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The Role of Water in Ensuring Healthy Soils

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Key Points

- Water is one of five critical soil components.
- Rising global temperatures are increasing the rate of soil moisture evaporation threatening soil fertility.
- Sandy soils, typical of Western Australia, can be highly water repellent, caused from a buildup of waxy organic substances on the particles contained in the top soil.
- Dryland salinity affects 29 million hectares of land in Australia.
- Waterlogged soils release increased amounts of nitrous oxide, a significant greenhouse gas.

Summary

Water is an essential constituent of healthy, productive soils. It serves to bind and secure the physical particulates in soil structure and is the medium by which natural chemicals and essential trace element nutrients are transported to plants. Without water, plants cannot grow and all plants need at least some water to survive. Many agricultural plants are highly water dependent. Maintaining the availability of water to plants while ensuring healthy, sustainably productive soils, relies on understanding the natural processes of climate and weather and managing complex and often conflicting physical and environmental factors.

Analysis

Water in Soil

Soil is comprised of several intrinsic physical components, in varying quantities. Mineral particles and aggregates consisting of clay, silt, gravel and sand; organic matter derived from decaying plants and animals, live micro-organisms such as bacteria, minute fungi and earthworms; and oxygen. The fifth component of soil, critical to soil formation and health, is water. Water enters soil both downwardly, though precipitation, or it is drawn up from deposits in underlying layers of rock or subsoil. This movement has the effect of binding the minerals together as it occupies the microscopic porous spaces between the mineral particles. As the water moves it facilitates the transportation of the micro-organisms and dissolved chemical nutrient such as nitrogen, potassium, phosphorus and carbon, which are essential to root development and plant growth. The importance of water cannot be overstated; in addition to sustaining all life on Earth, soil water provides a pool of dissolved nutrients that are readily available for plant uptake. It is therefore, important to maintain proper levels of soil moisture in all soils, natural and agricultural.

Evaporation and Draining

Water leaves soil in two ways: by evaporation and through drainage. The rate at which water evaporates from soil is dependent on factors such as humidity, cloudiness, air temperature, wind speed and vegetation. Not unsurprisingly, climactic conditions are key factors governing the volume and rate of soil-water evaporation. Analysis of records from the Australian Bureau of Meteorology shows that in the ten-year period to 2005, the generally dry conditions experienced in Australia's north resulted a total loss through evaporation of between 3200 – 4000 millimetres whilst in the southern regions the total loss was 1000 – 1800 millimetres. The figures demonstrate how higher temperatures, like those experienced in northern Australia, can affect the water retention rates in soil. The process of evaporation increases as temperatures increase, as does the moisture holding capacity of the atmosphere. For every 1°C increase in temperature, there is a seven per cent increase in the moisture holding capacity of the atmosphere. More moisture in the atmosphere ultimately leads to changes in rainfall patterns.

Importantly, there is a relationship between moisture loss through evaporation and the ability of soils to retain and conserve water. This is strongly influenced by the amount of organic carbon (basically defined as materials of plant and animal origin at all stages of decomposition as well as the living organisms in soils) that is stored in the soil. Increasing the amount of soil carbon in agricultural soils, in particular, can result in improvements in soil and water quality, reductions in the loss of soil nutrients, reduced susceptibility to erosion and, most importantly, a dramatic improvement in water conservation.

Closely linked with evaporation is **transpiration**, the process where plants absorb water through the roots and then give off water vapor through pores in their leaves. The water, after moving through the plant, is subsequently lost to the atmosphere through the stomata in its leaves or, put very simply, evaporation via a plant. Transpiration rates vary significantly between species of plant. Some agricultural plants have levels of transpiration which are not environmentally unsustainable and therefore, require human intervention, such as irrigation, to survive.

Drainage is the natural or artificial removal of surface and shallow, sub-surface water, constituting the other method by which water is removed from soil. Drainage occurs when part of the water in the saturated upper soil layers flows downward into the deeper layers, to be replaced by water infiltrating from the ground surface. When no water is left on the surface, the downward flow continues for a period, enabling air to re-enter the porous spaces, reducing saturation. When saturation is prolonged in soils with poor internal drainage, the consequence may be crop damage and poor plant health and yield. This situation, termed water-logging, can severely harm the physical properties of soil.

The structural characteristics of soil are critical to soil fertility and they can be severely affected by the absence, or abundance, of moisture that results from poor drainage. Combined with the amounts and proportions of mineral particles and aggregates, those characteristics govern the movement of water through soil and the ability for plants roots to penetrate. For example, in the sandy soils that are common in Western Australia, and the shallow soils that occur across much of northern Australia, the ability to retain water is particularly limited. During periods of low rainfall plant roots quickly become dry and their capacity to develop is limited. The lack of moisture also diminishes nutrient exchange from the soil to the plant which is necessary for plant growth.

Water Repelling Soil

Water repellence in soil results from waxy compounds coating soil particles. Decomposing waxy materials (hydrophobic chemicals) originating from native plant residues, coat the soil particles which, in turn, prevent water infiltrating into the soil profile. In poor, sandy soils (those less than five per cent clay), typical of the southern and eastern agricultural regions of Western Australia, water repellence is particularly significant and has been the focus of considerable research and analysis in recent years.

Measures to manage water repellence in sandy soils include applying clay to alter the soil dynamics by increasing the soil surface area, using soil-wetting agents and the promotion of bacteria that will break down the waxy material causing the problem. Alternative options to manage water repellence include creating furrows when seeding to trap water and to prevent runoff, growing plant species that are adapted to water repellent soils and adding organic matter. Whilst employing one or more of these options may assist in a small-scale, they are often not economical in a broad-acre farming application. For the immediate future, water repelling soils will continue to be one of the most significant factors limiting agricultural improvement.

Dryland Salinity

Dryland salinity directly reflects reduced precipitation combined with high evaporation levels. Periods of low rainfall cause a build-up of naturally occurring salts which would normally dissolve and drain away (leach) through the soil. The salt severely impairs plant development and growth, affecting crop establishment, growth and yield. In Australia, dryland salinity is prevalent across most southern regions and particularly in Western Australia where it affects 29 million hectares of land. Two types of salinity are experienced. Primary salinity is where lessening rainfall, in combination with high evaporation, is insufficient to leach the soil. Secondary salinity, refers to changes in land form and soil profiles caused by clearing the land for agricultural purposes. Native plants are replaced with introduced cropping varieties that are ill adapted to the soils and climactic conditions and which require large amounts of water.

Dryland salinity is not confined to Australia. The United Nations FAO records and reports on dryland salinity globally. It is a significant problem in the Great Plains region of North America, in Montana, North and South Dakota and reaching into the Canadian prairie provinces of Manitoba, Saskatchewan and Alberta. Dryland salinity is also a significant problem in South Africa, Iran, Afghanistan and, to a lesser degree, in Thailand and in India.

Different options exist to manage the problem of dryland salinity. In Western Australia, land managers and property owners cut deep furrows into their pastures to drain subsurface saline water. This allows the salt-affected water to naturally drain from higher ground into existing water courses. In combination with, and to augment the on-ground mechanical works, farmers plant salt-tolerant species such as Australian sandalwood, a tree native to semiarid areas of Southwest Australia, which also provides an economic return on their salinity mitigation. In the United States, agricultural soil has been successfully treated for dryland salinity by the practice of crop-fallow farming. This practice, which dates to medieval times, reduces the capacity of the soil to retain rain water which, in turn, results in greater salt removal through sub-soil seepage.

Other Soil Problems Related to Water

When the soil's physical capacity to retain moisture reaches its maximum, known as the soil "field capacity", other soil fertility problems occur. These can include waterlogging, soil water erosion and leaching.

In the case of waterlogging, water is physically restrained from draining and permeating down through underlying sub-soil levels. In agricultural soils, crop damage occurs when excess water prevents plant roots from respiring and can result in crop loss. Secondary to plant survivability in waterlogged soils can be the release of heightened levels of nitrous oxide, a significant greenhouse gas. Soils that are waterlogged are also highly susceptible to nutrient leaching which occurs when water filtering down through soil picks up and transports soluble chemicals. Those chemicals and trace elements are vital to promoting plant health and growth.

Erosion, caused by the movement of water, can be extremely damaging, particularly on poor fragile soils containing limited amounts of silt and clay aggregates necessary to maintain structural integrity. Soil water erosion occurs when rainfall strikes the surface of the soil with force sufficient to breakup and fragment the soil aggregates, and the micro particulates in turn wash into the pores. This action, in turn, stops the process of water infiltrating and draining into the soil. The water accumulates and then washes away as surface runoff. Damage occurs when the surface runoff, transports valuable topsoils with it. In Australia, measures to manage and avoid the consequences of topsoil runoff caused by water erosion, primarily concentrate on establishing and maintaining ground cover, either by growing crops and trees, or by introducing groundcover such as mulch or other organic matter. The ground cover reduces the erosive effects of rainfall and tree roots and is critical to maintaining soil structure and preventing movement, particularly on ground that is sloping. In recent decades, much of Australian agricultural land has been successfully mitigated against soil water erosion.

Conclusion

Soil fertility comprises three interrelated components: physical or structural fertility, chemical or nutrient fertility and biological fertility. Water is inextricably connected to these fertility components and the relationship is complex and interrelated. The movement of water through soil is also one of the foundation processes of terrestrial life on the planet and, while water is essential to healthy, fertile soils, soils are also essential to the clean water cycle. The environmental aspect of the soil and water relationship notwithstanding, it is the essential connection between soil, water and agriculture which perhaps presents the most compelling reason to understand and manage the relationship. As the global population heads towards a projected nine billion people by 2050, it may be the vital need to feed that population or the possible implications of we do not, that highlights most strongly the need to sustainably manage our soil and water resources.

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