Reducing vineyard water use: mechanisms, strategies and limitations

As competition for finite water resources increases in many parts of California, there will be a greater need to utilize both rainfall and applied irrigation as efficiently as possible to support vineyard production. Minimizing the non-productive losses of water is a key step towards reducing total vineyard irrigation requirements.

Introduction

This article intends to provide a basic background on the fate of water in vineyard systems, and suggests possible management practices to reduce non-productive losses of water. While this article focuses on vineyards irrigated with groundwater under Central Coast conditions, with specific examples from the Paso Robles area, the basic principles can apply to other regions with similar conditions and concerns. Water availability for irrigated crop production is becoming a limiting factor in many parts of the state and world; it is clear that grape growers and other agricultural water users will increasingly need to focus on minimizing non-productive losses of water to ensure sustainable long-term crop production.

There are two general sources of water available for growing vineyards in this area; the rainfall that falls on the vineyard itself, and supplemental irrigation from groundwater, which itself is recharged by rainfall that falls over the entire groundwater basin watershed. Growers of non-irrigated crops in areas with limited precipitation know that their crop production will be directly correlated with the amount of rainfall that is stored in the soil and subsequently available to the crop over the season. Therefore, by utilizing as much of the rainfall as is possible to meet vine water requirements, one can correspondingly reduce the need for irrigation applications. Likewise, if the evaporation losses from applied irrigations can be reduced, this too can reduce the total irrigation requirement as more of the applied water will be used for vine transpiration. These two strategies, of maximizing the storage of rainfall for use by the vines and of reducing non-productive evaporation losses wherever possible, will be the main focus of this article.

A third strategy to reduce irrigation water use is to reduce net vine transpiration. However this generally comes at the cost of lower overall vineyard productivity if carried out in a vineyard which is already under deficit irrigation, as the vast majority currently are. Thus efforts to reduce vineyard water use should mainly focus on maximizing rainfall storage for use by the vines and on reducing non-productive evaporation losses wherever possible.

Rainfall and evaporation patterns

The mechanisms of water addition and loss from the vineyard system are controlled to a large extent by the patterns of rainfall and evaporation rates throughout the year. Water loss outcomes of otherwise similar activities can be very different at different times of the year due to the seasonal variability of both the rainfall and evaporation patterns. An example of the seasonal rainfall pattern is shown in Figure 1; three-fourths of the rainfall occurs from

![Figure 1. Monthly average rainfall recorded at the City of Paso Robles (source: UC IPM Website). The magnitude of the monthly values will vary for different locations, but the general pattern is the same throughout the region.](image_url)
face can reduce the rate of water conduction to the surface and thus reduce evaporation losses of soil moisture. For this reason shallow summer tillage is a common practice in many non-irrigated farming areas to conserve soil moisture.

Rainfall wets the soil surface, and a considerable portion of this water may evaporate back into the atmosphere over time. Water applied with sprinkler irrigation is much like rainfall in that it wets the entire ground surface, and is thus exposed to large evaporative losses, particularly in the summer when evapotranspiration rates are high (Figure 3). This large loss of water to evaporation is one reason why sprinkler irrigation is not widely practiced in Central Coast vineyards. Exceptions include some vineyards which may be irrigated with sprinklers in the fall after harvest or during the winter, to compensate for lack of rainfall during dry years or to help manage soil salinity.

The bulk of vineyard irrigation is applied with above-ground drip systems, but these applications are also subject to appreciable soil evaporation losses from the wetted soil surface areas, even though these wetted areas are usually relatively small. Low-volume drip irrigation systems are often operated at a relatively high frequency compared to high-volume surface irrigation methods, which may have been applied once every few weeks. This high frequency of application of drip irrigation, often multiple times per week, helps maintain consistent soil moisture levels which in turn leads to consistent vine water stress levels. However, such high frequencies of water application also mean that the soil surface beneath the drip emitters remains relatively moist and hence is more prone to lose water due to evaporation.

Soil evaporation

The evaporation of water from the soil is a constant mechanism of water loss that is invisible to us and very often ignored, but it can result in large losses of water to the atmosphere that could otherwise have been utilized for growing crops. In general for a given soil, the greater the moisture content of the exposed surface, the greater the rate of evaporation loss under similar weather conditions. Because the evaporative demand is higher in the summer and lower in the winter, a similarly moist soil will evaporate water at a much higher rate in the summer than in the winter. As the soil becomes drier, the rate of soil water conduction to the surface is reduced and therefore the rate of evaporation loss decreases. Shallow tillage of the soil surface can reduce the rate of water conduction to the surface and thus reduce evaporation losses of soil moisture. For this reason shallow summer tillage is a common practice in many non-irrigated farming areas to conserve soil moisture.

We estimate the evaporation conditions over the season with the reference evapotranspiration rate (ET0). This is the amount of evaporation that would be expected to occur from a well-watered grass surface such as a large lawn. Solar radiation (sunlight) is the main driving force behind evapotranspiration, so rates are much higher in the summer when days are long and the sun is directly overhead, as compared to the winter when days are short and the sun is low in the sky. The CA Dept. of Water Resources ET0 map classifies much of the area east of Paso Robles as Zone 16 (Figure 2). The magnitude of both rainfall and evapotranspiration will vary across the region, but the relative seasonal patterns and their influence on water loss mechanisms will be similar throughout the area.
The evaporation rate from the small wetted areas beneath the emitters is relatively high due to the movement of hot, dry air from the surrounding dry soil areas (advection effect). The exposed dry soil surface in the row middles can become very hot on a summer day, with surface temperatures commonly exceeding 140°F. This hot surface heats the adjacent air, which is then capable of removing more moisture from the nearby wetted soil surface; this effect is identical to a clothes dryer using heated air to speed drying. Thus even relatively small wetted soil areas under drip emitters can lose appreciable amounts of water to evaporation in the middle of the summer.

Reducing this soil evaporation loss is achieved by minimizing the soil surface area which is wetted with irrigation, and reducing the amount of time that it remains wetted. In a properly designed drip irrigation system, the rate of water infiltration in the soil is determined by the irrigation application rate; if the emitter flow rate is too high for a particular soil, water will pond on the surface or flow laterally across the soil, leading to increased evaporation losses (Figure 4). The proportion of irrigation water lost to soil evaporation will be particularly high for newly planted vineyards because they require frequent shallow irrigations and have very little leaf canopy to shade the soil surface (Figure 5). Mature vineyards will often receive deeper irrigations and have larger leaf canopies to shade the wetted soil surface; both of these factors help reduce the soil evaporation losses.

The appropriate amending and tillage of soils during vineyard preparation and as a part of routine vineyard maintenance over time can help improve infiltration of water deeper into the soil. In areas with hardpans or other restrictions to infiltration, appropriate tillage will improve water movement downward past these layers. Wheel track areas become more compact over time due to the weight of tractors and harvest equipment; tillage of these areas as needed will help improve water infiltration. Drip-irrigated vineyards on soils with poor water infiltration may see much of the soil surface wetted during irrigation, and thus have unexpectedly large evaporation losses (Figure 6).

Many irrigation waters on the Central Coast contain appreciable levels of sodium. The addition of this sodium to the soil will gradually degrade the soil structure as the sodium disperses the soil aggregates into smaller particles that clog the soil pores. Sodium-affected soils have very dense structure with reduced infiltration rates; irrigation water applied to these soils tends to pond on the surface and move laterally, wetting a large surface area that may not include the vine root zone as intended (Figure 7). Maintaining the soil in a suitably permeable condition with appropriate amendments such as gypsum and organic...
With normal surface drip irrigation, the accumulat-
ed soil salts are pushed to the outer edges of the wetted
soil volume, but with sub-surface irrigation salts will also
accumulate at the soil surface directly above the wetted
soil volume. This pattern of salt accumulation above the
root zone with sub-surface irrigation can create more chal-
lenging salinity management situations. For example, if
limited rainfall moves the surface salts downward into the
root zone while the vines are actively growing, this can lead
to severe plant injury or even complete defoliation under
severe conditions. To prevent such damage, the irrigation
system would need to be operated during the rainstorm to
flush the salts out of the root zone. Considering the elevat-
ed soil salinity levels in some local vineyards, root zone soil
salinity management will be a key consideration if sub-
surface irrigation systems are to be used effectively.

An alternative salinity management scenario is
possible with watering stakes, as they can be switched be-	ween sub-surface and surface irrigation fairly readily by
moving the spaghetti supply line. In the summer the spa-
ghetti line is inserted into the stake, delivering water at the
target depth into the soil; in the winter the spaghetti line is
positioned outside the stake, delivering water to the sur-
face as with normal drip irrigation. The latter use will be
helpful to leach surface accumulations of salts below the
root zone (Figure 9). Whether this type of management is
practical and cost-effective on a commercial scale remains
to be seen.

In spite of their management limitations, the po-
Cover crop transpiration

Cover crops are commonly used in Central Coast vineyards, as they provide a wide range of benefits to soil health. These benefits include reduced erosion and rainfall runoff, nutrient cycling, and improved soil fertility and soil structure through organic matter inputs from roots and above-ground biomass. Cover crops also enable vehicle traffic in vineyards under wetter soil conditions than would be possible with bare soil. Cover crops can be intentionally seeded with a wide variety of species, or a grower may simply manage the native vegetation that germinates on its own at that location.

However, cover crops also transpire large amounts of water to grow. A full field of barley which grows to maturity can consume 15 to 20 inches of water over its entire growing season if such water is available to it; this is equivalent to about 9 to 12 gallons per square foot. In drier regions there is simply not enough water supplied by rainfall to meet both the cover crop water requirements while also fulfilling all of the vineyard water needs later in the season. The more water that cover crops consume from the limited soil moisture storage, the more irrigation that will need to be applied later in the season to make up for this loss.

Ideally one would take advantage of the benefits of cover crops, while not allowing them to deplete soil moisture storage that would otherwise be available to the vines. Whether or not the presence of the cover crop in the field has a net positive or negative effect on the overall soil moisture storage later in the season depends in large part on the particular rainfall pattern for the year, how late the cover crop is allowed to grow in the spring, the rooting depth of the cover crop, and the management of the cover crop residues after the growth terminates.

During the winter months the soil surface is relatively moist from rainfall, but the evapotranspiration rate is...
very low (see Figure 2). At this time, the rate of evapotranspiration from the cover crop will be about the same as the rate of evaporation from a bare moist soil, because the process of evaporation is limited by the very small amount of incoming solar energy rather than by the supply of water available to be evaporated or transpired. Thus, there is little additional water lost to the atmosphere by having the cover crop in place during typical wet winters. Because the cover crop improves soil infiltration conditions and reduces runoff, rainfall infiltration is generally improved with the cover crop compared to a bare soil, particularly on sloping ground. This leads to potentially significant net increases in soil water storage when a cover crop is present during the rainiest months. Thus a cover crop during the wet winter months will not consume much more moisture than will a bare moist soil, and may significantly increase total soil moisture storage by reducing runoff and increasing the infiltration of water deeper into the soil (see the December 2007 Grape Notes for more information).

However, if cover crops are allowed to continue growing beyond the wettest rainfall period and into the drier spring months, or if the winter has seen little rainfall, then the transpiration rate of the actively growing cover crop will be greater than the evaporation loss from a bare soil surface. As the bare soil surface becomes increasingly drier, the soil’s ability to conduct water to the surface to be evaporated is reduced; however, a cover crop can continue to exploit deeper soil moisture with its roots even when the soil surface has become quite dry. Because the reference evapotranspiration rate is also becoming increasingly higher throughout the spring, the rate of water consumption by the cover crop steadily increases as long as soil moisture is available for it to consume. In areas that reliably receive abundant winter rainfall, vigorous and deep-rooted cover crops are often allowed to grow late in the spring to produce desirable organic matter for the soil. This same practice under drier conditions will lead to large depletions of valuable soil moisture that will have to be made up for with additional irrigation later in the season.

If the goal is to maximize soil water storage of winter rainfall, the timing of cover crop termination should be done during the transition between the winter rainfall period when the cover crop provides a net benefit of increased water storage, and the drier spring period when the cover crop becomes a net consumer of water. The optimum date of this transition will vary from year to year, depending upon the particular rainfall conditions that winter. In a dry year, the cover crop growth should be terminated relatively early, while in an unusually wet year the cover crop can be allowed to grow later into the spring. Because most of the region’s rainfall occurs from December through March (see Figure 1), this is the period when a cover crop provides the most benefit in the form of soil protection and increased rainfall infiltration, at the least cost of water consumption. Active cover crop growth in April and beyond provides relatively little additional protection from erosion because rainfall is less likely to occur during this period, while the cover crop consumes increasingly larger amounts of water from the soil moisture storage.

Past research in the non-irrigated hillside olive groves of southern Spain (with a very similar Mediterranean climate) has indicated that the third week of March is about the average optimum date to terminate winter cover crop growth in that region to maximize rainfall soil water storage for use by the olive trees. Earlier grain farmers on the Central Coast also incorporated similar logic into their management of the non-irrigated winter wheat and barley crops; if the winter season was dry and crop growth appeared unpromising by spring, they would till the grain crop under and fallow the field for the remainder of the year, thus conserving the remaining soil moisture in the field for the following winter with hopes of a more productive crop. This type of variable cover crop management may not fit well with the use of self-seeding cover crops such as bromes and fescues that need to mature seed every year, but for annually-seeded cover crops this type of variable management can help maximize soil water storage of rainfall for later use by the vines.

How the cover crop growth is terminated and the fate of the cover crop residues will also have an effect on soil moisture storage. Mowing (mechanical or chemical) in which the cover crop residues remain on the soil surface will help prevent runoff and erosion from any spring rainstorms, and will reduce soil evaporation losses later in the season. Shallow tillage will also terminate the cover crop growth but the mulching benefits of the residues will be reduced. Deep tillage can bring moist soil to the surface where the soil water is lost to evaporation and as such may be avoided in the spring.

Other factors will also determine how cover crops are managed. If the site is prone to spring frost damage, then it may be more beneficial to have a bare soil surface achieved by tilling the cover crop in advance of the frost risk period. If the goal is to conserve moisture, the ideal system will terminate all cover crop growth while retaining all of the residues on the surface as a mulch layer.

Summer cover crops are not common in dry regions but can be found under some circumstances. In vineyards that practice sprinkle irrigation it is not uncommon to have actively growing cover crops or weeds in the row middles all season. In some vineyards summer cover crops are intentionally grown in the row middles with a separate drip irrigation line to provide additional soil organic matter and to create potential habitat for beneficial insects (Figure 1).
Losses of water from ponds are primarily due to seepage and evaporation from the water surface. If aquatic plants are present, this will include transpiration from these plants. For areas that rely on groundwater, seepage from ponds will gradually recharge the groundwater basin and thus will not contribute significantly to the overall water loss from the system in the long run. In other areas where seepage would not lead to recharge of a basin, seepage losses would be more detrimental. Properly lined ponds will lose little water to seepage.

The more significant loss of water from a pond is through evaporation from the water surface to the atmosphere. The rate of water loss depends upon factors such as the depth of the pond, the water temperature, and the evaporative demand of the atmosphere. Evaporation losses are relatively small in the winter, and much larger in the summer, following the same pattern as in Figure 2. For shallow agricultural ponds (< 2 m or 6.5 ft. deep), the rate of water loss to evaporation is approximately 1.05 times the reference evapotranspiration (ETo) rate.

Based on Figure 2, the annual ETo of the Paso Robles area is approximately 62.5 inches. A shallow pond which is kept filled year-round would be expected to lose approximately 65.6 inches of water a year to evaporation (1.05 times 62.5). Therefore a shallow pond with an area of one acre that is kept filled year round would lose approximately five acre-feet of water to evaporation. A pond which is filled with water only during portions of the year will have less evaporation loss; the amount of loss can be estimated using the factor of 1.05 multiplied by the monthly ETo values in Figure 2, for those months when the pond has water. Note that ETo values from other sources may differ from the DWR map value; current work is underway to assess the magnitude and patterns of ETo throughout the year.
benefit in the form of a high-value crop. Similar logic applies to any other factor which can prevent a vineyard from producing a normal crop, whether it be a lack of nutrients, or excessive disease or pest pressure.

In the operation of frost sprinklers, relatively large amounts of water are applied on a limited number of nights during the spring. The goal is to coat the tender vine tissues with water that is constantly in the process of freezing. During the freezing process water releases heat (the heat of fusion) that maintains the ice-encased vine tissue at 32°F and thus protects it from colder temperature damage. With standard impact sprinklers, most of the water falls on the ground surface, and relatively little actually coats the vine tissues. The water applied with sprinkler frost protection will have a similar fate as rainfall at that time of year; most will infiltrate into the soil, and a relatively small amount will evaporate into the air during the application. If the infiltration rate of water into the soil is lower than the application rate, then some water can be lost as runoff from the field.

Sprinkler frost protection is typically used from the end of March through late May, and thus the water applied to the soil surface is prone to larger soil evaporation losses in the days following the application than would be the case for earlier winter rainfall (see Figure 2). To help prevent erosion and runoff problems due to the operation of frost sprinklers, most of the water falls on the ground surface, and relatively little actually coats the vine tissues. The water applied with sprinkler frost protection will have a similar fate as rainfall at that time of year; most will infiltrate into the soil, and a relatively small amount will evaporate into the air during the application. If the infiltration rate of water into the soil is lower than the application rate, then some water can be lost as runoff from the field.

Sprinkler frost protection is typically used from the end of March through late May, and thus the water applied to the soil surface is prone to larger soil evaporation losses in the days following the application than would be the case for earlier winter rainfall (see Figure 2). To help prevent erosion and runoff problems due to the operation of frost sprinklers, most vineyards that use sprinkler frost protection will maintain actively growing cover crops throughout the spring frost period to increase the infiltration of the applied water and reduce runoff and erosion (Figure 13). However, these cover crops will transpire signifi-
significant amounts of water throughout the spring months regardless of whether or not the sprinklers are operated, and thus will use significant stored soil moisture throughout the spring as previously described. Extended operation of sprinklers will lead to increased soil moisture storage at deeper soil depths, beyond the reach of shallow-rooted cover crops. In dry years especially, this deeper soil moisture provides for vine water needs later in the season and can reduce the amount of irrigation that would otherwise need to be applied later in the season.

In locations where effective and viable alternatives to sprinkler frost protection exist, their utilization can help save water. Passive frost protection measures should be the first step in minimizing potential frost damage at any site. Where temperature inversion conditions are suitable, wind machines may be a viable tool. Taller vine training heights may also offer useful avoidance of the coldest frost temperatures. The avoidance of frost pockets and the use of later-budding varieties can minimize the need for frost protection. However, at some locations sprinklers may be the only viable frost protection method due to the extreme cold temperatures experienced.

If sprinklers are employed for frost protection, the total water use can be minimized by operating the sprinklers only when local temperature conditions specifically require their use. Water is applied unnecessarily if sprinklers are turned on too soon before the critical temperature period, or allowed to run too long after the risk of frost damage ends. The most accurate information upon which to base the sprinkler operation start time is from measurements of the ‘wet bulb’ temperature at the particular vineyard itself. Alternatively, calculations based on the dew point can be used to estimate the air temperatures when sprinklers should be started, but such measurements generally come from a regional weather station and may not be very representative of the conditions at a specific vineyard.

Directional or targeted sprinklers use a lower water application rate per acre by targeting their reduced spray volume only over the vine row; they may be an alternative to conventional impact sprinklers in some vineyards. Directional sprinklers require many more sprinkler heads per acre, and will require more maintenance to ensure that they are aimed to deliver their spray over the vine row as required. Directional systems may not perform well under breezy frost conditions if the spray drifts away from the vines, but such conditions are challenging for any frost protection method. With their lower flow rate requirement these systems may help reduce the need for separate water storage ponds and larger pumps as are often required for conventional impact sprinkler systems, particularly when operated over large acreages.

### Vine transpiration

All of the preceding discussion referred to water losses from the vineyard system which were not directly related to vine productivity per se. Vine transpiration of water makes up a large portion of the total vineyard water use, so reductions in this component have the potential for reducing overall vineyard water use the most. However, grape vines are no different from other plants in that their production of biomass is in general directly related to the amount of water that they transpire over the season. Vineyards with less total available water, whether provided by rainfall or irrigation, will tend to produce less fruit per acre (Figure 14). If the quality of fruit from such lower-yielding vines is considered to be better and is correspondingly valued at a higher price, then this production strategy may make economic sense; however, if the fruit value is not sufficiently compensated for at lower production levels, then a greater economic return per acre will be achieved with more irrigation if such water is available.

Deficit irrigation is the practice of applying less water than the crop can potentially transpire. Deficit irrigation to varying degrees is now common practice in wine grape vineyards throughout California. Regulated deficit irrigation targets these intentional and measured deficit periods to specific vine growth phases. Excessive water stress is generally avoided in the spring during the critical periods to specific vine growth phases. Excessive water stress is generally avoided in the spring during the critical

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Figure 14. Hypothetical relationship between the amount of irrigation applied and the relative yield, for deficit-irrigated vines under different rainfall conditions. In wetter regions, supplemental irrigation provides for a small portion of the total yield, while in very dry climates a large amount of supplemental irrigation is needed to achieve the same yield. Allowing a cover crop to consume large amounts of soil moisture is equivalent to shifting from a wetter to drier rainfall regime. Reducing the irrigation evaporation loss has the same effect as increasing the applied irrigation amount.
flowering and fruit set period; if winter rainfall was not sufficient to maintain vines with minimal stress levels during this period, early irrigations are usually applied to compensate. The period from fruit set to harvest is generally when deficit irrigation management is applied, but no single strategy as far as the timing or severity of deficits exists. Moderate levels of deficit irrigation (for example, applications of 65 to 70% of the potential full water use) are common to avoid excessive vegetative growth and to maintain desirable small berry size. In the survey of irrigation applications in Paso Robles vineyards, a wide range of deficit levels was observed during the period of July-August (see the April 2013 Grape Notes).

If vines which have been managed with moderate levels of deficit irrigation are subsequently exposed to more severe deficits by applying less irrigation in the summer, this will lead to reduced vegetative growth and fruit production over time. The full effects of such reduced irrigation amounts may not be observed immediately, as perennial crops such as grape vines can compensate for less growth to some degree by mobilizing stored carbohydrates from their permanent tissues, and by exploiting deeper soil moisture than they needed to previously. In an earlier irrigation study with Cabernet Sauvignon in the Paso Robles area, reduced irrigation treatments applied to mature vines during the period between fruit set and harvest resulted in fairly small reductions in yield in the first several years, primarily due to smaller berry size in the less-irrigated vines. However, as irrigation treatments continued into the fourth and fifth year of the study, the crop yield in the drier treatments began to drop off sharply, with the stressed vines producing smaller berries as well as fewer berries per cluster (Figure 15). In this study the drier irrigation treatments did not result in improved wine quality, and thus no increase in fruit value was attained by using lower irrigation rates relative to the moderate deficit irrigation treatment. Results at different sites may vary from the observations at this one location, but dramatic reductions in vine irrigation levels need to be approached with caution, and the understanding that they will over time generally result in lower production levels. Grape vines require less water than most crops, but they do need some minimal amount to survive, and more to produce an economically viable crop (Figure 16).

A variety of measurement tools are available to growers to help them apply the amount of irrigation required to best meet the vine water stress level that they are targeting. It is very difficult if not impossible to be able to implement a repeatable irrigation strategy that maintains uniform vine water stress levels from year to year unless some types of measurements are made that serve as a baseline target, simply because the growing conditions (rainfall, temperature, evaporation) are variable from year to year. Measurements of soil moisture content help determine the amount of moisture stored after the winter rainfall season, and can help document the moisture depletion in the spring and thus indicate when irrigation needs to begin. Soil moisture measurements over the entire soil profile can help determine at what depth vine roots are extracting moisture, and help avoid over or under irrigation of the root zone. Plant-based measurements of vine water stress such as the leaf water potential are labor-intensive, but provide an integrated measure of all the factors that affect vine water availability and uptake, and can serve as a useful

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**Figure 15.** Effects of reduced summer irrigation amounts on grape yield of Cabernet Sauvignon in Paso Robles. The indicated treatments are percentages of the control treatment that was irrigated at approximately 65% ETc. Treatments were applied to mature vines over five years; over time the drier treatments resulted in significantly lower yields.

**Figure 16.** Irrigated vines in dry climates which have been abandoned will eventually die off, particularly if other vegetation is allowed to grow and compete for the limited moisture from sparse rainfall.
target benchmark throughout the season. Climate-based irrigation scheduling seeks to adjust irrigation applications based on the changing evapotranspiration conditions that result from varying weather conditions and the particular crop demand. The combined information from these different measurement methods will provide the grower with the most accurate information to supplement their own physical observations of vine growth and stress levels.

Soil salinity management concerns

The groundwater used for irrigation on the Central Coast contains varying levels of salts; its use can lead to gradual increases in soil salinity levels if soils are not adequately leached. By its nature, deficit irrigation often results in limited to no leaching of soils during most of the summer irrigation season. To make up for this lack of leaching, particularly after dry winters when little natural leaching occurred, many growers apply larger leaching irrigations after harvest. A survey of soil salinity in vineyards that overlie the Paso Robles Groundwater Basin has shown a steady increase in soil salinity levels since the survey began in 2006. This observed increase in soil salinity conditions suggests that leaching has on average been insufficient in these soils. Reducing water use by cutting back on the application of leaching irrigations may save water, but at the cost of gradual degradation of soil quality and ultimately vineyard production as salinity levels increase above damage thresholds. If salinity levels continue to increase, growers may have no choice but to apply additional quantities of irrigation to leach the soils, alter soil management practices to encourage more water infiltration and leaching, and/or utilize more salt- and drought-tolerant rootstocks on replanted vineyards.

**Conclusion**

The standard drip irrigation practices used by typical wine grape growers are for the most part quite efficient in their use of water. Simple reductions in applied irrigation with no other changes in management will tend to result in lower vine transpiration and reduced crop yields per acre. To avoid these yield reductions, the net available water supply to vines can be increased by reducing preventable soil evaporation losses and by limiting excessive cover crop water consumption. Sprinkler frost protection and storage ponds can be managed to help minimize unproductive water losses. All of these practices are highly site-specific, so any changes in management should be based on the results from detailed local evaluations. As water supplies become less available, growers will have greater incentive to increase their overall efficiency of water use, as doing so will help avoid crop yield reductions.