when irrigated within a range of 20 to 80 percent of ET_o.

Thus, it is currently recommended to initially set irrigation schedules at 50 percent ET_o for established non-turf landscape plantings. Plant performance should be evaluated and irrigation increased or decreased in increments of 10% ET_o until the desired level of performance is attained with the least amount of water. Intervals between irrigation of these plant materials can be greatly extended from fall until spring.

Looking forward, since scientific information on landscape plant water use is so scarce, the University of California Cooperative Extension, with financial support from CLCA, is about to embark on a field research project aimed at expanding and refining the database on minimum water requirements of landscape plants.

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Crop Coefficients (K_c) For Cool-Season And Warm-Season Turfgrasses.

Month	Cool-season	Warm-season
January	0.61	0.55
February	0.64	0.54
March	0.75	0.76
April	1.04	0.72
May	0.95	0.79
June	0.88	0.68
July	0.94	0.71
August	0.86	0.71
September	0.74	0.62
October	0.75	0.54
November	0.69	0.58
December	0.60	0.55
Annual Average	0.80	0.60

Cool season species include tall fescue, ryegrass, bentgrass, and Kentucky bluegrass.

Warm season species include Bermudagrass, zoysiagrass, and St. Augustinegrass.