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# Orchard Floor Management Practices to Reduce Erosion and Protect Water Quality

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Soil erosion is a common problem in orchards, especially where growers use sprinkler and flood irrigation systems. Water-induced erosion results in the transport of soil particles into downstream waterways. These sediments may carry unwanted pesticides and nutrients that adhere to them. One way to comply with the increasingly stringent agricultural water quality regulations under state and federal water policy is to implement management practices that reduce soil erosion.

There are several management practices that you can employ to comply with water policy. Improvement of the soil's physical qualities through orchard floor management is an attractive option because it often results in improved yields, better water use efficiency, and reduced runoff. The goals of orchard floor management are to (1) protect the soil from water droplet impact, (2) enhance aggregate stability, (3) improve water infiltration, and (4) interrupt runoff pathways. Orchard floor management can include anything from the addition of soil amendments to changes in tillage practices. In this publication we introduce multiple management options that you can use to reduce soil erosion in an orchard system. In many instances, certain specific orchard floor management practices may be more or less compatible with particular harvesting or cultivation practices. The options presented here offer you the opportunity to test a few alternatives and then implement the practices that are best suited to your farm.

One way to minimize soil erosion is to implement management practices that improve soil structure. *Soil structure* is the arrangement of mineral particles into aggregates. A well-structured soil having stable aggregates can easily accommodate infiltrating water that decreases runoff and so reduces erosion (Figures 1, 2, and 3)

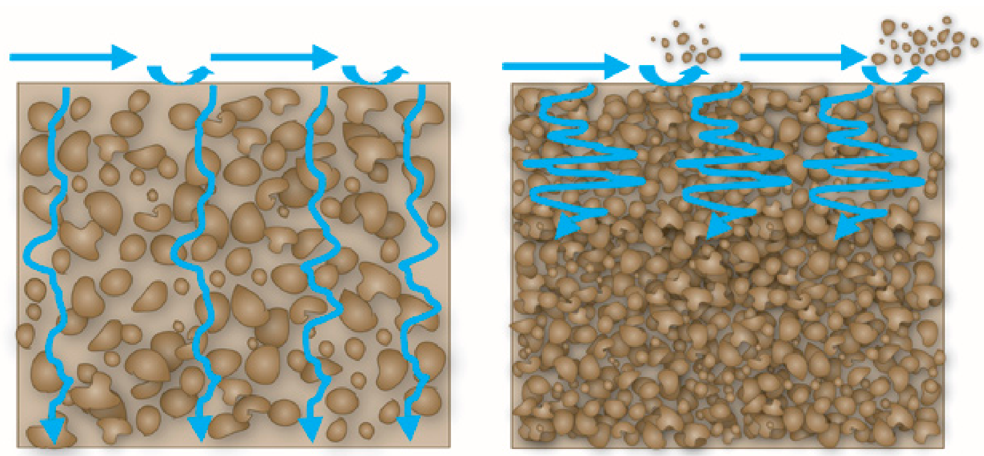


**Figure 1.** Comparison of porosity and water movement in an uncompacted, well-structured soil vs. a compacted soil. Compaction destroys macropores, reducing water infiltration. As a result, water runoff and erosion are accelerated.

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**Figure 2.** Example of a well-aggregated soil as indicated by the various sizes of surface aggregates. Photo courtesy of Tim McCabe, USDA–NRCS.

**Figure 3.** Example of a soil with poor structure and surface crusting. Note how the surface crusting causes irregular wetting patterns and the development of sheet and rill erosion. The impact of wheel traffic is visible at the lower left corner. Photo courtesy of Tim McCabe, USDA–NRCS.

(O'Geen and Schwankl, 2006). In addition, stable aggregates resist particle detachment, prevent the formation of crusts, and are less susceptible to compaction. The significance of well-aggregated soil is further summarized in Table 1.

## PROBLEMS ASSOCIATED WITH POOR SOIL STRUCTURE

### Soil Compaction

It is important to avoid soil compaction. Compaction reduces the number of large voids or pores between the solid soil particles. Compacted soils have low water-holding capacity, poor root penetration, and high runoff rates, and thus are highly susceptible to erosion. Compaction is caused by frequent or heavy traffic over the soil. Wet soils are highly susceptible to compaction even from light traffic. Orchard floor vegetation or mulch can protect a soil from compaction to some extent. To avoid compaction, constrain traffic with heavy equipment to times when the soil is dry. An alternative is to restrict farm traffic operations to established wheel paths.

### Surface Crusts and Hardsetting Soils

Surface crusts form in response to the physical disruption of soil aggregates or as a result of chemical processes associated with clay mineralogy and sodium content. As individual soil particles are detached from aggregates, finer particles are washed into cracks and pores creating a thin, dense layer that seals the soil surface. Crusting

**Table 1.** Soil quality is better in well-aggregated soils.

| Property/behavior | Well-aggregated soil | Compacted soil |
|---|---|---|
| Aeration | High | Low |
| Drainage | Good | Poor |
| Erosion | Low | High |
| Infiltration | High | Low |
| Plant available water | High | Low |
| Root penetration | Good | Poor |
| Surface crusting | Low | High |
| Susceptibility to compaction | Low | High |
| Water-holding capacity | High | Low |

increases runoff and accelerates erosion. Infiltration can be improved by light tillage when the soil is dry or the addition of soil amendments such as gypsum, soil organic matter, mulch, or a synthetic polymer such as water-soluble polyacrylamide (PAM) (Prichard and Fulton, 1995).

Certain soil textures such as loamy sands, sandy loams, sandy clay loams, and sandy clays with low shrink-swell capacity are susceptible to hardsetting, a compact and hard surface condition that develops when the soil is dry. Hardsetting creates a dense layer that is much thicker than surface crusts. Hardsetting typically occurs in soils with high exchangeable sodium or magnesium and low soil organic matter content. Surface applications of gypsum have been used to alleviate hardsetting conditions (Sumner, 1993).

## PRACTICES TO IMPROVE SOIL STRUCTURE AND REDUCE EROSION

### Soil Amendments

#### Soil organic matter

Soil organic matter (SOM) is one of the primary soil constituents that promote good soil aggregation or stable aggregates. The form of SOM that binds soil particles together into aggregates is called *humus*. Humus consists of highly decomposed organic material. To get the benefits of humus, you need to incorporate readily decomposable materials such as compost, manure, or green manure into the soil. A perennial cover crop is an ideal source of SOM. As fine rootlets die and decompose, they supply a continuous source of readily decomposable SOM.

**Figure 4.** Walnut leaf mulch in walnut orchard rows, Lake County.

Soil organic matter has many beneficial properties. For example, SOM can increase a soil's available water holding capacity, serve as a slow-release fertilizer, promote the formation and stability of aggregates, increase water infiltration, and enhance soil tilth, all of which contribute to decreasing soil erosion and increasing yields and plant health. Frequent tillage facilitates the loss of SOM. Since many orchard systems can be managed without tillage or under reduced tillage, there is great opportunity to bolster SOM reservoirs in these systems. For example, apple orchard soils in the state of Washington that received compost amendments had an improved capacity to accommodate water entry and greater resistance to surface soil structure degradation over conventional systems (Reganold et al., 2001).

#### Mulch

Mulch can consist of organic or inorganic materials. Examples of inorganic mulches are gravel, pumice, stone, and sand. Organic mulches usually are undecomposed materials such as rice hulls, wood chips, leaves, sawdust, and straw. Mulch protects the soil against raindrop impact and compaction, both of which destroy soil aggregates. An added benefit of mulch is that it reduces water loss to evaporation and so extends the period of time between irrigation events. In addition, mulching is an effective weed suppressant practice and can reduce herbicide usage (Figure 4). Mulch is best suited for sprinkler- or drip-irrigated systems. It is less effective for furrow irrigation because residues often float and clog furrows, resulting in incomplete distribution of water (Prichard et al., 1989). The costs associated with spreading and hauling mulch may make it unsuitable for some systems, and it is generally unsuitable for nut crops that are harvested off the ground.

#### Compost and manure

Periodic application of compost, manure, and some other organic materials is a proven method for improving the water-infiltration capacity of certain soils: those that suffer from weak structure due to low organic matter content (Meek, Graham, and Donovan, 1982; Martens and Frankenberger, 1992; Reganold et al., 2001). The cost may range from $40 to $80 per acre for typical rates of 3 to 5 tons of compost per acre, including spreading. The actual cost will depend on several factors:

- rate of application (Suppliers usually base their price on a given weight or volume spread.)
- inclusion in the compost (by the supplier) of inorganic amendments (e.g., gypsum) and fertilizers
- whether the cost of spreading (by the supplier) is included

Hauling distance from the production site is also a factor, although the price may be unaffected by distance if the customer is within the supplier's service region. Of course, the price will be lower if the customer picks up the material at the supplier's site.

Besides price, farmers should ask for information on the composting process to ensure that there has been sufficient heat to destroy any weed seeds. A temperature of above 130°F for 2 weeks is regarded as sufficient to kill most weed seeds and plant pathogens. Also, water content and total N-P-K content will be helpful when you compare the value of composts from different suppliers. When very high rates of compost or manure are to be applied (10 tons or more per acre) and if excessive salinity in soil or irrigation water is a concern, you should also consider the salt content of the material. Visual inspection of compost before purchase and information on the feedstocks used by the compost manufacturer will help you determine whether undesirable waste materials (plastic, wire, sticks, broken glass) are present.

Noncomposted poultry litter or cattle manure is also used at low rates (a few tons per acre) in orchards and vineyards and may be less expensive than composted materials. Noncomposted manure may be available for less than $10 per ton, and in some cases it is free for the hauling. Because manure is heavier than compost, transporting manure more than a few miles will reduce its cost advantage over compost and may make the manure prohibitively expensive. Raw manures tend to be more heterogeneous in composition than well-made compost and may be more difficult to spread uniformly. Custom spreading of manure and compost in orchards can cost $5 or more per ton of material. A potential advantage of noncomposted animal manures is that the nitrogen it contains will be more immediately available (unless the manure is highly weathered), whereas nitrogen in well-cured compost is more biologically stable and converts to the plant-available form over a period of years. However, if fresh manure is broadcast and left on the surface of the soil, some of its nitrogen will be lost as volatile ammonia. Bedding materials such as rice hulls and wood shavings in poultry manure will offer some long-term benefit to soil water infiltration. Non-composted cattle and horse manures can contain weed seeds, so these materials should be used with caution.

### Calcium materials

Adding calcium salts to soil and water increases the salinity as well as the soluble calcium of the irrigation water and soil water. Both of these factors improve water infiltration as the calcium promotes aggregation by binding clay particles together, which in turn promotes the stability of the soil aggregates (Singer et al. 1992). In some soils, this process can reduce the formation of hard, dense soil crusts and the blockage of large, water-conducting pores by fine clay particles.

**Lime ($CaCO_3$).** Lime can enhance the physical properties of acid soils (soils with pH less than 7.0). The calcium in lime helps bind clay particles together, promoting good soil structure. In addition, liming a soil to a neutral pH increases nutrient availability and decreases metal toxicities, and this improves orchard performance. The benefits of calcium in lime are greatest in soils with a significant amount of clay. This means that adding lime to promote aggregate stability in a sandy soil is not cost-effective. Lime should only be added to soils having a pH below 6.5. Lime is very insoluble in water and requires incorporation into the soil for rapid results. Application rates typically range from 2 to 12 tons per acre depending on soil type and pH.

**Gypsum ($CaSO_4 \cdot 2\ H_2O$).** Gypsum also enhances the physical properties of soil through the addition of calcium. Gypsum is a neutral salt that, when applied to slightly alkaline (pH greater than 7.5) or neutral soils (pH = 6.5–7.5), will improve aggregate stability with little or no effect on pH. The benefits of calcium in gypsum are greatest in soils with a loamy texture or a significant amount of clay. Adding gypsum to promote aggregate stability in sandy soils may not be cost-effective. Gypsum is very effective at reducing surface sealing and crusting and can promote water infiltration (Shainberg et al., 1989). Gypsum applied to alleviate soil surface crusting problems should be surface applied without incorporation (Singer, Munn, and Wildman, 1984). Gypsum is also used to help displace and remove sodium and to rehabilitate soil structure in salt-affected soils where the exchangeable sodium percentage exceeds 15% and the pH is above 8.5. Application rates of 2 to 3 tons per acre per year are common for improving infiltration and soil tilth. The cost of gypsum at the time of this writing ranges from $41 to $85 per ton, depending on the quality of the material.

### Acids and acid-forming materials

Commonly applied acid or acid-forming amendments include sulfuric acid, elemental sulfur, ammonium polysulfide, and calcium polysulfide. These materials all contain sulfur but no calcium (with the exception of calcium polysulfide). They supply exchangeable calcium indirectly by dissolving lime that is contained in the soil. The sulfur undergoes microbiological reactions to oxidize sulfur to $H_2SO_4$. The acid dissolves soil lime to form gypsum to be used as the soluble calcium source. Acids and acid-forming materials can only effectively produce gypsum in soils that contain free lime. Costs for acid and acid-forming amendments range from around $100 per ton for $H_2SO_4$ to $75 per ton for elemental sulfur.

### Synthetic polymers

Synthetic polymers such as anionic polyacrylamide (PAM) or polyvinyl alcohol (PVA) can be applied to the soil in irrigation water or as a spray to stabilize soil aggregates. Synthetic polymers can be effective aggregating agents in any soil texture. The polymers act like microscopic nets that are adsorbed onto soil aggregates. The nets provide structural support to aggregates and prevent their disintegration from the impact force of raindrops and shear forces associated with moving water (Sojka and Lentz, 1997). In many instances, soil erosion can be reduced by 95% with a 1- to 2-pound-per-acre application of PAM, costing less than $35 per acre (Sojka and Lentz, 1997). Low appli-

**Figure 5.** A legume cover crop in California's Central Valley.

cation rates of PAM (between 0.5 and 0.75 pounds per acre) applied 3 to 5 times a year have been observed to dramatically reduce sediment in runoff from sprinklers (Cahn et al., 2004). PAM is most effective when applied to tilled soils where it stabilizes aggregates disrupted by tillage. It is less effective on undisturbed soils where compaction and crusting may already exist.

PAM application is a safe and easy management option for reducing soil erosion. Studies have shown that PAM does not have negative effects on aquatic organisms. PAM is safe to use in water as long as you use specific agricultural grades of PAM with low levels of the acrylamide monomer in the formulation. According to the US Environmental Protection Agency, agricultural grades of PAM must contain less than 0.05% of the acrylamide monomer. In addition, PAM rapidly degrades when exposed to sunlight and through decomposition from soil microorganisms (Cahn et al., 2004).

## Orchard Floor Vegetation

In many situations it is neither practical nor feasible to add soil amendments as an erosion control practice. Cover crops are an excellent alternative to reduce soil erosion (Figure 5). They protect the soil from raindrop impact, prevent the formation of surface crusts, increase infiltration rates, and intercept sediment-rich runoff. Cover crops are also a great source of SOM.

A cover crop is a non-economic crop grown between orchard rows, often with herbicide-sprayed strips to prevent growth along the tree row. Cover crops can be annuals, which germinate and die in one season, or perennials, which live for more than one year. Both legumes and grasses are available as annuals or perennials, depending on species and variety. In addition, you can allow both winter and summer weeds to grow and can manage them like a cover crop. In some experiments, volunteer resident vegetation has been as effective at reducing surface crusts and managing infiltration and erosion as sown cover crops. This alternative is less costly and more convenient to manage (Folorunso et al., 1992; Bugg et al., 1996). A good source of information on the establishment and maintenance of cover crops is *Cover Cropping in Vineyards: A Grower's Handbook* (Ingels et al., 1998; UC ANR Publication 3338).

Critical aspects to consider are nutrient and water competition with crops, shade tolerance, crop height, and maintenance practices such as mowing. There is also a wide range in seed cost, depending on the chosen mix of species. Contact your local UC Cooperative Extension Office for information on which cover crops are best suited for your environment or check the following online resources for detailed information on selection, management, and profitability of cover crops:

UC SAREP Online Cover Crops Database
http://www.sarep.ucdavis.edu/cgi-bin/ccrop.exe

Managing Cover Crop Profitably
http://www.sare.org/publications/covercrops/covercrops.pdf

Like most management practices, cover cropping has disadvantages, too. All cover crops use water, some are invasive, some serve as habitat for pests, some can increase the potential for frost damage, and they may be costly to establish and maintain (Prichard et al., 1989). Growing a winter annual cover crop and then incorporating it or mowing it during the orchard growing season may be a good option, as it can protect the orchard against storm water runoff during the rainy season but eliminate competition during the growing season. If you use legumes, they also provide a good source of nitrogen when tilled into the soil in spring.

### Tillage Practices

Tillage is a common practice in agricultural lands throughout California. Although tillage performs several beneficial services, it can result in land degradation, as was the case during the Dust Bowl of the 1930s. Frequent tillage destroys soil aggregates and promotes the loss of soil organic matter. Light and infrequent tillage, however, can be beneficial as an erosion control practice to disrupt surface crusts and enhance infiltration. Increasing the surface roughness through tillage can decrease the erosive energy associated with moving water. The trend in tillage management today is to reduce the number of tillage operations in order to minimize compaction, improve the soil's physical health, and conserve energy.

#### Reduced tillage

*Reduced tillage* is defined as a management practice that leaves at least the orchard middles with plant residue on the soil surface year-round. To accomplish this, tillage practices are reduced or limited so they will create less soil mixing and soil disturbance (Weesies, Schertz, and Kuenstler, 2002). These operations leave crop residue on the soil surface to protect against raindrop impact. In addition, decreased tillage allows soil organic matter to build up. Research has shown that reduced tillage can reduce soil erosion by 60% (Cline and Hendershot, 2002).

#### Contour farming

Contour farming can be a very effective erosion control practice in steep and gently sloping land. All farming is done across the contour of the sloping field rather than up and down the slope. In many cases, contour farming can reduce erosion by 50% (Weesies, Schertz, and Kuenstler, 2002). This reduction can be further improved if you plant grass alleys between tree rows (Grismer, O'Geen, and Lewis, 2006).

## INCENTIVES FOR ORCHARD FLOOR MANAGEMENT

Future farming practices in California will be directly linked to the sustainability of our water resources. Well-planned orchard floor management practices protect water quality by reducing erosion and enhancing the physical quality of soils, and that can also translate into improved yields.

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