



Tree and shrub irrigation water requirements in Northern Arizona

Introduction

The goal of landscape irrigation is aesthetic; however, the recent drought in Northern Arizona has caused some to change their irrigation objectives. During periods of drought, the survival of plants on minimal water may be the goal rather than a thriving landscape.

The quantification of turf and landscape water requirements is improving rapidly. Several research groups have measured the water requirements of landscape plants. At the same time, many research studies have investigated the water requirements of many new species of water conserving grasses. In addition, experts in horticulture have set up guidelines for landscape irrigation, and university extension services are introducing ET calculation procedures that are relatively easy to understand and implement.

In spite of recent advances, the great majority of professional landscapers and homeowners do not invest the time required to properly adjust and maintain water flow rates and irrigation cycle times. Even some golf courses, with very high water costs, may not measure uniformities and adjust sprinkler heads accordingly. Although irrigators may think that systems are performing adequately, closer inspection (measurement) reveals that systems often have flow rates that are vastly different from the initial designed flow rate.

The alteration of landscape design (Flack, 1980) in order to conserve water has become a major conservation practice in cities with high water prices. Reduction in lawn sizes, increases in impervious area and planting of low water use plants and trees are implemented in landscape architecture designs that are adapted to the local climate. Landscape irrigation requirements may be reduced by 80% (Zajicek, 1993).

Plants water requirements

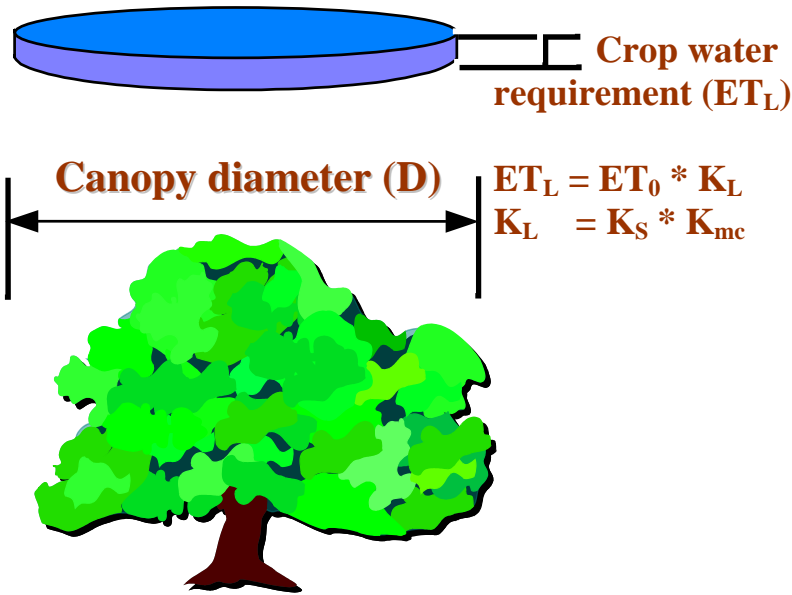
Urban areas are composed of diverse, disjointed spaces, each of which may possess different environment conditions. The amount of radiation in urban landscapes varies greatly (Clark and Kjølgren, 1989) and depends on direction, planting location and the degree of blockage by structures and taller trees. A site's openness and exposure, the extent and nature of surface covering, wind speed, and the degree of canopy closure, influence the demand of water by plants on a site. Examples of water conserving grasses and landscape plants can be observed at the Flagstaff Arboretum.

Irrigation scheduling is based on the rate of evapotranspiration (ET). For fundamentals of evapotranspiration, see <http://ag.arizona.edu/research/DIRT/az1194.pdf>. For use of evapotranspiration values in turf irrigation scheduling, see <http://ag.arizona.edu/research/DIRT/az1195.pdf>. Evapotranspiration from trees and shrubs is typically calculated based on the volume of water required by the plant. The daily volume required by the plant is the product of the daily depth required and the canopy area of the tree (figure 1).

The depth of water required per day is called the landscape water requirement (ET_L). The landscape coefficient (K_L) is the ratio between the reference evapotranspiration (ET_0) and the evapotranspiration of a specific plant. The reference evapotranspiration is the depth of water loss per day (in/day or mm/day) from well watered 10 cm long turf. Information on how to access reference evapotranspiration information for Northern Arizona is at http://ag.arizona.edu/research/DIRT/NAZTURF_BRO_DEC13_Webcolumns.pdf.

Equation 1 calculates the liters per day required by the plant. It was derived based on 78 % irrigation efficiency so irrigation efficiency is not included in the rest of these irrigation scheduling calculations. The 78 %

percentage is equal to $(\pi/4)$ and thus both terms drop out of equation 1. The assumed efficiency is high for a landscape irrigation system. If the system is not maintained at maximum uniformity and efficiency, then more water must be applied to the landscape, and the calculated water requirement must increase. The water use requirement can be calculated for individual plants or for a landscaped area. Equations 1 and 2 and figure 1 show how to calculate water requirement in liters per day or gallons per day for an individual plant.



$$LPD = ET_0 * K_L * D^2 \quad (1)$$

where

- LPD = water requirement, liters per day,
- ET₀ = reference ET, mm/day,
- D = canopy diameter, m,
- K_L = landscape coefficient, fraction.

In American units, the gallons per day is

$$GPD = 0.62 ET_0 * K_L * D^2 \quad (2)$$

where

- GPD = water requirement, gal per day,
- ET₀ = reference ET, in/day,
- D = canopy diameter, ft,
- K_L = landscape coefficient, fraction.

Figure 1. Evapotranspiration parameters.

Equations 3 and 4 and figure 2. Assuming 77 % efficiency, the water requirement in liters per day for an area with several plants is

$$LPD = 1.3 ET_0 * K_L * A \quad (3)$$

where

- ET₀ = reference ET, mm/day,
- A = area, a * b in figure 2, m²,
- K_L = landscape coefficient, fraction.

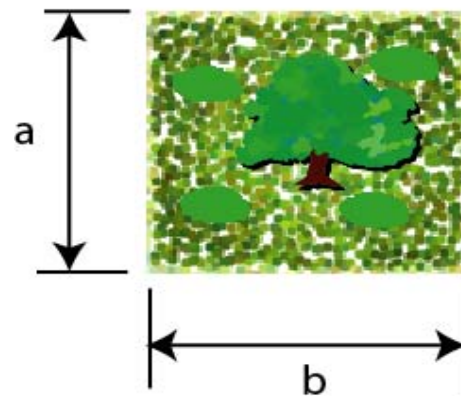


Figure 2. Landscaped area with trees, shrubs, and groundcover.

The water requirement in gallons per day assuming 78 % efficiency is

$$GPD = 0.8 ET_0 * K_L * A \quad (4)$$

where

ET_0 = reference ET, in/day,
 A = area, $a * b$ in figure 2, ft^2 ,
 K_L = landscape coefficient, fraction.

The landscape coefficient, K_L , is a function of several factors: plant species, shade, and plant density. Costello et al. (1993 and 2000), in California, developed the landscape coefficient (K_L) calculation: the ET_L (average evapotranspiration depth in the landscape) is the product of K_L and ET_0 . Further information on the landscape coefficient method and applications is at <http://www.owue.water.ca.gov/docs/wucols00.pdf>.

$$K_L = K_S * K_{mc} * K_d$$

where

K_S = Adjustment factor for a particular plant species (dimensionless)
 K_{mc} = Adjustment factor for shade or microclimate (dimensionless)
 K_d = Adjustment factor for plant density (dimensionless)

The species factors for low, medium, and high water use landscape plants are generally 0.2, 0.5, and 0.9, respectively. Costello and Jones (2000) classified 2,200 landscape plant species in four water use categories: High (H) = 70 - 90% ET_0 , Moderate (M) = 40 - 60% ET_0 , Low (L) = 10 - 30% ET_0 , and Very Low (VL) = <10% ET_0 . This information is in WUCOLS at <http://www.owue.water.ca.gov/docs/wucols00.pdf>. The water requirement of a plant depends on the climatic region. For example, a medium water use plant in a humid region might be a high water use plant in a desert region. Costello and Jones (2000) divided the state of California into 6 climate regions and classified each of the 2,200 plants as H, M, L, or VL based on the climate region in the WUCOLS handbook. Residents of Northern Arizona should use the High Desert classification (category 5).

The density factor, K_d , is 1.0 if tree cover is greater than 70 % or if shrub canopy cover is greater than 90 % (Costello et al., 2000). Studies show that water loss from orchards does not increase as canopy cover increases from 70% to 100%. Below 70% cover, however, orchard water loss declines (Costello et al., 2000). Studies have shown that orchard grass planted under orchards increases water loss by 25 % to 80 % (Costello, 2000). Landscapes planted in tiers (ground cover or turf, shrubs, and trees in the same landscape) have greater water loss than single level landscapes; thus, $k_d = 1.1 - 1.3$ in tiered, high density, landscapes. The density factor may range between 0.5 – 0.9 for low density plantings. The density factor is never less than 1 for K_L in equations 1 and 2, but it could be greater than 1.0 if a tree has shrubs or groundcover beneath it.

Plants near hot areas with reflected sun from buildings and roads will have an increase in ET , and the microclimate factor, K_{mc} , can range from 1.1 to 1.4 in these areas. If the landscape is close to reference evapotranspiration conditions, then the microclimate factor is set to 1.0. If the plants are in shade or protected from wind then they would have a low microclimate factor between 0.5 and 0.9 (Costello et al., 2000). For equations 1 and 2 with individual plants exposed to sunlight and direct wind during the entire day, then the microclimate factor may increase to 1.2.

Example 1. An Austrian black pine is 15 feet in diameter. Reference ET_0 is 0.19 inches on June 23. The tree is partially shaded by other trees. There are no plants under the tree. How many gallons per day are required on this date?

First the scientific name for Austrian black pine is found on page 118 of the WUCOLS handbook: *Pinus nigra*. Then, the classification for Austrian black pine is found on page 88 of the WUCOLS handbook. It is classified as a medium water use plant (M) in region 5. Therefore, the species coefficient is 0.5. Because there is some shade, the plant does not receive full sun so estimate the microclimate coefficient as 0.8. There are no plants beneath the tree so estimate the density factor as 1.0.

Use equation 2 to calculate the gallons per day

$$GPD = 0.62 ET_0 * K_L * D^2 = 0.62 (0.19 \text{ in}) * (0.5 * 0.8 * 1.0) * 15^2 = 11 \text{ GPD}$$

Example 2. One Austrian black pines, 15 feet in diameter, is planted in an area with trailing rosemary groundcover (*Rosemarinus 'Prostratus'*) and blue sage (*Salvia chamaedryoides*). This landscape is shown in figure 2. The a and b dimensions are 25 and 30 ft, respectively. Reference ET_0 is 0.19 inches on June 23. The landscape is in direct sunlight. There are no plants under the tree. How many gallons per day are required on this date?

All plants are classified as a medium water use plants (M) in region 5. Therefore, the species coefficient is 0.5. Because there is no shade, the microclimate coefficient as 1.0. This is a tiered landscape with shrubs, ground cover and trees so estimate the density coefficient as 1.2 .

Use equation 4 to calculate the gallons per day

$$GPD = 0.8 ET_0 * K_L * D^2 = 0.8 (0.19 \text{ in}) * (0.5 * 1.0 * 1.2) * 25 * 30 = 68 \text{ GPD}$$

References

Costello L. R., N. P. Matheny, and J. R. Clark, 2000. A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California The Landscape Coefficient Method And WUCOLS III. University of California Cooperative Extension and California Department of Water Resources

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