Precision Turfgrass Management for athletic fields

PRECISION TURFGRASS MANAGEMENT (PTM) is a new concept for the turfgrass industry; but, it is based on the same principles as Precision Agriculture (PA), which has been evolving since the early 1990's. Both PTM and PA are based on these foundational principles:

• Site-specific management is the first premise of PA and PTM, the application of inputs (water, fertilizer, cultivation operations, salinity leaching fraction, etc.) *only where needed, when needed, and at the amount needed*. The idea is to foster more precise and efficient application of inputs by management on a smaller area basis than the current practice, such as at the single irrigation head area of influence or a sub-area on a sports field.

• "Intensive" site-specific information is necessary to make wise site-specific decisions. Site sampling is across the whole area, not just selected locations, and on a close sample-grid in order to define the degree and nature of spatial variability for all measured parameters.

• Key soil and plant properties must both be measured to allow accurate definition of spatial variability and to allow investigation of the relationships of measured parameters. For example, PA did not rapidly advance until mobile platform devices were developed that could determine key soil factors that could be related to plant data from remote sensing or crop yield mapping.

• Mobile, multiple-sensor devices are necessary to measure multiple factors in a timely manner on a close spacing and across the whole site. Unfortunately, the mobile devices developed for PA are not well-adapted to turfgrass situations, so lack of appropriate devices has hindered PTM development.

• All data are GPS-labeled (global positioning system), which allows the data to be imported into powerful geographic information system (GIS) programs for geostatistical analysis, comparing measured parameters at specific locations, and in order to develop detailed map presentation.

Recently, the Toro Company has developed mobile, multiple-sensor units specifically designed for turfgrass sites that supports several PTM field applications that are discussed later (Figure 1, top). The Toro Precision Sense 6000 device has a mapping speed of 2 mph, which covers about 2.5 acres per hour using a grid of 8 x 8 feet sample grid or approximately 900 samples per high school football field.

Parameters for Performance Testing of Sport Fields

COMPREHENSIVE Site-Assessment parameters that can be determined with mobile PTM devices are noted by a * for currently available devices or with a ** for those with a high potential for a device to be developed in near future.

Soil Surface Characteristics. Each determination should be conducted under two field conditions, namely: during dry period with irrigation system is used; and field capacity such after a rain to produce field capacity conditions across the field.

• Surface hardness/resiliency (Clegg Impact Tester)*
• Surface hardness/compaction. Surface penetrometer (< 1.0 inch)*; deep
• penetrometer (4 inch)*
• Surface levelness. Any minor or major depressions**
• Traction (torsion device with twisting action)**
• Shear strength/stress (divot device)**
• Soil moisture content – surface 0-4 inches*

SOIL PROFILE

• Soil type and clay type
• Soil physical lab analysis
• Profile description. Surface or subsurface layers
• Infiltration
• Surface drainage – slope, contouring patterns (flat field, crowned, pocketed);
• Subsurface drainage – tiles, slit trenching
• Soil fertility tests

TURFGRASS COVER

• Turf type
• Turf uniformity and density**
• Grass sward height
• Stress indice – NDVI (plant density and color; degree of stress)*
• Bare ground – precent, wear patterns*
• Weeds – precent and types
• Rooting depth
• Thatch or mat

IRRIGATION WATER AUDIT

First Phase – system maintenance

• Evaluate and "maximize" system performance
• Determine head to head spacing measurements and effect on water distribution*
• Determine malfunctioning sprinklers, nozzles, system pressure, head alignment, etc. *
• Scheduling settings and capability
• Irrigation water quality test

Second Phase – water distribution (two options)

• Catch-can assessment (traditional water audit approach) – determines water distribution as affected by irrigation system design and performance
• Soil moisture distribution based water audit (i.e., new soil water audit approach) using GPS, GIS, mobile sensor platforms* – determine soil moisture spatial distribution as affected by irrigation system, soil texture/organic matter content, wind, drainage, and any factor affecting soil moisture content.

Fixtures and Surrounds. Factors that may affect player safety.
• Goals, fences, etc
• Sprinkler placement & maintenance
• Surrounds – spatial mapping may be of use in some cases, drainage

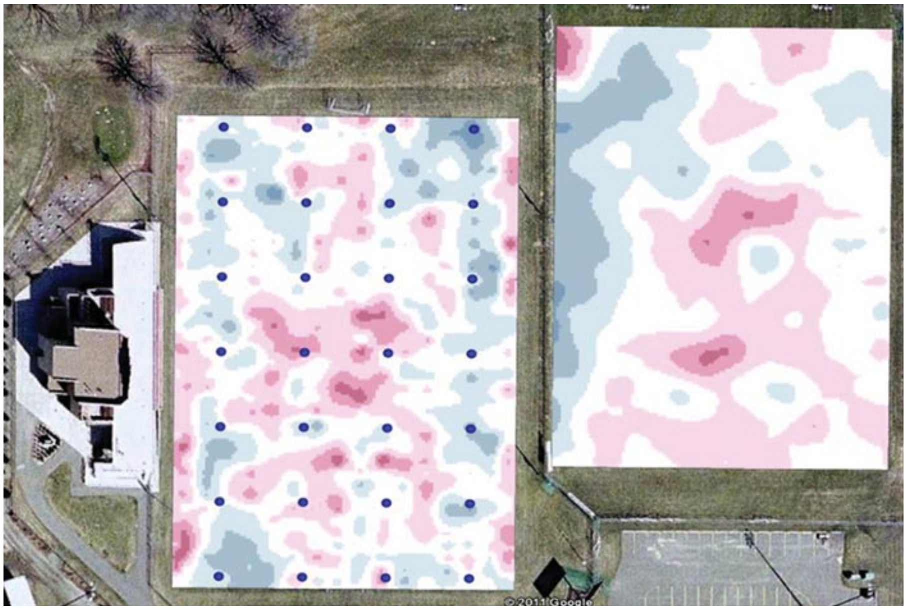
>> **Figure 1. MOBILE SPATIAL MAPPING** devices for sports fields. Top: mulitple sensor device to map soil moisture, salinty, penetrometer resistance, turf quality, and topographic relief. Bottom: accelerometer device that is similar to the Clegg Accelerometer to determine surface hardness (images courtesy of The Toro Co.).

The multiple-sensor device determines several parameters, all with GPS labeling, namely: a) soil volumetric water content (%VWC) in the surface 0 to 4 inch zone; b) soil salinity in the surface 0 to 4 inches; c) surface hardness by penetration resistance as force to insert the probes in top 0 to 4 inch; d) plant performance by normalized difference vegetative index (NDVI), which is a measure of plant density and color; and e) topography slope and aspect at one foot intervals using current GPS data, but more refined topography information is possible with more expensive GPS units. Additionally, a mobile accelerometer similar to a Clegg Impact Soil Tester is in final testing and other measurement devices are in development (traction, shear, surface levelness, etc.) that can be attached to the mobile platform (Figure 1, bottom).

APPLICATIONS OF PTM IN SPORTS TURF

Performance Testing and New Soil-Based Water Audit Applications. An evident application of the scientific methods and protocols of PTM to sport fields would be performance testing, the determination of key surface conditions for various purposes, including: a) assessing current conditions relative to player safety and field playability (benchmarking); b) developing field standards; c) guiding maintenance operations; and d) as a key component in formulating a site-specific, comprehensive "sustainable sports turf management program."

Determining surface standards is not a new research area, but started with considerable efforts in the 1980's and continues to the



>> **Figure 2. SOIL HARDNESS** determined by the Toro accelerometer presented in standard deviation format maps that illustrate the lowest and highest hardness areas in a field. These can often be related to soil moisture and traffic patterns. Blue dots are irrigation heads.

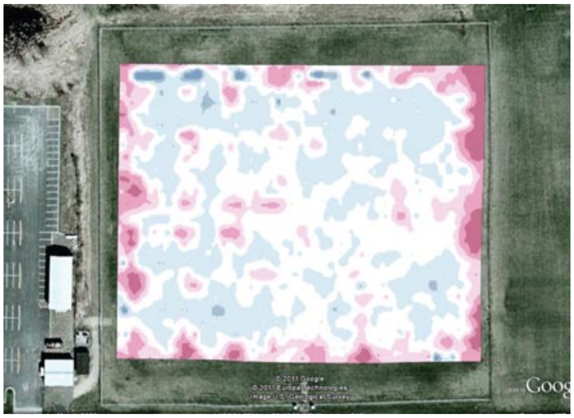
current time. However, in recent times the term "performance testing" has been used to describe assessment of surface conditions of sport fields.

Regardless of the terms used, a common theme of almost all surface characterization research to date has been to sample only 4 to 6 sites on a sports field due to: the necessity of using several individual hand-held instruments to obtain the necessary multiple soil and plant information; difficulty in inserting hand-held instruments into the soil surface; and high labor/time/cost requirements for sampling which precluded closer grid-sampling. These limitations are reflected in current approaches for performance testing such as the PASS system which is low tech but also results in much less information.

An exception of using only a few sample sites is a study by Miller on hardness of soccer fields where an 80 sample grid was used and geostatistical analysis techniques were applied, but only Clegg Impact hardness was measured. There has also been the occasional use of mobile spectral reflectance devices to determine plant performance primarily as NDVI across the whole sport field surface area, but without associated soil data. The PTM approaches and technology provide the opportunity for performance testing to evolve to a more geospatially precise assessment of sports field playing surfaces along with better mathematical treatment of relationships of measured parameters and detailed GIS-based visual presentations in spatial maps (Figure 2).

An overview of the site information obtained in a comprehensive, sports field site-assessment can aid in understanding how PTM concepts and technology can be integrated into performance testing. Henderson and Stiles et al. provide excellent reviews of various hand-held devices that have been used for surface assessment. Of the soil surface characteristics, soil hardness, traction, and shear strength are the most important factors for player safety and playability. Soil hardness as determined by a Clegg Impact Tester or by penetrometer resistance is a function of soil moisture (most important factor), compaction, percent clay, thatch/mat, and soil organic matter content. As soil moisture decreases below field capacity, soil hardness dramatically increases. Thus, spatial variability in soil hardness should first be determined under normal irrigation conditions during dry periods since uniformity of irrigation water application, as affected by system design and scheduling, dramatically influences soil moisture spatial distribution, and thereby, soil hardness. But, to determine how soil hardness is affected by traffic-induced soil compaction, data should be obtained at field capacity, i.e. to eliminate the influence of irrigation system on soil moisture uniformity. Soil compaction spatial variability is a function of traffic patterns, soil type, and soil structure. Traction and shear strength are also strongly affected by soil moisture as well as grass type, degree of coverage, thatch/mat/OM content, soil texture, and soil structure (compaction). Thus, traction and shear strength should also be determined under both drier and field capacity conditions.

Because soil moisture has such a dominant influence on soil hardness, traction and shear strength, a new, soil-water audit approach is especially useful for investigating the spatial relationships of soil moisture level versus these surface characteristics (Figures 3, 4). The new water audit is based on spatial mapping with the Toro Precision Sense 6000 of soil VWC during a dry-period when the irrigation system uniformity of water application would be exhibited. In contrast to the traditional catch-can audit, the soil VWC-based audit considers any factor influencing soil moisture distribution (irrigation system design and performance, wind distortion, runoff, high ET areas, etc.) and mapping is of the whole area and surrounds if necessary. A proprietary GIS-based software program allows geostatistical analysis of spatial variability of soil VWC and other measured parameters as well as GIS map display at three critical spatial levels, which are: a) across the whole sports field (Figure 3); b)



>> **Figure 3. SOIL MOISTURE** variability of a soccer field presented in standard deviation format to reveal the areas with the lowest and highest soil moisture (see std dev legend). The arrow identifies irrigation head No. 13.

within the zone of influence of each individual irrigation head to assess any head distribution problems and provide insight into potential causes (Figure 4); and c) assessing head spacing and system performance issues. The software program has been developed as a practical decision-support system to provide information on how uniform is soil VWC status (and all other measured parameters) at these spatial levels and to generate recommend corrective measures or fixes at each spatial level in order to enhance water application efficiency. If an irrigation system is not well-designed, the degree and nature of design flaws are characterized and illustrated. For practical and cost-effective use of multiple-sensor, mobile PTM platform information, decision-support systems software such as described is critical in order for large quantities of data to be processed, analyzed, and presented in a timely manner.

On non-sports field sites, the soil moisture-based water audit would be used to assess water-use efficiency and conservation. But, for sport fields, of most importance is the spatial variability in soil moisture as related to the player safety and field playability factors of soil hardness, traction, and shear strength; while still receiving the other water audit benefits. Plant performance can also be assessed by spectral reflectance (NDVI) and possibly mobile digital imaging devices in the future. Spatial differences in NDVI can be related to traffic patterns (wear and soil compaction aspects) as well as soil moisture distribution.

OTHER PTM APPLICATIONS FOR SPORTS FIELDS

In addition to performance testing and soil-based water audit applications, site-specific cultivation and salinity mapping are other applications of PTM applicable to sport fields. Penetration resistance data obtained at field capacity can determine areas requiring cultivation. The salinity data on sites with saline irrigation water can be used to determine spatial variability of soil salinity and aid in developing site-specific leaching programs. Surface hardness of infill systems has also been investigated on a preliminary basis. Over time, other measurement devices such as the ones identified in the sidebar will likely be developed that will allow other PTM field applications.

Performance testing on sports fields can be significantly advanced by using PTM concepts and technology. Of special importance is to move beyond the practice of sport field “site-assessment” being based on only 4 to 6 sample areas per field and the lack of exploring inter-relationships of soil surface characteristics. ■

Dr. Robert N. Carrow is with the Crop and Soil Science Dept., University of Georgia-Griffin Campus; Dr. Van Cline is Toro’s manager of agronomics and turf. *The authors would like to acknowledge The Center for Advanced Turfgrass Technology for research funds and Kathy Rice of the CATT for her expertise in development of the Decision Support System software package.*