IRRIGATING SIERRA NEVADA FOOTHILL CROPS EFFICIENTLY

TO CONSERVE WATER

* Second Draft

By
Dick Bethell
County Director
University of California Cooperative Extension
El Dorado County

Irrigating Foothill Crops Efficiently To Conserve Water

Introduction

The costs and difficulties of developing new water supplies to meet the needs of a growing population makes conservation of existing supplies especially attractive. Through careless and uniformed irrigation, much water is lost to runoff, excessively deep percolation and evaporation that could otherwise be saved for later use.

The farmers participating in the El Dorado Irrigation District's Irrigation Management Service (IMS) not only save 2000 acre feet of water annually, but are achieving better crop performance at lower costs. The many foothill growers who are unable to participate in an organized IMS program can still employ IMS knowledge awnd concepts to achieve similar results.

This phamplet presents an overview of that information and dicusses how to plan and carry out an irrigation management program for an individual farm.

WATER REQUIREMENTS

Cropped fields loose water in two ways: 1.) direct evaporation of water from the soil surface and 2.) transpiration, which is water vapor lost through pores (stomates) in plant leaves. This combination evaporation from the soil and transpiration from the plant is called evapotranspiration (ET). It is normally considered the "crop water requirement"; that is, the amount of water actually used by the crop.

Orchard

Orchard and vineyard water requirement and irrigation management studies conducted by The University of California Cooperative Extension in El Dorado County from 1977 through 1982 showed that most El Dorado County crops could be successfully produced with water quantities ranging from slightly to substantially below the crop water requirement. For example, orchards subjected to some stress between irrigations produced fruit with better flavor and suffered only a slight yield loss. Vegetative growth was reduced in tree tops and centers. Sunlight penetrated into trees better, increasing photosynthesis and fruit quality.

Further reductions in orchard water supply progressively decrease fruit size. Crop yield is not only lowered, but crop marketability is drastically diminished. Consumers demand large size fruit.

Vineyard

Greater water stress can be tolerated by wine grapes. Vine water requirements should be met early in the season to establish the foliage canopy needed for maturing the crop. Thereafter, water stress can be increased to stop further foliage development. Grape berry size and yields are reduced, but the concentration of sugars and flavor constituents makes for a better wine.

Conifers

Native fir species are natural conservers of water and perform quite well with low water supplies in Christmas tree plantations. They make their annual growth during the spring when the water supply is ample. Monterey pine, which grows as long as temperatures are favorable, needs it's water requirement fully met for sustained growth.

Irrigated Pasture

Irrigated pasture performs best under a full water requirement regime.

There are other major influences on water requirements besides the crop type. They are the amount of ground covered by the crop, elevation of the farm, slope direction of the planted field, crop load, overall site exposure, the presence and management of other vegetation, and crop adaptation to dryness.

Ground Covered by Crop

Many crops do not totally shade the ground, especially during early stages of growth. Evaporation of water from dry soil surfaces between plants is very low. In such cases, the water requirement or ET rate is determined by the area of leaf surface intercepting sunlight; or, to put it another way, the percent of soil surface shaded by the crop. For this reason the water requirement for mature orchards and vineyards leafing out in the Spring and for newly planted orchards or vineyards is considerably less than maximum ET. As growth increases, ET reaches it's maximum when foliage nearly covers the ground.

Elevation

As elevation increases, water requirement decreases. Table 1 shows this influence on the water requirements of certain foothill crops as determined by the University of California studies.

	Inches of Water Required Per Season				
	Pear-Apples	Stone Fruits *	Wine Grapes	Pasture	Christmas Trees
500-1000	**	**	**	50	**
1000-1500	**	**	22	46	**
1500-2000	44	44	18	43	**
2000-2500	39	39	15	**	9
2500-3000	36	36	13	**	7
3000-3500	33	33	10	**	6
3500-4000	31	31	**	**	6

Table 1. Water used by various crops during a normal season at different elevations. These figures reflect average slope and crop conditions.

* Early maturing stone fruit will not require as much water as post-harvest water requirements are less.

** No data collected.

Slope Direction

South and southwest slopes increase the water requirements of the crop by as much as 25% over north slopes. Many foothill farms are located on mountain ridges that slope from east to west with north and south facing slopes tapering towards river canyons. Irrigation systems should be designed to irrigate plantings on different slopes as separate blocks.

Crop Load

Orchards with heavy crops can use up to 50% more water than orchards that failed to set crops.

Site Exposure

Besides solar radiation, other climatic factors help determine the ET rate. These include temperature, wind and humidity. Hot dry winds on highly exposed sites may cause up to 25 percent more water loss.

Other Vegetation

Weeds or a covercrop consume water from the same soil in which the crop is growing. This use needs to be included in the crop's water requirement. Unmanaged, this vegetation can use more than a third of a mature orchard's water requirement, and can deplete rain or irrigation water stored in vineyard and Christmas tree plantation soils. Carefully managed, this vegetation can be used to minimize soil erosion with only a modest increase in the crop water requirement.

Crop Adaptation To Dryness

Most tree and vine crops have mechanisims for adapting to dryness. They also can become water dependant with excessive irrigation. If irrigation amounts or frequencies are gradually decreased, trees and vines make internal osmotic adjustments to maintain a favorable cell water status. They also increawse water extraction from deeper parts of the soil profile. Foliage will alter shape and alignment to reduce exposure to solar radiation. Stomate closesure increases to conserve water. These adaptive mechanisms allow trees and vines at best, to suffer only modest decreases in productivity, and, at worst, to survive during droughts.

IRRIGATION REQUIREMENT

Water requirement should not be confused with the irrigation requirement. The water requirement is the water actually used in growing the crop. The irrigation requirement is the water that must be applied to replace the water used by the crop. Delivering and applying water to the land involves some losses by evaporation, surface runoff and percolation below the root zone. These loses can be minimized by good irrigation practices, but are difficult to eliminate. They are much more likely to occur with furrow and flood irrigation than with sprinkler or drip irrigation. Even the best application systems (drip, micro sprinklers and permanent set sprinklers) lose 10 to 15% of the water applied. Portable sprinkler systems lose about 25%.

In general:

Irrigation requirement = ET - Effective Rainfall + Irrigation System Losses

Effective rainfall is winter rain water stored in the soil available to plants plus any subsequent rainfall used by the growing crop. The irrigation requirement is less for deep rooted crops on deep soils, as more of their water requirement comes from stored rainfall, provided winter rains fill the soil profile.

The irrigation requirement can vary tremendously from one farm to another. For example, pears grown on a four foot deep soil on a north slope at 3200 feet elevation may require less than 20 inches of irrigtion per season compared to up to 55 inches required for pears grown on a south slope at 1500 feet on a two foot deep soil.

The higher elevation orchard stores about 8 inches of rainfall, twice as much as the lower orchard. It uses six inches less water than an orchard on a south slope at the same elevation. Less water needs to be applied at the higher elevation, which lowers irrigation system water losses.

WHEN TO IRRIGATE

"How often should I irrigate?" is a commonly asked question. The question itself implies that there is a fixed interval between irrigations.

In the previous discussion on water requirements, it should have become apparent that water is not used uniformly throughout the season. Use in the spring is low because weather is cool and plants are developing their new foliage. High summer solar radiation increases water use. Harvesting of crops and cooler fall days again lower the use rate. Table 2 shows this seasonal variation in water demand in two foothill pear orchards.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	TOTAL
Orchard A			1.0	3.5	5.4	8.3	9.5	8.8	5.9	2.4			44.8
Orchard B			0.7	1.7	3.6	5.5	6.3	5.8	3.9	1.6			29.1

Table 2. Monthly water use in acre inches of water in two environmentally different foothill pear orchards.

Four methods for scheduling irrigtions are practical for foothill agriculture. They are:

1. Use established irrigation management services offered by irrigation districts or private consultants. Few irrigation districts currently offer these services, but as districts are confronted with developing expensive new water supplies, they may find it cheaper to offer irrigation management services to extend their existing water supplies. Private consultants are available. They frequently use neutron probes to measure soil water. These devices monitor water depleted from the soil, making it easy to calculate the irrigation requirement. Neutron probe costs and technical requirements deter individual growers from acquiring and using them. More information on IMS programs and neutron probes is available in "Irrigation Management For the Sierra Nevada Foothills of California". *

2. Tensiometers are excellent for scheduling irrigations for orchards, vegetables, berries, pasture and drip irrigation in vineyards. Tensiometers measure the tension by which soil holds water. As a soil drys, the tension increases. Guidelines for irrigating different crops have been established based on the amount of tension that affects plant performance. Tensiometers do not function after tensions of 80 to 90 centibars are reached. About 50% of the available soil water normally has been used at this point. Crops which are not irrigated until soils are dryer (fir Christmas trees, sprinkler irrigated wine grapes after canapies are developed) must use other soil moisturing measuring instruments such as gypsum blocks or neutron probes for accurate scheduling.

   Growers must learn how to use and maintain tensiometers properly to develop confidence in them for scheduling. "Questions and Answers About Tensiometers" University of California Leaflet 2264 is useful for doing this and can be obtained at most UC Cooperative Extension county offices.

   * "Irrigation Management For The Sierra Nevada Foothills of California" was prepared by the University of California Cooperative Extension and published by the United States Bureau of Reclamation, 2800 Cottage Way, Sacramento California 95825.

Tensiometers cost about 30 dollars per instrument. They can be used for a number of years after they are installed. Care must be taken to remove guages in winter or to cover them to protect them from freezing.

3. Water budget scheduling using ET data published in newspapers or broadcast on radio can be an economical way of scheduling irrigations. To do this effectively, the amount of water that can be removed from the soil between irrigations needs to be determined. Soil survey reports available at U.S. Soil Conservation Offices are useful in calculating this amount. After an irrigation, daily ET's are added together until water used equals the allowable amount of water that can be safely removed between irrigations. For improved accuracy, adjustments should be made for elevation and slope direction as they differ from the base site from which the ET information was generated. More information on ET amd water budget scheduling is available in "Basic Irrigation Scheduling", University of California leaflet 21199.

4. Maintaining your own evaporation pan gives a good visual estimate of the water requirement right at your own farm. Pans can be made from wash tubs, 55 gallon barrels or any other comparable container that provides an exposed water surface. Care should be taken to keep animals from drinking from them or swimming in them. As with scheduling option 3, the quantity of water that can be depleted from the soil between irrigations must be determined. When this amount is depleted, start irrigation. If using sprinklers, irrigate long enough to refill the evaporation pan.

Some farmers through experience can visually assess the crop need for irrigation. Such experts are the exception. Experience with the El Dorado Irrigation District IMS program showed that most farmers made serious errors in scheduling irrigations, and that even the most astute schedulers occasionally exercised poor judgment in timing irrigations. Some farmers like to irrigate frequently to avoid the possibility of plant stress. This increases evaporation losses from a more wet ground surface and may stimulate plants to use more water.

HOW MUCH TO IRRIGATE

To irrigate efficiently, the amount of water applied at each irrigation must be accurately estimated. To do this one needs to know:

1. The depth of the root zone. A shovel or backhoe can be used to expose the root zone for examination. The root zone of

mature orchards and vineyards usually occupies the full depth of most foothill soils.

2. The soil type to determine how much water the root zone contains. Soil survey reports produced by the U.S. Soil Conservation Service contain this information. Foothill soils usually hold about 1.5 to 2.0 inches of available water per foot of soil depth.

3. The amount of available water that can be depleted from the soil profile before irrigation is needed. This ranges from 30 to 95 percent for various crops.

4. The percent of ground covered by the crop. When 70 to 80 percent of the ground is shaded by the crop, full ground cover and full ET can be assumed. Use this formula when less than full cover occurs:

   Crop ET = ET x % canopy

   For example.

   Crop ET = .2 inch per day x 50%
   = .1 inch per day

5. The irrigation system efficiency (See section on How Long To Irrigate).

When 50% of the stored soil water has been used, irrigate:
- fruit and nut orchards before harvest
- most vegetables
- Montery pine Christmas trees
- irrigated pasture
- wine grapes while foliage to mature crop is forming

When 85 - 95% has been used, irrigate:
- fir Christmas tree species
- wine grapes with developed canopies
- orchards and vineyards after harvest

Watch field for signs of permanent wilt to avoid crop damage.

As discussed earlier, normal irrigation practices result in some losses during application. These normally range from 10 to 25%. If they exceed 25%, then repair or redesign the system to improve efficiency of the application. The amount of irrigation water to apply is determined by dividing the amount of available water depleted from the soil by the application efficiency. (See section on How Long To Irrigate to evaluate application efficiency).

Example of Amount of Water to Apply

A mature orchard fully covers the ground. Rooting depth is 3 feet of loam soil that contains 6 inches of available water. The orchard is irrigated by permanent-set sprinklers after 3 inches of the available water is depleted from the soil. 3.53 inches of irrigation are applied because this sprinkler system has been found to be 85% efficient in replacing water used by the crop (3 inches divided by 0.85 = 3.53 inches).

Whether scheduling irrigations with tensiometers, using water budget calculations or observing an evaporation pan, errors may be made in estimating the amount of water to apply. Applications should be checked for their accuracy. This can be done with a shovel or soil probe* to determine the depth of wetting. When checking orchards or vineyards, do this the third day after irrigation to allow the soil to fully drain.

Tensiometers may be placed at different depths at the same site to evaluate wetting. The first tensiometer is usually placed 18 inches deep and a second at 30 inches to 36 inches when the root zone is 3 to 4 feet. A third tensiometer may be needed to assess the depth of wetting in deeper soils. When there is no change in reading on the deepest instrument after an irrigation, water may not be reaching it. If the deepest instrument reads 0 to 10 for most of the interval between irrigations, too much water may have been applied, resulting in water losses to percolation past the root zone. A zero reading on tensiometers may occur when dryness has sucked water out of the instrument. Make sure the tensiometer is full of water before reading.

Amount to Apply With Drip Irrigation

Drip irrigation is viewed as the best way to conserve water. Actually, drip irrigation is only slightly more efficient than well designed sprinkler irrigation, and the amounts of water to apply can be more difficult to estimate, as only a small percentage of the ground area is wetted. This can lead to over irrigation with drip systems and loss of water to deep percolation. The formula shown below, and the checks for irrigation accuracy just discussed, can be used to insure efficient drip or microsprinkler irrigation.

* Soil probes suitable for foothill use should be made of 3/8 inch steel rods, 4 or 5 feet in length, with a handle welded onto one end. Soil probes that remove a core of soil so wetness can be examined are available from agricultural supply stores and mail order catalogues.

Canopy Area Formula

Gallons per plant per day = ET (inches/day) x plant spacing (ft^2) x .622 (gal/in ft^2)

Example: Gallons/plant/day = .2 x (7 x 8) x .622
= 7 gallons per plant per day

HOW LONG TO IRRIGATE

The following steps need to be taken in determining how long to irrigate:

1. Determine the rate water is applied by your irrigation system. This is expressed as inches of water applied to the ground surface per hour for sprinklers and gallons per hour per emitter for drip irrigation. Microsprinkler application rate may be expressed in either gallons per hour or inches applied.

2. Assesss soil ability for filtration and penetration of water. Infiltration refers to the ability of water to move into the soil surface. If runoff occurs soon after the system is turned on, the application rate is too high for the water to infiltrate readily into the soil. Penetration refers to how the water moves through the soil. If a layer of soil resists penetration, the upper soil will fill and runoff will occur some number of hours after irrigation was started. The system should be shut off for awhile, or the application rate lowered to avoid runoff.

3. Check system application uniformity. There are many opportunities for lack of uniformity in applications. Changes in elevation causes pressure changes at sprinkler and drip orifices and different flow rates. Differences in nozzle size, nozzle wear, sprinkler types and system design can lead to lack of uniformity of water applied, and cause water losses to runoff and deep percolation. Pressure compensating emitters and sprinkler flow control devices are available to adjust for elevation changes. Proper system maintenance is very important for good application uniformity. Sometimes systems are poorly designed or water pressure is not adequate for efficient operation. If systems design assistance is needed, consult local U.S. Soil Conservation Service personnel for assistance in answering design questions.

Test the application uniformity of your irrigation system. For a sprinkler system, place cans at various points in the field to catch water while the system is running. Use a measuring cup to catch water from a drip emitter for a given length of time. The degree of variability represents the inefficiency of the application.

When a desirable application rate and system uniformity have been achieved, calculate how long it will take to complete irrigation. To do this, divide the amount of water to be applied by the rate of application.

An example for sprinklers:

The irrigation requirement is 4 inches applied to the field surface. The application rate is 0.16 inches per hour applied by a permanent set sprinkler system.

$$\frac{\text{4 inches}}{\text{0.16 inches per hour}} = \text{25 hours of irrigation time}$$

An example for drip:

The irrigation requirement is 32 gallons per plant per week. Emitters apply 1 gallon per hour and each plant has 2 emitters.

$$\frac{\text{32 gallons}}{\text{1 gal/hr x 2}} = \text{16 hours of drip irrigation/week}$$

FINE TUNING CONSERVATION EFFORTS

A number of things can be done to enhance your conservation efforts:

* Check for and repair all leaks in the system.

* Check and replace worn sprinkler nozzles. Repair or replace malfunctioning sprinklers.

* Shut the system off exactly at the designated time for the completion of irrigation.

* Check your application amount by using catch cans, checking with a shovel or soil probe and by reading your meter at the beginning and the end of irrigation. Meter readings, if available, show cubic feet used. Divide this reading by the area of the irrigated field to obtain the amount of water applied in inches.

  For example:
  The meter shows 6000 cubic feet at the start of irrigation and 8000 at the end. 8000 - 6000 is 2000 cubic feet of water applied. The field is 100 feet wide and 120 feet long or 12,000 square feet.

  $$\frac{\text{2000 cubic feet}}{\text{12,000 sq. feet}} = \text{0.16 ft. or 1.9 inches water applied to the ground}$$

  Compare this amount with the amount planned for irrigation.

* Suppress competing vegetation. Winter vegetation often robs orchards and vineyards of stored winter rainfall before the crop even starts to use water. Summer weeds may use more than a third of the water in cropped fields. They should be cultivated, mowed, or sprayed to control them. Applying preemergent chemicals to control weeds in the row and planting a low water using dwarf grass between rows, can strike a good compromise between preventing soil erosion and conserving water. A mixture of dwarf rye and dwarf fescue called Companion grass is performing well in orchards. Chemical weed control saves more moisture than cultivation. Cultivating exposes moist soil which increases evaporation.

DB/dl

Summary Of Steps To Develop An Individual Irrigation Management Program

Efficient irrigation depends on knowing when to irrigate, how much water to apply, how long to run your system and having an efficient irrigation application system.

When to Irrigate

* Don't irrigate at fixed intervals.

* Minimize the frequncy of irrigations to reduce ground surface evaporation.

* Refill the soil to reduce the frequency of irrigations.

* Select a method or combination of methods for scheduling irrigations accurately.

    Tensiometers - accurately measure need for water up to about fifty percent depletion of soil moisture. Not good for scheduling in dryer soils.

    Water Budget - requires a daily record of ET and establishing the point of depletion where irrigation should be started. Requires adjustments for your site. A Tensiometer can be used to set irrigation point.

    Evaporation Pan - When on site, no site adjustments are needed. Depletion point at which irrigation is needed must be established the same as for the water budget method. Other methods - gypsum blocks, neutron probes and other devices are good, but more difficult to acquire. Visual assessment of crop condition often lacks accuracy.

How Much To Irrigate

* Identify depth of root zone with a shovel, backhoe or from crop guidelines.

* Identify soil type and amount of available water the root zone holds.

* Identify the allowable depletion of soil water for various points throughout the season. (See main text)

* Estimate the percent ground covered by the crop. Make adjustments in the amount of water required when not at full cover.

* Divide water used since last irrigation by the irrigation system efficiency to get amount of irrigation to apply.

How Long To Irrigate

* Determine how much water your irrigation system applies per hour.

* Observe whether the water infiltrates and penetrates without runoff at this rate.

* Check the application uniformity at various points along your irrigation system. Upgrade system if needed to improve application efficiency.

* Divide the amount of water to be applied by the rate of application to determine hours to run your irrigation system.

Fine Tune

* Repair leaks, replace worn and defective parts, clean plugged orifices and take other actions to keep system operating efficiently.

* Shut system off at designated time.

* Test adequacy of applications with shovel, soil probe or tensiometers.

* Minimize water removed by non-crop vegetation. Mow, disc, apply herbicides or use of low water using ground covers as appropriate for the crop and site.

DB/dl

Tensiometer Guidelines

for Foothill Orchards and Vineyards

Orchard - Sprinkler Irrigation

Mature Trees - install instruments at 18 inches and 36 inches under the tree canopy. Before harvest irrigate at 60 centibars on 18 inch instrument. After harvest irrigate at 80 centibars after water column has broken. (Refill instrument before next reading.)

Non-bearing - place instrument into center of root zone. Irrigate at 30 to 40 centibars.

Vineyard - Sprinkler Irrigation

Mature Vines - install instruments at 18 inches and at the lower part of the root zone between vines in the vine row. Irrigate at 60 centibars on 18 inch instrument while vine canopy is developing. After canopy is developed, irrigate when deep instrument reads 70 to 80 centibars or after vine shoot extension has ceased, but before interior leaves dry from stress.

Non-bearing - install a tensiometer into center of root zone. Irrigate at 30 centibars.

Orchard - Drip Irrigation

Mature trees - install tensiometers at 18 inches and at 3 to 4 feet at emitter site. Irrigate when either instrument reads 30 centibars.

Non-bearing - install a tensiometer in the center of the root zone with emitter close by. Irrigate when the tensiometer reads 30 centibars.

Vineyard - Drip Irrigation

Mature vines - install tensiometers at 18 inches and at the lower part of the root zone between vines in the vine row at emitter site. Irrigate at 50 centibars on 18 inch instrument while the canopy is developing. After canopy has develpped, irrigate when 18 inch tensiometer reads 80 centibars or just after water column has broken in the instrument. (Refill instrument before next reading.)

Non-bearing - install tensiometer into center of root zone with emitter close by. Irrigate at 30 centibars.

Tensiometers may be purchased locally from:

Jim Kosta - 626-8474

Ron Mansfield - 626-6521

For further information on the use of tensiometers "Question and Answers About Tensiometers" leaflet 2264 at the University of California Cooperative Extension Office, 311 Fair Lane, is available.

DB/dl