Irrigation Water Management Strategies for Drought

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A drought is forecast! My irrigation water supply will be cut back! What do I do? This is never good news. However, there are a few things you can do to minimize the impact of irrigation water shortages and limit the damage.

Crop Water Use and Response to Water Stress

To make good decisions on how to limit the impact of irrigation water shortages it is first important to understand how crops use water, and how they respond to water stress.

Crop water use changes drastically throughout the season!

This is due to both the changing day lengths, weather, and crop maturity. Figure 1 shows some typical variations in crop water use. If the same irrigation schedule is followed all season then water will be inefficiently used.

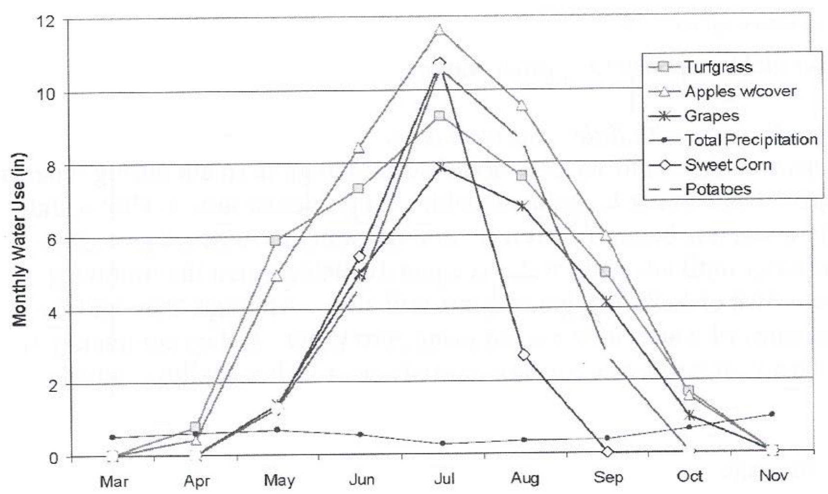

Figure 1. Crop water use changes drastically throughout the season.

20-30% cutbacks often don't hurt as much.

As seen in Figure 2, yield increases with additional applied water, but as a crop nears full irrigation the yield response per unit of additional water applied decreases until additional water does not increase yield. Most crops have yield response curves that are very similar. Because of this 20-30% cutbacks in applied water usually only result in relatively small yield losses. However, after that the yield losses are large. In very arid regions some irrigation water must be applied before any yield at all is possible. This leads to optimal planting strategies that are discussed below in the "farm less land" section.

Stress during the vegetative growth stage.

Try to avoid water stress during flowering, or yield formation. Conversely, water stress during the vegetative growth stages, or during end-of-season ripening often has the lowest effect on yield loss (Steduto et. al., 2012). Because water stress during flowering and yield formation causes the greatest yield losses it is often best to save the available water supplies for these times of crop development. Unfortunately these can often coincide with the times of maximum water use of the crops.

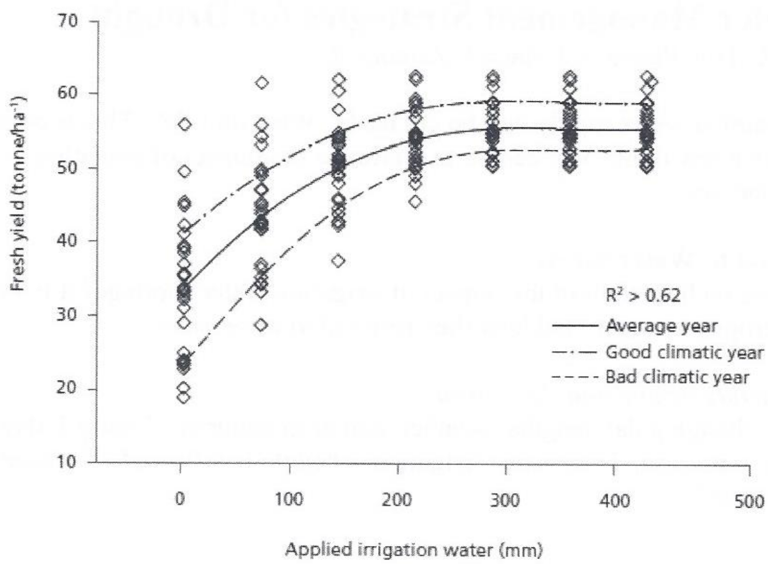

Figure 2. A generalized crop yield response to applied water.

Some perennial crops can go dormant with little long-term damage.

Many perennial crops are adapted to summer deficits and will go dormant during times of drought but will readily regrow when water is again available. Of particular note is alfalfa and many forage crops. In many cases it is better to severely limit the water to these crops so that they go into and stay in dormancy until adequate water is again available, often the following season. These crops will be brown or look bad, but they are still alive. Although they will be using drastically reduced amounts of water, they are not using zero water. If they completely run out of water they will die. This is of particular concern in sandy soils and/or shallow-rooted crops.

Increase On-Farm Water Storage

Put in a pond.

On-farm ponds can store water that is available during the winter, spring, and fall for use during the times of greatest needs or shortages, and often when the crop is most sensitive to water stress, which is usually during the middle of the summer. Obviously the bigger the pond is, the better. However bigger ponds can be quite expensive and there are sometimes permitting requirements. Building a pond may be worth the expense especially if perennial crop loss would require expensive and time-consuming replanting, or if droughts are common and regular.

Use the soil as water storage.

The soil is another great place to do on-farm water storage. Especially on deep soils that have large water holding capacities (silts and clays) it can be possible to fill the soil early in the season to the depth of the roots at times when water supplies are often more robust (fall, winter, or early spring) and then plan to deplete these soils throughout the season during times of coming water shortages (summer). Consider your average winter precipitation and try to maintain space in the soil for that snow melt or rainfall to avoid deep percolation water losses over the winter or early spring.

Plant crops that use less water

Consider planting crops that have a shorter season (harvested early in the year) and/or a season that coincides with predicted availability of the water supply. Figure 1 demonstrates how different crops use water at different times of year and Figure 3 shows differences in the total amount of water that different crops might use due to shorter growing seasons or deliberate water stress (such as with wine grapes). With perennial crops it is often best to try to keep them alive and thus there is less flexibility.

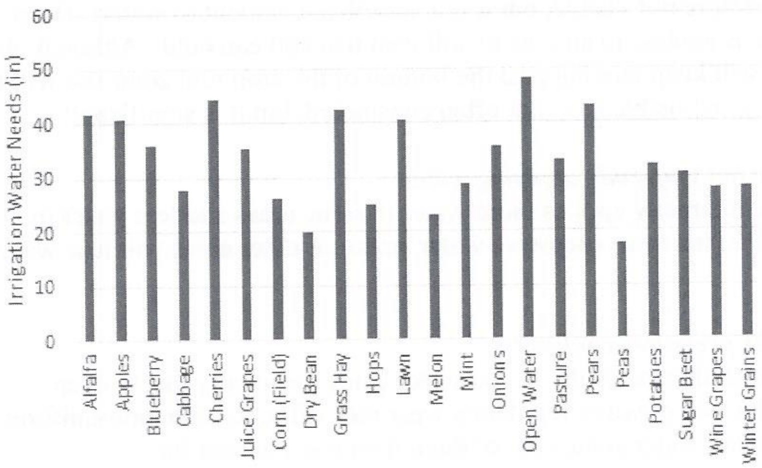

Figure 3. Irrigation water requirements estimates (inches) over a typical season and planting scenarios for a few selected crops in Eastern Washington/Oregon

Also, depending on when the water supply will be limited, it may help to plant different mixtures of crops that use water at different times. For example if water is uniformly limited throughout the season, then a grower might choose to plant spring grains that use water early in the season and then potatoes whose water use peaks after spring grains are typically harvested. The strategy might be different if water is shut off completely sometime during the middle of the summer. All of these things of course depend on the length of the season, when water is delivered and in what quantities, the weather, and the crop varieties planted.

Farm less land

Consider the yield response to the applied water curve for your crop and area. As discussed above, applied water reductions of 25-30% often result in only small reductions in yield. After that however, yield losses with additional reductions are steep. Also consider that in many arid areas some irrigation is required to achieve any yield at all as it requires water to get the crop germinated and growing and because of this, large areas of partially irrigated land (irrigated at 60% of necessary water or less) may not be advisable for these areas. Therefore, based on the best estimates of available water, it might be advisable to only plant the acreage that can be irrigated at 75-80% of the full irrigation water requirement. The rest of the land should be left fallow.

Example: You are expecting *half* of the water you are normally allocated to plant 100 acres.

1. Figure the number of fully irrigatable acres: 100 acres / 2 = 50 acres.
2. Figure number of acres if irrigated at 75%: 50 acres / 75% = 50 / 0.75 = **66.7 acres**. This leaves 33.3 acres fallow.

In areas with more rainfall such as Western Oregon or Washington where rainfall can be expected to create at least a limited amount of yield, then planting all of the acreage and then spreading the limited amount of available irrigation water across the whole acreage may be preferable since it would be in the linear area of yield-to-water-applied response curve as in Figure 2.

Improve Irrigation Efficiency

Out of sight shouldn't mean out of mind.

The largest sources of irrigation water losses to a farmer are both not visible. They are losses to: 1) *water vapor* and 2) *deep percolation*. As the water travels through the air from the sprinkler nozzle a large portion of that water (up to 40% for big gun sprinklers) is evaporated. It is lost as water vapor and is therefore not visible, but it is a significant amount of water! Deep percolation is when more water is applied to an area of soil than that soil can hold. Although the water infiltrates into the soil it will keep moving past the bottom of the crop root zone and will be lost to the farmer. Again, this is not visible so is not often considered, but it is significant!

You can't be efficient if you are not uniformly applying water.

If the irrigation system inherently applies more water in some areas and less water in other areas then some areas will either have excessive water stress, or other areas will lose water to deep percolation.

Fix leaks, replace nozzles, check pressure regulators.

Water lost to leaks almost always results in that water being eventually lost to deep percolation. As sprinkler nozzles and pressure regulators wear they often result in non-uniform irrigation water application as more water comes out of them than was planned for.

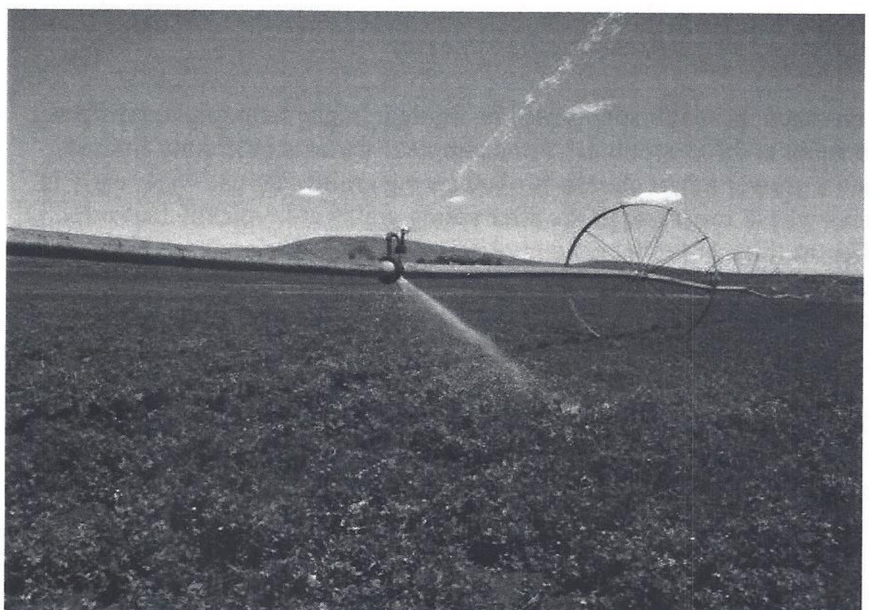

Figure 4. There was over three times as much water emitted from this leak than from the sprinkler nozzle.

Water less frequently with more water each time.

Irrigating frequently results in a greater total amount of time where water is available for evaporation from the wet crop canopy or wet soil surface (Figure 5). If more water is applied less frequently, then the water is pushed deeper into the soil and is unavailable for evaporation from the soil surface, but is still available for absorption and use by the crop roots. Be careful to not irrigate too deep such that it is lost to deep percolation!

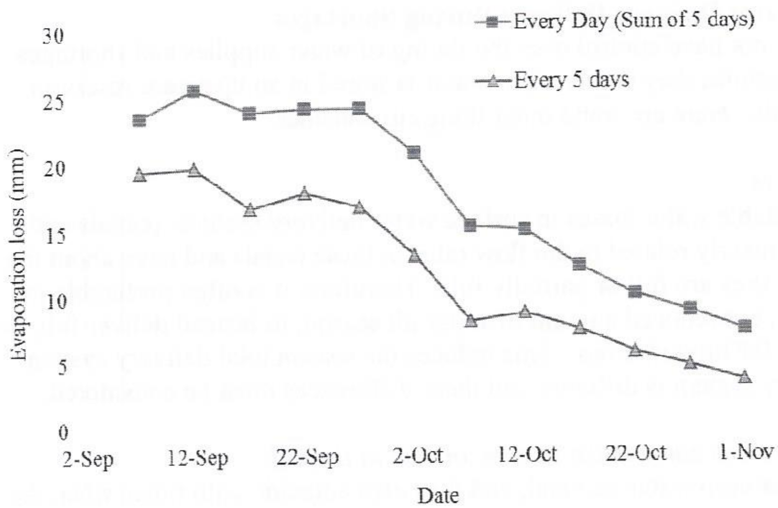

Figure 5. The same amount of water was applied but one plot was irrigated every day, and one plot was irrigated every five days. The additional water losses from evaporation are clear. This also shows how evaporation losses decrease as the weather cools off and the day length shortens.

Irrigation Scheduling

Using tools such as Irrigation Scheduler Mobile (http://weather.wsu.edu/ism) will help growers know when to apply irrigation water and how much to avoid or control water stress and to avoid over-irrigation and consequent losses to deep percolation. Soil moisture sensors can also be used to get an estimate of the soil water content for improved irrigation scheduling (Peters et al., 2012). These tools allow growers to respond to the highly variable crop water needs that change with the crop phenology and especially with the changing weather.

When water stress is unavoidable, a simple way to do irrigation scheduling during times of drought is to simply wait to irrigate until there is visible crop stress. This will help limit losses to deep percolation because the grower can have additional confidence that there will be adequate space in the soil to hold the applied irrigation water.

Water at times of lower evaporative loss potential.

If possible try to avoid watering at times when there is higher evaporative demand (hot and low humidity). At night the temperatures and wind speeds are often lower, and the humidity is often higher. These reduce evaporation potential and thus offer an opportunity for more efficient irrigation. It is not always possible to do this with agricultural irrigation, but it can sometimes be accomplished.

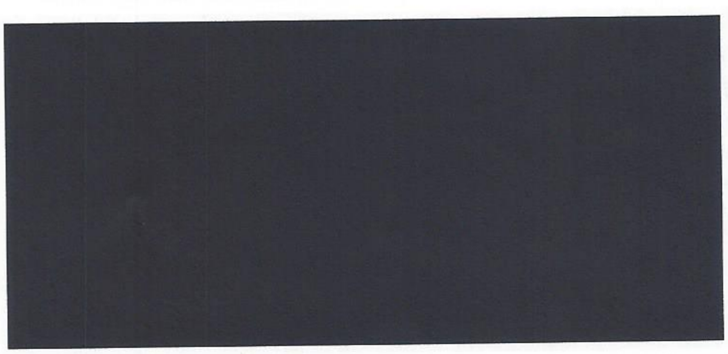

Figure 6. Irrigating at night. □

Considering Variations in Water Delivery Delivery During Shortages

Sometimes growers do not have control over the timing of water supplies and shortages throughout the season and sometimes they do, as when water is stored in an upstream reservoir. The latter is obviously preferable. Here are some other things to consider.

Consider Delivery System Losses

There are often unavoidable water losses in surface water delivery systems (canals and ditches). These losses are not linearly related to the flow rates in these canals and have about the same amount of losses whether they are full or partially full. Therefore, it is often preferable to instead of delivering a constant, but reduced amount of water all season, to instead deliver full, or near-full amounts of water, but for limited times. This reduces the season total delivery system losses. Of course every delivery system is different and these differences must be considered.

If possible, take the water limitations early in the season, or late in the fall.

These are times of lower crop water demand, and they also coincide with times when the crops are less sensitive to water stress (vegetative and end-of-season grain fill), depending on the crop of course. A strategy often employed by irrigation districts is to deliver water early in the spring to allow growers to fill their soils, then shut the water off completely for a few weeks during the springtime low ET rates, and then delivering water again during the hot part of the summer (often at a reduced rate) when crop water needs are high, and the crops are the most sensitive to water stress. If they are still water short in the fall they can again shut off early when water use rates are low again, when crops are senescing anyway, or when water shortages can induce perennial crops to go dormant early.

Irrigation System-Specific Strategies

Selecting a more efficient irrigation system, or making modifications to your existing irrigation system can have large, inherent, and long-lasting impacts to drought readiness.

Center Pivots

Water losses from center pivots can be reduced dramatically by lowering the sprinklers much closer to the soil surface. Figures 7, 8, and 9 below show how the height and operating pressure of the sprinkler packages on a center pivot can greatly affect the overall irrigation application efficiency. Low energy precision application (LEPA) and low elevation spray application (LESA; figure 9) have very high irrigation efficiencies especially when the sprinklers are operating below the top of the canopy and are thus highly protected from wind drift and evaporation losses. Additional information on the costs and benefits of converting center pivots to LEPA/LESA is available at Peters et al (2019).

When using mid elevation spray application (MESA), selecting sprinklers that use lower pressures, and throw larger drops such as wobblers or nutators are more efficient than sprinkler heads that use high pressure and create lots of smaller droplets (look “misty” when operating). High pressure impact sprinklers on top of a pivot lateral are sometimes chosen when the soil infiltration rates are very slow because they have low instantaneous application rates compared to the other methods. However, these runoff problems can be fixed in other ways that do not lose as much water to wind drift and evaporation such as using boom-backs to spread the water application pattern out or using tillage practices to increase the soil water storage.

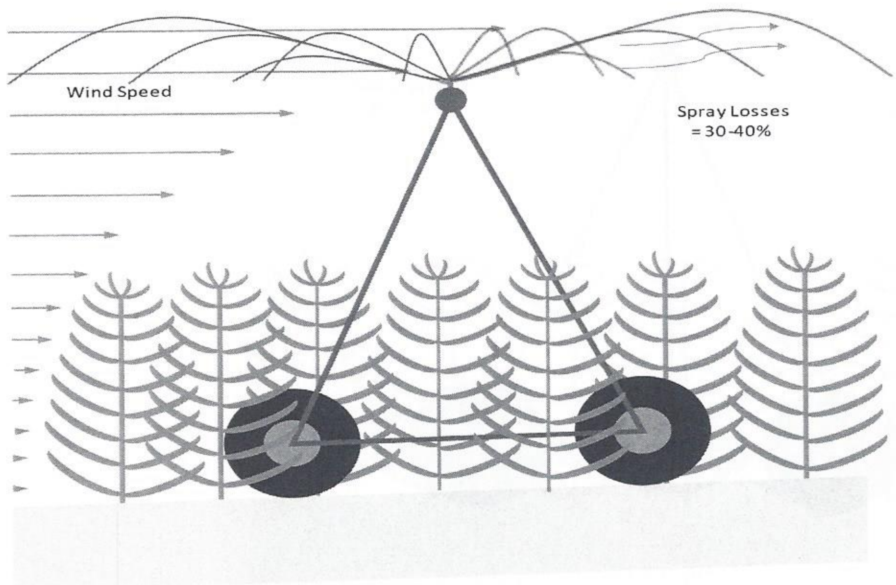

Figure 7. High pressure impact sprinklers lose 30-40% of their water to wind drift and evaporation and are especially susceptible to increased water losses and on windy days.

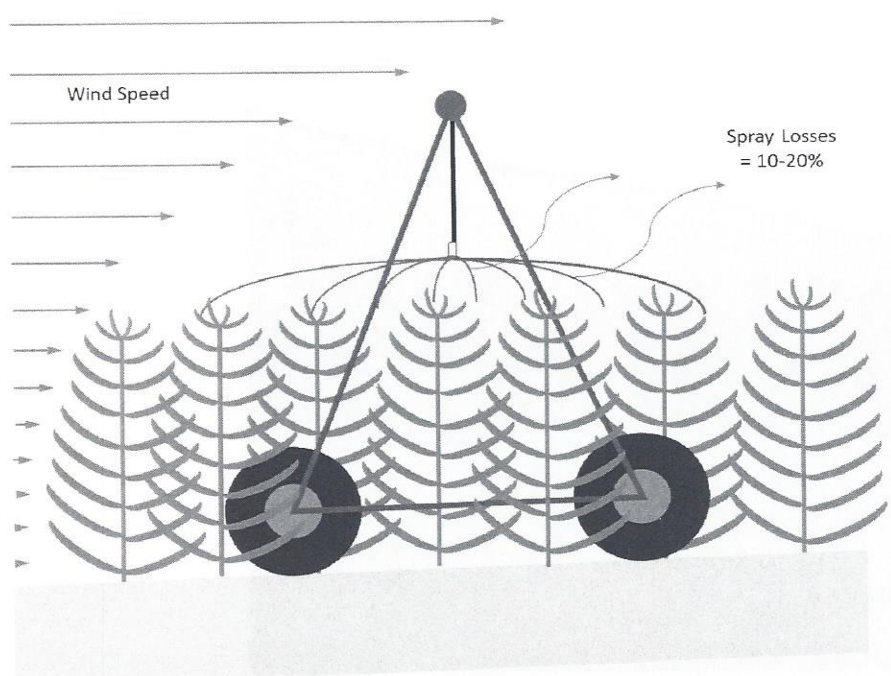

Figure 8. Mid elevation spray application (MESA) losses 10-20% of water to wind drift and evaporation.

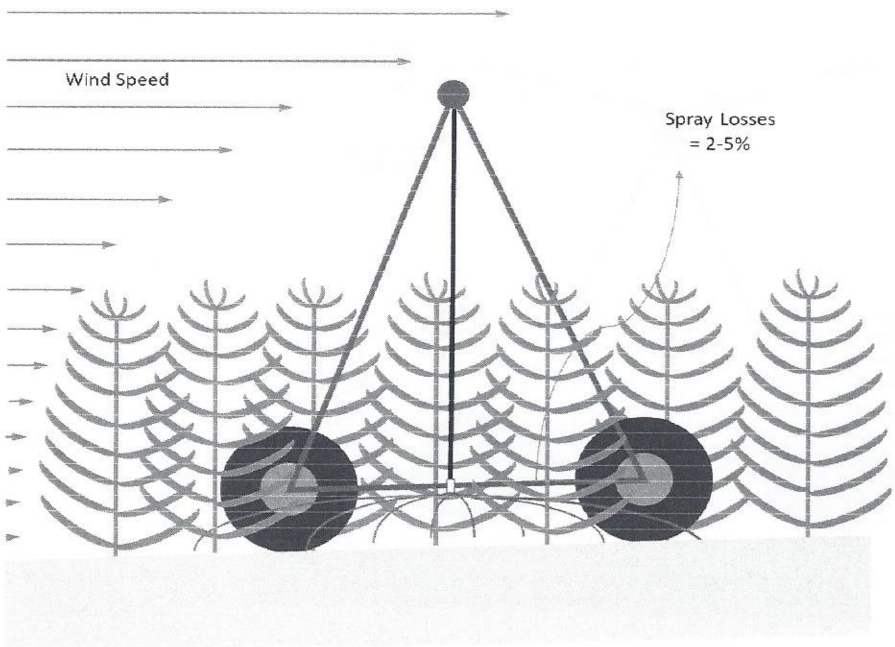

Figure 9. Low elevation spray application (LESA) has only 2-5% wind drift and evaporation losses.

Figure 10. Low elevation spray application sprinklers with mid elevation spray application sprinklers operating in the background.

Figure 11. Mobile drip irrigation systems are extremely efficient and apply water slowly to permit greater infiltration depths per pass.

On hot and windy days and with MESA systems, it may be advisable to simply turn the center pivot system off because not much of that water is getting to the ground anyway.

It is also advisable to slow the center pivot down as much as possible (until ponding and runoff become a problem underneath the outer spans) to limit water evaporation from wet soil and crop canopy. This results in less overall losses to evaporation from the wet soil and crop canopy. More water can also be applied per pass when tillage practices are used to increase the soil surface storage such as using a dammer-diker to create furrow or pits in the soil or planting rows perpendicular to slopes.

Drip Irrigation Systems

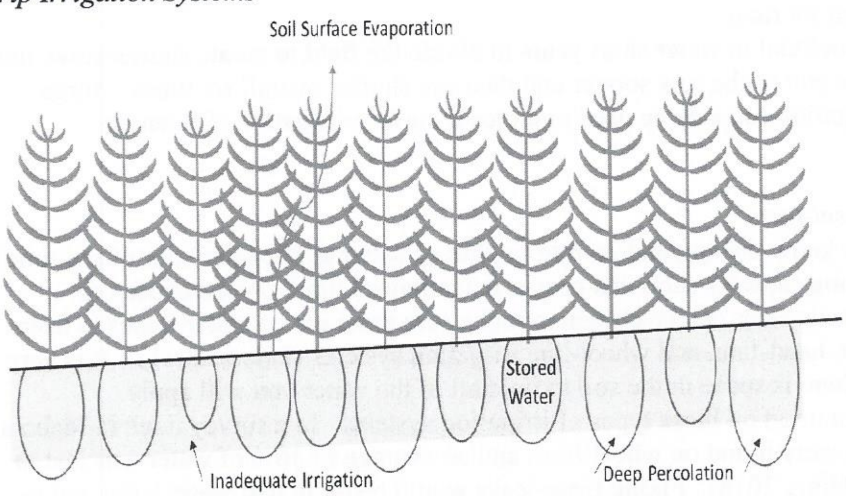

Figure 12. Drip irrigation is an inherently efficient system but water losses to deep percolation are still possible due to over-irrigation on non-uniform drip emitter flow rates.

Drip irrigation systems are already inherently very efficient as there is little opportunity for wind drift, and soil evaporation losses are also limited as not all of the soil surface is commonly wetted. Burying drip lines can increase the efficiency by further limiting water losses to soil surface evaporation, but this likely will only be a minor improvement. The biggest opportunities for improvement with drip irrigation is to do better irrigation scheduling to limit water losses to deep percolation and to increase the irrigation uniformity to ensure that the drip emitters are all flowing the same rate

Surface irrigation

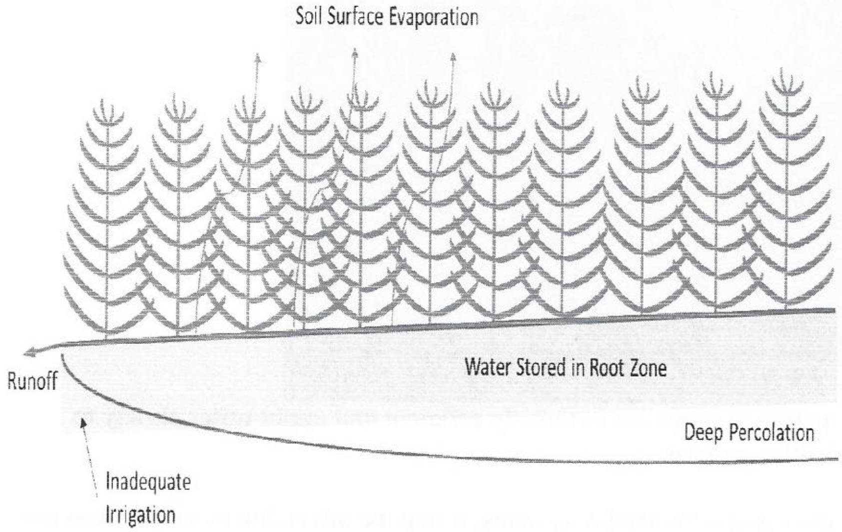

Figure 13. It is very difficult to adequately irrigate the bottom of a surface-irrigated field without over-irrigating the top of the field and creating runoff.

It is difficult to be efficient with surface irrigation since water has to commonly infiltrate the soil at the top of the field for many hours before the bottom of the field begins to receive any water. This results in inherent over-irrigation and water losses to deep percolation at the top of the field and often excessive water losses to runoff at the bottom of the field. A generalized rule of the thumb is that the furrow flow rates should be set such that the water should reach the bottom of the field in ½ of irrigation set time.

It can also be beneficial in water short years to divide the field to create shorter rows such that the water reaches the end of the row sooner and then use shorter overall set times. Surge irrigation or cutback irrigation can also be used to increase surface irrigation efficiencies (Reference).

Solid set, hand-lines, wheel-lines

It is important to know the application rate (inches of water applied per hour of run time) and the soil's water holding capacity such that proper irrigation set times can be chosen or alternatively different nozzle sizes can be chosen to make sure there are no water losses to deep percolation with solid set, hand-line, and wheel-line irrigation systems (Peters, 2011). It is very important to make sure there is space in the soil to hold all of the water you will apply.

Leaks are also common on these types of irrigation systems. In a survey done in Idaho an average of 12-16% leaks were found on wheel-lines and an average of 36% of water was lost to leaks on hand-lines (Neibling, 2016). Fixing these leaks would result in that water being put to much better use. Nozzles also wear such that they are larger than they are supposed to be for uniform and efficient irrigation. These can be replaced for a very low cost.

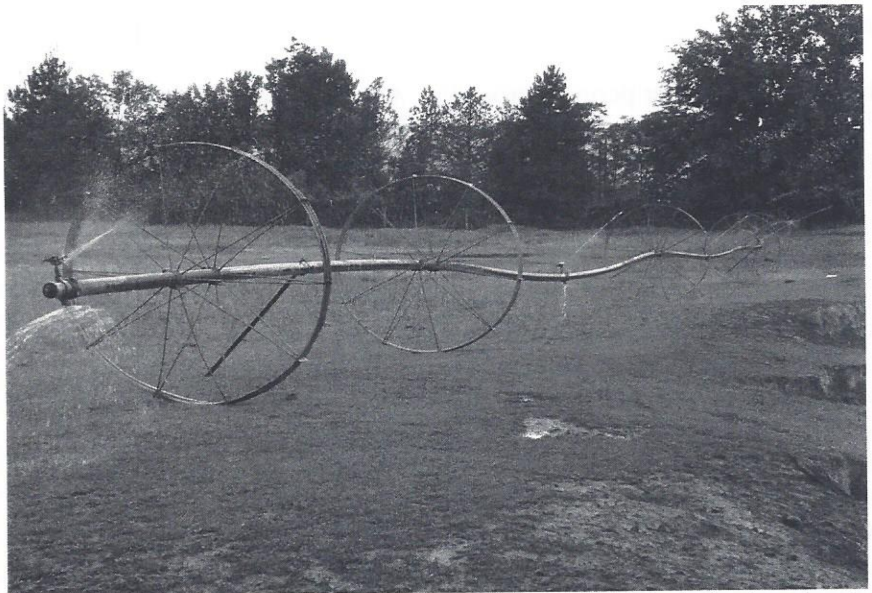

Figure 14. A wheel-line irrigation system not uniformly irrigating due to inadequate pressure and leaks.

Big Gun Sprinklers

Because big gun sprinklers operate at high pressures and throw water so far they have very large water losses to wind drift and evaporation (typically 40%). The wind really disrupts the big gun sprinkler patterns and this also creates irrigation uniformity problems. Because of this, there is a lot of opportunity for efficiency improvements for big guns sprinklers from being operated at night and by avoiding operation on windy days when possible. Big gun carts on hose reels can sometimes be replaced with boom carts that have a much higher uniformity and efficiency (only 15-20% losses) and operate at much lower pressures and have energy savings as well. Irrigation efficiency and uniformity of big guns can also be increased by decreasing the pressure and increasing the set overlap distance (Peters and McMoran, 2010).

Figure 15. A boom cart being pulled in on a hose reel in a potato field.

Crop-Specific Strategies

Alfalfa

Alfalfa is adapted for growth under periodic droughts. A wide variety of research has shown that during water shortages it is usually best to take the first cutting or two, and then shut the water off completely about the middle of the summer and allow the alfalfa to go dormant (reference). Brown is not necessarily dead and the alfalfa will come back to life and produce good yields when water becomes available again.

Grass Hay

Most grasses grown for hay in the Pacific Northwest grow the best in cool climates and slow down production during the middle of the summer. During droughts it may be advisable therefore, to fully irrigate in the spring and take the first one or two cuttings and then deficit irrigate to a level just enough to keep the grass alive during the middle of the summer and not graze or cut it during this time. Most grasses will go dormant during droughts, but excessive droughts to many species that are not adapted for water shortages can cause thinning of the plant density in the field. As water becomes available again in the fall it can be irrigated back to health and a possible last cutting or get it ready for fall and winter grazing. If droughts are likely to recur regularly then more drought tolerant species should be selected.

Tree Fruit

As tree fruit are usually higher value crops they are usually the last to be chosen for water deficits. During droughts the overall water use rate of the orchard can be reduced by eliminating or not irrigating the cover crop (by using drip irrigation). Some evidence is emerging that tree fruit can withstand mild water deficits.

Potatoes, Onions, and Other Vegetables

Options include increasing the planting density and harvesting early as soon as the water runs out to harvest more, but smaller produce or use them for seed or for a specialty variety or for a market that prefers smaller produce. Some vegetable varieties are more water stress tolerant and these could be selected for planting. In general, vegetables do not respond well to water stress and the economic losses from imperfections and reduced sizes are substantial such that most growers choose to take their water reductions in other areas besides their vegetable fields.

Lawn and garden

Lawns can take quite a bit of water stress without dying. They look less lush of course, and many home and business owners prefer to not have this visual reduction. However reduced watering can result in significant water savings especially to municipalities. Many lawn irrigators should use longer set times, and irrigate less frequently. This pushes roots deeper and reduces evaporative water losses from the wet grass. Often irrigating once per week is sufficient. Irrigating twice per week in dry and hot areas may be necessary during the middle of the summer. Using smart timers that adjust for the variation in water use can save significant amounts of water and often justify their costs in reduced water bills. A simple method of irrigation scheduling is to shut your system off, and wait for visible water stress, then irrigate much longer than you normally would. Poke a shovel or probe into the soil to get an idea of the depth of irrigation water penetration.

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