Irrigation Water Management Strategies for Drought

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A drought is forecast! My irrigation water supply will be cut back! What should 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. This publication is for agricultural irrigation managers and presents ideas for minimizing the impact of drought and getting the most benefit out of the limited water that is available. Many of these suggestions require additional information and caveats that we will not take time to discuss in the interest of brevity and readability but give references for further reading.

Don't Irrigate When It's Not Needed

Figure 1 shows some typical variations in crop water use. In general, the highest irrigation amounts are required during the summer and decrease during the fall and spring. This is due to changing day lengths, weather, and crop maturity. However, if the same irrigation schedule is followed all season, then water will be inefficiently used. In particular, it is easy to lose excess irrigation water to deep percolation during the spring and the fall when crops need less water.

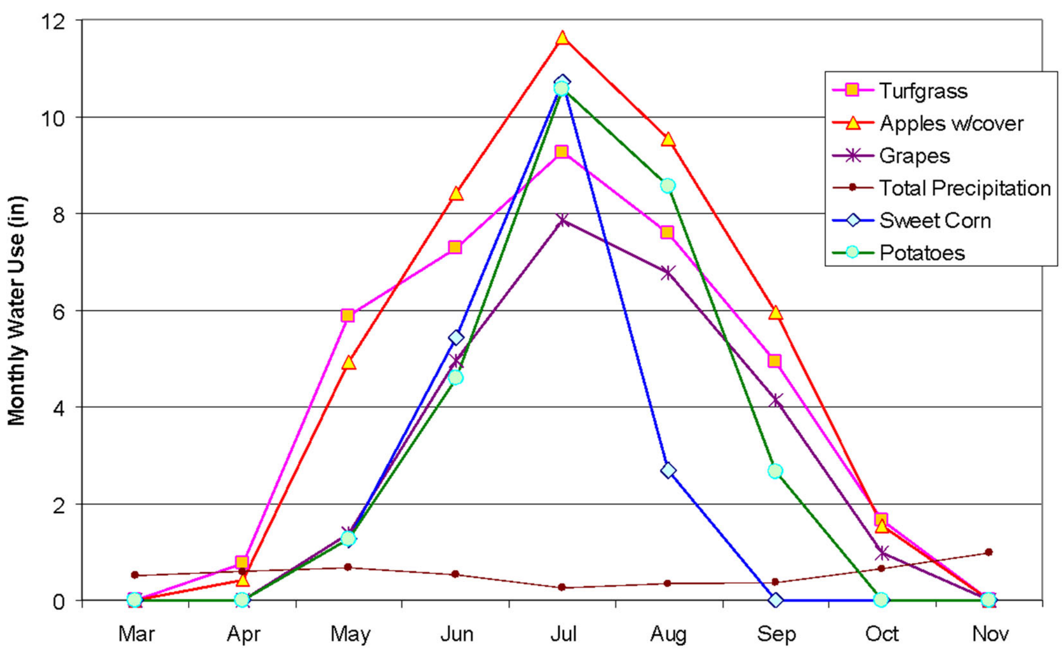

Figure 1. Crop water use changes drastically throughout the season. Mean water use estimates for Eastern Washington.

Moderate Water Stress Only has a Small Impact

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 (in Figure 2, where the curve goes flat). Most crops have yield response curves that are very similar (Peters, 2020). Because of this, 20-30% cutbacks in applied water usually only result in relatively small yield losses. Less than 5-10% of yield losses have been reported for water cutbacks up to 30% on cotton, sweet corn, and spearmint (Costa et al., 2007; Okwany et al., 2012; Erteck et al., 2013; Chuanjie et al., 2015). However, additional water stress beyond that (for example 50% water reductions) result in quite large yield losses for each inch of water that cannot be supplied. In very arid regions some irrigation water must be applied before any yield at all is possible or yields may be so low that harvesting is not economical (Figure 2). Because of this, evenly spreading the available water across all acres is often less optimal than completely not irrigating some land. This leads to optimal land allocation and planting strategies that are discussed below in the "Farm Less Land" section.

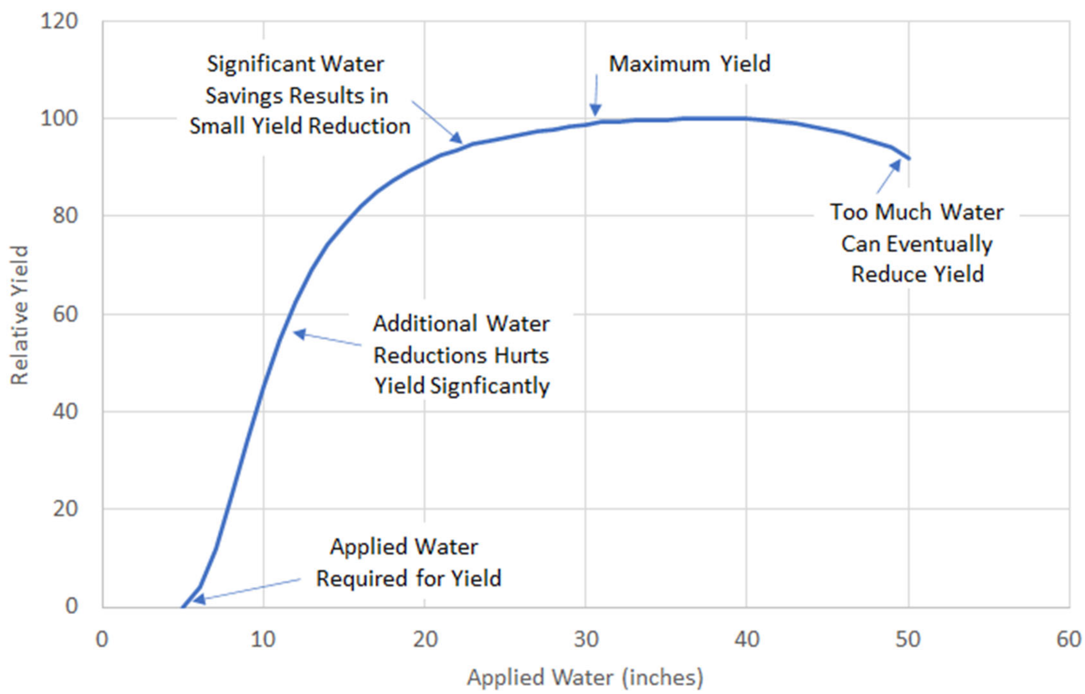

Figure 2. A generalized crop yield response to applied water through irrigation or rainfall.

Farm Less Land

If there is less water, it often makes sense to just plant fewer acres and leave some fallow for that season. How much less land to plant is an important consideration. Consider the yield response to the applied water curve for your crop and area (Figure 2). As discussed above, applied water reductions of 25-30% often result in only small reductions in yield; however, additional reductions may cause steep yield losses. Also consider that in many arid areas some irrigation is required to achieve any yield if water is required for germination and growing, and because of this, large areas of partially irrigated land (irrigated at 50% 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. Calculate the number of fully irrigatable acres: 100 acres / 2 = 50 acres.

2. Calculate the number of acres if irrigated at 80%: 50 acres / 80% = 50 / 0.8 = **62.5 acres**.

This leaves 37.5 acres not irrigated (dry). Since the goal is often the greatest profit returns to the farm, and because the costs per acre of tilling, planting, spraying, and harvesting are fixed, it may be advantageous to irrigate a bit more (i.e. use 80-85% instead of 75%) and thus plant fewer acres and hopefully get higher yields on the limited acreage that is planted and irrigated.

In areas with more rainfall, such as Western Oregon or Western Washington where rainfall can be expected to create at least a limited amount of yield without irrigation, planting all of the acreage and then spreading the limited amount of available irrigation water across the whole acreage may be preferable. In these areas, the combination of rainfall and irrigation would allow crops to grow and be in the linear area of yield-to-water-applied response curve (Figure 2).

For center pivots, an easy way to farm less land, given a lower flow rate delivered, is to simply shut off some of the sprinklers. Good candidates for this are the sprinklers located towards the center, as this area often has poor yields, is a little harder to farm, and it is difficult to irrigate uniformly anyway.

Water Stress During the Crop's Vegetative Growth Stage Hurts Less

Try to avoid water stress during flowering or periods of time when the plant is deciding how much to produce such as tuber initiation for potatoes. Also try to avoid water stress during critical growth stages, such as when the plants are trying to create healthy viable seeds or produce. Water stress during these times hurts total yield and produce quality significantly. Conversely, water stress during the vegetative growth stages, when the crop is creating vegetation to capture sunlight to eventually create produce, but is not building grain or produce, has the lowest effect on yield loss (Steduto et. al., 2012). Water stress during the end-of-season ripening stages often has a lower effect on yield as well. Because water stress during flowering and yield formation causes the greatest yield losses, it is often best to save the available water supplies for use during these times of crop development. Unfortunately, these growth stages often coincide with the times of maximum water use demand (middle of the summer).

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 other forage crops. In many cases it is better to severely limit the water to these crops allowing them to go into and stay in dormancy until adequate water is again available, which is often the following season. These crops will turn brown or look bad, but they are still alive (dormant).

Although these crops will be using drastically reduced amounts of water, they still use and need at least a small amount of water to survive. If crops completely run out of water such that the soil is dusty dry (permanent wilting point) they will die. This is of particular concern in sandy soils that have lower water holding capacity and for shallow-rooted crops.

Increase On-Farm Water Storage

Put in a Pond

On-farm ponds can store water from times of the year that it is more available such as the winter, early spring, and late fall, and make it available during the times of greatest needs or shortages or when the crop is most sensitive to water stress, which is usually during the middle of the summer. Obviously, the more water that can be stored, the better. However, bigger ponds can be expensive to build, take up space, and there are sometimes permitting requirements. Not all soils are suitable for ponds (they leak too much) without being lined with clay or artificial lining materials. 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 for on-farm water storage. Especially on deep soils that have large water holding capacities (high silt and clay content), 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 available (fall, winter, or early spring) and then, plan to deplete these soils 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 spring rainfall to avoid deep percolation water losses over the winter or early spring.

Because deep percolation is more likely when deliberately building up the soil moisture in the early spring, consider applying the fertilizers later or in split applications as leaching and loss of these nutrients is also more likely.

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 typically use. Some might use less water due to a shorter growing seasons or use deliberate water stress (such as with wine grapes). Others require more water to keep them alive, and thus there is less flexibility (such as with perennial crops).

University plant breeders and seed producers have been working hard for many years to develop drought tolerant varieties for many crops. Make a few phone calls to your seed dealer or university extension specialist to see if there isn’t a more drought tolerant variety available.

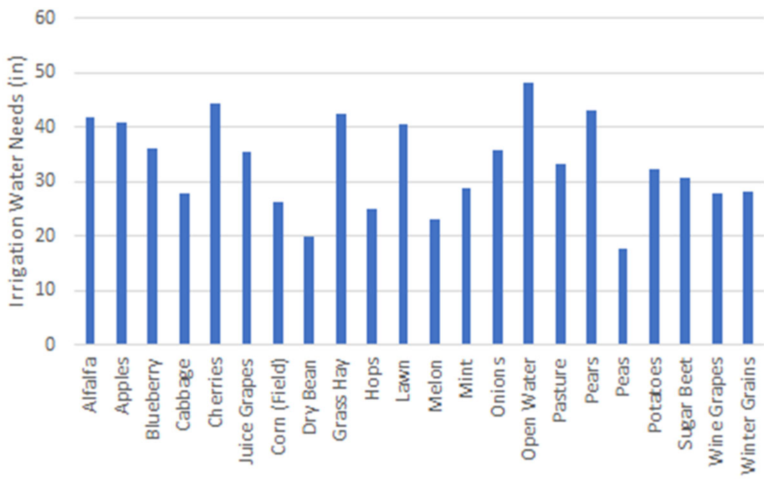

Figure 3. Irrigation water requirements estimates (inches) over a typical season and planting scenarios for a few selected crops in Eastern Washington/Oregon

Plant Different Crops to Take Advantage of Different Seasonal Water Use Timings

When there is reduced, but constant flow rate delivered throughout the season, it may help to plant a variety 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 switch the water to potatoes whose water use peaks after spring grains are typically harvested (Figure 4). The strategy might be different or not applicable if the water supply is shut off completely sometime during the middle of the summer. All of these strategies depend on the length of the growing season, the time and the amount of water delivered, the weather, and the crop varieties planted.

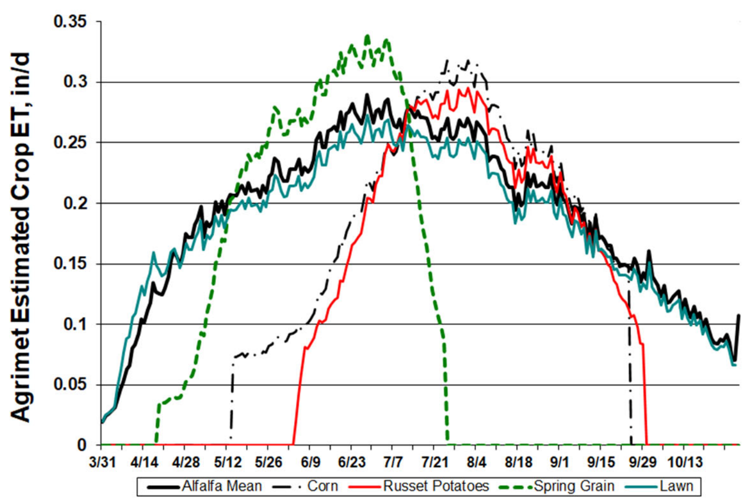

Figure 4. Planting a crop that uses water early such as spring grain, followed by crops that can be planted later, such as potatoes or corn, can help spread water supplies (graph by Howard Neibling).

Improve your Irrigation Efficiency

Out of Sight Shouldn't Mean out of Mind.

The two largest sources of irrigation water losses are both not visible to a farmer. They are losses via 1) water vaporization and 2) deep percolation. As the water travels through the air from the sprinkler nozzle, a large portion of that water is evaporated (up to 40% for big gun sprinklers). It is lost as water vapor and is therefore not visible, but it is a significant amount of water! Deep percolation occurs 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 your Irrigation System is not Uniform.

If the irrigation system inherently applies more water in some areas and less water in others, then some areas will either have excessive water stress and/or others will lose water to deep percolation. Irrigation uniformity, and therefore your water use efficiency, can be improved significantly by maintaining and operating the irrigation system properly. This includes operating it at the pressure and flow that it was designed for, making sure nozzles are unplugged, fixing leaks, and replacing sprinklers and hoses that are not operating as intended.

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 5. Water leak in wheel line. The leak flow rate is over three times that of the sprinkler (photo by Troy Peters).

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 6). If more water is applied less frequently, then the water is pushed deeper into the soil where it 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 water is lost to deep percolation!

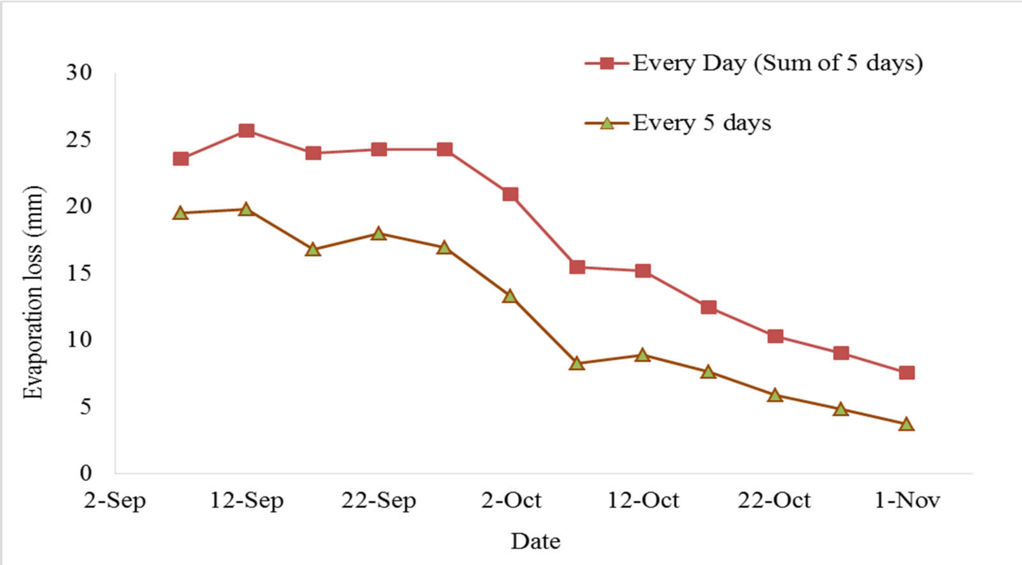

Figure 6. On bare soil the same amount of water was applied but one plot was irrigated every day, and one plot was irrigated every five days. The additional water losses from evaporation from the every-day irrigation are clear. This also shows how evaporation losses decrease as the weather cools off and the day length shortens.

Reduce Soil Surface Evaporation

Covering the soil with a plastic or organic mulch or pine bark nuggets can drastically reduce water losses from the soil due to evaporation. No-till, or strip-till reduces soil surface evaporation, reduces water losses from the tilled soil (Mitchell et al., 2012), and increases the soil surface water storage, all while using less tractor hours and diesel! (Jasa, 2013).

Irrigation Scheduling

Using tools such as Irrigation Scheduler Mobile (http://weather.wsu.edu/ism) will help growers know when to irrigate and how much to apply to avoid (or control) water stress or 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., 2013). These tools allow growers to respond to the highly variable crop water needs that change with the crop developmental stages and especially with the changing weather.

When water stress is unavoidable, another 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 water losses to deep percolation because the grower can be confident that there will be adequate space in the soil to hold the applied irrigation water even if the irrigation system is not perfectly uniform. Some visible signs of water stress are leaves that are a darker green color, curled or wilted leaves, stunting, and early onset of flowering or reproductive growth stages.

Water at times of lower evaporative loss potential

If possible, try to avoid watering at times when there is higher evaporative demand. Sunny, hot, windy, and low humidity conditions increase the evaporation potential and therefore lower irrigation application efficiency, especially for sprinkler irrigation. At night, the temperatures and wind speeds are often lower, and the humidity is often higher (Playán et al., 2005; Sadeghi et al., 2017) and thus offers an opportunity for more efficient irrigation (Figure 7). It is not always possible to only irrigate when the evaporative potential is low, but it can sometimes be accomplished when there is water delivery flexibility and when using irrigation systems with high design capacities (ability to get a lot of water out to the field quickly).

Figure 7. Irrigating at night.

Considering Variations in Water 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 more 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 loss whether they are full or partially full. Therefore, instead of delivering a constant but reduced amount of water all season, it is often preferable to instead deliver a full, or near-full amount 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 Water Limitations Early or Late in the Growing Season

These are times of lower crop water demand, and they also coincide with times when the crops are less sensitive to water stress (e.g., vegetative stages and end-of-season grain fill), depending on the crop. A strategy often employed by irrigation districts is to deliver water early in the spring to allow growers to fill their soil profile, then shut the water off completely for a few weeks during the springtime when ET rates are low, and then deliver water again during the hot part of the summer (often at a reduced rate) when crop water needs are high and at the most sensitive stages to water stress. If the districts are still short of water in the fall, they can again shut off early when water use rates are low, crops are senescing, or when it is okay for water shortages to 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 8, 9, and 10 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 10) have very high irrigation efficiencies especially when the sprinklers are operating below the top of the canopy and are protected from wind drift and evaporation losses (Lamm et al., 2006). Additional information on the costs and benefits of converting center pivots to LEPA/LESA is available at Peters et al (2019).

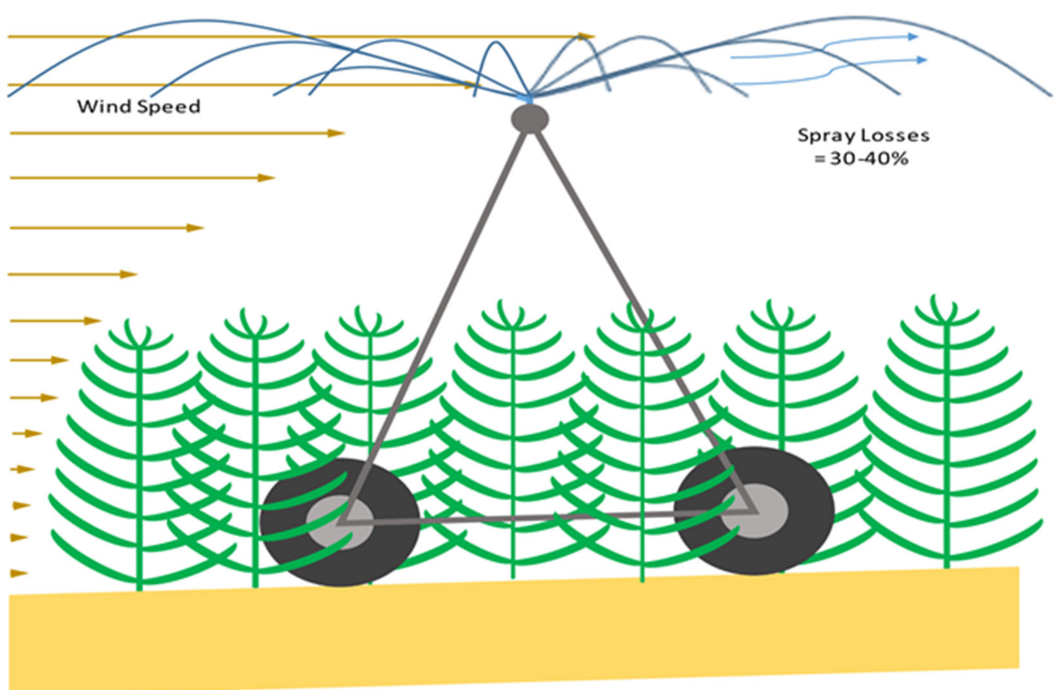

Figure 8. High pressure impact sprinklers lose 30-40% of their water to wind drift and evaporation and are especially susceptible to increased water losses and on windy days.

When using mid elevation spray application (MESA; Figure 9), selecting sprinklers that use lower pressures, and throwing 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 over other methods because they have low instantaneous application rates and can be used in places where soil infiltration rates are very slow to avoid runoff. However, runoff problems can be fixed in other ways that do not lose as much water to wind drift and evaporation. These include using boom-backs to spread the water application pattern out or by using tillage practices to increase the soil infiltration and surface water storage, such as reservoir tillage using a dammer-diker implement or creating furrows or rills perpendicular to the slope.

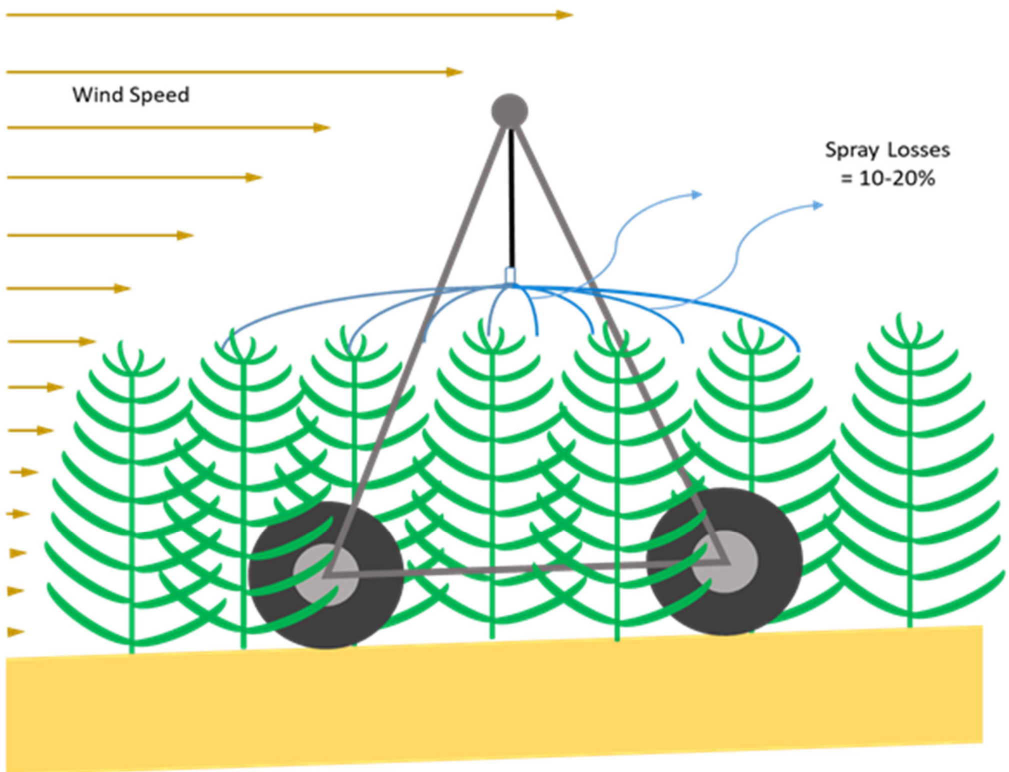

Figure 9. Mid elevation spray application (MESA) losses 10-20% of water to wind drift and evaporation.

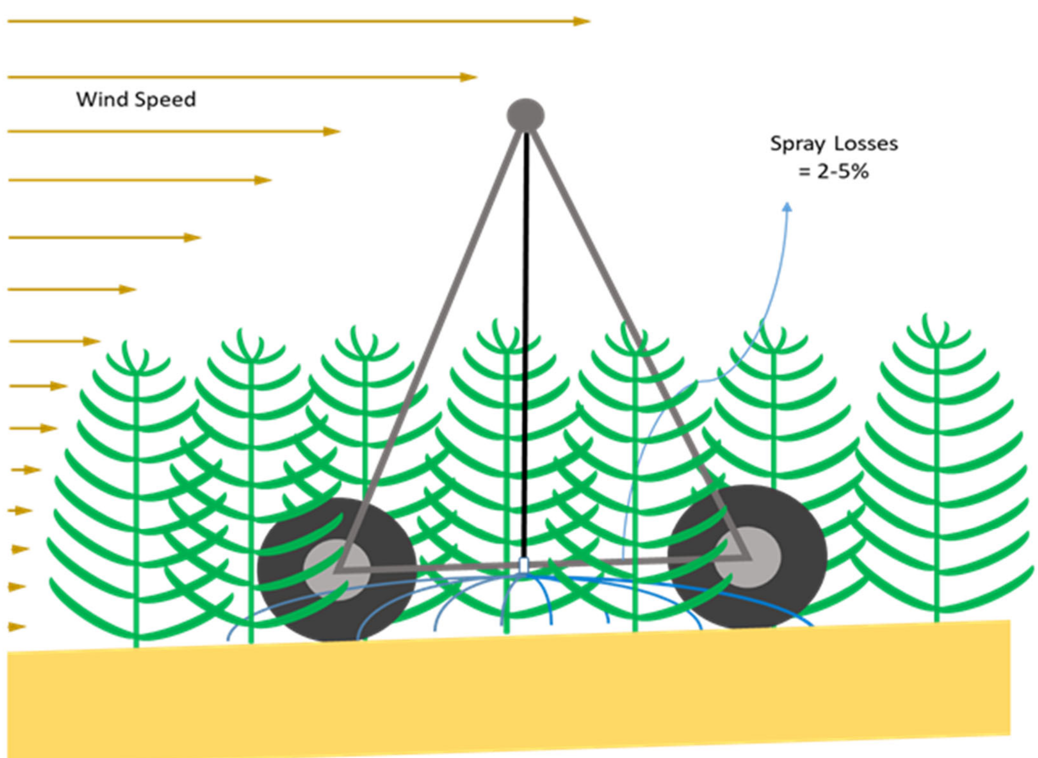

Figure 10. Low elevation spray application (LESA) has only 2-5% wind drift and evaporation losses.

Figure 11. Center pivot irrigation with low elevation spray application (LESA) and with mid elevation spray application sprinklers (MESA) operating in the background irrigating the spearmint field in Toppenish, Washington (photo by Behnaz Molaei).

Figure 12. Alfalfa irrigation using a center pivot with a mobile drip irrigation (MDI) system in Umapine, Oregon. The MDI systems are extremely efficient and apply water slowly to permit greater infiltration depths per pass. (photo by Behnaz Molaei).

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 due to evaporation and wind losses.

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). This results in lower overall losses to evaporation from the wet soil and crop canopy. More water can be applied per pass when tillage practices are used to increase the soil surface storage, such as using a dammer-diker to create furrows or pits in the soil, or when planting rows perpendicular to slopes, or when more organic matter or crop residues are left on the soil surface.

Center pivots can also drag drip tubing (mobile drip irrigation, Figure 12). These systems work well, are extremely efficient, and are better than LEPA or LESA at getting the water into the soil (less runoff). However, they are more costly due to the filtration requirements and the additional hardware needed. More information on these systems is available from Peters (2021).

Drip Irrigation Systems

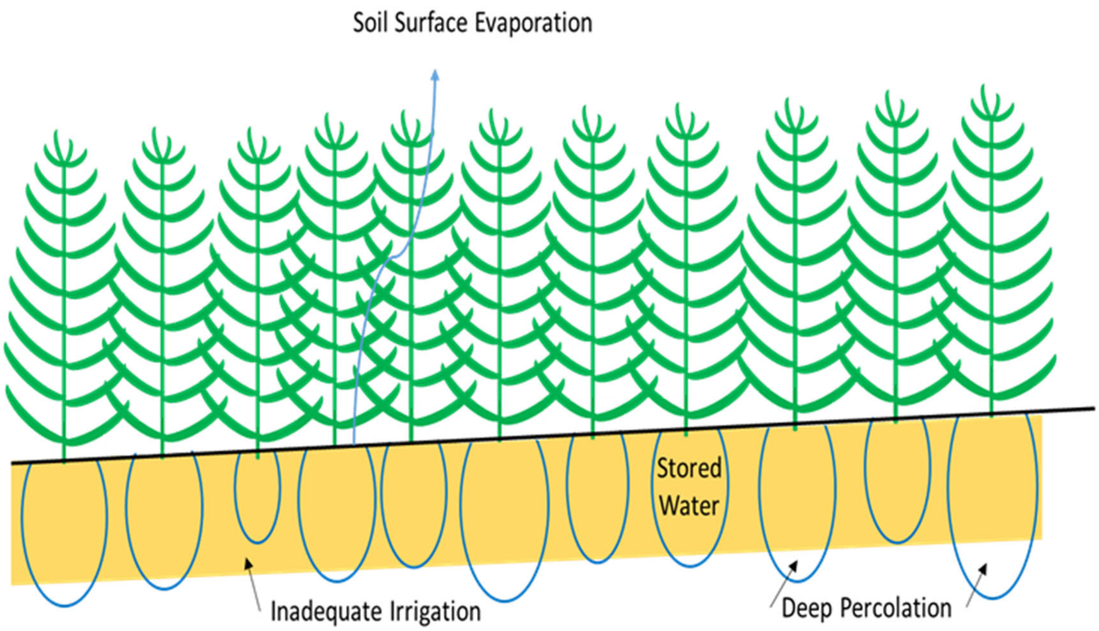

Figure 13. Drip irrigation is an inherently efficient system but water losses to deep percolation are still possible due to over-irrigation on non-uniform drip emitter flow rates.

Drip irrigation systems are inherently efficient as there is little opportunity for wind drift, and soil evaporation losses are limited since not all of the soil surface is usually wetted (Figure 13). Burying the drip lines can increase efficiency by further limiting water losses to soil surface evaporation, but this will probably be only a minor improvement. The biggest opportunities for improvement with drip irrigation are 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

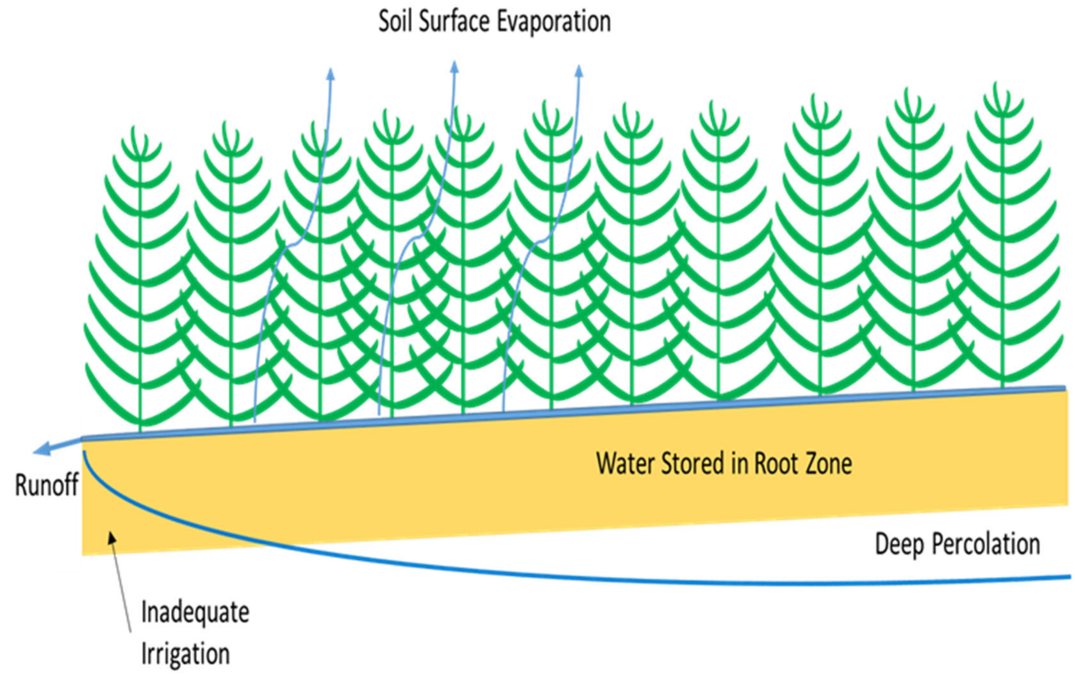

Figure 14. It is very difficult to adequately irrigate the bottom of a surface-irrigated field without over-irrigating the top of the field and creating runoff.

It is difficult to be efficient with surface irrigation since water must commonly infiltrate the soil at the top of the field for many hours before the bottom of the field begins to receive any water (Figure 14). 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 general rule of thumb to adjust furrow flow rates so that the water reaches the bottom of the field in half of the irrigation set time.

Another alternative that could be beneficial in water short years is to divide the field to create shorter rows, so the water reaches the end of the row sooner, and shorter overall set times can be used. Surge irrigation (using on-off pulses of water down the furrow) or cutback irrigation can also be used to increase surface irrigation efficiencies (Valipour, 2013).

Solid Set, Hand-Lines, and Wheel-Lines

It is important to know the application rate (inches of water applied per hour of run time) and the soil water holding capacity so proper irrigation set times or alternative nozzle sizes can be chosen to assure no water is lost to deep percolation with solid set, hand-line, and wheel-line irrigation systems (Peters, 2011). It is very important to make sure there is enough space in the soil to hold all of the water applied. Online tools are available to help with these calculations (http://irrigation.wsu.edu).

Leaks are also common on these types of irrigation systems. In a survey done in Idaho, the average water loss from leaks on wheel lines was 12-16%, and 36% for hand-lines (Neibling, 2016). Fixing leaks also helps avoid poor uniformity of the system because of inadequate flow and pressure (Figure 15). Fixing leaks results in water savings and lower pumping power bills. Over time nozzles wear and the orifice size becomes larger, thus, at any given pressure, the flow increases resulting in non-uniform application and thus lower irrigation efficiency. Nozzles can be replaced for a low cost.

Figure 15. A wheel-line irrigation system not uniformly irrigating due to inadequate pressure and leaks (photo by Troy Peters).

Big Gun Sprinklers

Big gun sprinklers operate at high pressures and throw water to far distances resulting in large water losses to wind drift and evaporation (typically 40%). The wind really disrupts the big gun sprinkler patterns creating additional irrigation uniformity problems. Hence, there are great opportunities to improve the efficiency of big guns sprinklers by operating at night and by avoiding operation on windy days when possible. Moreover, higher irrigation efficiency and uniformity of big guns can be achieved by decreasing the pressure and increasing the set overlap distance (Peters and McMoran, 2010). However, very low pressures create uniformity problems.

Big gun carts on hose reels can sometimes be replaced with boom carts that have a much higher uniformity and efficiency (approximately 15-20% losses; Figure 16). Boom carts can also operate at lower pressures resulting in large pumping energy savings.

Figure 16. A boom cart being pulled in on a hose reel in a potato field (photo by Troy Peters).

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 allowing the alfalfa to go dormant (Orloff et al., 2015). When alfalfa goes dormant and is brown, it is not necessarily dead. Above-ground growth will be limited, but it will become active and produce good yields when water becomes available again (Orloff et al., 2015).

Grass Hay

Most grasses grown for hay in the Pacific Northwest (cool season grasses) grow best in cool climates and have slower 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 species that are not adapted for water shortages can cause thinning of the plant population in the field. As water becomes available again in the fall it can be irrigated and restored to health allowing a possible last cutting or getting it ready for fall and winter grazing. If droughts are likely to recur regularly, then more drought tolerant species should be selected such as many of the wheatgrass varieties.

Tree Fruit

As tree fruit are higher value crops, they are usually the last to be chosen for water deficits. Some evidence is emerging that tree fruit can withstand mild water deficits. Cover crops are commonly grown in orchards for maintaining soil structure, encouraging water infiltration, and reducing erosion, among other benefits (Roper et al., 2021). However, during droughts, the overall water use rate of the orchard can be reduced by eliminating or not irrigating the cover crop (or by using drip irrigation). Consider selecting cover crops that require minimal maintenance (low fertilizer, mowing, weed control) and that are drought tolerant or have lower water requirements. Tree fruit also sometimes requires additional water resources for evaporative cooling. There are alternatives to using water for evaporative cooling such as shade netting or some calcium-based products. Shade netting has also been shown to significantly reduce the overall orchard water use.

Potatoes, Onions, and Other Vegetables

In general, vegetables do not respond well to water stress and the economic losses from reduced quality, size, and yield are substantial. Thus, most growers choose to reduce water in other areas besides their vegetable fields. Strategies during drought conditions may include increasing the planting density and harvesting early (as soon as the water runs out). This will result in more but smaller produce that might be used for seed for vegetatively produced crops like potatoes, or for a specialty market where smaller produce is often preferred. Some vegetable varieties have more water stress tolerance, and these could be selected for planting. Because the quality reduction from water stress is clear and causes significant reduction in prices, many growers over irrigate to be safe resulting in water and fertilizer losses to deep percolation. During a drought irrigation scheduling becomes more important to avoid over irrigating.

Grains

Because grains are so important to the nation's food supply and are largely produced in dryland farming areas with uncertain water supply, many drought tolerant varieties have been developed. Water stress during the vegetative growth stage limits grain yields the least. Timing the water cutoff (last irrigation) is also important for water savings and for maximum yield (Neibling et al. 2017).

Lawn and Garden

Lawns can tolerate significant water stress without dying. Water stressed lawns look less lush, and many home and business owners prefer to not have this loss in visual appeal. However reduced irrigation 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 (Goss, 2006). 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 or when the soil is very sandy or shallow. Using smart irrigation timers that adjust for the variation in water use throughout the season can save significant amounts of water (up to 70%) and often justify their costs in reduced water bills (Dukes, 2012).

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.

Selecting drought tolerant landscaping plants may allow green lawns with the minimum amount of water application (Brun, 2015 and Maleike, 2001). Using mulch composed of pine bark, gravel, or compost will help reduce water evaporation from the soil surface. Another strategy is to establish an 'ecolawn', a low input alternative to a conventional perennial grass lawn. Generally, it consists of a mix of broadleaf and grass species mutually compatible and ecologically stable that stays green through the dry summer months due to its lower water and fertilizer requirements (Castagnoli, 2013).

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