Mobile Mapping and Input Reduction for Golf Courses

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There has been much discussion around sustainable and organic golf course management, the carbon footprint of a golf course, how a golf course affects global warming, climate change, etc. This debate will be around for awhile and it is anyone's guess as to when we will have any definitive answers. No matter where you stand on the issues, many things can be done that reduce our use of resources which in turn will reduce costs. Better utilization of resources will not only be better on the environment as a whole, it will more than likely also save money.

The objective when managing a plant community, whether it is a corn field or a golf course, is to get the maximum outputs for the least amount of inputs. While the hope is to maximize yield when growing corn, it is to maximize the quality and playability on the golf course. From experience, we all know that it doesn't take much initial input to get a response, but as we increase the inputs we begin to get less return from those inputs. Eventually, increased inputs will not provide any further positive returns and may actually become detrimental. Applying the optimum inputs to every site in every situation can be an incredibly difficult task. The agricultural community has been effectively implementing Precision Agriculture over the last few decades. One benefit annual agricultural field production practices have over turfgrass is the regular access to the soil under the crop as it is turned over. Turfgrass is a perennial crop that doesn't afford us that opportunity. Like precision agriculture, understanding the variability across a site, such as a golf course, can provide aid in developing management techniques that will make the most of the inputs.

The process of better utilizing the resources that we invest on a golf course begins with understanding the potential for varying our inputs according to site requirements and developing application methods whereby we can optimize those inputs. Another way to look at this is to see it as increasing efficiencies; efficiencies in water, fertilizer, pesticides, labor, equipment use, etc. In order to achieve increases in efficiencies, we need to be able to precisely manage and apply all the inputs. Being precise requires that we understand more about the site conditions that we are managing so that we know what to apply where and when.

In an attempt to determine the potential need for precision applications we initiated a large project collecting soil samples and data with hand-held devices in an attempt to understand to what degree spatial soil variability existed across golf course fairways. What we discovered is that there can be great variability both between fairways and even within a fairway for soil moisture, compaction, soil texture, soil organic matter, soil chemical composition, and turfgrass vigor.

This research led to the conclusion that there is opportunity to better understand each site and adapt the maintenance accordingly with the hope of better utilizing inputs and creating a more healthy plant community. However, it became quite obvious that spatially frequent soil sampling or even closely spaced hand collected data could not be performed readily in a cost effective way. The quantity of soil samples required to determine the spatial variability across an entire golf course would be tremendously expensive to collect and process. And while data collected with handheld sensors may be somewhat more economical, it is still very labor intensive and quite taxing on the person collecting the data.

In order to speed up the process and collect the parameters of interest simultaneously, we developed a mobile sampling vehicle ***(see Figure 1)*** that collects soil moisture, salinity, compaction, and plant reflectance on a spatially frequent pattern of up to 1000 samples per fairway. The data is all marked with a GPS coordinate allowing for the development of different Management Maps (see Figure 2). These maps are then used to develop management zones that can be used to precisely apply inputs. This article will highlight some of the ways this new mobile mapping platform can be used to provide a more precise understanding of site conditions that will allow managers to better utilize the resources available to them.

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Figure 1. Mobile Sampling and Mapping Platform. Measures soil moisture, compaction, salinity, and plant reflectance while continually moving.

Figure 2. Soil moisture map for a portion of a golf course. The variability in soil moisture can be very dramatic. The darker the blue the higher the moisture content.

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Irrigation systems have come a long way from the days of impact sprinklers on the top of quick-couplers. We now have electronically operated, valve-in-head rotors with precision engineered nozzles designed to deliver a very uniform coverage across the entire length of its throw and can be controlled individually from a remote computer. Although we have very precise control over what runs when and for how long, we are still uncertain as to exactly how frequently they should run and for exactly how long. It can also be very difficult to ascertain if a system is operating at its full potential. Sprinkler heads can sink or lean over time and nozzles wear and can be damaged. Some of these slow changes can be difficult to diagnose as problems because we slowly adapt our irrigation practices as they occur.

Spatially frequent soil moisture, compaction and plant reflectance data can provide for analysis of various aspects of irrigation management. The data can show some simple, relatively inexpensive things that can be done to improve the efficiency of the system or how the entire programming process can be adapted to optimize its performance.

Simple Beginnings

Individual head efficiency or uniformity of coverage can have a dramatic affect on the overall irrigation efficiency. Worn nozzles and heads that are too deep or have tipped slightly over time do not uniformly apply water to its area of coverage. Any time a head is not applying water as it was originally intended, you are likely to get a situation where the runtime is going to have to be increased to supply adequate water to all areas covered by that head. Additionally, applying extra water to get an adequate amount to one area, results in other areas receiving too much water. Leveling and raising heads as well as replacing nozzles are relatively inexpensive practices to begin increasing efficiency. Maps produced from data collected with the mobile sampler are shown in Figure 3. They are examples of what appear to be worn or damaged nozzles creating wet or dry patterns around the sprinkler heads.

Irrigation Management Zones

Irrigation programming is currently being performed as best possible given the information that is available. Often adjusting run-times for each sprinkler head as we gain experience with the sites and learn where there are wet and dry areas. Because we are now able to collect spatially frequent site data, we are proposing a paradigm shift in how irrigation programming is performed. Understanding the variability of a site allows us to develop a program grouping irrigation management zones based upon the similarities of the sites rather than by the traditional by-hole method that has been used until now. Figure 4 displays this concept showing four distinct irrigation management zones on this golf course. Rather than irrigating all the fairways, and the entire fairway, during each irrigation event, the frequency and amount of irrigation would vary according to the requirements and needs of each irrigation management zone. This new concept could allow the opportunity to extend irrigation events for some zones out by a day or multiple days. Extending the time between irrigation events allows for the increased likelihood that a rainfall will occur that will fulfill, at least partially, the irrigation needs of the area.

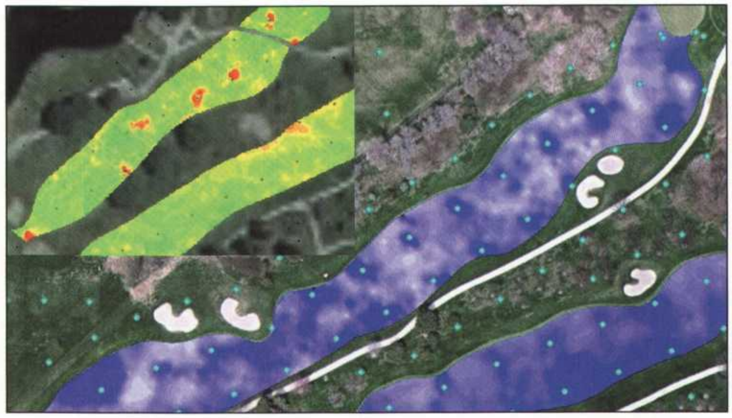

Figure 3. Two different nozzle problems at two different golf courses. In the upper left corner is a plant reflectance map showing high stress around or near a number of the sprinkler heads. The lower and right portion of the picture is another course with much wetter soil conditions near most of the sprinklers.

Figure 4. Map of Irrigation Management Zones. Irrigation programming based upon this concept can conserve water and reduce pumping costs.

When installing a new irrigation system or renovating an old one, it is advisable to run a control wire to every sprinkler. This may increase the initial cost somewhat, but will easily pay for itself over the life of the system through reduced pumping costs. Sprinklers that will be managed similarly can still be tied together at the controller to reduce the number of stations required, but this gives you the flexibility to irrigate the site as required and provides for future modifications as they become necessary.

Compaction

Compacted soil is not only a difficult growing condition but it also increases runoff potential because of reduced infiltration of water into the soil. The reduced infiltration can result in droughty conditions even when adequate rainfall or irrigation is applied too quickly. Additional water has to be applied to provide adequate moisture to the rootzone. Getting water infiltration to the deeper parts of the rootzone is important because it promotes deeper rooting and is less susceptible to loss due to evaporation. This mobile sampling technology has the potential to aid in adjusting how irrigation is applied allowing for increased infiltration and increased irrigation efficiency and reducing the potential for runoff.

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Understanding the spatial variability of compaction, and locating the most problematic places easily, makes it possible to aerify only the areas of concern ***(see Figure 5).*** This can be especially beneficial during

Figure 5. Compaction Management Map for a fairway with arrows representing the natural flow of cart traffic due to course design. Pinks represent higher compaction, white is average, and blues are lower compaction.

the growing season where solid tine or water injection aerification could be used for improved infiltration which again will provide for improved irrigation efficiency and increased gas exchange. This will increase the health of the plant making it more resistant to stress and pest problems and also reduce the amount of labor and fuel required to complete the task.

Salinity

Although not generally a problem in the northern regions of the United States, salt accumulation can be a problem in more arid regions. Recently, there has been an increase in the number of locales that require golf courses to use reclaimed water for irrigation. As this trend continues, we may see an increase in the number of salt affected sites. Anywhere that has even short-term droughts can expect to see salt accumulation, and given that cool-season grasses tend to be less tolerant of saline conditions, salt management could become an important aspect of managing sites using reclaimed water.

Again, understanding the variability of a site allows one to better understand how salts accumulate across different areas of a golf course and allow the manager to leach only those areas that require it. This type of leaching technique has the potential to significantly reduce the water consumed. Water used in leaching is for the most part "wasted." Its only purpose is to push excess salts below the plant rootzone. While it is important to the health of the plant to remove the salts, all the water leached beyond the rootzone is out of reach of the plant. ***Figure 6*** demonstates what a Salinity Management Plan looks like at a golf course irrigating with brackish water.

Maintaining soil moisture in the optimum range is important to having the healthiest plant environment. Too little moisture creates stresses that can greatly reduce a plant's productivity; however, too much can also be detrimental. Saturated soils contain little oxygen required for the plant during respiration and create an environment that is conducive to anaerobic microbes that often produce by-products that can be toxic. Saturated conditions, especially in finer textured soils, are more conducive to compaction which can then reduce infiltration. The excess water provides an environment for some diseases to spread more readily to plants that are more prone to infection because of the wet conditions.

Spatial mapping done at the right time provides the opportunity to understand the exact areas that may need to be included in a drainage project. You can see the before and after soil moisture patterns in ***Figure 7*** where drainage was installed to help alleviate an excessively wet condition. Plant reflectance data, not shown here, also showed a thin turfgrass canopy where the soils were excessively wet. Removing the excess water will provide a healthier growing environment for the plants and allow them to better tolerate stressful conditions.

In-Ground Sensors

Recent advances in technology have provided us with reliable stationary in-ground sensors that can measure soil moisture, salinity and temperature. Using the Irrigation, Compaction, and Salinity Management Maps developed from the mobile sampling vehicle provides the information required for placing these sensors in the key management zones on the golf course. The sensors then provide the feedback necessary to objectively make irrigation and salinity management decisions. Using this approach requires

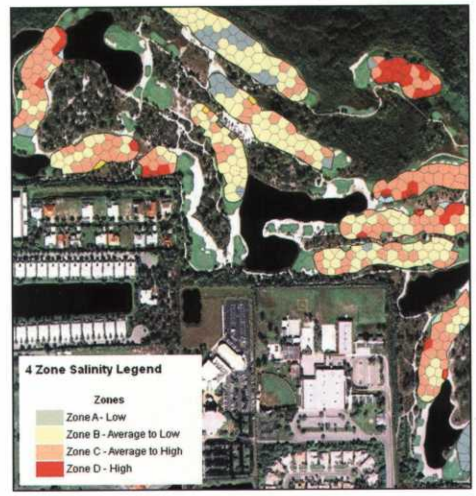

Figure 6. Salinity Management Map for an entire golf course.

only one or two sensors per management zone; many fewer than the hundreds that are sometimes mistakenly thought to be needed to fully monitor a golf course.

Final Thoughts

It is possible now, with the technology presented here, to greatly improve your water use efficiency. As other technology matures and evolves, you will likely see equipment developed that allows you to apply even more of your resources in an increasingly precise way.

Whether by choice or through legislation, we will continue to see pressure toward reduced inputs. As an industry, it would be to our advantage to be proactive and take steps that show we are continually improving our resource utilization.

Figure 7. Drainage. The left picture shows soil moisture levels before installation of drainage with after drainage soil moisture levels on the right. The dotted line represents the drain tile installation. The darker the blue the higher the soil moisture.