Irrigation

Why?
Plant roots absorb water from, the soil; water travels up the plant (in the xylem) and evaporates through stomata in leaves (primarily); this "evaporation through plant tissues" is called transpiration. If there isn't enough water in the soil so that it is readily available to a plant several negative things start to happen in the plant. These may include stomatal closure (photosynthesis stops), various physiological stresses, wilting and death of plant parts or whole plants.

The amount of available water that a soil can store in the root zone of crops is typically several time less than the total amount of water that crops use over the season (e.g., summer) in a place like California's Central Valley. Therefore, irrigation is used on most crops to replenish the water stored in the soil.

How much to add and when?
It is useful to think of the soil as a big sponge that can hold water for plants to extract. The amount of water that a soil can hold and release for plant use varies from soil to soil, but it is typically equal to about 5% to 15% of the total soil volume. When measuring water as related to irrigation, we typically measure it in inches. Most of use are used to thinking of inches of rainfall and inches of evaporation or of water stored in the soil are similar measurements. The amount of water stored per foot of soil tends to increase as we move from course textured soils, such as sands, to finer textured soils, such as clays. When we get to the clays, structure becomes important in helping determine water-holding capacity. Thus, as indicated below, clays hold more available water than sands, and clays with good structure hold more water than those with poor structure do.

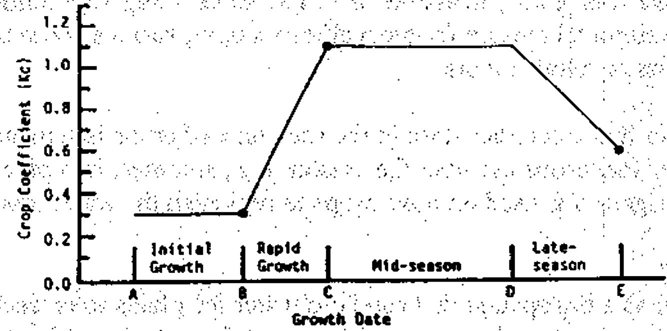
Soil Type	Available water - typical (inches of water/foot of soil)
Sand	0.6 +/- 0.1
Fine sandy loam	1.2 +/- 0.2
Silt loam	1.4 +/- 0.3
Clay loam (good structure)	1.6 +/- 0.4
Clay loam (poor structure)	1.0 +/- 0.2

Thus, the soil type and the rooting depth of the crop determine the total amount of water that the soil can store for a given crop. For example, if a crop's roots go three feet deep and it is growing on a fine sandy loam, we can estimate that the soil can hold up to 3.6'' of water for the crop. This tells us how much available water the soil can hold, but we need to remember that we don't want to purposely wait until all of the available water is gone before irrigating. Rather, a rule of thumb is to irrigate when about half the available water is gone. In our example, this would be when about 1.8'' of water has been used (and 1.8'' of available water remains).

Now that we know how to estimate the amount of available water the soil can store, we need to estimate the rate at which it is used up. Water use is the combination of any evaporation (E) from the soil surface and any transpiration (T) out of plant surfaces (e.g., leaves). Typically we combine these two and talk about evapotranspiration (ET). ET is controlled by two main factors:

1. Potential Evapotranspiration (ET_0), which is the amount of ET that would occur if the crop were a mature, well managed grass with plenty of moisture in the soil. ET_0 is a function of weather. It is greatest under hot, dry, sunny, windy conditions. In much of California it may vary from 0.0'' per day in the winter to about 0.35'' per day during the summer.

2. Crop factors: When crops are young and small, actual ET is only about 1/3 x ET_0 because the small plants don't transpire much and the soil surface typically dries out quite a bit between irrigations (there is very little evaporation off a dry soil surface). When a crop is full sized and still green, actual ET will be much closer to ET_0. We can approach this quantitatively through the "Crop Coefficient" (K_C). K_C varies primarily with the size of the plant (in the case of annual crops) and amount the amount of foliage (in the case of deciduous perennials). How K_C for an annual crops tends to vary during the season is depicted in the figure below.



3. Therefore, actual evapotranspiration is a product of both weather conditions (which determine ET_0) and crop factors (which determine K_C). Mathematically, $ET = ET_0 \times K_C$.

Thus, in our example, if it is a relatively hot, sunny period and the crop is full sized we'll guess that K_C = 1.0, so ET = ET_0, which would be around 0.3''/day. Since we are willing to use up 1.8'' of water before we irrigate, it would be 6 days between irrigations. We would want to replace the 1.8'' of water that had been lost to ET and, in reality, we would also want to add a little more water than that because irrigation applications are never completely efficient and uniform. For this reason, we might want to another 20% (0.36" in this example) to our irrigation.

When crops have shallower roots, the amount of water applied per irrigation is less, but the frequency of irrigations may have to increase. With deeper roots, irrigations can be less frequent but larger amounts of water must be applied. In practice, once they are beyond the seedling stage, most (but not all) vegetables are irrigated about once per week in Davis in the summer (unless they are on drip irrigation and are irrigated more frequently). Deeply rooted crops, such as tomatoes may be irrigated less frequently, if watered deeply.

Because of the level of complexity of managing small, diversified organic farms, the use of 'budgeting' method described above in the actual scheduling irrigations on such farms is often quite limited. However, this method is quite useful in getting an idea of how often to irrigate and how much water to add at each irrigation. In practice, the timing of irrigations can very quite a bit and other cultural operations often determine when irrigation will occur. For example, irrigation scheduling typically needs to be coordinated with other activities in the field, such as cultivation and harvesting.

Other methods for making irrigation decisions:
There a few methods of conveniently measuring the moisture content of a soil. These include *tensiometers*, which accurately measure soil moisture only when the soil is fairly moist. On the other hand, *gypsum blocks* are more useful when the soil has low levels of available moisture. Direct observations of the soil can be very useful in determining irrigation needs. It is important to sample the soil from all of the rooting depth of the crop. Soil probes or augers are more useful than shovels for taking soil samples that are more than a few inches deep. Once you have a sample in hand, you can estimate the amount of available water in the soil using the following chart.

How?

There are many irrigation methods available. In California row crop production, the most common methods can be classified as furrow, sprinkler and drip irrigation. The general features of these methods include:

Furrow:

- water moves by gravity at 'zero' pressure in open furrows and ditches (sometimes pipes)
- requires: 'level' field; high volume (low pressure) water source; labor to set up and manage each irrigation; little in materials
- saturated infiltration - furrows typically remain wet for a few to several days
- impossible to put on small amounts of water
- water 'subs' into bed by caplillary action
- uniformity/efficiency: quite variable; function of field layout and management

Sprinkler:

- water moves through pipes at high pressure (e.g 50 -. 60 psi)
- requires: significant material costs (capital); labor to move pipe (usually); energy to develop pressure; (does not require 'level' field)
- do not want saturated infiltration (= ponding, which can lead to serious crusting and runoff)
- maximum application rates: 0.15"/hour (clay) to 0.75"/hour (sand)
- application frequency and amount flexible, especially so if permanent set up (or similar)
- uniformity/efficiency: relatively easy to get right - a function of design, wind and reasonable management

Drip

- water moves through drip line at low pressure (e.g., 10 -20 psi)
- requires: frequent purchases of drip line; some pressure; management of sediments, algae, salts, breaks/leaks; relatively low in-season labor; (does not require 'level' field)
- drip line can be above or below ground (below especially good at reducing weed problems)
- application frequency and amount very flexible - often can irrigate daily with little effort
- uniformity/efficiency: function of design and reasonable management (but, length of rows limited by pressure loss over distance)

Appendix 1: Estimating Soil Moisture By Feel

SOIL MOISTURE LEVEL (% OF FIELD CAPACITY)	COARSE (SAND)	LIGHT (LOAMY SAND, SANDY LOAM)	MEDIUM (FINE, SANDY LOAM, SILT LOAM)	HEAVY (CLAY LOAM, CLAY)
0 –25% No available soil moisture. Plants wilt. Irrigation required. (1st range)	Dry, loose, single grained, flows through fingers. No stain or smear on fingers.	Dry, loose, clods easily crushed and will flow through fingers. No stain or smear on fingers.	Crumbly, dry, powdery, will barely maintain shape. Clods, breaks down easily. May leave slight smear or stain when worked with hands or fingers.	Hard, firm baked, cracked. Usually too stiff or tough to work or ribbon[1] by squeezing between thumb or forefinger. May leave slight smear or stain.
25 –50% Moisture is available, but level is low. Irrigation needed. (2nd range)	Appears dry; will not retain shape when squeezed in hand.	Appears dry; may tend to make a cast[2] when squeezed in hand, but seldom will hold together.	May form a weak ball[2] under pressure but will still be crumbly. Color is pale with no obvious moisture.	Pliable, forms a ball; will ribbon but usually breaks or is crumbly. May leave slight stain or smear.
50 –75% Moisture is available. Level is high. Irrigation not yet needed. (3rd range)	Color is darkened with obvious moisture. Soil may stick together in very weak cast or ball.	Color is darkened with obvious moisture. Soil forms weak ball or cast under pressure. Slight finger stain, but no ribbon when squeezed between thumb and forefinger.	Color is darkened from obvious moisture. Forms a ball. Works easily, clods are soft with mellow feel. Will stain finger and have slick feel when squeezed.	Color is darkened with obvious moisture. Forms good ball. Ribbons easily, has slick feel. Leaves stain on fingers.
75% to field capacity (100%) Soil moisture level following an irrigation. (4th range)	Appears and feels moist. Color is darkened. May form weak cast or ball. Will leave wet outline or slight smear on hand.	Appears and feels moist. Color is darkened. Forms cast or ball. Will not ribbon, but will show smear or stain and leave wet outline on hand.	Appears and feels moist. Color is darkened. Has a smooth, mellow feel. Forms ball and will ribbon when squeezed. Stains and smears. Leaves wet outline on hand.	Color is darkened. Appears moist; may feel sticky. Ribbons out easily, smears and stains hand, leaves wet outline. Forms good ball.