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Soil Quality: Managing Cool, Wet Soils

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Soil Quality:

Managing Cool, Wet Soils

Dealing with cool, wet soils

When dealing with cool, wet soils, the first thing is to realize that this is a complex system. Major alterations of individual properties (physical, chemical, biological) can impact the whole soil ecosystem in the absence of conservation practices.

This technical note will show that by mimicking nature through limiting physical disturbance and increasing crop diversity, one can better manage cool, wet soils.

Before beginning to optimally manage cool, wet soils, we must first understand a few basic principles that will lay the foundation for best management practices.

One major soil function is to permit water infiltration. Soil infiltration is often reduced by tillage. Tillage destroys soil aggregates. Destruction of soil aggregates negatively impacts soil porosity (air spaces in the soil). When soil porosity is reduced, infiltration (the rate water travels in the soil) is reduced and the subsequent runoff is increased; furthermore, free exchanges of gases between soil and atmosphere are hampered. Roots need a porous medium for gas exchange and water availability to achieve optimum growth. Water infiltration into cool, wet soils is important for several reasons, particularly its effects on the freeze/thaw cycle and soil structure.

This technical note will illustrate that cool, wet soils can be managed without disrupting the soil ecosystem.

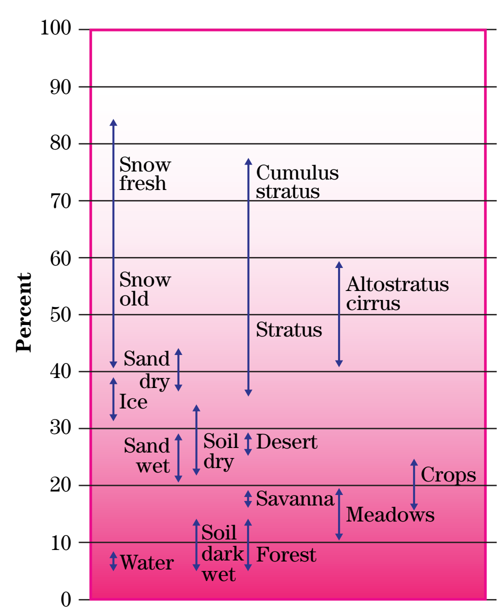
Understanding the natural system

Understanding the natural system is crucial in understanding the problems associated with cool, wet soils. Snow cover is one of the most important climatic features of cool, wet soils because of its influence on energy and moisture budgets. Snow is highly reflective. Without snow cover, the ground absorbs about four to six times more of the Sun's energy.

In areas where snow cover is disappearing earlier in the spring due to climate change, large amounts of energy that would have melted the snow can now directly warm the soil. Snow cover accounts for the large differences between summer and winter land surface albedo. The albedo of an object is the extent to which it diffusely reflects light from the Sun. Most land areas have an albedo of 10 to 40 percent. The average albedo on Earth is about 30 percent. Dark, wet soils have an albedo roughly of 6 to 15 percent, and dry soils have an albedo of 22 to 34 percent (fig. 1) (Grobe 2006). Crops have an albedo of 16 to 25 percent. Dark soils have low albedo, which means they absorb more sunlight (electromagnetic radiation) and reflect very little, thus heating up quicker than lighter colored soils. A daily life example of the albedo effect is people who wear dark clothes in the summer put themselves at greater risk of heatstroke than those who wear light-colored clothes.

Researchers and farmers both find that it takes a longer time for wet soils to warm up. The reason wet soils take longer to warm up is the high specific gravity of water, which means it takes a lot of energy to heat

Figure 1 Percentage of diffusely reflected sun light in relation to various surface conditions of the earth (Grobe 2006)



the soil water. Even though color and texture impact how quickly soils warm up, it is the soil water in cold climates that plays the largest role in the soil warming process in the early spring. This is why it is important to have good infiltration in soils.

A light-colored soil with a high albedo that is saturated with water will reflect the light, the soil will not absorb the heat from the light, and the high water content will delay the soil from warming. In other words, dark soils heat up faster than light ones. Dark color is a reasonable indicator of soil carbon. Therefore, in theory, increasing soil carbon will darken the soil's color and decrease its albedo, potentially leading to warmer spring soil temperatures. But in reality, that does not always occur. Soils with high organic matter content hold more water. More water means more energy is needed to warm the soil profile. The best way to warm the soils is to increase infiltration, and to increase infiltration, decrease tillage.

Snow cover impacts soils

The effects of snow and frost on soil water dynamics are extremely complex. Partitioning of snowmelt into soil surface infiltration and runoff is influenced by soil drainage characteristics, soil frost conditions, infiltration, soil water storage capacity, and snowmelt rates. Zhao and Gray (1999) report that numerous studies found seasonal infiltration is inversely related to the total moisture content of a soil at the time of melt.

Research has shown that soil freezing can alter the dynamics of water flow and nutrient cycling during snowmelt (Brooks and Williams 1999). Seasonal snow packs in the northern latitudes are well known to reduce soil freezing by insulating the soil surface; frost depth generally varies inversely with snow depth. Lack of snow or a late snowpack accumulation results in soil freezes that are deeper and of longer duration than when the snowpack is established in early winter (Shanley and Chalmers 1999).

A study of drainage in agricultural land indicated that high water content soils at the onset of freezing reduced infiltration of snow melt (Schimel and Kieland 1996). Freezing influences the potential for interaction between snowpack nutrients and soil microbes, which are critical regulators of nutrient cycling and retention during these periods.

Concrete frost, which is partially saturated soil that freezes so pores are filled with ice, has very low permeability that greatly reduces infiltration of snowmelt or rain and promotes overland flow. Soils in no-till systems have less concrete frost because no-till soils have larger soil pores compared with the same soil under conventional tillage. Soils in conventional-tilled systems have a smaller soil pore, which creates more concrete frost.

When soil aggregates are destroyed, pore spaces between soil aggregates are decreased. With decreased pore space, it is easier for ice to bridge the gap between the remaining aggregates, which creates an impermeable surface like concrete, thus the term "concrete frost." Concrete frost inhibits infiltration, water flow, and nutrient cycling by soil microbes (fig. 2).

Granular frost occurs when unsaturated soils freeze (fig. 3). This results in a more permeable soil, allowing more infiltration and less overland flow than concrete frost.

Figure 2 Conceptual diagram of concrete frost

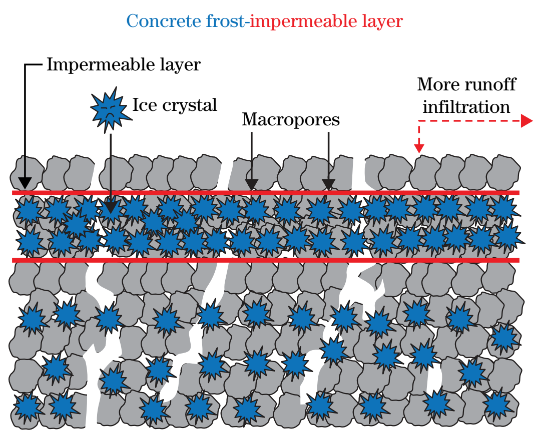
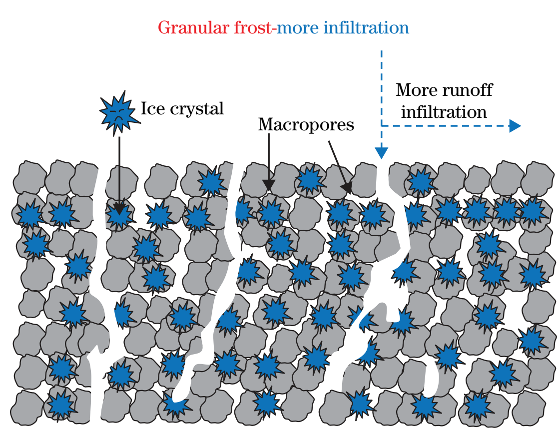


Figure 3 Conceptual diagram of granular frost



Increasing granular frost

During the winter months, soils function best in a **granular frost condition**. This occurs when permeable soils freeze under unsaturated conditions. Although the soil is frozen, infiltration still occurs and overland flow is minimized. Good soil structure with intact soil aggregates will increase infiltration rates, thus decreasing the water content in the soil. Granular frost in soils reduces the opportunity for ice to bridge the pore spaces between the aggregates, maintaining permeability.

How can the soil system be managed to increase soil function and productivity?

The better the soil is functioning (e.g., infiltrating), the fewer problems there will be with concrete frost and other associated water issues (Johnson and Lundin 1991). Functioning soils capture needed rain throughout the growing season. During the winter months, soils will infiltrate and drain water throughout the soil profile as quickly as possible, which reduces water accumulation on the surface. Figure 4 shows what happens when soil pores are reduced in size.

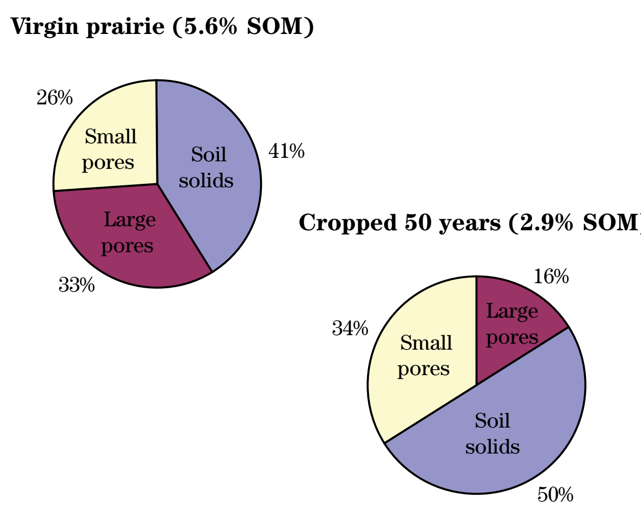
Soil quality principles that increase soil function in cool, wet soils:

- *Reduce physical and chemical soil disturbance (tillage and pesticides)*—managing a soil with tillage is like fixing a Swiss watch with a sledge hammer. Using the wrong tool can create a worse problem. Physical disturbance, like tillage, depletes organic matter, increases soil crusting which reduces infiltration, increases concrete frost by reducing average pore space, and disturbs microbial function. All these factors impact water infiltration and nutrient availability throughout the growing season. Another type of disturbance that can be harmful to the soil ecosystem is "chemical disturbance." Certain fungicides, insecticides, and herbicides can be harmful to soil fungi, bacteria, and earthworms. These living organisms are critical for increasing infiltration and nutrient cycling. Tillage in cool, wet soils can create a string of events that can cause more harm than good.

  Most wet areas in a field are wet because they receive additional water from higher places on the landscape by surface or subsurface flow and do not have an outlet for the excess water. Runoff is increased because tillage destroys the surface porosity needed for water to soak into the soil. One pathway water takes to infiltrate the soil is between soil aggregates. Tillage shears soil aggregates, leaving fewer pathways between aggregates and clogging the spaces that remain with the smaller pieces of smashed aggregates (fig. 5) (Laws and Evans 1949). Another way tillage impedes infiltration is by destroying worm and root channels. Pores that are not continuous with the soil surface do not conduct water down into the soil very well.

Figure 4 Reduced pore size caused by tillage

Figure 5 Effect of 50 years of continuous cropping on soil porosity (Adapted from Laws and Evans 1949)



The net result is more water in low areas with no place to go but up (evaporation). When the weather and soil are cool in the spring, evaporation is a slow process. The best way to warm up the soil in these conditions is to use a pinwheel placed in front of a no-till drill. The pinwheel will push away the residue from the seedling, thus allowing the soil to warm next to the seedling without disturbing the soil. In sod or pasture applications, ripple coulters throw less soil and work well in heavy soils.

- *Use cover crops*—Cover crops are a good way of solving water problems in the winter. Cold-tolerant cover crops such as winter wheat and rye, which survive through the winter, have the ability to utilize excess moisture and increase soil strength to ensure an earlier planting date. Ongoing research by Osborne and others (2002) in Brookings, South Dakota, indicates that soil bearing strength and trafficability is increased with cover crops. The study revealed that conventional-tilled fields and fields that grow no cover crops have a lower bearing strength versus no-till fields with cover crops (fig. 6). Soils with cover crops have more root and worm channels. The roots in cover crops act like stabilizers in the soil, similar to rebar in concrete. Improved bearing strength may be related to the above biomass characteristics and the root system. In general terms, the experiment illustrated the ability of cover crops to utilize excess soil moisture and increase soil strength compared to conventional tillage or no cover crop (Osborne et al. 2002).

  Some other benefits of cover crops are:

  – Cover crops increase nutrient cycling.

  – Cover crops enhance soil habitat for all types of soil microbes.

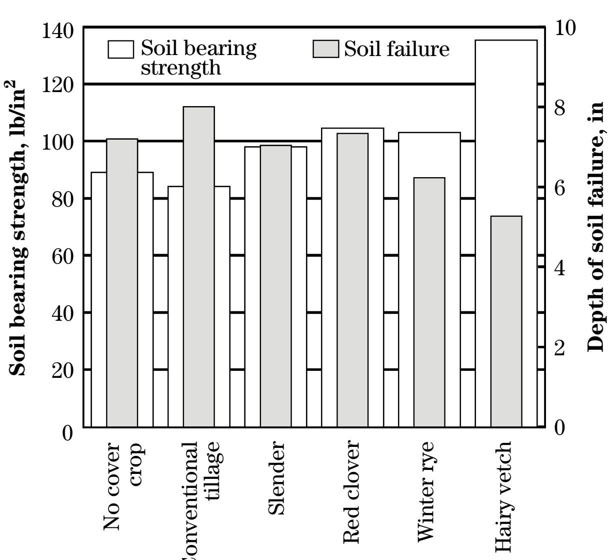
  – Cover crops improve water cycling in the soil profile.

  – Cover crops increase soil biodiversity.

- *Reduce compaction*—Nature has built-in processes that will reduce soil compaction cycles of wetting and drying and freezing and thawing. In the last 30 to 40 years, farming practices have changed drastically, creating situations where natural rejuvenation of the soil environment by wet-dry and freeze-thaw cycles is inadequate to maintain optimum conditions for crops.

  Performing field operations on wet soils, using multiple field operations for crop production, eliminating perennial crops from crop rotations, and using heavy equipment contribute to more extensive and deeper compaction.

Figure 6 Bearing strength of soil (Osborne et al. 2002)



Management strategies for eliminating compaction:

- *Stay off wet soil*—Soil is most susceptible to compaction when soil water in the 3- to 6-inch soil depth is near field capacity or wetter. Under such moisture conditions, the potential for compaction increases as soil clay content increases and soil organic matter decreases.
- *Reduce tillage*—Tilled soils are more susceptible to compaction than no-till soils. Tillage contributes to the breakdown of soil structure by compressing and breaking soil aggregates, which are necessary for good air and water movement and good root growth. Tillage also results in the loss of soil organic matter, which is important to soil aggregate stability. Using a pinwheel in front of the no-till drill will help remove the residue away from seedling allowing the soil to warm up quicker.
- *Build organic matter in soil*—Organic matter promotes the development of good soil structure and decreases soil bulk density. It helps bind soil particles together as aggregates so they are not as easily cracked, split, or compressed by tillage or wheel traffic. Reducing disturbance and increasing diversity will increase organic matter.

- *Increase diversity of rotations with perennial crops or deep rooted crops*—When crop rotations include alfalfa, clover, or grass, soils usually are less compact than soils in fields without these rotations. The deeper rooting depth of alfalfa and clovers helps keep the soil more porous and overall produce more organic matter.

Conclusion

Nature is very complex. Trying to alter the way the soil ecosystem functions is usually expensive, ineffective, and detrimental in the long run. As we mimic the natural soil ecosystem by using cover crops and minimizing chemical/physical disturbance, the effectiveness of our efforts to manage cool, wet soils is accelerated.

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