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Principles for Landscape Water Conservation

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Repeated droughts, warm temperatures, and climate change mean that water conservation will remain a necessity in California. Conservation can occur via a qualitative approach, in which general principles are applied, or it can be done via a quantitative approach, in which landscape managers calculate how much water is needed and used. (The two approaches can also be combined.) With the quantitative approach, measurements can provide specific information and allow numerical comparisons to be made. However, not everyone enjoys calculations or wants to do them, and it is not necessary to perform calculations to save landscape irrigation water.

This publication is divided into two sections: one that explains the general principles for water conservation in landscapes and provides details for implementing those principles, and a second section on calculations for landscape water use.

In California, water use can be divided into environmental, agricultural, and urban sectors, which respectively account for 50, 40, and 10 percent of total use. (The environmental sector includes uses such as streamflow, Delta protection, and fish habitat.) For further details, see the fact sheet on water use in California on the website of the Public Policy Institute of California, ppic.org/publication/water-use-in-california/. In urban areas, about half of water is used outdoors, and of that fraction, about half is used for landscape irrigation. Water use has a direct cost for an individual homeowner or business, as well as an ecological impact.

Seven principles for xeriscape

In the mid-1980s, there was a strong movement in the western United States toward understanding, developing, and promoting water-conserving landscapes. Conferences were held to discuss the use of drought-tolerant plants and a then-new design approach called xeriscape (figs. 1, 2, 3, and 4). Derived from the Greek word ξηρος (*xēros*), meaning "dry," the idea was to conserve water while maintaining an aesthetically attractive landscape. The National Xeriscape Council, formed in 1986, published seven principles that apparently originated with Denver Water and its associated volunteers. These useful and time-tested principles, listed here in order of their importance for water conservation in California, have become widely incorporated into landscape strategies:

- efficient irrigation
- use of mulches
- planning and design
- appropriate plant selection
- practical turf areas
- appropriate maintenance
- soil analysis

See figs. 1–4 for examples of xeriscapes.

Efficient and effective irrigation

This is the key to any attempt at water conservation. Without attention to irrigation design and scheduling, the other principles

Figure 1. Example of a xeriscape landscape on the UC Davis campus.

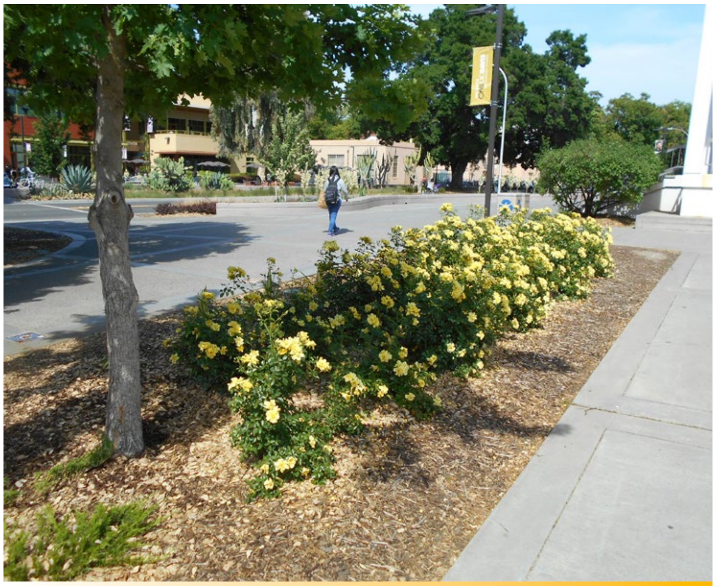

Figure 2. Example of a xeriscape landscape on the UC Davis campus.

Figure 3. Succulents used in a xeriscape on California's Central Coast.

Figure 4. A xeriscape found in the Mojave Desert.

have no value. Plant selection, maintenance, and other strategies alone do not save water. It's irrigation scheduling—how often and how much water is applied—that results in water savings, so this principle is fundamental.

Effective irrigation depends on 1) the design of the irrigation system, 2) how uniformly water is applied, and 3) how well water applications are scheduled according to plant needs. The original design and the ongoing repair and management of the system must emphasize these three components. An efficiently designed and managed system places water accurately and evenly in the plant root zone and at a rate that minimizes runoff. Properly scheduled irrigations apply water at intervals that avoid stressing plants with excessively wet or dry conditions.

A basic approach to irrigation scheduling is to irrigate and monitor. In other words, irrigate and then check the soil between irrigations to see how fast it is drying (soil dries from the top down). A long-blade screwdriver, shovel, or soil probe can be used to check soil wetness.

Drip irrigation may have advantages for shrubs and trees because of precise placement around plants and lack of overspray onto driveways or sidewalks. However, like any irrigation system, drip irrigation is effective only if consistently and properly managed, with water applied according to plant needs. Drip systems tend to require more frequent maintenance than other types of irrigation systems.

For turf areas, several types of emitter heads are available. For irregularly shaped areas, fan-spray heads are often used, but fan-sprays do not apply water uniformly over an area and apply water faster than most soils can absorb (fig. 5). Heads with lower application rates, such as multiple or multistream rotary nozzles, should be used in most cases. These nozzles also apply water with better uniformity than fan sprays.

Irrigation systems that apply water nonuniformly lead to waste because managers usually irrigate until the driest spots are wet enough. For example, when uniformity is only 50 percent, achieving the desired moisture level in a dry area will cause about twice as much water as necessary to be applied to wet areas.

Irrigation scheduling is about frequency and duration of watering—how much and how often—which will depend on how fast plants use water and the capacity of the soil to store water. Set the amount of water (duration) so that the root system is irrigated to a proper depth. This should not change. For a turf area, ideally this should be 12 inches. Set the frequency of irrigation to reflect plant water use as influenced by the environment. Sometimes multiple irrigations within a short period are required to avoid producing runoff, and to allow water to reach the root system and fill the appropriate soil volume with water.

Figure 5. Irrigation of turf with fan-spray emitters has led to runoff.

Plant water needs are dependent upon weather; plant size, age, shape, and species; leaf area and leaf characteristics; and the location of the plant in the landscape (whether it is part of a group or isolated and exposed, for example). The amount of water available to plants depends on the soil texture and the extent (spread and depth) of the plant's root system.

Plant water use can be estimated by reference evapotranspiration (ETo), which is the sum of evaporation and transpiration from an area of unstressed cool-season turfgrass or alfalfa. ETo values for various locations and times of year can be found on the California Information Management Information System (CIMIS) website, cimis.water.ca.gov/. ETo changes dramatically from winter to summer in most of California. Therefore, irrigation schedules should be adjusted at least quarterly. Fall and spring are transition times when managers may want to adjust irrigation timing monthly. The irrigation run time (duration) should be based on the time needed to fill the root zone with water. As noted above, once this is determined, it should not change. Frequency (how often the system operates) can be increased or decreased depending on season.

To measure the rate of sprinkler-water application, place cans or coffee mugs in a grid pattern and then run the system for a specific time period. For drip systems, application rate can be calculated from the drip emitter specifications. These values can be compared to the reference ETo for the month or season of interest. (See this publication's second section for calculations.)

Mulches

Mulches reduce surface evaporation, provide insulation so soil temperatures can be cooler, and suppress weeds. Bark or other organic mulches are preferred over rock or plastic to reduce absorbed and reflected heat. Adding mulch is an easy step that confers direct benefits. Be sure that the material is coarse and doesn't retain water.

Mulching can be an effective water conservation tool in several ways. The greatest benefit of mulches is their ability to shield the soil surface from solar radiation, which reduces soil temperature in summer and retards evaporation. Bark or other organic mulches are preferred and will improve soil structure over time as they decompose. Rock mulch may injure plant stems by reflecting heat onto them.

Protecting soil from the drying effect of wind is another major benefit. Mulch also dissipates the impact of water droplets, lessening soil erosion. Many kinds of mulches have high infiltration rates, allowing irrigation water to enter the soil instead of being lost as runoff. As long as the mulch material is sufficiently coarse, with low water-holding ability, mulches also protect drip irrigation lines from degradation caused by exposure to the sun. And they reduce weed seed germination, which is important because many weeds are prodigious users of water.

Mulches can have disadvantages in certain situations. For example, the collar area of trees and shrubs may stay too wet, leading to root disease, so mulch should be kept from contact with trunks.

Planning and design

In the context of water conservation, design is about placing plants with similar water requirements together. This "hydrozoning" allows irrigation to be adjusted to optimize the application of water to the plants within an irrigation zone. Otherwise, adequately irrigating plants that require more water can result in increased irrigation to all plants on a given irrigation line. Zoning can be achieved by placing plants in neighboring locations, by appropriate irrigation design (ensuring all plants on a given irrigation line have similar water requirements), or both. Zoning also helps reduce insect, weed, and disease problems that can result from over- or underwatering.

For turf, it is easiest to irrigate uniformly by confining plantings to simple geometric shapes, such as rectangles. Designing for water conservation does not preclude the use of plants that consume more water, or features such as pools and fountains, but rather emphasizes their relationship to the overall design. Xeriscape or water-conserving design does not require an expanse of cactus and gravel. Proper design makes good ecological sense in arid regions and is especially important considering California's limited water supply (fig. 6).

The function of the landscape should be considered from the beginning of the design process. Plants may be included for aesthetic purposes alone, but unnecessary expanses of plants could be eliminated. A tasteful accent grouping of plants can make a strong statement and use less water than rambling shrubs or turf. Properly placed trees can provide summer shade for buildings and reduce the need for air conditioning. Features such as patios and other hardscapes require no water. Container plants can provide color accents (fig. 7).

Appropriate plant selection

Plant selection is important to the extent that it allows reductions in the frequency of irrigation and the amount of water applied. In almost all landscapes, adjusting the irrigation schedule may result in large water savings. Further modifications, such as

Figure 6. The very limited water supply at the Bakersfield National Cemetery has led to the use of a xeriscape design.

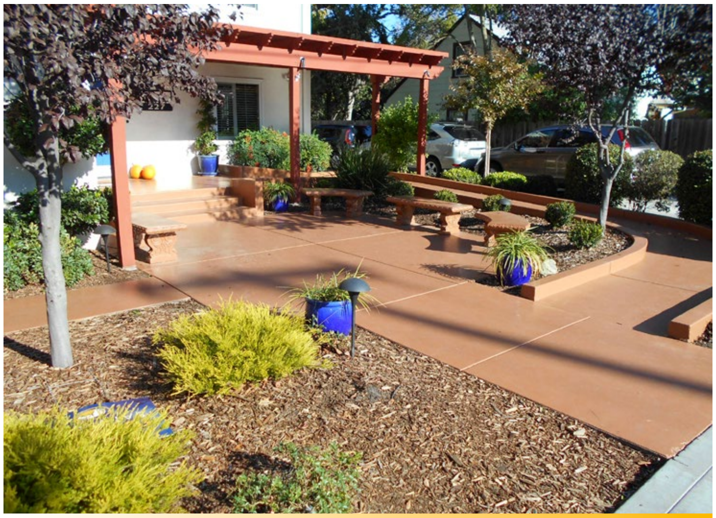

Figure 7. Use of hardscapes and container plants can lessen the need for landscape irrigation.

changing the types of plants used, may result in additional water savings by allowing additional reductions in irrigation.

All plants use water. Although some plants use less water than others, in an absolute sense no plants *conserve* water. Water is vital for transport of nutrients and sugars within the plant, and is required for photosynthesis.

The water requirements of landscape trees, shrubs, and ground covers shown on various plant lists are mostly based on observation or on the natural history of a species. Terms that distinguish among plants—*drought-tolerant*, *water-conserving, high-water need, or ordinary plants*—may not be defined quantitatively (numerically) or may not be based on data from research experiments and measurements. Water use for various plants has been assigned via an expert (Delphi) approach in the Water Use Classification of Landscape Species (WUCOLS) database, ucanr.edu/sites/WUCOLS/, and about half of the WUCOLS recommendations align with the results for plants that have been tested in the UC Landscape Plant Irrigation Trials program, ucanr.edu/sites/UCLPIT/. However, lack of quantitative data regarding specific trees, shrubs, and groundcovers prevents precise comparisons when designing or evaluating a landscape.

Another approach is to group plants that can endure high levels of water stress, regardless of their typical water use. Plants that can endure dry periods, as observed in nature, should be planted together.

Figure 8. Desert plants, such as this Encelia shown in the Mojave Desert, may not perform well under irrigated conditions.

Use plant species that are well suited to local conditions. For much of California, plants from areas with a Mediterranean climate are well suited. California natives may be used, but California is a large state and what is native in one location may not thrive in another. And not all native plants are water-conserving. Plants from arid areas or the desert may be poorly adapted to an irrigated landscape, as many are sensitive to overwatering and may develop root rot (fig. 8).

Practical turf areas

Turfgrass can be efficiently irrigated, and some turfgrasses use less water than others. Warm-season grasses need less water than cool-season grasses, with further water savings if a warm-season grass is managed with deliberate deficit irrigation (less irrigation than optimal). In most home landscapes, irregularly shaped turf areas and lack of uniformity of the irrigation system result in overwatering. Reducing turf areas may result in less applied water.

Quantitative data exist for turfgrass water use. To compare turfgrass water requirements, use ETo. Cool-season grasses such as tall fescue and Kentucky bluegrass can maintain an acceptable appearance and growth at about 60 percent of ETo. Warm-season grasses, such as bermudagrass and zoysia, can receive about 40 percent of ETo. But warm-season grasses save water only if irrigation is managed accordingly.

Turf should be considered for its function and not only its appearance. Lawns are well suited for play areas, pets, and frequent foot traffic. Other kinds of plantings can be substituted for turf where foot traffic is absent, or hardscape can be used where people walk frequently.

When properly selected and managed, turf is water-thrifty. In nature, grasses tolerate the semiarid conditions of the Great Plains and the steppes of Asia. However, in many if not most cases, turf areas are poorly irrigated by systems that apply water much faster than the soil can absorb it. Since the water can't infiltrate the soil, longer run-times programmed in response to dry areas can lead to runoff, wasting water.

Appropriate maintenance

The need for appropriate maintenance applies in nearly any landscape, even when water conservation is not a top concern. However, maintenance decisions can affect water need. For example, mowing height affects turf water need (taller is better), and pruning decisions affect shade levels, which in turn affect water need.

Appropriate maintenance of irrigation systems is critical for water conservation. Periodically run the irrigation system during the day to check for missing or damaged sprinkler heads and drip emitters, broken risers, leaky valves, and sprinkler coverage. Repair as necessary and in a timely manner.

Plants may need to be pruned so as not to block irrigation emitters. On the other hand, overpruning of plants may reduce shade and lead to water stress for understory plants. If turf is cut at too low a height, brown areas can result.

Soil analysis

In many landscapes soil nutrient levels are adequate, and soil chemical analysis may not directly inform water savings. Soil characteristics do not affect how much water plants need. However, soil tests often give descriptions of soil texture—the composition of soil as percentages of sand, silt, and clay particles—and understanding soil texture is important for knowing how to irrigate. Sandy soils have less water-holding capacity, and hence plants in sandy soils need to be irrigated more frequently than plants in soils of finer texture, such as silts and clays. Coarse-textured soils also have higher infiltration rates compared to fine-textured ones. So water can be applied faster on coarse soils but must be applied very slowly to fine-textured soils to avoid runoff. Adding compost to sandy soils can increase their water-holding capacity, and additions to clay soils can improve their water infiltration rate. An online app known as SoilWeb, casoilresource.lawr.ucdavis.edu/gmap/, can be used to estimate the water-holding properties of the soil. Find and click on a location on the map to find information about the soil type. Look for "Available Water Storage" in the "Map Unit Data" section.

For optimum performance under reduced irrigation, plants need to develop an extensive root system. To identify different layers of soil, or obstacles to root systems, use soil probes or augers. Such identification can be valuable background information for irrigation system design. Check the site for impediments to drainage. Such impediments can be a compacted layer or a clay layer, for example. Web Soil Survey, websoilsurvey.nrcs.usda.gov, may also be helpful.

An irrigation regime in which small amounts of water are frequently applied can lead to an accumulation of soil salts, which will need to be periodically washed through the soil profile (leached). Drainage is necessary for leaching to be effective. A simple test to evaluate drainage is to dig a hole about the size of a 5-gallon nursery container, fill it with water, and note about how long it takes for the water to drain. Limited drainage can indicate the need to provide surface drainage or to select landscape plants tolerant of wet conditions. Proper leaching is another reason for infrequent, but deep, applications of water.

Sample calculations for water use in a landscape

Our overall approach for estimating water use and conservation in a landscape is to compare irrigation (plus rainfall, if any) with reference evapotranspiration (ETo) for a given time period. As noted above, ETo is a baseline value for water use by an unstressed stand of cool-season turfgrass or alfalfa. ETo is typically given in units of inches per day, and values may be obtained from historical data found on the CIMIS website or real-time data from a weather station.

Agricultural crop water use has an extensive research base. When a crop has reached a closed canopy, we can model water use as if the crop were a single plane. We can then calculate expected water use by multiplying ETo by a crop coefficient, Kc, which is specific to the crop and season. Kc is dimensionless, and Kc values are almost always less than 1.0.

However, quantitative Kc values have not been determined by research for the vast majority of landscape plants, with turfgrasses the exception. Also, most landscapes contain many different plants with varying heights and canopy coverages. To circumvent this limitation, the Model Water Efficient Landscape Ordinance (MWELO) in California specifies for new and retrofitted landscapes an evapotranspiration adjustment factor (ETAF), which is an overall landscape coefficient analogous to Kc. For residential landscapes, the target ETAF adjustment factor is 0.55, and for commercial landscapes it is 0.45. Thus, for a residential landscape, if we find water use is greater than 0.55 × ETo, we can try to reduce applied water. On the other hand, if we find that water applied to a landscape is equal to or less than 0.55 × ETo, we're on the right track.

Let's look at how to calculate the volume of applied water, which includes irrigation water and rain, measured in units of depth. (We speak of receiving a half-inch or inch of rain in a storm, for example.) Depth (units of length) multiplied by surface area (units of length squared) gives us a volume (units of length cubed). All this is easy in the metric system, but with English units a few conversion factors are necessary. Since areas of landscape are typically given in square feet, and applied water in inches, we make the appropriate unit conversions to calculate the volume of water applied in units of cubic feet.

For example, given a landscaped area of 2,500 square feet and irrigation of 1 inch, we would make the following two calculations (showing unit conversions and cancellations):

$$1.0 \text{ in} \times 1.0 \text{ ft}/12 \text{ in} = 0.083 \text{ ft}$$

$$0.083 \text{ ft} \times 2{,}500 \text{ ft}^2 = 208 \text{ ft}^3$$

We will leave this result in units of cubic feet, although we could convert to gallons (7.48 gallons per cubic foot).

To estimate past water use in the landscape, we can use a water bill. We will assume that landscape irrigation is either shut off during winter months or run at minimal levels. Thus, water used during winter months provides a baseline value for nonlandscape (indoor) water use. For a summer month, we note the amount from the water bill and subtract the winter baseline value for indoor use. We further assume that little water has been used outdoors for washing cars, washing sidewalks, and so on.

Most home water providers measure water in units of CCF, where 1 CCF equals 100 cubic feet. Let's suppose our July water bill shows 33 CCF used. We have checked our winter water bills and we subtract 7 CCF for indoor water use, leaving a net of 26 CCF for outdoor applied water—that is, 2,600 cubic feet. We will assume all of that went to landscape irrigation.

To obtain a value for depth of applied water to the landscape, we can divide the volume of water by the area of the landscape:

$$2{,}600 \text{ ft}^3/5{,}000 \text{ ft}^2 = 0.52 \text{ ft}$$

$$0.52 \text{ ft} \times 12 \text{ in}/1.0 \text{ ft} = 6.24 \text{ in}$$

How are we doing with respect to ETo? ETo maps for California are available on the California Irrigation Management Information System (CIMIS) website, cimis.water.ca.gov/. (See the "Spatial CIMIS" heading on the opening page, then click on "ETo Zones Map" to find areas, or zones, with similar ETo values and to see a table listing historical ETo by month for each zone.)

The large urban areas, such as Los Angeles, include several ETo zones, so let's use a simpler case. Let us consider a place within the San Joaquin Valley in ETo zone 12, which includes Fresno, Madera, Merced, and Stockton. For July, the historical ETo in zone 12 is 8.06 inches. We can compare that number to our estimate of 6.24 inches applied to the landscape. We see that our value of 6.24 inches is lower than the historical ETo, and that's good.

To obtain a quantitative comparison, we do the following calculation:

$$6.24 \text{ in}/8.06 \text{ in} = 0.77$$

This number is actually our value for the landscape ETAF, or adjustment factor. That seems like a reasonable starting point for water conservation. However, to fall beneath the desired ETAF value of 0.55 for a residential landscape, the applied water needs to be 4.43 inches or less.

$$0.55 \times 8.06 \text{ in} = 4.43 \text{ in}$$

Therefore, we think we can work toward additional water savings.

Conclusion

The focus of landscape water conservation and most effective efforts to reduce water use is irrigation management. Other steps or changes can aid in reducing the need for water, but of themselves do not result in water savings unless irrigation is reduced, either by reducing run-times (duration) or days of watering (frequency). Once the run-time necessary to add the amount of water that refills the soil is determined, it should not be altered. Only the frequency should be changed to match plant water use and soil water depletion.

This is the "water deeply, but infrequently" mantra that helps plants grow deep roots. Larger root systems can "mine" a larger soil volume and gain access to larger volumes of water stored in the soil. Checking soil between irrigations can inform irrigation clock settings. Adjusting irrigation for seasonal changes can result in major water savings. Confirming that all of the applied water infiltrates the soil and does not run off ensures that no water is wasted.

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