The New California Landscape

DROUGHT TOOLKIT

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UC Agriculture and Natural Resources (UC ANR) and

The State of California Department of Water Resources

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UCCE Master Gardener Program

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2015 UC Master Gardener Program Drought Workshop

The New CA Landscape

Overview & Water-wise Peer Sharing

Agenda

10-10:30 UC Master Gardener statewide drought response
Missy Gable, Statewide Program

10:30-11:45 Maintaining an existing landscape
UCCE Academics

- Overview
- What is plant water use?
- Irrigation auditing & scheduling
- Turf
- Maintaining landscape plants
- Maintaining edible plants
- Staying fire safe

11:45-12:15 Lunch

12:15-1:30 Planning a low water landscape
UCCE Academics

- Irrigation updates/changes
- Calendaring change
- Alternatives to turf
- Native plants and Mediterranean plants
- Hydrozoning
- Smart meters, graywater and rainwater collection

1:30-1:45 Break

1:45-2:45 California drought overview and regulations
UCCE Academics, Department of Water Resources representative

- Status of California water supply
- State regulations

2:45-3:45 Water-wise Peer Sharing
Lauren Snowden, Statewide Program

3:45-4 Wrap Up & Looking to the future
Lauren Snowden, Statewide Program

NEW CA LANDSCAPE

Drought and Fire Resources List

UC ANR PUBLICATIONS

- ☐ Sustainable Landscaping in California (8504) $0
- ☐ Water Conservation Tips for the Home Lawn and Garden (8036) $0
- ☐ Managing Turfgrasses during Drought (8395) $0
- ☐ Mowing Your Lawn and Grasscycling (8006) $0
- ☐ Lawn Watering Guide for California (8044) $0
- ☐ Drip Irrigation in the Home Landscape (21579) $7

View UCANR Publications: http://anrcatalog.ucdavis.edu/

RESOURCES

- ☐ Keeping Landscape Plantings Alive Under Drought or Water Restrictions (http://cagardenweb.ucanr.edu/files/184688.pdf)
- ☐ Easy Calculators for Estimating Landscape Water Needs (http://ucanr.edu/sites/UrbanHort/Water_Use_of_Turfgrass_and_Landscape_Plant_Materials/Easy_Calculators_for_Estimating_Landscape_Water_Needs/)
- ☐ Landscape Irrigation System Evaluation and Management (http://ucanr.edu/sites/UrbanHort/files/160836.pdf)

UC ANR FIRE RESOURCES

- ☐ Landscaping Tips to Help Defend Your Home from Wildfire (8322) $0
- ☐ Home Landscaping for Fire (8228) $0

View UCANR Publications: http://anrcatalog.ucdavis.edu/

POWER POINT PRESENTATIONS

- ☐ UC Master Gardener Drought
- ☐ Creating and Maintaining a Fire Safe Landscape

See your coordinator (located on coordinator website)

ONLINE TRAINING

- ☐ Water and Drought Online Seminar Series, by California Institute for Water Resources (http://ciwr.ucanr.edu/California_Drought_Expertise/Insights_Water_and_Drought_Online_Seminar_Series/1)
- ☐ Scheduling Irrigation, How Much and When by Loren Oki (http://ccuh.ucdavis.edu/public/ysb-series/past-events-folder/ysb-low-water-use-landscaping/uc-davis-11-8-2014/presentations-handouts/scheduling-irrigation-l-oki/view)

WEBSITES

- ☐ Arboretum All-Stars (http://arboretum.ucdavis.edu/arboretum_all_stars.aspx)
- ☐ California Department of Water Resources (http://ciwr.ucanr.edu/)
- ☐ California Center for Urban Horticulture (http://ccuh.ucdavis.edu/public/drought/map)
- ☐ California Institute for Water Resources (http://ciwr.ucanr.edu/California_Drought_Expertise/)
- ☐ California Garden Web-Managing Water Sustainability (http://cagardenweb.ucanr.edu/General/Managing_Water,_Sustainably/)
- ☐ California Garden Web- Drought: Gardening Tips (http://cagardenweb.ucanr.edu/Drought_/Drought_Gardening_Tips_/)
- ☐ California Garden Web- Drought: Irrigation Tips (http://cagardenweb.ucanr.edu/Drought_/Drought_Irrigation_Tips_/)
- ☐ California Garden Web- What is my climate zone? (http://cagardenweb.ucanr.edu/Your_Climate_Zone/)
- ☐ Cal Fire
- ☐ California Irrigation Management Information System (CMIS)
- ☐ California Soil Resource
- ☐ California Water Districts and Association (http://library.ucr.edu/?view=wrca/grants/districts.html&sitesearch=California water)
- ☐ Plantright (http://www.plantright.org)
- ☐ Save Our Water (http://saveourwater.com/)
- ☐ Sunset Climate Zones (http://www.sunset.com/garden/climate-zones/climate-zones-intro-us-map)
- ☐ UC Master Gardener Program Statewide Blog

LEGISLATION

- ☐ **AB 2100** Prohibits a Home Owner's Association from imposing a fine or assessment against a member for reducing or eliminating irrigation during a drought emergency declared by the Governor or local government
- ☐ **AB 2104** Home Owner's Association can't prohibit Cash for Grass. Home Owner's Association's landscaping guidelines or policies are void and unenforceable if it prohibits the use of low water plants as a replacement for existing turfgrass.
- ☐ **Prop 1** Water Bond. $7.545 billion bond
  - $810M Regional Water Security
    - $100M Conservation.
    - $200M Multi-benefit Stormwater
    - $510M Regional Water Management Project
  - $725M Water Recycling
  - $900M Groundwater Stability
  - $270M Water Storage

NOTES

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Table of Contents

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Ten Ways to Conserve Water in Your Home Landscape in [NAME] County

1. Select water-efficient plants that grow well in your climate and microclimate

2. 'Hydrozone': Place plants with similar water needs together and irrigate them accordingly (high, medium, low, and very low zones)

3. Let roots of established plants dry out between irrigations, water deeply and infrequently slightly below the root zone

4. If you do not use or enjoy your lawn consider replacing it with drought-tolerant plants. If you decide to keep your lawn - water it based on UC's *"Lawn Watering Guide"* available online at: http://ucanr.org/freepubls/docs/8044.pdf

5. Mix soil amendments (compost, etc.) evenly and deeply into sandy and clay soils (40% or more by volume) before planting

6. Spread a 2 - 3" layer of mulch on top of soil around garden plants and trees

7. Water early in the morning

8. Control weeds

9. Avoid over-fertilizing

10. Sweep walkways and driveways , do not hose them down with water

Have a Home Landscape or Gardening Question?
Contact us!

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Website: [mg.ucanr.edu]

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Home
Drought
Flowers
Gardening Basics
Gardening Classes & Events
Glossary: A - M
Glossary: N-Z
Growing Berries in Your Backyard
Growing Grapes (table, wine, raisins) in Your Backyard
Indoor Plants
Landscape Trees, Shrubs, & Vines
Lawns
Links
Nut & Fruit Trees & Vines
Poisonous Plants
Vegetables
What is my climate zone?

What is my climate zone?

Still in need of more information? *Advice to Grow By - Ask Us HERE!*

Most gardening books, catalogs, and seed packets refer to plant hardiness zones, climate zones, or growing zones. Temperature hardiness climate zones are based on normally expected high and low temperatures and serve as guides to help you know which plants will grow where you live.

Buy map" title="Generalized Plant Climate Map of California Buy map" />

Generalized Plant Climate Map of California

Buy map

Temperature is not the only factor in figuring out whether a plant will survive in your garden. Soil types, rainfall, day length, wind, humidity, and heat also play their roles. Even within a city, a street, or a spot protected by a warm wall in your own garden, there may be microclimates that affect how plants grow. The zones are only a guide and a good starting point, but you still need to determine for yourself what will and won't work in your garden.

Of 24 climate zones defined in the Sunset Western Garden Book and the 20 zones defined by the United States Department of Agriculture (USDA), California has 20 and 16, respectively.

The USDA plant hardiness map divides North America into 11 hardiness zones. Zone 1 is the coldest; zone 11 is the warmest. When you order plants from catalogs or read general garden books, you need to know your USDA zone in order to be able to interpret references correctly. The American Horticultural Society has also issued a Plant Heat-Zone Map.

Gardeners in the western United States sometimes are confused when confronted with the 11 Hardiness Zones created by the USDA, because we are used to a 24-zone climate system created by Sunset Magazine. The Sunset zone maps, considered the standard gardening references in the West, are more precise than the USDA's, since they factor in not only winter minimum temperatures, but also summer highs, lengths of growing seasons, humidity, and rainfall patterns.

University of California
The California Garden Web

SKIP TO CONTENT SITE MAP Enter Search Terms

UC Master Gardener Program

- Home
- Drought
  - Drought: Gardening Tips
  - Drought: Irrigation Tips
- Flowers
- Gardening Basics
- Gardening Classes & Events
- Glossary: A - M
- Glossary: N-Z
- Growing Berries in Your Backyard
- Growing Grapes (table, wine, raisins) in Your Backyard
- Indoor Plants
- Landscape Trees, Shrubs, & Vines
- Lawns
- Links
- Nut & Fruit Trees & Vines
- Poisonous Plants
- Vegetables
- What is my climate zone?

SHARE PRINT

Drought: Irrigation Tips

Water is an essential resource for all aspects of life. With California's shortage of rain and snow this year, conserving our limited water supply is critical. Follow these simple recommendations for conserving water in your home landscape.

Adjust Irrigation

Irrigation controllers are commonly used to set start times, frequency and duration of a home's sprinkler or drip system. Over irrigation is very common, most home landscapes irrigation times and frequencies can be reduced by 20 to 40 percent with little to no effects on landscaping.

Irrigation Adjustment Tips:

- Gradually reduce water use by 10 percent increments over the course of a few weeks - giving lawns, trees and plants time to adjust
- Find your irrigation controller manual online, visit www.SaveOurH2O.org
- Install a "Smart" irrigation controller which automatically adjusts using current weather data, historical weather patterns and/or soil moisture sensor
- Check for and repair leaks
- Adjust sprinkler heads to maximize coverage, avoid watering sidewalks and patios
- Install a drip irrigation system, grouping plants with similar water needs together on one drip irrigation line

Irrigation Scheduling Worksheet:

Calculate lawn and landscaping needs using the Irrigation Scheduling Worksheet from the UC Division of Agriculture and Natural Resources and UC Davis. This worksheet will generate an annual calendar to irrigate a single hydrozone based on local historical evapotranspiration (ET), distribution uniformity (DU) assessment information, soil type, and desired soil wetting depth. The worksheet will also accommodate irrigation that is restricted to specific days of the week (designated irrigation days).

- Landscape Irrigation Worksheet
- Landscape Irrigation Scheduling Worksheet Instructions
- Landscape Irrigation System Evaluation and Management

Lawn Watering

A lawn is almost always the single largest user of water in the home landscape, over irrigation is very common. Homeowner's should adjust lawn irrigation systems monthly in response to changes in temperature and weather. Calculate your turf's exact water needs using the three easy steps outlined below.

Water-saving Lawn Tips:

- Replace nonessential turf with ground covers, mulches, or decks and walkways
- Water at night, ideally between 9:00 p.m. and 6:00 a.m. - helps reduce evaporation and wind interference with sprinkler patterns

- Mow lawn higher during very warm weather

3 Steps for Calculating Lawn Watering Needs:

1. What type of lawn do you have?
2. What is your sprinkler output?
3. How many minutes do you need to water your lawn?

Learn More: Lawn Watering Guide for Homeowners >>>

Recycled Water

Using recycled water, or graywater, to irrigate landscape plants helps conserve water, electricity and reduces water bills. An estimated 30 to 50 percent of home water consumption results in graywater, which can be recycled into the landscape. Most homes can supply one-half to 3/4 of water-efficient landscape needs using graywater.

Recycled Graywater Sources:

- Residential washing machines
- Bathtubs
- Showers
- Sinks

NOT Graywater Sources:

- Kitchen sink
- Dishwasher
- Toilets

Because of health risks recycled water and/or graywater is not approved or recommended for use on edible plants. Graywater should only be used on non-edible, ornamental landscapes.

Check with the California Department of Housing and Community Development (HCD) Division of Codes and Standards website. Greywater regulations are always evolving check with HCD and local agencies before planning or installing a graywater system.

Learn More: Use of Graywater in Urban Landscapes >>>

Resources

Landscape Irrigation Scheduling Worksheet - ***NEW!***

California Institute for Water Resources

Drip Irrigation in the Home Landscape (UC ANR Publication)

Easy Calculators for Estimating Landscape Water Needs

Keeping Landscape Plantings Alive under Drought or Water Restrictions

Graywater Use in Urban Landscapes

Lawn Watering Guide for California

Managing Turfgrass During Drought

Managing Water, Sustainably

Questions & Answers About Water Conservation and Drought in the Landscape

UCCE Irrigation Scheduling Worksheet

Water Conservation Tips for Home Lawn and Garden

PUBLICATION 8006

Mowing Your Lawn and "Grasscycling"

ALI HARIVANDI, Environmental Horticulture Advisor, UC Cooperative Extension, Alameda, Contra Costa, and Santa Clara Counties; and **VICTOR A. GIBEAULT,** Environmental Horticulturist, UC Riverside.

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Division of Agriculture and Natural Resources
http://danrcs.ucdavis.edu

This publication replaces ANR Leaflet 2587, *Mowing Your Lawn.*

An attractive lawn depends on proper mowing, in addition to other cultural practices such as irrigation and fertilization, to look its best. Mowing at a height and frequency that complement the growth habit of the grass results in a uniform, dense turf that discourages weeds and supports the turf area's intended use. Mowing too low weakens grass, causing sod to thin out, encouraging weed invasion, making the lawn more susceptible to pests, and possibly over time killing the lawn. Mowing too high produces a ragged, unattractive lawn and encourages the buildup of thatch, a spongy layer of plant debris. Mowing frequency is as important as mowing height in maintaining a healthy lawn and should be determined by the growth rate of the grass, which in turn depends on climatic conditions and the lawn maintenance program.

HOW HIGH TO MOW?

Optimum cutting height is determined by the growth habit of a particular grass and its leaf texture (i.e., the length and width of leaves). A grass's survival depends on its producing adequate leaf surface for food production through photosynthesis. Mowing too low removes too much of the grass's food producing area. As the grass literally starves, the lawn thins and looks poor. Conversely, mowing too high can hurt the appearance or usefulness of the turfed area.

No single mowing height is best for all turfgrasses; mowers must be set differently for each grass. Table 1 shows the ranges for optimum mowing heights for California lawns. Within its optimum mowing height range, each grass species will be healthier and have a deeper root system the higher the grass is mowed. Also, within its recommended mowing range, a grass that is cut higher is more tolerant of drought, heat, traffic, shade, disease, and pests than one that is cut lower.

WHEN TO MOW?

You can determine when and how often to mow your lawn by taking into account the growth rate of the grass during each season and the lawn appearance desired. Cool-season grasses will require more frequent mowing in the spring and autumn since these grasses grow most during this period. Warm-season grasses require more frequent mowing during summer months. Mow formal, ornamental areas more frequently than informal-use areas.

As a general guide, follow the *one-third rule:* mow often enough so that no more than one-third of the length of the grass blades is removed at any one time. For example, if you maintain a turf-type tall fescue lawn at 2 inches, mow it when the grass height reaches 3 inches. This may mean mowing tall fescue once a week during the spring and every two weeks during the summer. Table 1 also gives the height at which you need to mow your lawn in order to best maintain your desired lawn height. A lower-mowed lawn will require more frequent mowing than that same lawn would if mowed higher.

WHAT TO DO WITH THE CLIPPINGS?

Grass clippings make up a surprisingly large portion of California's solid waste stream during the growing season. With few exceptions, it is actually best to leave the clippings on the lawn after mowing. This practice, termed "grasscycling," is growing in popularity as California communities try to reduce the amount of waste going to landfills. Grass clippings decompose quickly and release valuable nutrients back into the soil.

Grasscycling can be practiced on any healthy lawn as long as the turf is properly managed. Unfortunately, many people treat a lawn as if it were a crop: overwatering and overfertilizing it to encourage maximum growth, and then "harvesting the crop" by bagging the grass clippings and transporting them to a landfill.

Successful grasscycling requires proper mowing. Cut the grass when the leaf surface is dry, keep your mower blades sharp, and follow the one-third rule. With frequent mowing, you will have short clippings that will not cover the grass surface if left on the lawn and will quickly decompose.

There are times, however, when grasscycling is not appropriate. Prolonged wet weather, mower breakdowns, or other circumstances that reduce mowing frequency and thus lead to an excessive volume of clippings probably dictate that the grass clippings should be bagged. But do not throw those clippings away! Grass clippings make an excellent addition to a backyard compost pile. Clippings can also be used as mulch to provide weed control and prevent moisture loss in flower beds and around trees and shrubs. In some situations, however, you should not mulch with clippings: if the clippings are of an invasive species such as bermudagrass or if herbicides were recently applied to the lawn, the clippings can be harmful.

Table 1. Proper mowing heights and mower types for common California turfgrasses

Grass type	Climate adaptation	Mower height setting	Mow when grass reaches this height	Mower type
Bentgrass	cool-season	½–1 inch	¾–1½ inches	reel
Bermudagrass (common)	warm-season	1–1½ inches	1½–2¼ inches	reel or rotary
Bermudagrass (hybrid)	warm-season	½–1 inch	¾–1½ inches	reel
Buffalograss	warm-season	1–2 inches	1½–3 inches	rotary
Kentucky bluegrass	cool-season	1½–2½ inches	2¼–3¾ inches	reel or rotary
Kikuyugrass	warm-season	1–1½ inches	1½–2¼ inches	reel or rotary
Perennial ryegrass	cool-season	1½–2½ inches	2¼–3¾ inches	reel or rotary
Tall fescue	cool-season	1½–3 inches	2¼–4½ inches	reel or rotary
St. Augustinegrass	warm-season	1–2 inches	1½–3 inches	rotary
Zoysiagrass	warm-season	½–1½ inches	¾–2¼ inches	reel or rotary

MOWING EQUIPMENT

The two basic mower types are reel and rotary. A reel mower (Figure 1) shears grass with a scissors action and is better for fine-textured turfgrasses or where a low mowing height is desirable. A rotary mower (Figure 2) depends on impact cutting with a high-speed rotating blade, and is better suited to higher cutting heights and coarser-textured grasses. The type of mower recommended for best appearance of each grass species is given in Table 1.

The blades of a reel mower are powered either by a gear train connected to the wheels (hand-powered or push models) or by a gasoline engine. The blades of a rotary mower are driven by an electric motor or gasoline engine. If you use a gasoline-powered mower add fuel away from the grass, since an accidental gasoline spill will injure plants. If you use a non-battery electric mower, take care to avoid running over the cord.

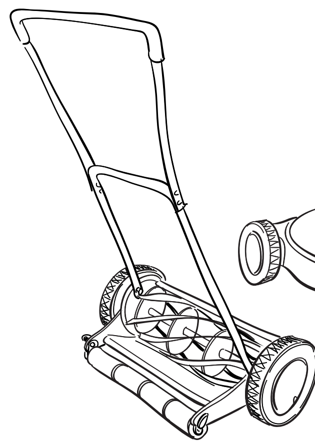

Figure 1. Reel-type mower

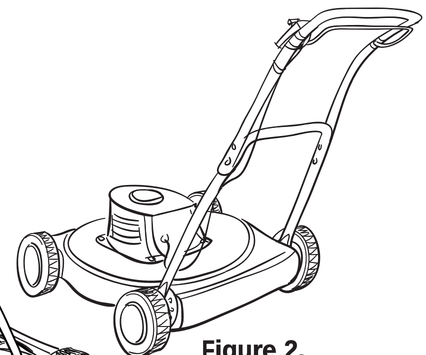

Figure 2. Rotary-type mower

You can adjust the mowing height on a reel or rotary mower. For a reel mower, simply place the mower on a flat surface and measure the distance from that surface to the bedknife. To adjust a rotary mower, look for index markers on the adjusters or consult your manual for instructions on height adjustment. Adjust to the desired height, but never adjust the mower height while the mower is running!

You can grasscycle with most mowers by removing the mower collection bag to allow clippings to drop on the lawn. However, if your mower does not have a safety flap covering the opening where the bag fits into the chute, purchase a retrofit kit before using the mower in this manner. Some lawnmower manufacturers have developed mulching or recycling mowers that cut grass blades into small pieces and force them into the soil. These mowers are effective for grasscycling and have become very popular. Several brands of recycling mowers are available in California.

MOWER SAFETY

- Study the instruction manual for manufacturer's recommendations on care and use of the mower.
- Never leave a running mower unattended.
- Keep people (especially children) and pets away from mowing operations.
- Before you mow, clear the lawn of all rocks, sticks, and other objects the mower can throw. Flying objects are hazardous.
- Keep hands and feet clear of moving parts.
- Work across slopes, not up and down.
- Don't pull a rotary mower backward unless absolutely necessary to maneuver the mower out of a tight spot.
- Stop the motor or engine or disengage the cutting blade when moving the mower across a driveway, walk, or unmowed area.

- Stop the engine or motor before you clean or adjust the mower.
- Remove the sparkplug wire (gasoline models) or disconnect the electrical supply (electric models) before working on the mower.
- Keep any gasoline in a safety can, and not in a glass jar or other improvised container.

ADDITIONAL MOWING TIPS

- Mow grass mixtures in a way that favors the predominant or most desirable grass.
- Do not mow wet grass: it sticks to mower blades and clogs the mower.
- Change the direction of mowing periodically to prevent a "washboard" effect.
- Sharpen lawnmower blades regularly. Dull mowers leave a ragged appearance from crushed or uncut grass blades, and damaged grass may be more susceptible to disease.
- Do not drastically or suddenly change the cutting height. If the grass has become too tall, re-establish the recommended height by mowing more frequently for a while and gradually lowering the mowing height of successive cuttings, following the one-third rule.
- Since mowing stresses the grass, do not mow a lawn under drought or other climatic stress conditions. Grass that is suffering from lack of water should be watered and allowed to dry before being mowed.
- Mow a shady lawn slightly higher and less frequently than is normally recommended for that grass species. Shade reduces photosynthesis, and slightly higher mowing heights allow more leaf surface that compensates for the lower light levels.

FOR MORE INFORMATION

You'll find detailed information on many aspects of turfgrass and landscape care in these UC ANR publications:

Pests of Landscape Trees & Shrubs, publication 3359
Turfgrass Irrigation Scheduling, publication 21492
Turfgrass Pests, publication 4053
Turfgrass Water Conservation, publication 21405
UC IPM Pest Management Guidelines for Turfgrass, publication 3365-T

Also of interest:
Grower's Weed Identification Handbook, publication 4030
Weeds of the West, publication 3350

To order these publications or to request of catalog of UC ANR publications, slide sets, and videos, contact

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UC PEER REVIEWED

PUBLICATION 8395 / AUGUST 2009

Managing Turfgrasses during Drought

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INTRODUCTION

Most of California has a Mediterranean climate characterized by long, hot, dry summers, and turfgrasses must be watered to survive under these conditions. Californians must learn how to use water more efficiently as demand and cost rise and drought conditions continue.

Warm-season and cool-season grasses are used as turfgrass in California, based on their climatic adaptability. The warm-season species include common and hybrid bermudagrasses, St. Augustinegrass, seashore paspalum, zoysiagrass, buffalograss, and kikuyugrass. These grasses are used in the San Joaquin Valley, southern California, and parts of the greater San Francisco Bay Area. The cool-season grasses include tall fescue, perennial ryegrass, Kentucky bluegrass, fineleaf fescues in mixes, and specialty grasses such as creeping bentgrass and rough bluegrass. Turfgrasses can be irrigated at different levels. The Optimum irrigation is the amount of water needed for the most efficient growth, maximum quality, and best appearance of the respective turfgrasses. Deficit irrigation provides sufficient water to maintain adequate turfgrass appearance with less growth. In contrast, survival irrigation provides only enough water to allow survival and potential recovery of the desired species when adequate water is again available. Under survival irrigation, growth and quality are drastically reduced.

Figure 1 presents the percentage of reference evapotranspiration (ETo) obtained from the California Irrigation Management Information System, relative to the three irrigation levels for warm- and cool-season turfgrasses. Figure 1 also

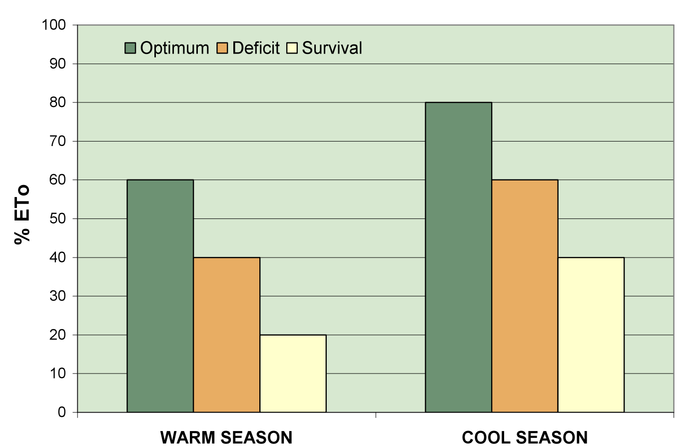

Figure 1. Turfgrass water requirements (as % of ETo) at optimum, deficit, and survival levels of irrigation.

indicates that both cool-season and warm-season turfgrasses, when irrigated at deficit levels, can save at least 25 percent of irrigation water needed for optimum growth. Irrigation at a survival rate would be at 30 percent of optimum for warm-season turfgrasses and about 50 percent of optimum for cool-season turfgrasses.

If water rationing is needed, both cool-season and warm-season turfgrasses can be irrigated at less than optimum levels. Where possible, using warm-season turfgrasses can result in considerable water savings compared with cool-season turfgrasses.

Background

Turfgrass directly affects the way most Californians live. It provides the play medium on many recreational facilities, cools the immediate environment, reduces reradiated heat, and provides an aesthetically pleasing and functional home landscape. In addition, the turfgrass industry has a significant direct economic impact on our economy and indirect impact on our tourist economy.

Many recreational facilities depend on uniform, vigorously growing, well-maintained turf that is able to recuperate from heavy use. These include soccer, baseball, and football fields, as well as golf courses, bowling greens, lacrosse and polo fields, general use and specialty parks, and school playgrounds. Turfgrasses provide a safety cushion that is especially beneficial in contact and physically intensive sports. Additionally, sites such as homes, industrial parks, cemeteries, greenbelts, roadsides, and dog parks can benefit from low-growing and traffic-tolerant green vegetation like turfgrasses.

Most Californians now live in urban and suburban centers where glass, steel, concrete, asphalt, buildings, and cars prevail; turfgrasses directly influence these immediate environments in positive ways. Actively growing turfgrasses reduce high summer ground surface temperatures due to transpirational cooling. Turfgrasses and other landscape plants reduce discomforting glare and noise. Soil erosion, dust, and fire danger are reduced or eliminated on turfed surfaces. Turfgrasses also increase infiltration of water into the soil profile and also enhance the quality of the water moving through or below the turfgrass system.

How Turfgrasses Use Water

Water enters a turfgrass plant through its root hairs, which are located near root tips. Water then moves upward through the plant to the leaves. A very small amount of the water taken up is used for plant growth, and the rest of the water transpires out of the plant through the stomatal pores. Water can also be lost from the turfgrass site by evaporation from leaf or soil surfaces. The water use rate is the total amount of water lost by a plant through evaporation and transpiration and used for growth, per unit of time. Because the amount of water used by turfgrasses for growth is so small, the water use rate is usually calculated as the evapotranspiration (ET) rate, which is the total rate of water loss by evaporation plus the rate of water loss by transpiration.

ET is expressed in units of depth and time such as inches (in) or millimeters (mm) per day, per week, or per month. Turfgrass ET depends on temperature, solar radiation, day length, wind, relative humidity, and other environmental factors. However, the ET rate also varies by species and the cultural practices used in maintaining the turf.

Water use rates have been established for the most commonly used warm- and cool-season turfgrass species. Research at Texas A&M in the late 1980s evaluated comparative water use rates among turfgrasses commonly grown in the United States. The comparative water use rates for those grasses used in California are presented in table 1. In the northern part of California and in the mountain regions of the state, turfgrasses are exclusively cool-

Table 1. Evapotranspiration rates of turfgrasses commonly grown in California

Relative ranking	ET rate (in./day)	Cool-season turfgrasses	Warm-season turfgrasses
very low	< 0.24		buffalograss
low	0.24–0.28		bermudagrass zoysiagrass
medium	0.28–0.33	hard fescue Chewing's fescue red fescue seashore paspalum St. Augustine grass	
high	0.33–0.39	perennial ryegrass kikuyugrass	
very high	> 0.39	tall fescue creeping bentgrass annual bluegrass Kentucky bluegrass rough bluegrass annual ryegrass	

Note: 1 inch = 2.54 cm.
Source: Adapted from Beard and Beard 2004.

Table 2. Suggested Kc values (% of ETo) for irrigation strategies resulting in optimum, deficit, and survival performance levels for selected turfgrasses grown in California.

Turfgrass performance level	Cool-season turfgrasses	Warm-season turfgrasses
	Kc*	Kc
optimum	0.80	0.60
deficit	0.60	0.40
survival	0.40	0.20

Note: * Kc (crop coefficient) is a dimensionless number that is multiplied by the ETo value to arrive at an estimate of crop ET, or water requirement.

season species. In other areas of the state, warm-season turfgrasses are grown extensively, and they perform well particularly in warm inland climates and desert areas. Both cool-season and warm-season species are grown in major populated areas of the state. Differences in water use rates have been noted between cultivars within all turfgrass species. Currently, research is underway throughout the United States to develop species and cultivars that have low water use rates. The lower-water-use turfgrasses have a low leaf-blade area and include species with narrow leaves with slow vertical extension rates and grasses with high shoot densities and high leaf numbers.

Warm-season turfgrass species use significantly less water than cool-season species. This is because warm-season grasses are more efficient at photosynthesis and are able to continue high-level carbohydrate production even under mild water stress when their stomates are partially closed. By contrast, cool-season grasses use a less efficient photosynthetic process and cannot produce enough carbohydrate to maintain growth unless their stomates are nearly wide open. Thus, when water is limited, transpiration rates of cool-season turfgrasses are generally higher than those of warm-season turfgrasses.

The effects of irrigating several species of turfgrasses below their optimal levels were investigated at Irvine, California. Cool-season grasses tested were Kentucky bluegrass, perennial ryegrass, and tall fescue; warm-season turfgrasses were hybrid bermudagrass, zoysiagrass, and seashore paspalum. Irrigation regimes supplied 100, 80, or 60 percent of calculated ET for each species. For acceptable turfgrass quality, 36 percent less water was required by the warm-season species than by the cool-season species.

Similar irrigation regimes can be created for any area of the state using ETo information and the crop coefficient (Kc) values (expressed as a percentage of ETo needed to satisfy water needs of a specific plant species) in table 2.

Water Use Versus Drought Resistance

The ET of a turfgrass is not synonymous with its ability to resist drought. Drought resistance includes mechanisms of drought avoidance (i.e., of retaining moisture within the plant) and of drought tolerance (i.e., of minimizing the damage to tissues caused by water deprivation).

Plant characteristics that contribute to drought avoidance include deep root systems with high root hair length and density, rolled leaf blades, thick cuticle (or ability to quickly form a thick cuticle following water stress initiation), reduced leaf area, slow leaf extension rates, and leaf orientation and density. Examples of turfgrasses with good drought avoidance mechanisms are common bermudagrass and seashore paspalum (both warm-season species) and tall fescue (a cool-season species).

Turfgrasses can also tolerate drought by escape (e.g., buffalograss, which tolerates drought with a dormancy mechanism) or by high tolerance to tissue dehydration (e.g., St. Augustinegrass). Through these mechanisms, turfgrass species have different levels of drought resistance (table 3). Comparison of the water use rates (table 1) and drought resistance (table 3) gives insight into the performance turfgrass species. Several turfgrasses, such as bermudagrass, seashore paspalum, and buffalograss, have both low water use rates and high drought resistance mechanisms. Other turfgrasses, such as tall fescue, have high water use rates and medium drought resistance. Still others, such as the ryegrasses and bluegrasses, have high water use rates and fair or poor drought resistance.

Some turfgrasses and ground covers can survive with very little applied water, as evidenced by a research study conducted at the South Coast

Table 3. Drought resistance comparisons of turfgrasses commonly grown in California.

Relative ranking	Cool-season turfgrasses	Warm-season turfgrasses
superior	—	bermudagrass (common) bermudagrass (hybrid) buffalograss
excellent	—	seashore paspalum zoysiagrass
good	—	St. Augustinegrass kikuyugrass
medium	tall fescue	—
fair	perennial ryegrass Kentucky bluegrass creeping bentgrass hard fescue Chewing's fescue red fescue	—
poor	colonial bentgrass annual bluegrass	—
very poor	rough bluegrass	—

Field Station, Irvine, California, in which plants were irrigated at 60, 40, and 20 percent of calculated ET. Of the 27 plant species tested, common and hybrid bermudagrasses and seashore paspalum performed best under very low irrigation regimes. Buffalograss also produced comparatively good cover and quality.

Irrigation and Other Cultural Practices for Turfgrass

Irrigation

The goal of irrigation management is to apply the correct amount of water at the correct time to optimize water uptake by the root system. It is also important to reduce the amount of water lost to runoff from the soil surface and deep percolation below the root zone. Regular water audits, ensuring that equipment is operating correctly, and using soil probes or soil moisture measuring devices help fine-tune irrigation schedules, promote healthy turfgrass, and decrease water waste.

Effective irrigation involves filling the root zone soil profile with each irrigation. This requires calculating the amount and frequency of water application based on weather data (used to estimate the ET of the turfgrass), the plant's rooting depth, and the water-holding capacity of the soil. These factors may also be used to plan deficit irrigation strategies.

Evapotranspiration and CIMIS

The California Irrigation Management System (CIMIS) provides irrigation managers, scientists, and water agencies with an accurate, site-specific means of estimating plant water demand based on the climatic parameters that drive evapotranspiration in plants. Reference evapotranspiration (ETo) approximates the water use of an irrigated grass pasture. Water use (ET) by turfgrasses is estimated by means of a correlation factor, the crop coefficient (Kc), according to the formula

$$ET = ETo \times Kc$$

Turfgrass Kc values fluctuate slightly during the season based on the percentage of plant cover, growth rate, root growth, stage of plant development, and turf management practices. For practical purposes, the Kc of cool-season turfgrasses is 0.8, and the Kc for warm-season turfgrasses is 0.6. Numerous CIMIS stations are located in varying climatic zones throughout California; daily water use information (i.e., ETo) is accessible online for most areas of California at the CIMIS website, http://www.cimis.water.ca.gov/cimis/welcome.jsp.

Soil water availability

The amount of water available for use by turfgrasses varies by soil texture and pore size and by the rooting depth of the turfgrass. After soil is irrigated and free drainage has taken place, the soil is full of water, or at field capacity. As plants extract the water from the soil, eventually the soil will become so dry that plants cannot be sustained. At this point (often called the permanent wilting point or percentage) there is still water in the soil but it is tightly held by mineral and organic particles and is unavailable for plant use. The total amount of water a soil can hold and the amount of available water a plant can absorb and use differ with different soil textures (table 4). These data, in conjunction with root depth, give the approximate amount of water that is available to a turfgrass plant.

Root system

Turfgrass species differ in their rooting depth and density Rooting depths vary from a few inches to many feet; they are also influenced by water patterns, soil characteristics, management practices such as mowing and fertilization, and by on-site compaction. The best method to determine root depth in a particular location is by digging into the

Table 4. Unavailable and available water for selected soil textures.

Soil texture	Total water (in/ft)	Available water (in/ft)	Unavailable water (in/ft)
sand	0.6–1.8	0.4–1.0	0.2–0.8
sandy loam	1.8–2.7	0.9–1.3	0.9–1.4
loam	2.7–4.0	1.3–2.0	1.4–2.0
silt loam	4.0–4.5	2.0–2.1	2.0–2.4
clay loam	4.2–4.8	1.8–2.1	2.4–2.7
clay	4.5–4.8	1.8–1.9	2.7–2.9

Note: 1 in/ft = 8.3 cm/m

soil and looking at the roots. Table 5 is a general guide to root depths. The available soil water is determined by multiplying the available water by the effective depth of the root system. Table 6 shows the amount of water available to turfgrasses growing in various soils at selected root system depths. Since proper irrigation should supply water to the root system, root depths and soil texture play an important role in both the amount of water applied and irrigation frequency.

Table 5. Approximate root depths of common California turfgrasses under normal use conditions.

Cool-season grasses	Root depth (ft)
Kentucky bluegrass	0.5–1.5
perennial ryegrass	0.5–1.5
tall fescue	1.5–3.0
creeping bentgrass	0.3–1.5
annual bluegrass	0.1–0.3
Warm-season grasses	**Root depth (ft)**
bermudagrass	1.5–6.0
buffalograss	1.5–3.0
St. Augustinegrass	1.5–5.0
seashore paspalum	1.5–5.0
zoysiagrass	1.5–2.5

Note: 1 ft = 0.348 m.

Irrigation frequency

For scheduling turfgrass irrigation, the suggested depletion of available soil water is 50 percent before applying irrigation. In other words, irrigation is needed when one-half the available water that is present in a root profile is depleted. This practice allows for adequate water to be available at all times. If more than 50 percent of the available water is depleted (i.e., irrigations are not frequent enough), the turf suffers water stress.

Fifty percent of the available water divided by the ET equals the number of days of sufficient supply, or the number of days between irrigations. For example, for a cool-season turfgrass (Kc = 0.8) with a 12-inch rooting depth in a loam soil, the available water is 1.5 inches (from table 6). Fifty percent of 1.5 is 0.75 inches. If the ETo is 0.2 inches per day, the turfgrass ET equals 0.20×0.8, or 0.16 inches per day (ETo × Kc). It will take about 5 days ($0.75 \div 0.16 = 4.7$) to deplete 50 percent of the available water. It is normally desirable to water turf as infrequently as possible, so in this case the site would be irrigated by applying 0.80 inches (0.16×5) of water after 5 days.

Water application

The duration of sprinkler operation to resupply the water used by ET must be determined on-site and depends on how fast and how efficiently the water

Table 6. Water available to turfgrass under three soil textures and with three root system depths.

Soil texture	Available water (in/ft)	Water available (in/ft) to turfgrass at root depth		
		6 in.	12 in.	36 in.
sand	1.0	0.5	1.0	3.0
loam	1.5	0.75	1.5	4.5
clay loam	2.0	1.0	2.0	6.0

Note: 1 in/ft = 8.3 cm/m

is applied. The efficiency of irrigation is a function of system performance and management. Irrigation systems that are well designed, in good condition, and apply water uniformly will be much easier for managers to schedule.

The fieldwork to determine system performance can be either a brief, simple procedure or a complete, full inspection of all the irrigation system stations and hardware. Often referred to as an irrigation audit, the process is used to accurately determine the system precipitation rate (PR) and distribution uniformity (DU).

The precipitation rate is the rate at which water is delivered to the turfgrass area; it is measured in inches per hour. The distribution uniformity is a calculated statistic that indicates the amount of variation in the precipitation rate of the system. The precipitation rate and the distribution uniformity are the two most important irrigation system performance characteristics in calculating station run times and determining how evenly water is applied to the area.

Irrigation uniformity is important in turfgrass areas, since turfgrass consists of many small plants, each requiring access to soil and water. An irrigation system with poor uniformity yields areas that are too wet or too dry and nonuniform turfgrass performance. If there are dry areas, irrigation managers usually increase runtime to adequately irrigate them. In this case, water loss to deep percolation or runoff can be significant and may increase with poorer distribution uniformity. The distribution uniformity is only one measure of system performance; information on other statistical measures, such as the Christiansen's coefficient of uniformity and the scheduling coefficient, as well as procedures for determining precipitation rates can be found in *Evaluating Turfgrass Sprinkler Irrigation Systems* (ANR Publication 21503).

The actual run time is determined by dividing the crop coefficient (0.80 inches of water used, in the above example) by the precipitation rate of the sprinkler system. The run time is increased if the irrigation efficiency is considered. The distribution uniformity is a good estimate of the irrigation efficiency as long as the scheduling (management) is good and runoff is limited.

Using the efficiency in the above example, the run time (in hours) would be calculated by dividing 0.80 inches by the precipitation rate times the distribution uniformity; multiply by 60 to convert to minutes. More detailed information on irrigation scheduling can be found in *Turfgrass Irrigation Scheduling* (ANR Publication 21499).

Every effort should be made to prevent runoff. Application of water in short cycles, until the entire amount of water has been applied, is an effective way to reduce water waste due to runoff.

To prevent puddling or runoff on clay or compacted soils, and to prevent excessive drainage in sandy soils, plan on irrigating turfgrasses no less frequently than every third day. The total amount of water to be applied stays the same, but it should be adjusted for more frequent applications. In the example shown above, instead of applying 0.8 inches of water every 5 days, apply 0.5 inches every third day. If too much water is applied at once, water is lost to runoff or percolation below the root zone.

Deficit irrigation strategies

In drought conditions, it may be advisable to reduce turfgrass irrigation to the deficit level or even to the survival level (see fig. 1). If that is the case, in the example given above, instead of using a crop coefficient of 0.8, use the other reduced values given in table 2. This strategy applies less water than the turfgrass has used, which results in mild water stress. The available water will gradually become depleted below 50 percent. As mentioned previously, turfgrass species with drought resistance (especially warm-season grasses) reduce their water use rate as available soil water is used up. To maintain adequate turf quality, careful irrigation management is necessary and cultural practices may need to be adjusted.

Mowing

In addition to irrigation practices, mowing affects turfgrass growth, including root system development and water use. Higher cutting heights promote deeper root systems and higher water use rates. The higher water use rate with taller turf results from the more open canopy and reduced shoot density. Conversely, closely mowed turf has higher shoot density and a tight canopy, characteristics which reduce evapotranspiration.

The frequency of mowing also affects evapotranspiration. The long grass leaves of infrequently mowed turfgrass use more water. Infrequently mowed turf is also aesthetically and functionally inferior to turfgrass maintained consistently at an appropriate height.

The desired balance is achieved by mowing practices that enhance root system depth and density (and thus drought resistance) while efficiently using water.

Combining all factors involved, the turfgrass should be maintained at the tallest allowable height, within the recommended mowing height range, for the species being grown. Turf mowed at the tallest allowable height for the individual species and at a frequency that allows no more than one-third of the leaf blade to be removed best achieves that balance. Table 7 recommends mowing height ranges for selected turfgrasses.

Mowing turfgrasses when it is hot or when the soil is dry can injure the plants. When grasses are stressed by heat and drought, such as during a drought-declared summer, it is best to mow infrequently at a taller height.

Fertilization

Sufficient amounts of most nutrients required for turfgrass growth are normally available in native soils. However, all turfgrasses require nitrogen fertilizer, and in some soils they need phosphorus, potassium /or iron and other essential elements.

Turfgrass fertilization practices directly influence water use: fertilization, especially nitrogen fertilization, increases turfgrass growth, and the greater the growth rate, the greater the water use. Root and shoot growth increase as nitrogen nutrition is raised from a deficiency level. The resulting deeper roots and more vigorous topgrowth benefit the turfgrass. Excessive nitrogen fertilization is not beneficial and can result in excessive topgrowth, poor root growth, and water pollution. To avoid excessive water use, nitrogen fertilizer programs must be monitored to produce the least amount of topgrowth and the greatest rooting possible within the use parameters of the turf. During drought, it is advisable that the lowest amount of nitrogen be applied within the recommended range. Most cool-season grasses grown as general purpose turf require about 2 pounds of actual nitrogen per 1,000 square feet (about 1 kilogram per 100 square meters), applied during March through April and again during late September through mid-October. During this period, due to temperature and water availability, grasses can use nitrogen efficiently to develop deep and extensive root systems. Fertilizing based on these recommendations allows the grass to survive deficit irrigation, heat, and drought stresses much better. Avoid nitrogen fertilization of cool-season grasses from May through September. During this period, if nitrogen must be applied because of play or other special use it should be applied lightly and infrequently. During drought, nitrogen application to warm-season grasses should not exceed 0.25 pounds of nitrogen per1,000 square feet per month (125 grams per 1,00 square meters), between April and September.

Adequate potassium may increase the drought tolerance of turfgrass. In general, an application of 1 to 2 pounds of potassium (as K_2O) per 1,000 square feet (0.5 to 1 kilogram per 100 square meter) in spring (March through April) may provide increased drought tolerance during the summer months.

Soil Compaction and Thatch

Soil compaction reduces the root and shoot growth of turfgrasses and also lowers the water infiltration rates. Turfgrass quality decreases in compacted soils; water use decreases with the slower growing, poorer quality turfgrass cover. Soil aerification is recommended to improve aeration, which increases

Table 7. Mowing height ranges for commonly grown turfgrasses.

Turfgrass species	Cutting height range (in.)
Cool-season turfgrasses	
creeping bentgrass	0.2–0.5
colonial bentgrass	0.5–1.0
red fescue	1.0–2.0
Kentucky bluegrass	1.5–2.5
perennial ryegrass	1.5–2.5
tall fescue	1.5–3.0
Warm-season turfgrasses	
bermudagrass	0.5–1.0
zoysiagrass	0.5–1.0
seashore paspalum	0.5–1.0
St. Augustinegrass	0.5–1.5
kikuyugrass	0.5–1.0

Note: 1 in = 2.54 cm.

shoot and root growth, water infiltration rate, and water use efficiency.

Thatch is an intermingled layer of dead and living organic matter that develops between the soil surface and the green turfgrass tissue. It consists of roots, stems, stolons, and rhizomes. A deep thatch layer, if hydrophobic (water repellent), reduces or eliminates water infiltration into the turfgrass soil profile. Water use efficiency increases when thatch is maintained at acceptable depths (around one-half inch, or 13 mm) and is not allowed to dry out.

Aerification and dethatching should be undertaken in fall (October) or spring (March or April) for optimum results. Avoid aerifying and dethatching in midsummer when high temperatures may negatively affect the grass.

Other Considerations

- Conduct an irrigation system uniformity test (audit) in spring to identify and correct the irrigation system's inefficiency and non-uniformity (see *Evaluating Turfgrass Sprinkler Irrigation Systems*, UCCE Publication 21503).
- Irrigate late at night or early in the morning. At these times water loss by evaporation is minimal and distribution uniformity is usually good because of good water pressure and limited wind.
- Avoid runoff by ensuring that water application rates are not greater than soil infiltration rates (the rate water enters the soil). To avoid runoff, cycle water applications by applying the required amount of water over a series of consecutive shorter irrigations. Cycling should not be confused with watering every day, which is not recommended.
- Apply less water in shaded areas than in areas of open sun. Soil moisture measuring devices can be used to determine water needs of turfgrasses growing in various microclimates. In general, during the hot summer months, grasses planted in shade require about half as much water as same grass grown nearby in full sun.
- Repair and maintain irrigation systems. Observe system operation and make necessary repairs to increase uniformity and climate runoff.
- Act now if your facility is considering installing a new, more effective and more efficient irrigation system.
- Regrade mounds and redesign topographic features that create irrigation challenges. Turfgrass grown on slopes and mounds is prone to water loss due to runoff. Landscape design features that deflect irrigation water intended for turfgrass to elsewhere, such as sidewalks, driveways, and other hard surfaces should be modified.
- Investigate irrigating with recycled water. Drought will happen again!

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Keeping Plants Alive Under Drought or Water Restrictions … and Planning for the Future!

by Janet Hartin, Ben Faber, Loren Oki, and David Fujino

The California drought is a very serious issue that impacts all Californians. The purpose of this publication is to provide credible information regarding keeping outdoor plantings alive during drought and under water restrictions. Topics covered include symptoms of water stress, tips to conserve water in your current landscape, minimum water needs of various types of plants, and the best time to plant a drought-efficient landscape and tips for its success.

Overview

Figure 1 - Drought damage on a rose plant. Photo credit: UC IPM

Plants that do not receive enough water will eventually show signs of water stress. During a drought or under governmental restrictions aimed at water conservation keeping plants alive can be particularly difficult. Although plants vary in the amount of water they require for optimal growth and development, most exhibit characteristic symptoms when they are in need of water. Because plants need to be watered at an early stage of water deficit to prevent irreversible damage, it is crucial to check plants regularly for symptoms of drought, preferably during the afternoon when symptoms are most evident. Also ensure that damage identified as drought stress is not due to other conditions that can mimic drought such as frost, salts, insects, and diseases.

Figure 2 - Salt damage mimicking drought damage on avocado. Photo credit: UC IPM

Common symptoms of water stress include:

- Wilting or drooping leaves that do not return to normal by evening
- Curled or yellow leaves that may fold or drop, or foliage that becomes grayish and loses its green luster
- New leaves that are smaller or stem sections that are closer together than normal

- Lawn grasses that retain a footprint for several minutes

Tips to reduce water waste in your current landscape and garden:

Apply water when the plants most need it**.** A common mistake is to underwater newly planted ornamental and edible plants and overwater established mature plants. New transplants need more frequent and shallow irrigations than established plantings. Therefore, the middle of summer is not the preferred time to replace a high water using landscape with a drought-efficient landscape. Fall or spring are better choices.

Know the water needs of plants growing in your area and adjust them seasonally. As figure 2 below illustrates, a plant adapted to the San Francisco Bay area, Riverside, and Palm Springs areas will require the most water in the hot desert area of Palm Springs. This is due to higher rates of evapotranspiration which is closely linked to the water requirement of a plant. ET is the loss of water into the atmosphere from the soil and plant surfaces (evaporation) and from the plant actively taking up water (transpiration). A common mistake is to forget to adjust automatic timers downward going into the fall.

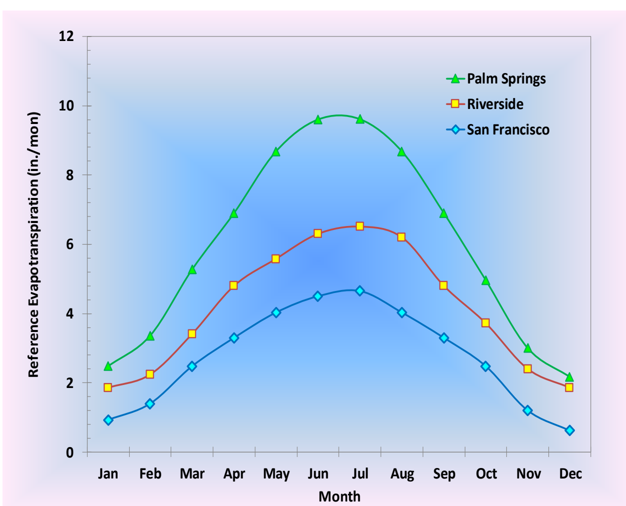

Figure 3- Differences in plant water use in the San Francisco Bay area, Riverside, and Palm Springs due to varying evapotranspiration (ET) rates. ***Source*****: Richard Snyder, Department of Land, Air and Water Resources, UC Davis**

Irrigate slightly below the root zone to draw roots down. A simple and effective way to do this is to gently dig into the soil to determine how deeply the water is seeping after irrigation.

Irrigate based on soil type. Water plants growing in sandy soils more often but for shorter periods of time than plants growing in clay-based soils. This will reduce water waste and the chance of groundwater pollution from fertilizers and pesticides leaching below the root zone in sandy soils, and water and chemical runoff from the surface of clay-based soils. Use the 'feel method' (Figure 4) to determine what type (texture) of soil you have. Figure 5 illustrates the drainage patterns that occur from irrigating sandy, loam (similar to compost-amended soils and clay-based soils. Note how much longer it takes the same amount of water to penetrate deeply into a clay soil compared to a sandy one and how much broader the water spreads horizontally.

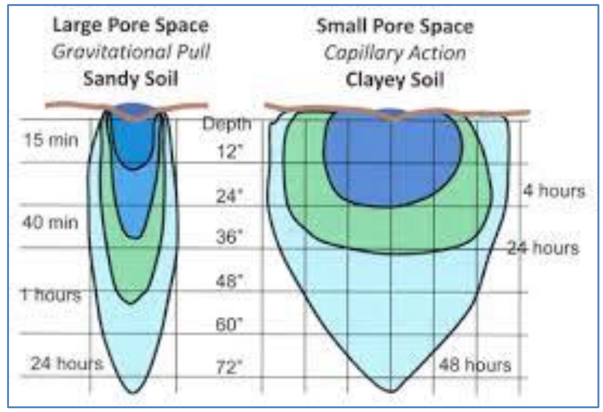

Figure 4 - Comparative movement of water downward and outward in sandy and clay soils
Credit: www.ext.colostate.edu/mg/gardennotes/213.html

Avoid summer planting. Converting a thirsty landscape to a drought tolerant one should be done in fall or spring rather than during the heat of summer. New transplants need more frequent and shallow irrigations than established plantings.

Irrigate early in the morning. Soil evaporation is lower than later in the day. While evaporation is also low during the night, fungal diseases may develop, particularly when overhead systems wetting leaves are used.

Don't irrigate plants showing signs of physiological drought. In the heat of a mid-summer day, many plants simply cannot absorb available water as quickly as necessary to compensate for water lost due to evapotranspiration (water loss from the plant and soil, respectively, into the atmosphere). This leads to temporary mid-day wilting known as physiological drought, which will not be alleviated by adding more water. Affected plants will recover on their own during the evening.

Consider installing a 'laundry to landscape' graywater system. The state and most local jurisdictions have lifted or greatly lessened restrictions on these types of systems which allow irrigating landscape plants with water from a washing machine if certain conditions are met. The updated code and its provisions for use of graywater to irrigate landscapes can be found in its entirety here: http://www.hcd.ca.gov/codes/shl/2007CPC_Graywater_Complete_2-2-10.pdf. Contact your local city public works department for specific information on local laws which may be more restrictive.

Consider installing a rainwater harvesting system. These systems collect rainfall from roofs and channel it via gutters, pipes, or swales, keeping it on the landscape rather than allowing it to run off. Properly functioning rainwater harvesting systems can significantly reduce the need for supplemental irrigation in areas of measurable rainfall.

Mulch. Apply and maintain a three to four inch layer of mulch around garden plants and trees to keep the water in and the weeds out! Be sure to keep mulch at least one foot away from tree trunks to avoid wet trunks and crowns, which can be subject to disease-forming pathogens.

Avoid overfertilizing. Applying too much nitrogen leads to an overabundance of foliar (leaf) production and the need for more water. Most mature landscape plants will get through a season or two with no supplemental fertilizations. Fruit trees and vegetables require adequate nutrients for crop production. When water is scarce fruit trees should not be fertilized; while the crop may be sacrificed, this practice reduces water requirement and will help keep the tree alive. Annual vegetables may get by on slow release nutrients supplied by organic matter and compost.

Figure 5 - A 3-inch layer of wood chip mulch conserves water, reduces weeds and water runoff. Photo credit: Gabriel Frank, www.gardensbygabriel.com

Control weeds. Weeds usually outcompete garden plants for water. Pull them when they are small making sure to remove all the roots.

Dust off the old broom. Sweep garden debris off of sidewalks and driveways rather than hosing them off.

How to keep various types of plants alive during drought and water restrictions:

Trees: Most homeowners wisely choose to use whatever water is available to save their mature landscape ornamentals and fruit trees. Watering older trees slowly and deeply with a garden hose

Studies have shown that California native oaks may benefit from supplemental summer irrigation during prolonged drought even though they are relatively drought tolerant. However, they are also easily over-irrigated leading to fungal diseases such as oak root fungus (*Armillaria mellea)* and crown rot (*Phytophthora* spp). Letting the soil dry out some between irrigations will help prevent these diseases. Water should be kept at least ten feet away from tree trunks and most should be applied in the outer two-thirds of the root zone which may extend two to three times beyond the canopy of the tree.

slightly below the deepest roots once in mid-spring and again in mid-summer will keep most established trees alive at least one season. Two seasons or more of drought stress can result in severe damage and even death of some species. Drought-stressed trees are often more prone to damage from diseases and insects, as well.

Although fruit and nut trees can be kept alive during severe water shortages a season or two, fruit production may be greatly reduced or stop altogether. To produce a standard crop, deciduous fruit and nut trees need water applied steadily from bloom until harvest. Citrus trees need adequate soil moisture during spring to set fruit and steady water in summer and fall to produce acceptable size, number, and quality of fruit.

Mature trees have extensive root zones that often grow laterally two to three times the canopy width and two to three feet deep (depending on the soil type, any compaction issues, and the irrigation schedule). Active water uptake by roots occurs in this area. This requires moving drip lines and emitters further and further away from the trunk as trees mature. Irrigating too close to tree trunks can result in crown and root rot and does not apply water into the root uptake zone of the tree.

Figure 6 - Plant only family favorites and avoid an oversized garden that is larger than your needs.
Source: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=13130

<u>Vegetables</u>: Vegetables are not drought efficient plants and are difficult to maintain during a drought. It is often wise to reduce the overall size of the garden and plant only your favorite types of vegetables when water is limited. Scheduling irrigations based on the water needs of the specific crop during critical periods of growth is essential for vegetable production. Hydrozoning (placing plants with similar water needs in the same area of the garden) allows gardeners using automated drip irrigation systems to target water applications based on water needs of individual zones, reducing water waste.

Mixing organic soil amendments such as compost evenly into garden soil at least one foot deep helps retain soil moisture in the rooting area of the plant, which can significantly lengthen the allowable interval between irrigations before drought symptoms develop. While the plant still requires the same amount of water, stretching the time a plant can go between waterings can make the difference in whether garden plants live or die during a drought or imposed water restrictions. This is especially true of tomatoes, beans, lettuce, and root crops such as carrots which require regular watering and are not tolerant of long, dry periods. Vine crops such as cucumbers and squash often fare better and can be kept alive by watering once or twice a week throughout the season. As a rule of thumb, water is most critical during the first few weeks after sowing vegetable seeds, immediately after transplanting seedlings and small plants, and during flowering and fruit production. And don't forget to add a three inch layer of mulch to hold the water in!

<u>Shrubs:</u> Most established shrubs can survive long periods of dry soil. One thorough spring watering and one or two thorough waterings in the summer keeps most mature shrubs alive for at least one season. As with other plants, prolonged drought can result in severe branch die-back and eventual plant death.

<u>Groundcovers</u>: Groundcovers often survive on about half the amount of water they would receive under optimal conditions, although some dieback may occur. To avoid serious drought stress, they should be watered once every three to six weeks from April through September, depending on location and soil conditions.

<u>Lawns</u>: Warm-season lawns, such as Bermudagrass, zoysiagrass, and buffalograss, are more drought-efficient than cool season grasses (e.g. tall fescue and ryegrass) and may survive several weeks of dryness even after partial dormancy. Conversely, cool-season grasses may die within a month or two of receiving no water. Signs of drought include wilted leaves and a bluish-gray appearance followed by yellow leaves that eventually turn brown. Established lawns, like all mature plants, prefer infrequent deep irrigations over frequent, shallower ones.

Once a lawn stops receiving adequate moisture, it will gradually turn brown and go dormant. A lawn that recently turned brown from drought can often be revived with thorough watering, but it may be difficult to revive a lawn that has been deprived of water for several weeks. This will depend on the turf variety, soil type, length of time since last irrigation, weather, and other parameters. Cutting the length of irrigation gradually over a few weeks to one-half of the amount of water listed in the **<u>UC Lawn Watering Guide,</u>** http://anrcatalog.ucdavis.edu/pdf/8044.pdf, will help ensure the survival of warm and cool-season lawns.

What about replacing your current landscape plants with more drought efficient ones?

Figure 7 – Beautiful, drought-efficient landscapes save water and time and reduce erosion and runoff. Photo Credit: www.ecolandesign.com

As previously stated, the heat of the summer is not the time to remove and replace your current landscape plants with drought efficient species. Plants that are not established – even drought tolerant natives - require more frequent watering than the same species growing for a season or two that have developed a deeper, more extensive root system. Fall is the best time to establish native plants and fall or spring are both good times to swap thirsty plants with more drought-efficient non-natives.

Also keep in mind that often it is the irrigation delivery system that is the real water waster – not the plant! This is particularly true of sprinkler systems used to water turf and groundcovers. Avoid expending a lot of time and labor only to discover that the original cause of your water waste still exists. On average, thirty to forty percent of water applied to lawns and groundcovers by sprinkler systems is wasted due to system leaks, low/tilted heads, broken sprinklers, unmatched sprinklers, and pressure and spacing problems. You can greatly improve the distribution uniformity (evenness of watering applied across your lawn or groundcover planting) and fine-tune the performance of your system by checking your system for these problems and performing a straightforward uniformity and precipitation rate test as described in the UC Lawn Watering Guide.

Tips for planting a new water-efficient landscape:

- Select water-efficient plants that grow well in your climate using Sunset climate zones rather than USDA zones since Sunset zones are smaller and more accurate. www.sunset.com/garden/climate-zones/climate-zones-intro-us-map

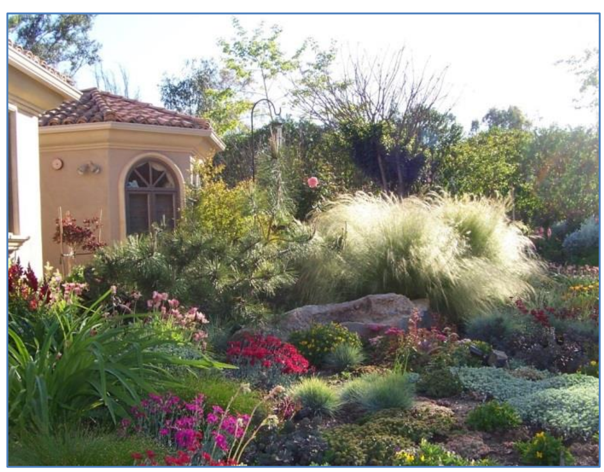

Figure 8 – Drought tolerant grasses and plants surround a home in Rancho Santa Fe, Calif. Photo credit:

- Hydrozone. Place plants with similar water needs together and irrigate them accordingly in high, medium, low, and very low categories. This is especially important when landscape and edible plants are irrigated by automated systems allowing precise scheduling valve by valve.

- Mix soil amendments (compost, etc.) evenly and deeply into sandy and clay-based soils (40% or more by volume) at least six inches deep before planting garden plants and small woody. This practices improves water retention in sandy soils and drainage in clay-based soils. (Avoid adding it to tree planting sites since roots prefer the higher-quality amended soils and grow outward instead of downward, resulting in poor anchorage and support for the maturing tree.)

- Choose drip over sprinkler irrigation. Unless hand-watering is practical and you are regularly home to ensure that plants receive adequate water (particularly during the first few weeks after planting) consider installing an automated drip system for ornamentals and edibles other than turf and groundcovers. Drip systems apply water directly into the root zone of the plant and soil evaporation is greatly minimized over sprinkler systems. Drip systems apply water much more slowly than sprinkler systems, reducing surface runoff and deep percolation and associated waterway pollution.

- Download other free UC ANR resources such as Sustainable Landscaping in California, http://anrcatalog.ucanr.edu/Details:aspx?itemNo=8504. For additional ideas to save water, recycle organic matter, reduce waterway pollution, reduce pests, conserve energy, and attract wildlife.

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University of California
Agriculture and Natural Resources | Master Gardener Program

Ten Tips for Vegetable Gardening During a Drought

UCCE Master Gardener Nancy Grove, San Mateo and San Francisco County

Photo Credit: Jennifer Baumbach, UCCE Master Gardener Coordinator, Solano County

Is it possible to grow a vegetable garden when water resources are scarce and water rationing could be imposed? Water responsibly, plant carefully, and select fruit and vegetable varieties that are drought tolerant. All of these sustainable gardening practices require less water – and help ensure your family has access to a variety of nutrient rich foods.

10 Simple Drought Tips to Reduce Water Use in your Backyard Garden

1. **Planting Time**
   Plant earlier in spring and later in fall. Planting earlier in the spring season takes advantage of the warm weather and reduces exposure to high mid-summer temperatures. Planting later in the fall minimizes the use

of supplemental water and takes advantage of seasonal rains to establish plants. For example, tomatoes and other nightshade crops such as peppers and eggplants, should not be planted until soil temperatures reach 55 degrees. With a warm spring this could be as early as mid-April. Remember to always use a soil thermometer for accurate soil temperature readings.

2. **Mulch, mulch, mulch!**
A 3 to 4-inch layer of mulch can reduce watering needs by as much as 50 percent. Mulch reduces water evaporation and keeps soil temperatures down during hot summer months. Grass clippings, dried leaves, pine needles, straw and shredded bark are all examples of natural mulches which can be used to cover the soil. Hay is not recommended because it contains seeds, which yields weeds and can become a problematic option.

Raised garden beds help retain water better than gardens planted in open soil.

3. Enclosed Spaces
Gardens planted in enclosed spaces, for example a raised garden bed, retain water better than gardens planted in open soil. Plant seeds and transplants in a hexagonal "off-set" pattern rather than in straight rows. A hexagonal arrangement groups plants closer together, which provides shade from leaves, keeping soil cool and water from evaporating.

4. Companion Planting
Companion planting is the practice of grouping crops together for mutual benefit. The Native American "three sisters" approach of planting corn, beans and squash together are the perfect example of companion planting. Tall cornstalks provide a structural support for the climbing beans, the beans return nitrogen back into the soil, and the squash spreads across the soil acting as a mulch and keeping the soil cool.

5. **Watering times**
The best time to water your garden is in the late evening and early morning hours, typically between 9 p.m. and 6 a.m. The cooler morning temperature and limited wind reduced water evaporation rates.

6. **Water Efficiently**
Overhead watering with a sprinkler system is not as efficient as drip irrigation. Compared to overhead sprinklers - drip systems can reduce water usage by up to half. Install a drip irrigation system, grouping plants with similar water needs together on one drip irrigation line. Drip irrigation systems are relatively easy to install for most do-it-yourself homeowners. The UC Division of Agriculture and Natural Resources

Drip irrigation system in home landscapes reduce water usage compared to overhead sprinkler systems.
Photo credit: Jack Clark

(UC ANR) book [“Drip Irrigation in the Home Landscape”] is a great reference on the materials, design and installation of a drip system.

7. **Control Weeds!**
   Pesky weeds compete for valuable water, sunshine and soil nutrients in your garden. Remove weeds before they have an opportunity to flower or spread. Visit the UC Integrated Pest Management (IPM) website for tips on controlling weeds to identify recommendations for specific weed species.

8. **Drought Resistant Crops**
   Purchase varieties of fruits and vegetable that do well in hot and dry climates. Many heirloom varieties from Mediterranean regions are prized for being drought tolerant. Smaller varieties bred for containers often produce a more bountiful yield per plant than standard varieties. Avoid water hogs! Some favorite water-efficient edibles from UCCE Master Gardeners include: asparagus, chard, eggplant, mustard greens, peppers, roma tomatoes, and California native strawberries. Check with a local UCCE Master Gardener Program about which varieties are recommended for your zone.

Select the correct size garden for your family, to reduce waste from overproduction.

9. **Peak Water Times**
   Fruit and vegetables have critical periods for increased water demands. For most plants once they become established watering times and amounts can be reduced until the flowering or fruit setting process begins. An increased amount of water should be reintroduced during this time. After this initial period of fruit set water can slowly be reduced again. In some cases, reducing water can improve the flavors of your harvest (think, dry-farmed tomatoes)!

10. **Garden Size**
    Determine the amount of fruits and vegetables needed to feed your family, does your family have two, four, or eight members? If you overproduced and wasted crops last year - decrease the amount of plants this year. Set up a garden exchange in your neighborhood so everyone grows less but still has a great variety!

The University *of* California, Master Gardener Program extends to the public free UC research-based information about home horticulture and pest management. In exchange for the training and materials received from the University of California, Master Gardeners perform volunteer services in a myriad of venues. If you are interested in becoming a certified UC Master Gardener contact your local UC Cooperative Extension (UCCE) office.

Home Landscaping for Fire

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UNIVERSITY OF CALIFORNIA
Division of Agriculture and Natural Resources
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More than 1,445 structures are destroyed by wildfire each year just within the jurisdiction of California's Department of Forestry and Fire Protection (CAL FIRE). However, many homes are also saved as a result of the owners' careful pruning and landscaping techniques that minimize ignition of vegetation and spread of fire to their homes (CAL FIRE 2005).

Incorporating fire safe concepts into the residential landscape is one of the most important ways you can help your home survive a wildfire. When conditions are dry and windy, the grasses, brush, trees, or other vegetation surrounding your home become a dangerous fuel source. Creating an area of defensible space (or area of reduced fuel) between your home and flammable vegetation reduces the risk of home ignition. When the vegetation is removed, pruned, or otherwise modified, the chance that its ignition will pose a serious threat to your home during a wildfire diminishes. Your home may be the most valuable investment you ever make. If you live in a high-risk fire hazard area, protect against the chance of losing that investment by implementing the recommendations in this publication.

Creating an area of defensible space does not mean you need a ring of bare dirt around your home. Through proper planning, you can have both a beautiful landscape and a fire safe home. The general concept is that trees should be kept furthest from your house, shrubs can be closer, and bedding plants and lawns may be nearest the house.

VEGETATION ARRANGEMENT

From a wildfire fuel standpoint, vegetation is often described in terms of its vertical and horizontal arrangement. Sometimes the arrangement is described in terms of vertical or horizontal fuel continuity. Vertical fuel continuity is also referred to as 'ladder' fuels (fig. 1).

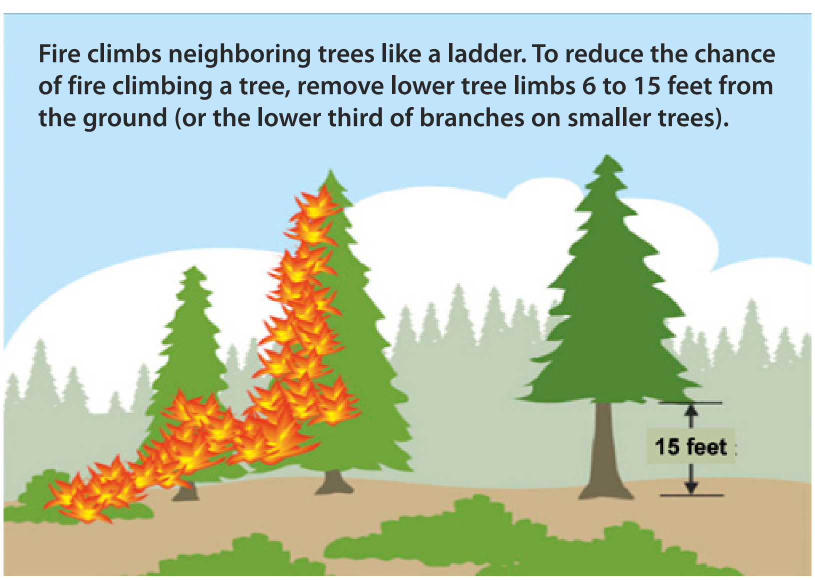

Figure 1. Eliminate ladder fuels to minimize the movement of ground fire into the crown of a tree. *Source:* Riverside County Fire.

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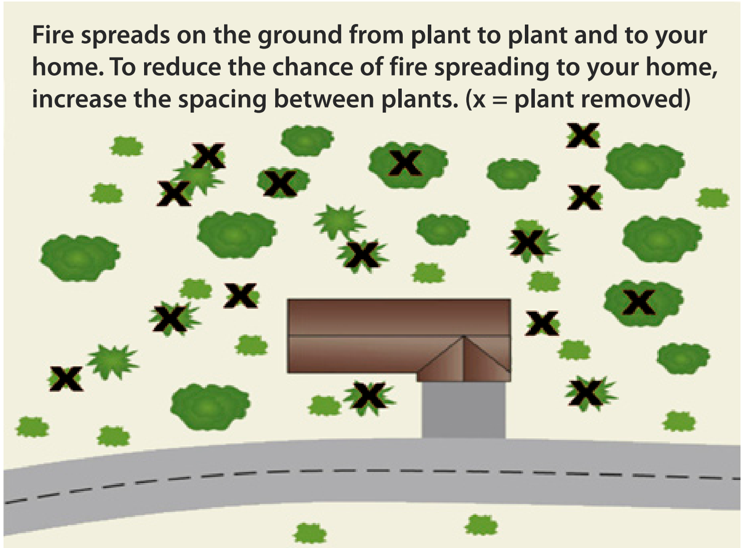

Figure 2. Horizontal arrangement of vegetation. *Source:* Riverside County Fire.

Most wildfires begin as surface fires. They will not reach the crown of a tree if the vertical fuel continuity has been eliminated. Once the fire reaches the crown of a tree, the heat intensity (the energy released and flame length when vegetation burns) is increased; this can then increase the combustibility of the surrounding vegetation. Therefore, it is important to prune taller trees by removing branches that are close to the ground.

Horizontal fuel continuity allows the fire to spread across the landscape. Breaking up the horizontal fuel continuity through wider spacing of the vegetation can greatly reduce the fire intensity (fig. 2). The wider the spacing between plants, the greater the wind velocity must be to spread the fire. The actual between-plant spacing depends on one's aversion to the risk of fire spreading to one's home, and the associated chance of losing it. Ultimately, choices regarding the selection, placement, and maintenance of near-home vegetation, plus choices regarding the material selection and maintenance of your home, will affect whether or not your home survives a wildfire.

TWO IMPORTANT ZONES AROUND YOUR HOME

A fire safe landscape consists of two zones: the home defense zone and the reduced fuel zone (fig. 3). The home defense zone is within 30 feet of the house. The reduced fuel zone lies beyond the home defense zone and extends out at least 100 feet from the house or to your property line. (See the metric conversion table at the end of this publication.) Greater defense zone widths are necessary when your home is on a steep slope or in a windswept exposure. Specific recommendations for each zone are described below and pertain to the State Responsibility Area (SRA) protected by CAL FIRE. Local Responsibility Areas that are protected by fire departments may have different requirements.

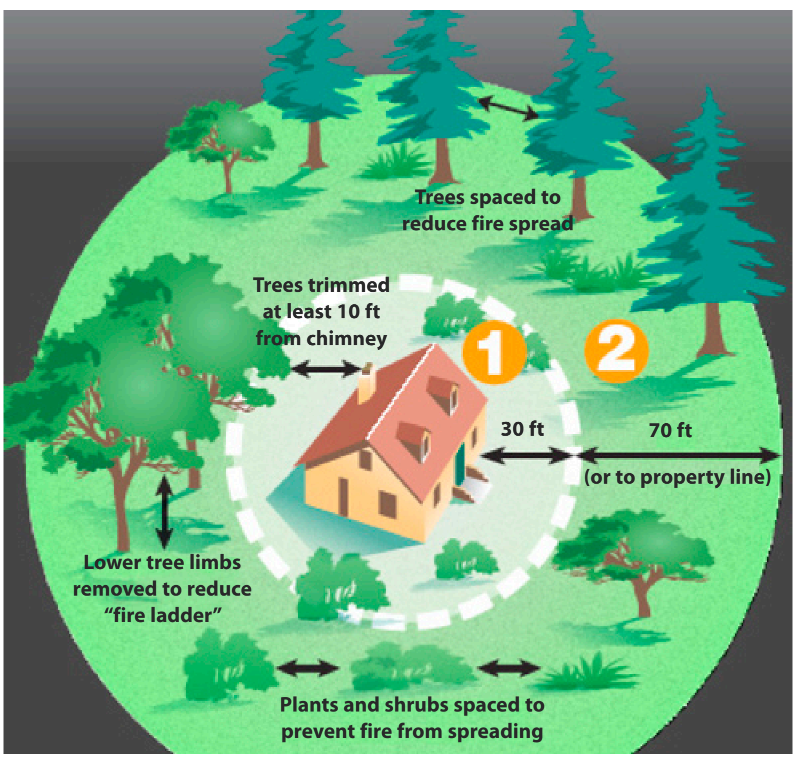

Figure 3. Keep branches trimmed at least 10 feet from your roof and eliminate combustible plants or material under the eaves and next to the house siding and vents. *Source:* CAL FIRE.

HOME DEFENSE ZONE

The 2005 revision of California Public Resources Code § 4291 requires the removal and clearance of all flammable vegetation and other combustible growth within 30 feet of the house, with certain exceptions. Single specimens of trees, shrubs, or other vegetation may be retained provided that they are well spaced and well pruned. In other words, the landscape condition should not support the spread of fire to other vegetation or to a building or structure.

The objectives of the home defense zone include the following:

- Maintain high moisture content in the vegetation.
- Decrease plant fuel density by increasing space between the branches.
- Shorten plant height.
- Create and maintain proper spacing between plants and the home.
- Remove combustible materials (such as firewood, twigs, needles and leaves, dry or cured grasses, shrubs, woodpiles, building materials, cardboard boxes, and solvents) within 30 feet of the home, garage, outbuildings, and propane or other fuel tanks.

Your home can be exposed to fire in three different ways:

Embers

These are glowing or burning pieces of vegetation or construction debris that are lofted during the wildfire. Embers can move up to a mile ahead of a fire storm. These small embers or sparks may fall on the vegetation near your home; on dry leaves, needles, or twigs on your roof; on the roof and then subsequently concentrate within 5 feet of the house; or under your deck with subsequent ignition of vegetation or debris that could then ignite and burn down your house. If ignited from embers that come from outlying areas, a continuous sequence of vegetation can carry flames from your landscaping to your house. The concentration of embers that land on the roof and roll off of it makes the removal of all flammable material within 5 feet of the house critical.

Radiant heat

This is the heat given off by burning materials that is transferred through the air to other materials or objects. Radiant heat from a fire near your house can heat the surface of combustible building materials to a point where combustion occurs.

Flame impingement

This refers to the transfer of heat by direct flame exposure. Direct contact with fire flames will heat the combustible building materials of your home. Depending on the exposure (i.e., time and intensity) of the flame, materials can ignite or break. For example, in a high-intensity fire, your siding material could ignite or the glass in your windows could break.

Fire Resistant Plants

Some landscape plants are described and marketed as fire resistant. It is important to remember that, given certain conditions, *all* plants can burn regardless of how they are classified. In general, select plants that are low growing, open structured, and less resinous. However, how your plants are maintained and where they are placed is as important as the species of plants that you choose. Cultural practices and landscape management (e.g., pruning, irrigation, and cleanup) have a greater impact on whether or not a plant ignites than does the species. When choosing plants for a fire safe landscape, select those with the following characteristics (Barkley 2005):

- High moisture content in leaves (as these ignite and burn more slowly). Deciduous trees are generally more fire resistant than evergreens, because they have higher moisture content when in leaf.
- Little or no seasonal accumulation of dead vegetation.
- Open branching habits (as they provide less fuel for fires).
- Fewer total branches and leaves (again, less fuel for fires).

- Slow growing, so less pruning is required (to keep open structure as noted above).
- Nonresinous material on the plant (i.e., stems, leaves, or needles that are not resinous, oily, or waxy). Junipers, pines, spruces, and firs are resinous and highly flammable.

How To Plant and Maintain Vegetation

Healthy lawn, ground cover, and perennials form a greenbelt in the home defense zone. Plants that are green and lush give better protection. If regularly watered and maintained to eliminate the accumulation of dry plant litter, these plants will be far less likely to carry fire to your home. While all plants will eventually burn, healthy ones with a high moisture content will be more difficult to ignite. Drip irrigation systems are effective and conserve water because they target where the water goes and control the quantity. Use sprinklers for lawns and ensure that your lawn is getting the right amount of water to keep it green, healthy, and thereby fire resistant. The home defense zone can contain the occasional individual shrub or tree that is located at least 10 feet from the house. By grouping plants of similar height and with similar water requirements, you can create a landscape mosaic that uses water more efficiently and is more likely to slow the spread of fire.

Use Noncombustible Materials

Use masonry, gravel, or stone walls to separate plant groups, thus adding to the variety and improving the fire resistance of your landscape. Another way to break up fuel continuity is to use decorative rock, gravel and stepping stone pathways, cement driveways and walkways, and retaining walls as your landscape's "hardscape" that is less flammable. Replace bare, weedy, or unsightly patches near your home with ground cover, rock gardens, vegetable gardens, and fire resistant mulches.

Mulch Conserves Moisture But Also Burns

Carefully choose the location of plants or garden beds that will need mulch. Mulches are valuable because they conserve moisture, reduce weed growth, and also cover up weed cloth. However, be careful not to use too much bark mulch in garden beds near your home or outbuildings. In general, fine (less than ¼ inch particles) or stringy mulches ignite and burn more rapidly than larger chunks. When exposed to fire, thick mulch layers (greater than 2 inches deep) tend to smolder and are difficult to extinguish. Do not use wood or bark mulches within 3 to 5 feet of the house. Instead consider colored rock or other less flammable material.

Where To Plant

Avoid putting plants in the following locations to minimize the movement of fire from vegetation to the home:

- adjacent to the siding
- under vents or eaves
- tree limbs over the roof
- under or near the deck

REDUCED FUEL ZONE

The reduced fuel zone is an area adjacent to the home defense zone. It extends out at least an additional 70 feet away from the house (for a total of 100 feet), where the ground slope around the home is less than 10 percent. In this zone the trees and brush should be thinned out. To determine the additional distance required for slopes of more than 10 percent, multiply the number of degrees over 10 percent for the uphill and sides by three and add it to 100. On the downhill side, multiply the number of degrees over 10 percent by five and add to 100. The key words here are "at least." Your local fire department or insurance company may ask that a larger area be treated. Contact them for requirements in your area.

Trees

For slopes that are less than 20 percent, trim or space existing trees so that there is 10 feet of space between the tips of their limbs. Increase the space to 20 feet for slopes that are 20 to 40 percent. For steep slopes over 40 percent, 30 feet of spacing is needed (Simmerman and Fischer 1990). When planting trees, allow for future growth by spacing them 20 to 30 feet apart. If trees are over 18 feet tall, prune limbs up to a height of 6 to 15 feet to reduce the possibility of surface fires spreading into the tree crowns. In order to avoid stress to the tree, no more than one-third of a tree's live limbs should be removed by pruning. Eliminate other ladder fuels by removing all shrubs from around the base of trees.

Shrubs

Due to flammability, shrubs should not be used as a visual screen for propane tanks, firewood piles, or other flammable materials. To reduce the fire-spreading potential of shrubs, only plant varieties that are widely separated, low growing, deciduous, and nonresinous. These can be planted individually or in small clumps. The spacing between plants depends on the slope of property. The rule of thumb for spacing (Smith 1998) is:

Slopes	Spacing
0 to 20 percent	2 times the height of the shrub
20 to 40 percent	4 times the height of the shrub
greater than 40 percent	6 times the height of the shrub

Yard waste from landscape maintenance can create another fire hazard. This debris should be promptly and legally disposed of to provide a clean, neat landscape. Some Fire Safe Councils provide free chipping programs to assist in the reduction of fuel around the home.

Annual Maintenance

Maintenance is critical to fire safety. Over time, plants grow vertically and horizontally; mulches dry out, and leaves and needles accumulate within and around vegetation. All of these contribute to the fuels on which a fire can feed. Even in fire safe landscapes, the accumulation of leaf litter and other debris can give fire a chance to start under porches and decks and on roofs. Regular cleanup is necessary to maintain the fire resistance of your landscape. This is especially true during the fire season. In general:

- Keep plants green during the dry season and use supplemental irrigation if necessary.
- Move and stack firewood at least 30 feet from your home during the fire season. The wood can be moved closer to the home during the winter months when you would be using it.
- Mow grasses during the green growing season to reduce the potential for fast-moving surface fires. Sparks that can be generated when mowing in dry grass during the fire season can ignite a fire.
- Clean all needles and leaves from the roof, eaves, and rain gutters to protect the roof. Clearing against the foundation provides protection against ignition of the siding.

- Clear all vegetation and other flammable materials from beneath your deck.
- Keep trees trimmed at least 10 feet from your chimney and trim all dead limbs hanging over your house or garage.
- Annually check and prune trees and shrubs to maintain the recommended distance between plants.

Lack of attention to these recommendations can result in plants accumulating dead twigs, leaves, and branches, whether or not they are characterized as “fire resistant.” Lack of maintenance can easily result in vegetation that is very flammable.

Privacy

Many landowners move to the country in order to have either more space or screened space between them and their neighbors. Creating a fire safe landscape does not have to reduce your privacy. If possible, maintain your visual screen outside the reduced fuel zone or at least 100 feet from the home. Within this zone, arrange vegetation in small, well-spaced groups that can still provide a visual screen of your neighbor’s house, while breaking up the horizontal fuel continuity and thereby protecting your home from fire.

BEYOND THE REDUCED FUEL ZONE

When your parcel is greater than an acre or two, you should also consider treating the vegetation all the way to the property line. Many people purchase their property because of the surrounding aesthetics. Protecting your home is very important, but most people would be disappointed to save their home and yet have the surrounding environment burned in a fire.

The same treatment guidelines apply when reducing fuel beyond the reduced fuel zone. Create horizontal and vertical space throughout the vegetation, whether it is shrubland, woodland, or forest.

CONCLUSION

How much or how little homeowners do with their landscaping in fire-prone areas is a measure of their risk aversion to losing their home. The best way to protect your home against fire is to keep the surrounding area clear of fine fuels (dry leaves, grass, or other dry vegetation touching your house), design your landscape to be fire safe, and use appropriate building materials and routine maintenance.

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State Board of Forestry and Fire Protection. 2006. General guidelines for creating defensible space. State Board of Forestry and Fire Protection Web site, http://www.bof.fire.ca.gov/pdfs/4291finalguidelines2_23_06.pdf.

Tennessee Department of Agriculture. N.d. Firewise landscaping. Tennessee Department of Agriculture Division of Forestry Web site, http://www.state.tn.us/agriculture/forestry/lit/firewise4.pdf#search='Tennessee %2C%20fire%20landscaping.

METRIC CONVERSIONS

English	Conversion factor for English to Metric	Conversion factor for Metric to English	Metric
inch (in)	2.54	0.394	centimeter (cm)
foot (ft)	0.3048	3.28	meter (m)
yard (yd)	0.914	1.09	meter (m)
mile (mi)	1.61	0.62	kilometer
acre (ac)	0.4047	2.47	hectare (ha)

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Publication 8228

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UC PEER REVIEWED

Publication 8322 / April 2008

Landscaping Tips to Help Defend Your Home from Wildfire

PAMELA M. GEISEL, Academic Coordinator, UC Statewide Master Gardener Program; **DONNA C. SEAVER,** Program Representative, UC Statewide Master Gardener Program.

You can have both a beautiful landscape and a defensible fire-safe zone around your home. A minimum defensible space of 100 feet around your home is required by California law (Public Resources Code 4291). This space consists of a 30-foot Lean, Clean, and Green zone and a 70-foot reduced fuel zone. The goal is to protect your home while providing a safe area for firefighters. Local terrain and wind patterns may make it prudent to have an even larger zone. Check with your local fire department for defensible space requirements in your area. Current regulations also allow an insurance company to require additional clearance.

The accompanying three-panel poster provides useful guidelines for people who are establishing or maintaining defensible space around their homes. We recommend using the following publications as support documents for the poster:

- **Home Landscaping for Fire**—ANR Publication 8228. This publication discusses how and where to plant and maintain vegetation, including hydrozoning, use of hardscape, and annual maintenance.
  http://anrcatalog.ucdavis.edu/pdf/8228.pdf
- **Homeowners Check List–How to Make Your Home Fire Safe**—
  California Department of Forestry and Fire Protection (CAL FIRE)
  http://www.fire.ca.gov/about_content/downloads/CDFchecklist2006.pdf
- **Why 100 Feet?–Protect Your Home…and Property**—
  California Department of Forestry and Fire Protection (CAL FIRE)
  http://www.fire.ca.gov/about_content/downloads/CDFWHY100FEETBROCH2006.pdf
- **100′ Defensible Space: Make Your Home Fire Safe**
  http://www.fire.ca.gov/about_content/downloads/Defens_space_flyer4_11final.pdf

Additional Information on Specific Points in the Poster

Fire Resistant Plants *(from Home Landscaping for Fire)*. It is important to remember that, given certain conditions, all plants burn regardless of how they are classified. In general, select plants that are low growing, open structured, and less resinous. However, how your plants are maintained and where they are placed is as important as the species of plants that you choose. Cultural practices and landscape management (e.g., pruning, irrigation, and cleanup) have a greater impact on whether or not a plant ignites than does the species. When choosing plants for a fire safe landscape, select those with the following characteristics:

- High moisture content in leaves
- Little or no seasonal accumulation of dead vegetation
- Open branching habits
- Fewer total branches and leaves
- Slow growing, so less pruning is required
- Nonresinous material on the plant (i.e., stems, leaves, or needles that are not resinous, oily, or waxy). Junipers, pines, spruces, and firs are resinous and highly flammable.
- Examples: yarrow, candytuft, rock rose, creeping rosemary, goldmoss sedum

Defensible Space Landscaping in the Urban/Wildland Interface: A Compilation of Fire Performance Ratings of Residential Landscape Plants. This is a UC "work in progress" online publication (http://nature.berkeley.edu/~fbeall/HODefSpaceGuide.pdf) that provides more detail about fire resistant plants.

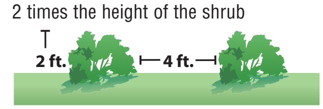
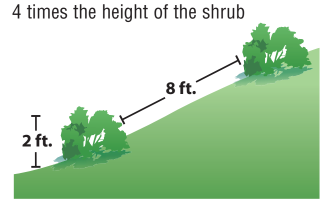
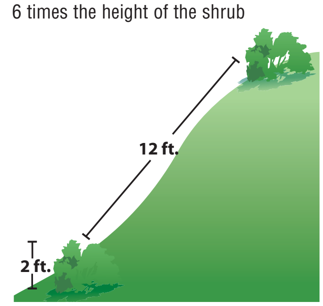
Fire Resistant Plant Information Specific to El Dorado County Areas. Look under the ***Fire—Wildland/Urban Interface*** heading at http://ceeldorado.ucdavis.edu/Natural_Resources/NR_Publications.htm

Reduced Fuel Zones Greater than 100 Feet (from *Home Landscaping for Fire*) The reduced fuel zone is an area adjacent to the 30-foot Lean, Clean, and Green zone. It extends out *at least* an additional 70 feet away from the house (for a total of 100 feet), where the ground slope around the house is less than 10 percent.

To determine the additional distance required for slopes of more than 10 percent, multiply the number of degrees over 10 percent for the uphill and sides by 3 and add it to 100. On the downhill side, multiply the number of degrees over 10 percent by 5 and add it to 100. Your local fire department or your insurance company may ask that you prepare a larger defensible area. Contact them for requirements in your area.

Trees. For slopes that are less than 20 percent, trim or space existing trees so that there is 10 feet of space between the tips of their limbs. Increase the space to 20 feet for slopes that are 20 to 40 percent. For steep slopes over 40 percent, 30 feet of spacing is needed. When planting trees, allow for future growth by spacing them 20 to 30 feet apart. If trees are over 18 feet tall, prune the lower limbs up to a height of 6 to 15 feet. In order to avoid stress to the tree, no more that one-third of a tree's live limbs should be removed by pruning. Remove all shrubs from around the base of trees.

Shrubs. To reduce the fire-spreading potential of shrubs, only plant varieties that are widely separated, low growing, deciduous, and nonresinous. These can be planted individually or in small clumps. The spacing between plants depends on the slope of the property. The rule of thumb for spacing is illustrated below (illustrations courtesy California Department of Forestry and Fire Protection [CAL FIRE]).

Slope	Spacing
0 to 20% 	2 times the height of the shrub 
20 to 40% 	4 times the height of the shrub 
Greater than 40% 	6 times the height of the shrub 

Please contact your local master gardener for more information or go online to http://camastergardeners.ucdavis.edu.

We gratefully acknowledge support for this project from the *Elvenia J. Slosson Research Endowment for Ornamental Horticulture.* Content for this publication was excerpted from *Home Landscaping for Fire* (ANR Publication 8228), by Glenn Nader, Gary Nakamura, Mike De Lasaux, Steve Quarles, and Yana Valachovic; *Why 100 Feet? Protect Your Home . . . and Property, and Homeowners Check List: How to Make Your Home Fire Safe,* California Department of Forestry and Fire Protection (CAL FIRE). Poster design by Will Suckow Illustration. Spanish translation by Myriam Grajales-Hall and Andrew Kramer. Poster illustrations courtesy of CAL FIRE.

Resources Accessible online

Web Sites

California Department of Forestry and Fire Protection (CAL FIRE)
http://www.fire.ca.gov/

California Master Gardeners
http://camastergardeners.ucdavis.edu/

Center for Fire Research and Outreach
http://firecenter.berkeley.edu

El Dorado County Master Gardeners Fire Resistant Landscaping
http://ceeldorado.ucdavis.edu/Master%5FGardener/Firesafe_Landscaping.htm

Homeowners Wildfire Mitigation Guide
http://groups.ucanr.org/HWMG

Wildland Fire (Los Angeles County Cooperative Extension)
http://celosangeles.ucdavis.edu/Natural_Resources/Wildland_Fire.htm

En Español

Fire Safety Education en Español (CAL FIRE)
http://www.fire.ca.gov/education_es.php

Publications/Brochures

Abiotic Disorders of Landscape Plants: A Diagnostic Guide University of California ANR Publication 3420
http://anrcatalog.ucdavis.edu/LawnGarden/3420.aspx

ANR Core Issues and Target Opportunities
http://ucce.ucdavis.edu/files/filelibrary/5728/21855.pdf

A Property Owner's Guide to Reducing Wildfire Threat University of California ANR Publication 21539
http://anrcatalog.ucdavis.edu/FireSafety/21539.aspx

Are You Doing the Right Thing the Wrong Way?—Equipment Use California Department of Forestry and Fire Protection (CAL FIRE)
http://www.fire.ca.gov/about_content/downloads/EquipmentUse2006.pdf

Defensible Space Landscaping in the Urban/Wildland Interface: A Compilation of Fire Performance Ratings of Residential Landscape Plants
http://nature.berkeley.edu/~fbeall/HODefSpaceGuide.pdf

Fire in California's Oak Woodlands
http://nature.berkeley.edu/forestry/sodsymposium/Fire_in_Cal_Oak_Woodlands_McCreary_623041.pdf

General Guidelines for Creating Defensible Space
State Board of Forestry and Fire Protection (BOF) (CAL FIRE)
http://www.bof.fire.ca.gov/pdfs/Copyof4291finalguidelines9_29_06.pdf

Home Landscaping for Fire
University of California ANR Publication 8228
http://anrcatalog.ucdavis.edu/pdf/8228.pdf

Homeowners Check List: How to Make Your Home Fire Safe
California Department of Forestry and Fire Protection (CAL FIRE)
http://www.fire.ca.gov/about_content/downloads/CDFchecklist2006.pdf

Making Your Property Fire-Safe
http://ucce.ucdavis.edu/files/filelibrary/1359/41666.pdf

S.A.F.E. Landscapes 2008 Calendar
http://ucce.ucdavis.edu/survey/survey.cfm?surveynumber=2100

S.A.F.E. Landscapes in the WUI (Wildland Urban Interface)
http://ucce.ucdavis.edu/files/filelibrary/1359/41665.pdf

Why 100 Feet?—Protect Your Home…and Property
http://www.fire.ca.gov/about_content/downloads/CDFWHY100FEETBROCH2006.pdf

100' Defensible Space: Make Your Home Fire Safe
http://www.fire.ca.gov/about_content/downloads/Defens_space_flyer4_11final.pdf

En Español

Proteja su propiedad de los incendios de maleza
(A Property Owner's Guide to Reducing Wildfire Threat) University of California ANR Publication 21545
http://anrcatalog.ucdavis.edu/FireSafety/21545.aspx

For More Information

You will find related information in these titles and in other publications, slide sets, CD-ROMs, and videos from UC ANR:
Abiotic Disorders of Landscape Plants: A Diagnostic Guide, Publication 3420
A Property Owner's Guide to Reducing Wildfire Threat, Publication 21539
Home Landscaping for Fire, Publication 8228

To order these products, visit our online catalog at http://anrcatalog.ucdavis.edu. You can also place orders by mail, phone, or FAX, or request a printed catalog of publications, slide sets, CD-ROMs, and videos from

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Ask a UC Master Gardener

Landscaping Tips to Help Defend Your Home from Wildfire

Through proper planning, you can have both a beautiful landscape and a fire safe zone around your home.

Begin by creating and maintaining a *Defensible Space* of 100 feet around your home that includes:

- A ***Lean, Clean, and Green Zone*** of 30 feet, ***plus***
- A ***Reduced Fuel Zone*** of 70 feet

Note: Even greater defense zone widths are necessary when your home is on a steep slope or in a windswept area.

Please contact your local master gardener for more information http://camastergardeners.ucdavis.edu

We gratefully acknowledge support for this project from the *Elvenia J. Slosson Research Endowment for Ornamental Horticulture.*

Content for this publication was excerpted from: *Home Landscaping for Fire*, ANR Publication 8228, Glenn Nader, Gary Nakamura, Mike De Lasaux, Steve Quarles, Yana Valachovic; *Why 100 Feet? Make Your Home Fire Safe*, and *Homeowners Checklist – How to Make Your Home Fire Safe*, California Department of Fire Protection (CDF).

Project management: Pamela M. Geisel; Donna C. Seaver. Spanish translation: Myriam Grajales-Hall, Andrew Kramer. Poster design: Will Suckow Illustration. Poster illustrations: CDF.

October 2007 MG_07.2.1

Create a Defensible Space of 100 Feet Around Your Home

First, create a *Lean, Clean,* *and Green Zone*

by removing all flammable vegetation and combustible materials within 30 feet immediately surrounding your home.

- Keep trees trimmed at least 10 feet from chimneys and remove dead branches hanging over structures.
- Remove build-up of needles and leaves from roof and gutters.
- Remove dead and dying plants, fallen leaves, needles, twigs, bark, cones, pods, small branches, etc.
- Regular maintenance (pruning, weed control, adequate irrigation) is necessary to maintain the fire resistance of your landscape.
- Increase spacing between plants.
- Landscape with fire resistant plants – low growing, open structured, and less resinous.
- When clearing vegetation use care in operating equipment such as lawnmowers.

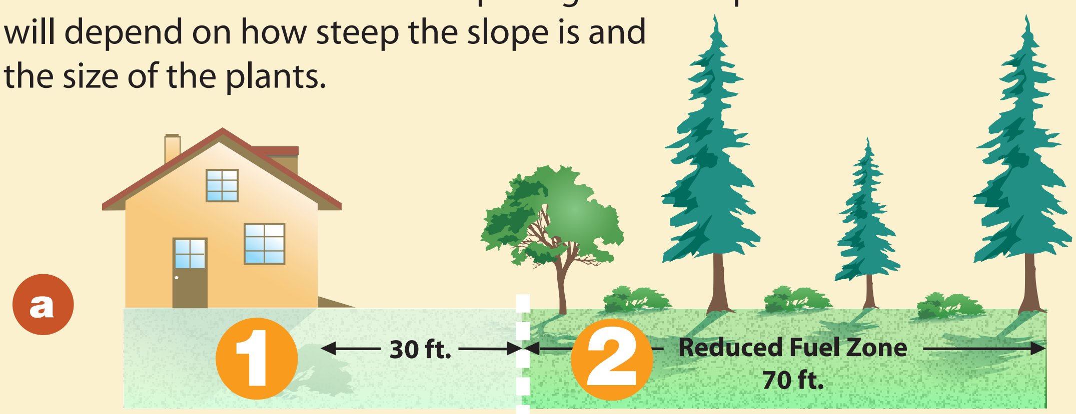
Create a Defensible Space of 100 Feet Around Your Home

Next, create a *Reduced Fuel Zone*

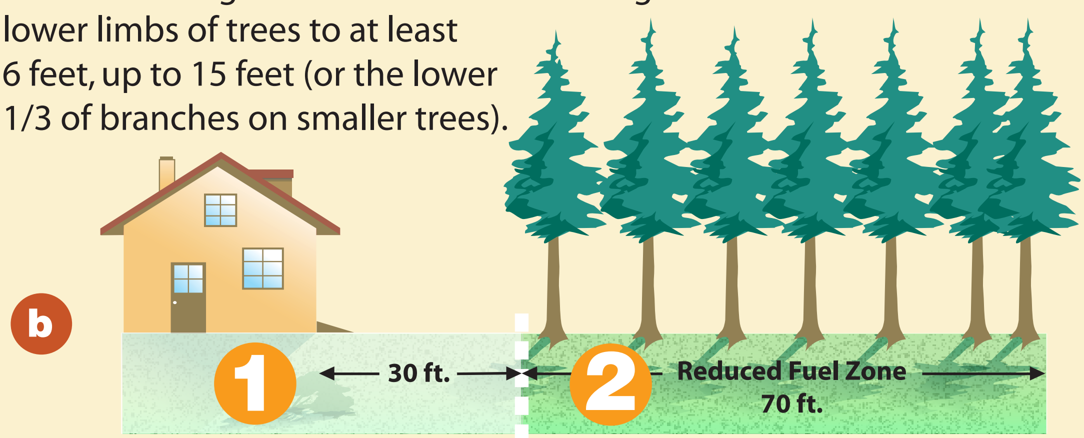
adjacent to your *home defense zone*, extending out at least an additional 70 feet, or to your property line. Greater defense zone widths are necessary when your home is on a steep slope or in a windswept area.

Open space between plants improves the chance of stopping a wildfire. You have two options:

a) Create horizontal and vertical spacing between plants. The amount of space will depend on how steep the slope is and the size of the plants.



b) Large trees do not have to be cut and removed, but plants growing beneath them that are greater than 4 inches in height should be removed. Remove lower limbs of trees to at least 6 feet, up to 15 feet (or the lower 1/3 of branches on smaller trees).



Access 51 page document: http://ucanr.org/sites/urbanhort/files/80223.pdf

Landscape Irrigation
System Evaluation and Management

David A. Shaw and Dennis R. Pittenger

University of California Cooperative Extension

University of California Cooperative Extension
April 2009

Landscape Irrigation System Evaluation and Management

* *

Contents

Preface

This publication presents practical information and field procedures for evaluating landscape irrigation hardware performance and determining irrigation schedules. These guidelines will enable the user to develop a superior irrigation management program that will optimize plant growth and health without wasting water. Emphasis is given to water conservation strategies that are effective during periods of restricted water use.

Green Industry personnel, at all levels of experience and training, should be able to understand and implement the information. The authors have avoided the use of technical jargon where possible. The main body of the handbook describes the overall procedures and the appendices contain formulae and other reference information.

Field evaluations and scheduling techniques require an irrigator to have a basic knowledge of water measurement calculations. The necessary calculations can be performed with either a hand-held calculator or with a computer, utilizing software or web-based irrigation management programs. While both calculators and computers will provide the same useful solutions, the computer programs offer time savings and a printed irrigation schedule useful for controller programming. Irrigation scheduling web sites and software sources are listed in Appendix F.

This publication is a working revision of *Landscape Irrigation System Evaluation and Scheduling for Southern California*, written by David A. Shaw and Paul F. Zellman. The publication supplements information presented at U.C. Cooperative Extension classroom and field demonstration sessions.

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Access spreadsheet file: http://cagardenweb.ucanr.edu/Drought_/Drought_Irrigation_Tips_/

Irrigation scheduling worksheet

This spreadsheet will generate an annual calendar to irrigate a single hydrozone based on local historical evapotranspiration (ET), distribution uniformity (DU) assessment information, soil type, and desired soil wetting depth. The worksheet will accommodate irrigation that is restricted to specific days of the week (designated irrigation days).

Description

This tool will calculate and determine an irrigation schedule for one irrigation zone for a calendar year. The user enters information about the site location including: CIMIS ETo zone (using the included map), soil type (use the Soil Web application available online if needed), DU assessment information, the year of the desired irrigation schedule, and the desired depth to wet the soil. Some water providers restrict the days of the week when irrigation can occur and those days can be accommodated.

An irrigation assessment needs to be conducted and the catch can values from the assessment is entered into the spreadsheet. If runoff occurred from the site or significant puddling or pooling appeared, the duration of the irrigation when that occurred is also entered. From those values, irrigation information is calculated including DU, precipitation rate, minimum irrigation duration (lower boundary), and recommended duration (upper boundary). If runoff occurred, valve cycling will be calculated to determine the length of the cycle (duration) and number of cycles per irrigation event. This information can be used for programming an irrigation controller. Because of rounding, cycling may deliver less water than the upper boundary amount and that amount is determined.

The irrigation calendar shows the days that irrigation should occur based on historical ET and days of the week when irrigation is allowed. If there are restrictions when irrigation occurs and ET rates are high, sometimes the irrigation cannot “keep up” with water demand. So this spreadsheet will “look ahead” to see if and irrigation may be required in the next day or so (depending on the number of days when the next irrigation is allowed) and may schedule an irrigation on an earlier allowed day if necessary.

Before using this spreadsheet, an irrigation assessment needs to be conducted to determine the distribution uniformity of the irrigation system. If needed, instructions to conduct this assessment are in: **Landscape Irrigation System Evaluation and Management** which can be retrieved at: http://ucanr.org/sites/urbanhort/files/80223.pdf

Using the spreadsheet

All of the entries on the first page of the spreadsheet are optional. On the remaining pages of the spreadsheet, information that is required is denoted by green boxes. The blue colored boxes indicate where optional information could be entered.

1. Descriptive information about the irrigation zone is entered on the **Irrigation System Information** tab.
2. Provide information on the **ET_0, Soil, C.C., Irr Info.** tab of the spreadsheet including:
    a. Location- Enter information that identifies the irrigation zone.
    b. ET_0 zone- These are ET zones as defined by CIMIS. Use the map on the **ET_0 Zones Map** tab to identify the zone where the site is located. Then, on the **ET_0, Soil, C.C., Irr Info.** tab, use the pull-down list and select the ET_0 appropriate zone number in the cell.
    c. Soil texture- Use the pull-down list and select the soil texture of the site. If you don't know the soil type, use the **SoilWeb** application for computers and smart phones at: http://casoilresource.lawr.ucdavis.edu/soilweb/.
    d. Catch can throat area- Identify the type of catch can used and enter the throat area in the appropriate green space. If you used a non-standard catch can, you'll need to determine the throat area. If you used a round can, you can enter the diameter of the throat (in inches) in the space provided and the area will be calculated. Enter the calculated area in the green space.
    e. Year of the schedule- Enter the year for the desired irrigation calendar.
    f. Soil wetting depth- Enter the depth that the soil should be wetted. The recommended depth for turf is 12 inches. Wetting depths for trees and shrubs varies by type. Trees should be irrigated to 2 to 3 feet.
    g. Days of the week when irrigation is allowed- Check the box next to each day that irrigation is allowed. If there are no restrictions, **make sure all of the boxes are checked**.

3. On the **Catch Can Field Worksheet** tab, data about the catch can test is entered:
   a. Run time- Enter the duration in minutes that the valve was on during the catch can test.
   b. K_L or Ks- Enter the K_L (landscape coefficient) or Ks (species coefficient) for the hydrozone. The Ks for cool and warm season turfs are 0.8 and 0.6, respectively. During drought, these can be reduced to 0.6 and 0.4 respectively, but expect a decline in appearance.

      A guide to K_L is available in the WUCOLS IV document ("User Manual, Categories of Water Needs", http://ucanr.edu/sites/WUCOLS/).
   c. Valve on-time to run off- If run off, pooling, or puddling occurs, enter the duration the valve was on when that appeared. A run separate from the DU assessment could be used to determine if and when it appears. Make sure the soil is sufficiently dry after the catch can test if a separate run to determine runoff is done. If no runoff appeared, then leave this cell blank.
   d. Catch can volumes - Enter the catch can volumes in the spaces provided. There should be at least 24 and no more than 40 catch cans used. The total number of cans should also be a multiple of four. The boxes are shaded to help to assure the correct multiple of cans.
   e. Targeted catch can volumes- There is an optimum targeted volume of water to be caught in the catch cans based on the throat diameter. Try to capture the volume of water indicated. This is a guide only and it is okay to catch more or less. In any case, DO NOT exceed the capacity and cause the catch can to overflow. Be sure to measure the water volumes in milliliters (mL).

4. From the information and data provided, a summary of the calculations is presented on the **Irrig Summary** tab and includes:
   a. Distribution uniformity of the lowest quartile (DU_{LQ})
   b. Precipitation rate (PR) in inches per hour
   c. Scheduling multiplier
   d. Inches of irrigation required to wet to the desired depth
   e. Valve on-time (lower boundary) to wet to that depth
   f. Maximum valve on-time that includes the scheduling multiplier component (upper boundary).

Information that is used to program the irrigation controller is presented and considers the valve on time (duration) that generated runoff, if runoff appeared, and the number of cycles required to provide the amount of water needed to wet to the desired depth. For example, the controller might be programmed to run 4 cycles of a 6 minute on-time for a valve. To program this into a controller, for example, 6 minutes would be entered for the run time and there would be 4 start times: 4:00 am, 5:00am, 6:00am, and 7:00am.

The run time and number of cycles are determined using the time to run off, if it is entered, and will determine the combination that will provide at least 90% of the desired amount of water to be applied. Note that due to rounding, the total run time may be less than the time to run off that was entered and the percentage of the upper boundary that would be applied is displayed.

Also provided is the infiltration rate of the soil for informational purposes only.

5. A calendar for each month of the year indicating days when the irrigations should occur is displayed on the **Irrig Calendar** tab. This considers the days of the week when irrigations are allowed. The calendar also determines if the year is a leap year or not and adjusts accordingly.

6. The **ET_0 Zones Map** tab is the only sheet to which the user might refer for information needed to complete the form on the **ET_0, Soil, C.C., Irr Info.** tab.

7. Other worksheet tabs are hidden and should not need to be accessed by users and include:

   Soil Information which contains a table of soil data that is used to calculate the amount of water needed to irrigate to the desired depth.

   DU Calcs "mL.", where the DU calculations take place. The cycling calculations are also conducted on this page. The % Applied Target is entered here by the spreadsheet programmer and is set t 90%.

   Daily ET_0 is used to determine daily ET_L or ET_S, when irrigations are needed. This tab also includes information used to generate the calendars for each year so that the dates and days of week are correct. It also stores information of days irrigation is allowed.

   Irrig Sched is used to determine when the irrigations should occur. The columns within a month are: day of week, date of month, allowed irrigation day (0=no, 1=yes), cumulative ET, and if this is a day to run the irrigation. This sheet will determine if the "trigger" (Amount applied) would be reached in the next day or so (which depends on how many days per week irrigation is allowed) and then allow an irrigation before the ”trigger” is reached. This is done so that the irrigations can “keep up” with ET. This is especially necessary if irrigation is allowed only one or two days per week and ET rates are high. At one day allowed per week, and in high ET zones, it is likely that the irrigation cannot keep up without irrigating deeper than desired.

8. Lastly, the **Instr Refs Auths** tab includes instructions how to use the spreadsheet, references and contributors to the worksheet.

Printing

Macros are included to assist with printing all or portions of the spreadsheet:

Crtl-Shift-A:	All sheets
Ctrl-Shift-I:	Instructions
Ctrl-Shift-S:	Irrigation system info; ETo, Soil, CC, Irr, Rain; and Catch Can Field
Ctrl-Shift-C:	Irrig Summary and Irrig Calendar

Notes

Cells that contain formulas on sheets that can be accessed by users are protected from alterations.

I understand that there are limitations to this sheet, especially when it recommends many cycles. Of course there are controllers that won’t be capable of running 10 start times, for example. Numerous start times are used to reduce the occurrence of runoff by limiting the valve on time to the interval when runoff was observed. This points to the importance of reducing PR or increasing infiltration rate to reduce the possibility of runoff.

This worksheet was developed using MS Excel 2010.

Thanks,

Loren
lroki@ucdavis.edu

These instructions and notes apply to:
Irrigation Worksheet mL v1.20.xlsm
March 16, 2015

University *of* California
Agriculture and Natural Resources | UCCE Master Gardener Program

Use of Graywater in Urban Landscapes in California

Prepared by:

Janet Hartin, UCCE Environmental Horticulture Advisor
San Bernardino, Riverside, and Los Angeles Counties

Ben Faber UCCE Soils and Water/Subtropicals Advisor
Ventura and Santa Barbara Counties

Definition and Overview

The use of graywater (also spelled greywater, grey water and gray water) to irrigate landscape plants is increasing throughout the United States, particularly in California and other arid states. Municipalities are rapidly amending their codes to encourage the use of home graywater systems. This publication describes what graywater is, basics of laundry to landscape systems, and associated benefits and risks of graywater systems to humans and other animals as well as to plants.

In California, under Health and Safety Code § 17922.12, graywater is defined as "untreated wastewater that has not been contaminated by any toilet discharge, has not been affected by infectious, contaminated, or unhealthy bodily wastes, and does not present a threat from contamination by unhealthful processing, manufacturing, or operating wastes. Graywater includes, but is not limited to, wastewater from bathtubs, showers, bathroom washbasins, clothes washing machines, and laundry tubs, but does not include wastewater from kitchen sinks or dishwashers."

A construction permit is no longer required for the installation of a single-family or two-family residential graywater irrigation system from a washing machine to an outdoor irrigation or disposal field as long as it does not alter the household plumbing (graywater is accessed from the hose of the washing machine, not by cutting into plumbing), and complies with the following:

1. *If required, notification has been provided to the Enforcing Agency regarding the proposed location and installation of a graywater irrigation or disposal system.*
2. *The design shall allow the user to direct the flow to the irrigation or disposal field or the building sewer. The direction control of the graywater shall be clearly labeled and readily accessible to the user.*
3. *The installation, change, alteration or repair of the system does not include a potable water connection or a pump and does not affect other building, plumbing, electrical or mechanical components including structural features, egress, fire-life safety, sanitation, potable water*

supply piping or accessibility. (Note: The pump in a clothes washer shall not be considered part of the graywater system.)

4. *The graywater shall be contained on the site where it is generated.*
5. *Graywater shall be directed to and contained within an irrigation or disposal field.*
6. *Ponding or runoff is prohibited and shall be considered a nuisance.*
7. *Graywater may be released above the ground surface provided at least two (2) inches (51 mm) of mulch, rock, or soil, or a solid shield covers the release point. Other methods which provide equivalent separation are also acceptable.*
8. *Graywater systems shall be designed to minimize contact with humans and domestic pets.*
9. *Water used to wash diapers or similarly soiled or infectious garments shall not be used and shall be diverted to the building sewer.*
10. *Graywater shall not contain hazardous chemicals derived from activities such as cleaning car parts, washing greasy or oily rags, or disposing of waste solutions from home photo labs or similar hobbyist or home occupational activities.*
11. *Exemption from construction permit requirements of this code shall not be deemed to grant authorization for any graywater system to be installed in a manner that violates other provisions of this code or any other laws or ordinances of the Enforcing Agency.*
12. *An operation and maintenance manual shall be provided. Directions shall indicate the manual is to remain with the building throughout the life of the system and indicate that upon change of ownership or occupancy, the new owner or tenant shall be notified the structure contains a graywater system."*

All other graywater systems aside from 'laundry to landscape' types described above require a construction permit prior to erection, retrofitting, construction and installation as stated in the California plumbing code. Examples include:

- Simple System. A graywater system serving a one- or two-family dwelling with a discharge of 250 gallons (947 L) per day or less.
- Complex System. A graywater system that discharges over 250 gallons (947L) per day.

The updated code and its provisions for use of graywater to irrigate landscapes can be found in its entirety here: http://www.hcd.ca.gov/codes/shl/2007CPC_Graywater_Complete_2-2-10.pdf

It is important to note that cities, counties, and other local jurisdictions can impose stricter guidelines than the state; homeowners interested in installing graywater systems should contact their local jurisdiction for specific regulations concerning graywater handling and use.

Important definitions included in the California graywater code:

Irrigation field: an intended destination for graywater in the receiving landscape including but not limited to a drip irrigation system, mulch basin, or other approved method of dispersal for irrigation purposes.
Disposal field: an intended destination for graywater including but not limited to a mulch basin or receiving landscape feature, graywater leach field, or other approved method of disposal.
Mulch basin: a type of irrigation or disposal field filled with mulch or other approved permeable material of sufficient depth, length and width to prevent ponding or runoff. A mulch basin may include a basin around a tree, a trough along a row of plants or other shapes necessary for irrigation or disposal.

The Basics of 'Laundry to Landscape' Graywater Systems

Laundry-to-landscape graywater systems are relatively simple to install and inexpensive. The number of cities and counties approving the use of these graywater systems without requiring permits is rapidly increasing. Metropolitan areas including Berkeley, Los Angeles, San Francisco, Santa Barbara, San Diego, and Santa Rosa no longer require permits for these systems. Some even offer rebates to install graywater systems and many offer regular workshops on system design and installation. Specific details regarding system requirements, rebates, and workshops can be found below:

Berkeley:
http://www.ci.berkeley.ca.us/Planning_and_Development/Energy_and_Sustainable_Development/Graywater_Clothes_Washer_System__Laundry_to_Landscape.aspx

Los Angeles: http://ladbs.org/LADBSWeb/LADBS_Forms/InformationBulletins/IB-P-PC2014-012Graywater.pdf.

San Francisco: http://sfwater.org/modules/showdocument.aspx?documentid=55

Santa Barbara County: http://www.waterwisesb.org/documents/greywater.pdf

San Diego (City): http://www.sandiego.gov/water/recycled/graywater.shtml

Santa Rosa: http://ci.santa-rosa.ca.us/departments/utilities/conserve/Pages/Graywater.aspx

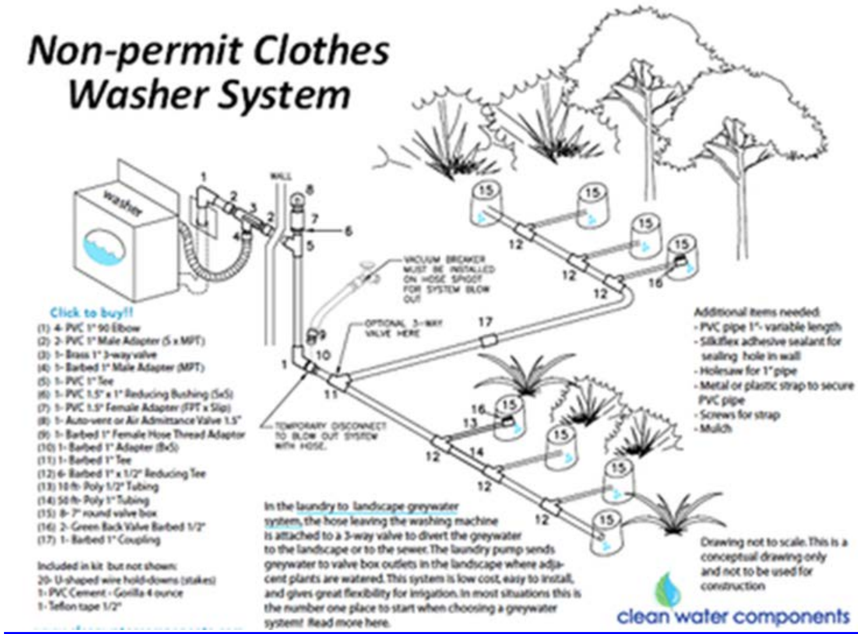

Figure 1 - Diagram of a 'laundry to landscape' graywater system (source: Clean Water Components).

How do 'laundry to landscape' graywater systems work?

The hose exiting the clothes washing machine is attached to a valve that separates graywater from water destined for the sewer. All water can be channeled directly into the sewer when bleach or powder-based detergents are used, when a graywater use quota is exceeded a detailed explanation with examples is found on page nine (9) of the San Francisco Greywater Design Manual for Outdoor Irrigation: http://sfwater.org/modules/showdocument.aspx?documentid=55) or when a rain event occurs raising the groundwater level. Graywater is directed to and contained within an irrigation or disposal field (refer to definitions above). A vacuum break or backflow prevention device may also be needed.

When using 'laundry to landscape systems' it is important to select appropriate detergents and related cleaning products to reduce the chance of adverse effects on irrigated plants and the environment. Refer to 'Impact of graywater on plant health' below for help selecting appropriate detergents and other products that are recommended for these systems.

Figure 2 - A 'laundry to landscape' graywater system 3-way valve separates water destined for the sewer from water used to irrigate landscape plants (Source: http://centralcoastgreywater.org/)

The simplest 'laundry to landscape' graywater systems often discharge water directly into mulch basins via mulch shields. Leaving an air space between the pipe and the ground helps prevent plant roots from growing into and clogging the graywater pipe.

Mulch basins constructed by replacing several inches of soil with coarse organic mulch to irrigate flowerbeds and small ornamentals are common and are generally not problematic to plant growth.

Figure 3 - An example of a 'mulch shield' (source: greywateraction.org).

However, basins constructed within the drip line (see figure 4) of mature trees are not recommended and can result in injury to established roots and unstable and unsafe trees subject to failure over time. How can this happen? Small, restrictive mulch basins may result in roots that grow in circular patterns and never grow outward beyond the mulch basin into native soil injuring tree roots and creating unstable trees subject to failure.

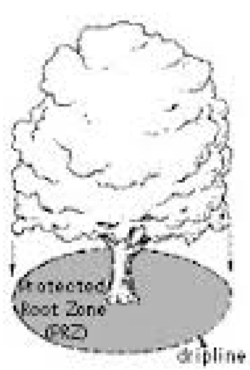

Figure 4 - Basins constructed within the drip line of mature trees are not recommended.

Tree roots should not be cut into or severed within the dripline. Irrigation water should be applied within the dripline and not on or near the main trunk (source: Univ. of MN Coop. Extension).

If mulch basins are used, they must be sized correctly to prevent surface pooling and in accordance with Table 16A-2 in the plumbing code shown below. Remember that graywater may not be allowed to sit unused for more than 24 hours and that the discharge point (disposal field) must have a two inch or greater layer of mulch, rock, or soil or a solid shield to minimize human contact.

The sizing of the mulch basin depends mainly on soil texture (sandy loam, clay loam, etc.). Graywater percolates quickly through sandy soil, requiring minimal mulch. In slower-percolating clay loam soil, a larger mulch basin is required around the valve box to prevent graywater pooling. Large wood chip mulch is more durable and longer lasting than smaller wood chip mulches or shredded fiber and is therefore preferred. A series of holes/valves that are between 3/8 inch and one inch are added to reduce backpressure on the pump. Mature trees may require ten or more mulch basins to avoid overloading the pump and to achieve even distribution. For instance if each basin is four inches in diameter (12.6 square feet) ten basins will irrigate 126 square feet of rooting area. Remember that mulch decomposes over time, requiring regular augmentation to maintain the required two inch depth.

Table 16A-2 Design Criteria of Six Typical Soils

Type of Soil	*Square Feet*	*Gallons*	*Square Meters*	*Liters*
	Minimum square feet of irrigation/leaching area per 100 gallons of estimated graywater discharge per day	*Maximum absorption capacity in gallons per square foot of irrigation/leaching area for a 24-hour period*	*Minimum square meters of irrigation/leaching area per liter of estimated graywater discharge per day*	*Maximum absorption capacity in liters per square meter of irrigation/leaching area for a 24-hour period*
Coarse sand or gravel	*20*	*5.0*	*0.005*	*203.7*
Fine sand	*25*	*4.0*	*0.006*	*162.9*
Sandy loam	*40*	*2.5*	*0.010*	*101.8*
Sandy clay	*60*	*1.7*	*0.015*	*69.2*
Clay with considerable sand or gravel	*90*	*1.1*	*0.022*	*44.8*
Clay with small amounts of sand or gravel	*120*	*0.8*	*0.030*	*32.6*

Other Graywater Systems

'Branched drain' types (shown below) of graywater systems rely on gravity to distribute graywater to mulch basins. While often capturing graywater from showers, they can also be used in conjunction with washing machines as 'laundry to landscape' systems. They only work when plantings are located below the water source since they do not contain an external pump. 'Branched drain' systems are excellent methods of watering trees and shrubs. The final exiting point of each branch are trees and shrubs in mulch basins.

Figure 5 - Example of a 'branched drain' graywater system relying on gravity (source: centralcoastgreywater.org).

While these systems are relatively maintenance-free and efficient once installed the installation process may be difficult and homeowners may want to hire an expert to install them. Like other 'laundry to landscape' systems, no filters need to be changed and no additional wiring or pumps are required and cleanouts can be incorporated for regular, easy flushing.

Laundry drum graywater systems pump household water into a surge tank which is a large barrel or watertight storage container. Simple systems take advantage of gravity to move water downhill but are not suitable for upward elevations. The water drains out of the bottom of the drum into a hose that the homeowner can move around the yard as needed. Laundry drum systems are inexpensive and efficient methods of irrigating landscape plants. They are well suited to residential landscapes as well as small plantings maintained by apartment renters. When uphill pumping is required, drums (watertight temporary storage containers) connected to effluent pumps that move graywater uphill are needed. (Since no filters are used in these systems, they are not compatible with drip irrigation due to clogging.)

How much graywater can be harvested by a household washing machine?

On average, between ten and 25 gallons of water is generated per washing machine load from a horizontal-drum machine (side loader) and about 40 gallons per washer load from a vertical drum machine that loads from the top. Since the maximum flow rate from newer high efficiency washers may be as low as 1.5 gallon per minute (far less than that of many top-loading machines) it is important to limit the number of outlets per zone. (The average amount of graywater generated by one person per day recycled via a laundry to landscape system is estimated at 15 gallons. In comparison, per capita daily graywater production from showers, bathtubs, and lavatories is estimated at 25 gallons.)

How many trees and shrubs can be irrigated using graywater from a 'laundry to landscape' graywater system?

It depends on the amount of graywater generated, the climate zone, and the water requirements of the plants. Here are some examples. Two hundred gallons of graywater generated each week can keep four 100 sq ft canopied high-water requiring mature trees well irrigated and healthy in Sacramento and Riverside/San Bernardino (inland climate zones) but is only enough to keep two high-water requiring trees healthy in hotter desert climates. Conversely, high-water requiring trees in coastal climates will perform well on much less water. Low-water requiring plants in coastal areas require the least amount of water under all circumstances.

The table below illustrates how many gallons of water per week well-established trees and shrubs of various canopy sizes require in July, the highest water-demanding month of the year. Keep in mind that under drought and water restrictions most plants can be kept alive on less than half of these rates.

Gallons of Water per Week Required
(for optimal growth)

Climate	**Relative Water Requirement of Tree/Shrub (July)**	**50 square foot canopy**	**100 square foot canopy**	**200 square foot canopy**
Coastal (historical evapotranspiration = 1 inch/week)	Low	10	19	38
	Medium	16	31	62
	High	25	50	100
Inland (historical evapotranspiration = 2 inches/week)	Low	19	38	76
	Medium	31	62	124
	High	50	100	200
Desert (historical evapotranspiration = 3 inches/week)	Low	28	57	114
	Medium	47	93	186
	High	75	150	300

(Table adapted from CA Dept. of Water Resources 'Using greywater in your home landscape' CA Dept. of Water Resources. 1995. Source: http://www.water.ca.gov/wateruseefficiency/docs/graywater_guide_book.pdf))

Can homeowners install their own 'laundry to landscape' graywater systems?

Yes, but installing a system correctly requires time to acquire the necessary knowledge as well as knowing what components to purchase and where to locate them. Before starting, it is wise to consider enrolling in a 'how to' class offered by local government jurisdictions. 'Greywater Action' is a non-profit consortium that provides training on the design and installation of graywater systems to interested individuals, companies, and agencies. The 'Greywater Action'


Figure 6 - Example of a residential landscape irrigated by a graywater system (source: sunset.com).

website contains a list of upcoming workshops as well as a list of trained personnel who have completed their training course. http://greywateraction.org/business-directory/.

Other useful websites that detail design and installation are: Oasis Design, www.oasisdesign.net the San Francisco Greywater Design Manual, http://sfwater.org/modules/showdocument.aspx?documentid=55

Larger Scale, Complex Graywater Systems

Complex, multifaceted graywater systems using pumps, filters, and even 'Smart Controllers' linked to weather stations to target irrigations based on real-time plant water needs are now being used to irrigate expansive plantings at apartment, condominium, and other facilities. These systems require permits. Due to the required plumbing, pumping, filtering, energy requirement and overall cost their use is generally not justified in single family households with fewer than four or five residents. However, while the cost to design and install these systems can be high, their flexibility and efficiency often outweigh these disadvantages on large scale sites.


Figure 7 - Casa Dominguez, an affordable housing development in Los Angeles, uses washing machine-generated graywater to irrigate its landscape (Source: CA planning and development report).

Sand-filtered drip systems are excellent examples of these high technological systems that fill a distinct and important void in the area of graywater reuse and water conservation. Graywater is temporarily stored in a tank with an effluent pump until it is needed for irrigation. Hair, lint, and other debris must first be filtered out before the graywater can be run through tubing and emitters without clogging the system. An obvious advantage of these systems over simple mulch basins that require digging of trenches in root zones of trees is that root damage is prevented and tree roots are not prone to circling and girdling in the mulch area over time. Other advantages are that these systems can irrigate uphill, downhill, and at level elevations, are fully automated and can be used in conjunction with 'Smart controllers' and in most cases use all graywater generated. (If too little graywater is available potable water can be temporarily piped through the system instead.)

For specific information on plan preparation, design, construction, and management of complex graywater irrigation systems, contact the American Society of Irrigation Consultants (ASIC) http://www.asic.org/ or the Irrigation Association, http://www.irrigation.org.

Benefits and Risks of Using Graywater Systems

Specific benefits of using graywater to irrigate California landscapes include:

- reduced reliance on potable water sources to irrigate landscapes,
- reduced energy load otherwise required for pumping and treating potable water,
- a sustainable, steady, and reliable water harvesting source in areas of the state with low rainfall where the potential for rain harvesting is negligible.

Along with many potential benefits come potential risks, which should be carefully evaluated before deciding whether to install a graywater system. Graywater varies substantially in quality and potential risks from site to site. Without adequate natural rainfall, any system (including graywater) that discharges wastewater into garden soil can potentially add damaging concentrations of salts to the soil which can negatively impact plant health. Many household cleaning products, as well as many shampoos, soaps, and detergents, contain compounds which can pose significant human and environmental health concerns and can injure and even kill plants at high dosages over a short period of time. Others can cause significant damage from smaller dosages over a longer period. Products containing high levels of sodium should not be used in 'laundry to landscape' systems and accumulated salts may need to be leached regularly through the soil. Products high in sodium include some detergents, whiteners, and water filtered through softener systems. In general, liquid detergents are lower in sodium and therefore preferred over powdered products. Chlorine-based bleach should be avoided; oxygenated bleaches containing hydrogen peroxide are an excellent alternative.

Impact of Graywater on Human Health

Because of the recent changes regarding graywater reuse under California and other state statutes, research pertaining to the long-term impacts and risks of graywater reuse on human health, plant health, soil chemistry, and ground and surface water quality is very limited. An overview of current research-based information follows.

Research examining the microbial constituency of graywater indicates that direct contact with graywater can pose a health risk to humans. Pathogens can enter graywater through food sources in the kitchen, which is why use of graywater generated from kitchen sinks and dishwashers is not recommended. Also, because pathogens can enter graywater through fecal matter, water contaminated by dirty diapers should be avoided.

Pathogens posing the greatest concern in graywater include bacteria such as enterotoxigenic *Escherichia coli*, *Salmonella* spp., *Shigella* spp., *Vibrio cholera, Campylobacter* spp., *Clostridium perfringens*, *Legionella* spp.; protozoans such as *Giardia* spp. and *Cryptosporidium* spp.; and viruses such as enteroviruses, hepatitis A, rotavirus, and Norwalk virus.

Some contaminants and pathogens active in sewage and sewage effluent can be translocated to fruits and vegetables grown in proximity. Results from study to study vary widely. Several studies found that microbiological contamination in municipal wastewater used to irrigate agriculture crops can pose significant risks from viruses, bacteria and pathogenic protozoan/helminthes under certain conditions. A wide variety of growing conditions and maintenance practices as well as climate and microclimate influence adverse outcomes. Since graywater can contain some of the same contaminants as raw sewage (although in lower concentrations) such as fecal coliforms, they can register above international drinking, bathing, and irrigation water standards. Graywater can also contain pathogens derived from food handling, and opportunistic pathogens found on skin. While to date there have not been any documented cases of graywater resulting in public health impacts, caution should be exercised since it is difficult to trace illness back to its source in many cases.

In any case, graywater should not be applied directly to edible plant parts or root crops. To be safe, it should be applied only to nonedible ornamental plants and splashing graywater on neighboring edible plants should be avoided. Graywater should not be applied through sprinkler systems, since droplets containing harmful microbes can become suspended in the air and inhaled.

Impact of Graywater on Soil Chemistry and Water Quality

Limited research has addressed the fate of microorganisms found in graywater and their resulting impact on indigenous soil microorganisms, soil chemistry, and water quality. Infiltration through soil, rock, and other materials that serve as filters can significantly diminish the threat of water pollution from graywater use. Unfiltered graywater accumulating in surface water and graywater seepage into nearby wells can diminish water quality resulting in waterways pollution. Graywater, by California statute, cannot come in close contact with groundwater. The California plumbing code states, "no irrigation or disposal field shall extend within three (3) vertical feet (915 mm) of the highest known seasonal groundwater, or to a depth where graywater contaminates the groundwater, ocean water or surface water." When graywater is applied per these provisions risks are greatly reduced and/or prevented.

Impact of Graywater on Plant Health

Because graywater is often rich in nutrients required for plant growth, ornamental plants may benefit from its use. However, graywater may include high levels of sodium, potassium, and calcium which can increase pH (alkalinity). Since many California soils are alkaline (pH above 7.0) to begin with, soil tests should be conducted to determine if added sulfur is needed to reduce the pH to optimize growth of alkaline-sensitive plants. Ornamental plants vary dramatically in their sensitivity to the wide array of potentially harmful salts found in graywater, particularly over a long-term basis. In general, evergreen trees are more salt sensitive than deciduous trees. Very little is known regarding the impact of graywater use on annual bedding plants. More research is needed on the impact of graywater on plant health since the chemical composition of graywater is different than that of treated wastewater and surfactants are widely used in household cleaning products.

Regardless of what graywater system is chosen, the following precautions should always be taken:

- Carefully label all valves and pipes associated with your graywater system and prevent backflow.
- Do not store graywater more than 24 hours.
- Wear gloves and do not come into direct contact with graywater.
- Do not let graywater pool or run off of the soil surface or come into contact with well water.
- Do not irrigate edibles with graywater or allow it to splash on neighboring edible plants.
- Do not irrigate turfgrass or ground cover areas with graywater, since potentially harmful microorganisms can remain on the surface.
- Do not use graywater contaminated with human waste, infectious disease organisms, grease, paint residue, gasoline, solvents, or other chemicals found in household and industrial products.

- Keep the graywater system simple and avoid systems requiring heavy upkeep and maintenance. Contact a professional with experience designing and installing graywater systems if you lack the specific skills required for design and installation.

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