Shifting Watering Decisions from Art to Science

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Using water efficiently is a tough problem. We are trying to replace natural rainfall with artificial irrigation. With limited supplies of water, we must be certain that we are using water where, when and how much is needed. Accomplishing this goal drives us to utilize science and technology. We need more control and feedback to aid people in making decisions that optimize performance and minimize inputs.

Turfgrass like other plants requires water, sunlight and nutrients to grow. Nature serves as an excellent irrigation system by providing uniform applications (on a local basis) of high quality water through the process of precipitation. However, precipitation is not reliable in some seasons and/or locations and may be insufficient to support the plant community. Under these circumstance, human intervention in the form of irrigation is required to sustain plant systems. Rainfall is very challenging and difficult to duplicate, and as we use irrigation systems to supplement water not provided by nature, we need to take a great deal of care to use water efficiently.

Plants draw their water from the soil via their roots. Soil is a matrix of particles that provides a medium for the storing of water, gases like oxygen and carbon dioxide and plant nutrients. The soil has a finite capacity for storing water that is available to the plant. The full point or maximum amount of water the can be stored without significant losses due to deep percolation is called field capacity (full). As plants draw down the supply of water from the soil, the surface tension of water that binds water to the soil matrix begins to limit the availability of water to the plant. Eventually, there becomes a point where the plant can no longer withdraw water from the soil matrix (empty). This point is called the permanent wilting point. The difference in soil moisture between field capacity and the permanent wilting point is referred to as the water holding capacity of the soil and is dependent upon the texture of the soil. Texture is another way of saying the size of the soil particles. The job of the irrigator is to make sure that soil water is maintained at an appropriate level between Empty (Wilting Point) and Full (Field Capacity) that produces acceptable quality plants.

Figure 1. How big is the tank? In other words, water holding capacity depends on the soil type or texture.

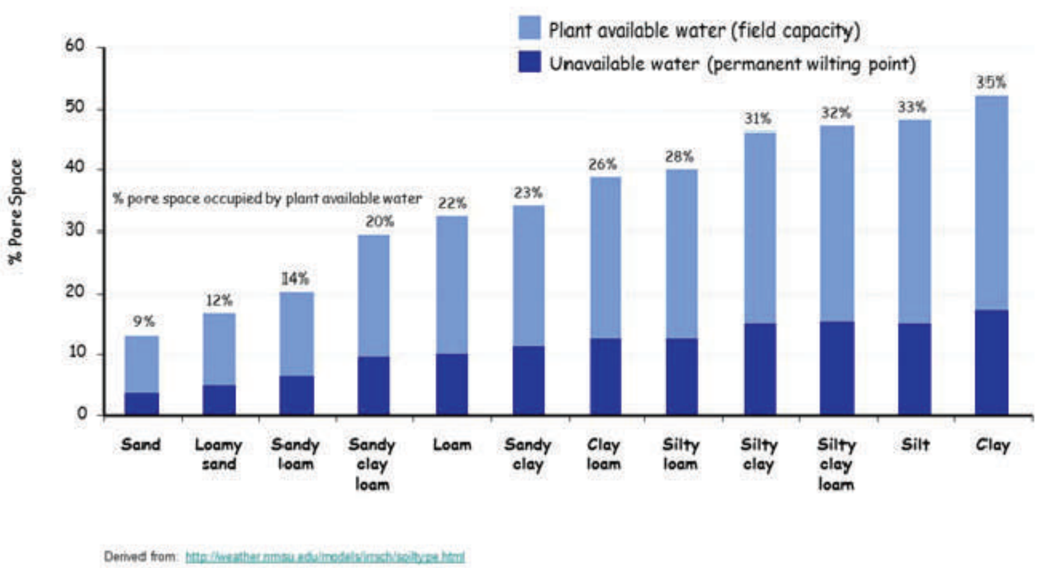
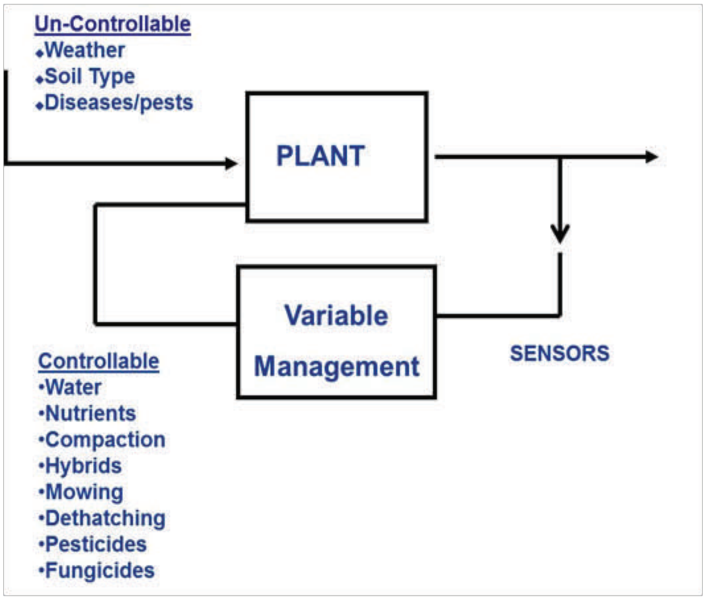


Figure 2. Schematic illustrating the controllable and uncontrollable aspects of managing soil moisture for healthy plants. Soil moisture sensors provide additional information to make better water management decisions.



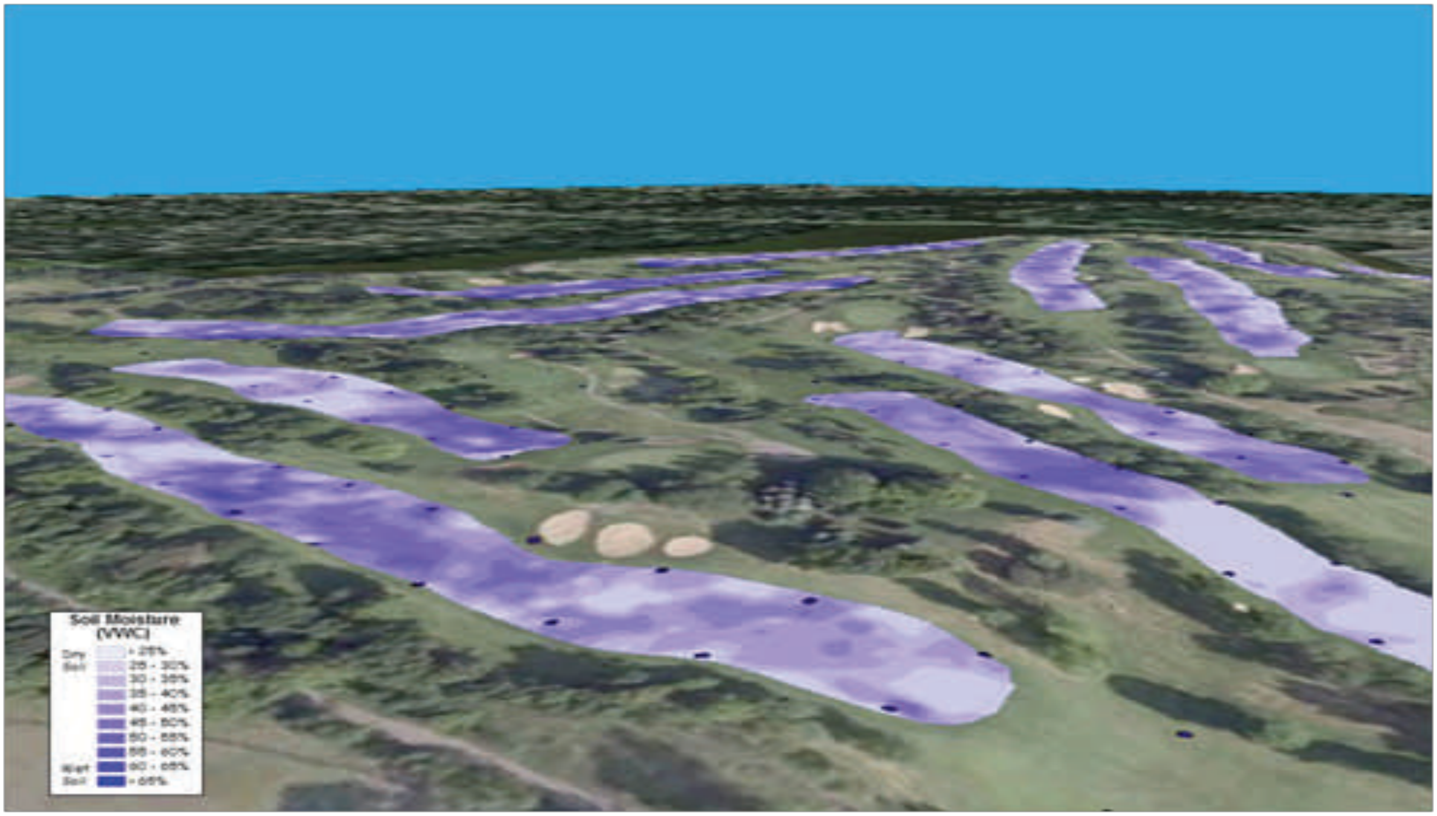
There are two critical aspects to assure the efficient use of water. First, we must be certain that water applied through irrigation actually gets to the tank that is the soil. Light irrigations and low application rates can result in significant evaporation from the the leaves, lowering the amount of water reaching the soil. If water is applied too quickly it will run off because it cannot be absorbed by the soil. If too much water is applied, soil moisture increases above field capacity (full) and the excess water is lost to deep percolation and is not available to the plant. We save water when we make sure that plants have sufficient water for growth, water is not wasted due to run off or deep percolation, and we maintain the soil water reservoir at levels that enhance the absorbtion of water that nature provides through rainfall. This requires precision, control, feedback and more points of distribution.

The use of technology to assist with management of irrigation is relatively new and began with the publishing by Howard Penman in 1948 of his equation to estimate the evaporation of water from an open water surface. This technology was further enhanced by John Monteith in 1965 and resulted in the development of an improved procedure for estimating evaporation from vegetation known as the Penman–Monteith equation. With the 1998 publication by Allen et al. of FAO Paper 56 "Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements," the international community has accepted the Penman–Monteith equation as best means of estimating evapotranspiration (ET). Evapotranspiration (ET) which uses measurements of temperature, wind, humidity and solar radiation, is an appropriate first step in making better watering decisions. However, if we go back to the tank analogy, making irrigation decision using ET alone is analogous to deciding to fill up the fuel tank in your car based on how much fuel you used. It is better than no information; however, if you do not know how full the tank was when you started the trip or how large the tank is you are in danger of going to the gas station more often than needed or worse yet, in danger of running out of fuel. Today, we are poised to make a major step forward in irrigation management by moving from estimating water usage (ET) to measuring soil water availability.

Future watering decisions will be made with the precise knowledge of the moisture status of the soil. We will be able to measure soil moisture with appropriately placed sensors. Moisture sensors are an old idea that did not work in the past. Why now? There were two reasons for the difficulty and delay in the widespread application of moisture sensors. One was sensor reliability. That problem has been solved. The incredible advancements in size, power requirements, capability and reliability of electronics have made things that were difficult or maybe impossible five years ago easy and relatively inexpensive today. The second reason for slow acceptance of soil moisture sensors was the common perception soil variability would make it impossible to install enough sensors to characterize the site. There is no doubt that more sensors are better than fewer sensors. Cameras with more pixels produce higher quality images than those with fewer pixels. However, it is not necessary to have a high density image if the intended use is only for viewing email. Similarly, when we install moisture sensors in a turf setting we need to shift our thinking from how we characterize all the variability on the site to understanding the needs of the site. Our ability to act is dependent on the density of the irrigation pixel which is an irrigation zone or head in the case of individual head control. We also need to change our mindset from how much variability there is to how we find places that are good indicators of water need.

There are many high quality moisture sensors available in the market today. Moisture sensors are available from the major irrigation suppliers like Toro and Rainbird, They are also available from instrumentation suppliers such as Spectrum Technology, Stevens and Decagon. These new sensors are very repeatable and can accurately characterize the soil moisture that is available to the plant. There is some discussion in the market about the absolute accuracy vs. relative accuracy (repeatability). It is my opinion that repeatability is critical. The measurement that matters to the plant is the status of soil moisture relative to the full and empty points. That requires knowing the volumetric water content and the soil texture. Accurately characterizing

Figure 3. For the first time, new technology provides information on the spatial variability of larger turfgrass areas for soil moisture. This allows for the strategic placement of soil moisture sensors to help manage irrigation water more efficiently.



soil texture is not simple. It is however very simple to install a sensor and learn the full and empty values for the soil water reservoir. Full is found after a significant rain event (or irrigation event). A rain event of 1 to 1½ inches will bring most soils to field capacity in the turf root zone. This empty point is the desired moisture depletion and is found by allowing the site to dry until the onset of wilt. You have now established the target watering zone. It is not necessary to know the volumetric water content or the soil texture on an absolute scale.

At The Toro Company, in partnership with university scientists, we have studied the variability that exists in golf course and sports turf sites. We started by taking measurements and soil samples by hand on tight grids at separations of a meter or two. The variability was significant but not overwhelming. It does, however, provide important information on the underlying soil conditions of the site. Efficient watering requires a knowledge of where soil moisture is relative to full and empty. Zones with heavier soils have larger water holding capacities, require lower watering frequencies and must be watered at rates that allow the water to be absorbed without running off. Lighter soils, retain less water and require that water be applied more frequently and in smaller amounts. Optimized watering requires watering based upon zones that are agronomically similar, not hole by hole. We want to water only when there is insufficient water to support the plant. We also want to make sure we have the soil reservoir prepared to receive rain which is accomplished by maintaining the reservoir below field capacity to enhance infiltration and minimize runoff into streams and surface water bodies. The best way to conserve water is to have the soil relatively dry when rain occurs. This also helps to minimize runoff into surface water bodies.

Conclusion

Water use efficiency is one of the most important environmental issues of the 21st Century. It is not about turning the water off, but rather one of prioritizing the demands on water and then ensuring the optimum use of water for the intended purpose. Water is often required to produce the quality turf surfaces that support golf and other recreational activities. However, we need to make sure that golf and other sports facilties use only the water needed to achieve an acceptable turf surface. Using less water is about using appropriate technology. The number of control points (heads) and proper placement of sensors can optimize irrigation efficiency and achieve the desired result of producing an acceptable playing surface while minimizing water use. It is about optimization, control, and measurement. Future irrigation systems will use an appropriate combination of heads (number, spacing and type) and smartly placed soil sensors in conjunction with weather forecasts to anticipate water requirements. Because each facility is unique, the way in which these new technologies are utilized for water conservation will be site specific to achieve the desired results.