Site-based Irrigation Control: *Using Sensors to Assess Agronomic Conditions*

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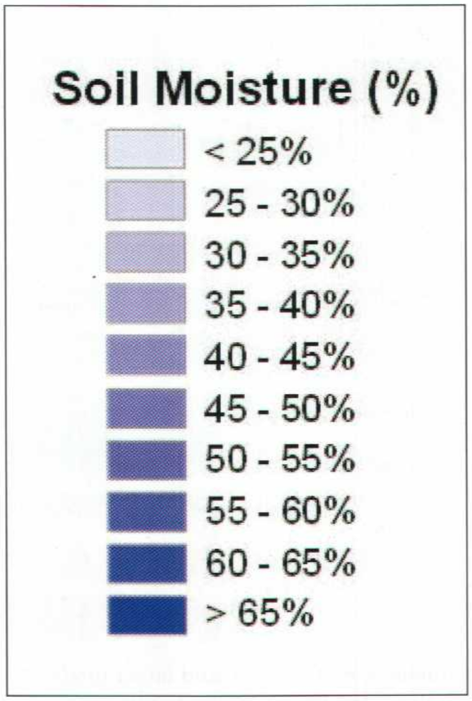
There's not much debate that water is the most important resource in growing quality turf. We can get by without a lot of other inputs, but we can't get by without water. It follows then that irrigation is the most important management practice. Irrigation management demands more attention and at times creates more anxiety than any other activity in a turf manager's routine. Inadequate water or a bad irrigation system can be the kiss of death.

Turf irrigation systems today are very sophisticated in their ability to distribute water efficiently. The industry has made great strides technologically over the past 20 years. We've developed low pressure systems, pressure compensation, low precipitation rate, matched precipitation rate and balanced precipitation rate heads, heads with variable arcs, more reliable valves, valves in heads and many other features that have improved system performance. Irrigation control is equally sophisticated. Water can be turned on and off automatically in a nearly endless combination of ways. We can control thousands of sprinkler heads on a golf course down to the individual head. We can communicate to satellites wirelessly. We can manually adjust individual head attributes to fine tune the way it waters. The list goes on.

The weak link in the irrigation process is the agronomic decision-making component. It's deciding where and when water is needed, how much should be applied and what type of cycling is necessary to optimize the amount that reaches the root zone. We know that better control over water equates to healthier turf. Optimizing soil moisture has benefits for the plant, the soil and play conditions. But historically we haven't had good tools to help make these decisions. And, the fact that the typical golf course has a tremendous amount of variability in soils, topography and microclimate makes it even more difficult to know precisely where water is needed and where it's not. Experience and observation over time along with some basic equipment like soil probes are all we've had to base adjustments on. So, the norm is to irrigate to keep the dry areas moist. No matter how much we manually adjust individual sprinkler heads or how much we adjust run times, we tend to end up with areas that are too dry and areas that are too wet. It amounts to a lot of trial and error for the turf manager who wants to fine tune his system. The lack of accurate information on which to base irrigation control has resulted in an industry-wide tendency to over-water.



Another concern that looms large for the turf industry is the pressure to reduce overall water use. Water is projected to be the resource issue of the century worldwide, both in terms of availability and quality. It's hard to imagine shortages in a water rich state like Minnesota, but water use restrictions are beginning to appear. The water situation will never be better than it is today, that's the reality. Water conservation is no longer an issue only in arid regions of the U.S. It's becoming an urban issue as well due to intense competition for limited supplies in densely populated areas. Because turf is an urban crop, it's an easy target for restrictions when supplies become limited. As a result, developing methods to more precisely control irrigation is necessary for two main reasons: 1) to grow the healthiest turf possible and 2) to conserve water in the process.

Site Variability

Precision irrigation is not possible without detailed information on the agronomic conditions that influence water dynamics on a site. Irrigation systems are designed to uniformly distribute water. The layout and spacing of sprinkler heads are the primary attributes that achieve uniformity. But the specific location of each sprinkler head in the landscape makes it unique. Uniformly applying water to the surface is one thing but getting it into the root zone and storing it uniformly for plant use is another. Once the water leaves the nozzle and hits the surface it's the specific set of site conditions within the arc of that head that determines the fate of the water. A carefully designed system that uniformly distributes water rarely produces a uniform supply in the root zone because of variation in conditions across the site. Until we understand the variability in those conditions and how the irrigation system is superimposed on the site there is no way we can optimize the irrigation scheduling to efficiently apply and store adequate water in the soil system. Precision irrigation therefore requires detailed information on the critical site conditions that influence water movement and storage. Collecting and analyzing this information requires a more technological and scientific approach to site assessment than we practice today.

So what are the critical conditions? Soil characteristics have the greatest influence on water availability. Soil texture, or the relative amounts of sand, silt and clay, determine in large part how a soil drains and how much water it can store. A coarse-textured, sandy soil drains quickly but holds little water, while a fine textured clay soil drains slowly but stores a larger volume of water. The organic matter content of a soil also influences moisture storage. The higher the stable

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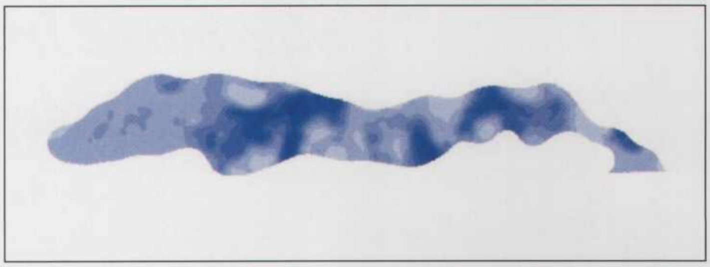
organic matter content of a soil (the darker the soil color) the more water it will hold. Texture and organic matter also determine a soil's fertility. Detailed soils information is invaluable in turf management but is rare. Analyzing and mapping soils is a tedious and expensive process. As a result, few golf courses have it. What complicates the soil situation further is the variability that typically occurs across a site. Soils form a continuum. There are rarely distinct boundaries between soil types which can, for all practical purposes, create an endless combination of soil conditions. It's not uncommon for golf course fairways, especially ones with significant topographic variation, to have significant variation in soils as well.

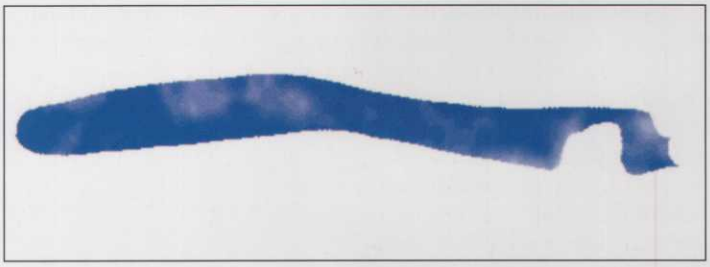
A second soil condition that significantly influences water dynamics is compaction. Fine-textured soils are generally more prone to compaction while sandy soils are more resistant. Compaction at the surface restricts water infiltration which can reduce the amount that makes it to the root zone, particularly if the compacted soils are on a slope. Compaction by definition reduces the amount of pore space that can hold water, so as compaction increases the amount of soil moisture available for root uptake is reduced.

A third factor that greatly influences water dynamics on a site is its topographic relief. In theory, water falling on a flat surface does not move. Water falling on a sloping surface runs off. Significant relief on a golf course fairway can cause tremendous movement and variation in where water ends up. Depressions and swales tend to be wetter while hilltops and slopes tend to be drier.

What really complicates the situation relative to water dynamics on a site are the interactions between factors. It's easy to visualize the influence of any one of the above site conditions on plant available water, but when you consider combinations of factors it gets much more complex. For example, water on a fine-textured soil subject to compaction on a slope acts differently than water on the same soil subject to the same compaction but on the flat. Or, soil moisture levels in a sandy soil with little compaction on a slope will be different than moisture levels in a medium-textured soil on a flat area subjected to cart traffic. On any given site not only can the variability within each specific site condition vary widely, but the number of combinations of conditions can make the situation mind-boggling. All this becomes important when you visualize a pattern of sprinkler heads overlaid on this site variability, and understand that each sprinkler head must be uniquely programmed to achieve maximum water use efficiency without compromising turf quality. Again, it becomes clear that the task of controlling irrigation to produce a high quality turf while conserving water is impossible without detailed site information.

So how do we get this kind of information? A lot of research and development has been done in what's called 'precision agriculture' to document site conditions in order to increase production by optimizing inputs. Similar R&D is being conducted in turf using a variety of sensors to capture important site data, and then mapping it using geographic information systems (GIS) for use by turf managers. Technologies now exist to collect and present the data in usable forms. Work is currently being done to develop systems and processes to do it cost effectively. All of the site conditions described above can now be measured and mapped to help turf managers make better irrigation decisions specifically and better management decisions in general. Here





are examples of the types of data that can be collected:

Soil Moisture

Soil moisture can be measured directly using a technique called time domain reflectometry (TDR) or indirectly using a technique called electromagnetic induction. Both can yield maps showing soil moisture variation across a site as illustrated above on two golf course fairways.

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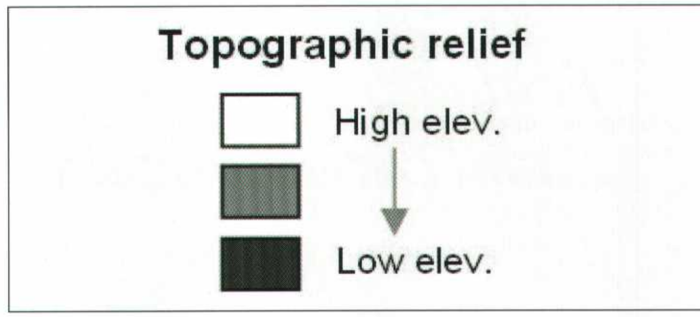
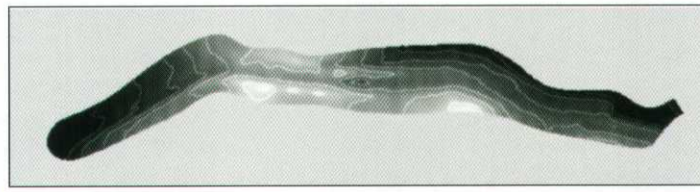
Soil Compaction

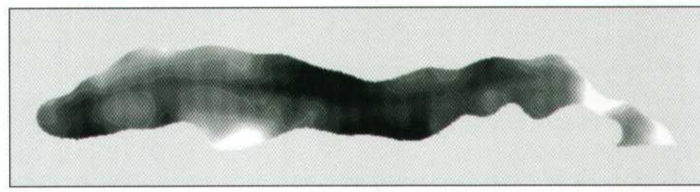
Soil compaction can be measured by different types of instruments. The maps shown here were created from data collected by a device called a penetrometer which measures soil resistance to a probe being pushed into it. This type of information is useful in analyzing soil moisture variation, identifying causes of weak or stressed turf or in targeting aerification.

Topographic Relief

Some turf managers have topographic contour maps created using conventional techniques from aerial photographs. These topo maps are useful but the information is typically not available in a digital or computerized format. The maps at right were created from elevation data captured from GPS. GPS or global positioning systems not only provide two-dimensional location data (latitude and longitude) but also provide the third dimension or elevation data. GPS can map this data in a variety of ways including color contoured images showing relief from high to low or as conventional contour maps. When elevation data is digitized it allows much more flexibility in analyzing topographic conditions including slope steepness and slope orientation.







Turf Performance

Sensors exist that measure the characteristics of reflected light from a plant canopy to quantify the level of vigor or stress depending on your perspective. This data can then be used to generate maps. This technology has been studied for several years in agriculture and other plant applications, and is known to deliver reliable information on plant performance. Turf is an excellent application for the technology since the plant canopy is dense and uniform. The technology's strength is its ability to provide an accurate assessment of turf conditions quickly and automatically. Its primary limitation, however, is that it doesn't distinguish between causes of stress. Because the information is stored in a digital format it can be analyzed in a number of ways. Each mapping technique also creates an historical data base that allows the analysis of trends or changes in conditions over time.