Monitoring Spatial Variability in Soil Properties and Turfgrass Stress: Applications and Protocols

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Precision Turfgrass Management (PTM)

Spatial and temporal variability of soil, climatic, plant, and irrigation application aspects are challenges for traditional agriculture and turfgrass/landscape sites. Precision Agriculture (PA) evolved as a means to facilitate site-specific management in contrast to uniform whole-field management for the purposes of: a) efficiently targeting application of inputs where, when, and at the appropriate rate in a site-specific manner; b) environmental stewardship via control of non-point source pollutant movement of fertilizers, pesticides, and salts; c) to assess and sustain soil quality, and d) to enhance crop performance (Corwin and Lesch, 2005a, 2005b). These same purposes will stimulate traditional turfgrass management toward a Precision Turfgrass Management (PTM) approach that supports sustainable practices (PTRI, 2007).

Site-specific management requires site-specific information – i.e., information from the site to make management decisions. Similar to PA, PTM must obtain accurate and timely information by integration of sensor and electronic technologies, including: global positioning systems (GPS), geographic information systems (GIS), and plant, soil, and/or climatic sensors via mobile platforms, in-place, or combinations (Johnson et al., 2003). However, there are considerable differences between PA and PTM. First, turfgrass systems allow easier access to sites, including data acquisition during dry-downs from irrigation or rainfall events; and for periodic monitoring over a season. Second, site access allows plant stress monitoring to evaluate turfgrass performance with mobile spectral units as a useful substitute for end of year crop yield (Jiang and Carrow, 2007; Bell et al., 2002). Third, specific sensor arrays or technological approaches may differ from PA. One example is the wide-spread use in PA of electromagnetic induction (EM) to determine apparent soil electrical conductivity (ECa), which provides spatial information on soil texture, moisture, and salinity depending on whether the soil is saline or non-saline (Corwin and Lesch, 2005a, 2005b). Turfgrass sites allow use of electrical resistivity (ER) with the 4-wenner array probe arrangement to determine ECa since turf does not have a dry, fallow surface and irrigated turfgrass allows ER probe contacts with little canopy penetration (Rhoades et al., 1999). Also, time-domain reflectrometry (TDR) for direct determination of volumetric water content in the surface zone is easier with a turfgrass surface than an agriculture field that may have a dry zone at the surface.

For progress to be made in PTM, it is necessary to define key, specific applications and then to develop systematic protocols to address each application, similar to the approach of Lesch and Corwin (2005a, 2005b) and Yan et al. (2007) in PA. While a number of applications of spatial mapping are possible within PTM, we will focus on three major issues, namely: water-use efficiency/conservation, soil salinity, and soil compaction.

Applications

Water-Use Efficiency/Conservation. Water-use efficiency/conservation is a dominant environmental issue confronting the turfgrass and irrigation industries (Kenna and Beard, 2007). Mobile spatial mapping of site conditions has potential for PTM, especially for enhancing water-use efficiency and conservation on complex sites with a high degree of spatial and temporal variability. To achieve progress in this area, we identified six specific field applications for spatial mapping that would significantly improve water management. Initially, the emphasis may be on golf courses or other complex sites since they exhibit a high degree of soil, plant, environmental, and irrigation-based variability and success in this arena would allow application to other less challenging sites. The six related but specific field applications are:

1. Use of mapping information to identify relatively easy-to-correct changes in irrigation design and/or scheduling for uniformity of water application or soil status;
2. Defining site-specific management units (SSMU) on non-saline sites – SSMU information is essential to achieve the purposes of PTM stated earlier as well as to assist irrigation scheduling, aid in evaluating efficiency of the irrigation system, and correct in-place sensor placement.
3. For current irrigation systems, evaluation of system design across the whole site for degree of uniformity of water application (distribution uniformity, DU) based on soil moisture distribution rather than the traditional catch-can approach to determine if the system is efficient – i.e. the core of a *New WaterAudit approach* that would entail integrating field applications 1, 2, 3, and 5.
4. For newly installed irrigation systems, use the New WaterAudit approach for assessment of design for uniformity (i.e. incentive for better design) a few weeks after turf establishment; and as a tool to aid turf managers in irrigation scheduling and to maximize the use of their new system in the least amount of time after installation;
5. Determining the best locations (key indicator sites) for placement of in-situ sensor arrays within representative SSMU areas. Carefully selected sites for in-place sensors would allow real-time and more robust on-going data with the least number of sensor locations.
6. Use of the mobile spectral mapping during routine mowing to assess system problems from either equipment malfunction or scheduling.

By focusing on individual issues/problems (i.e., field applications) for spatial and temporal mapping of turfgrass sites, this aids in formulating appropriate procedural protocols for each application. Protocols can differ somewhat depending on the objectives for each specific field application and will be discussed later.

Salinity. Salinity is an increasing issue on turfgrass sites due to use of irrigation water sources that are often more saline than in the past, development of more salt-tolerant turfgrasses such as *Paspalum vaginatum* (seashore paspalum), and golf courses established on coastal sites (Duncan and Carrow, 1999; Carrow and Duncan, 1998). Important field applications of spatial and temporal mapping for saline sites are:

- All of the field applications noted in the water conservation section are just as important for salinity management since efficient and effective leaching is the key management strategy for saline sites (Carrow et al., 2000). Irrigation system design for uniformity and flexibility coupled with efficient scheduling are essential necessary for good leaching.
- However, prior to leaching, it is important to determine spatial distribution of soluble salts across the landscape and within the soil profile (Cassel S., 2007). Additionally, mapping over time can determine temporal changes in salt distribution patterns. Mobile salinity mapping assists in identifying where to leach, how much water to apply (minimal leaching requirement), and whether leaching is effective. This is a *New SaltAudit* approach.

Soil Compaction. On recreational sites soil compaction is a primary management problem that affects water and salinity movement and retention (Carrow and Petrovic, 1992). Mobile platforms to spatially map soil compaction could aid in site-specific cultivation and where irrigation scheduling may need to be altered.

Protocols

In 2003, a USDA-ARS sponsored workshop on Precision Agriculture concluded that "protocols for conducting geo-referenced field-scale ECa surveys and guidelines for interpreting the ECa measurements are needed to insure reliability, consistency, and compatibility of data" (Corwin and Lesch, 2005a). Based on this need, a survey protocol for the ECa approach in PA to determine soil spatial variability and define SSMUs was developed by Corwin and Lesch (2005a) along with a case study (Corwin and Lesch, 2005b). The term "protocol" was used in a very broad sense to refer to all aspects necessary to achieve detailed site assessment information. The PA protocol categories are applicable to PTM and provide a grid for focusing research efforts. With some change to reflect a PTM situation, the procedural protocols are:

- Mobilized Measurement Equipment.
- Site Description/Goals and Geo-Referenced Data Collection with the mobile units.
- Soil Sampling Design, Sampling, and Soil Core Analysis for validation of SSMU areas and to determine SSMU soil chemical and physical characteristics.
- GIS Database Development and Graphic Display
- Descriptive and Spatial Statistical Protocols
- Display, Reporting, and Interpretation Protocols for Information Packaging directed to the end-user in a concise, accurate fashion.
- Information Transfer System Protocols.

Protocol details will differ for PTM compared to PA, and protocols will also differ to some extent for each field application. As with any new technology or approach, it is necessary to focus onto real-world problems – i.e., field applications. Therefore, we would suggest systematic development of detailed protocols and case studies for each field situation within the various applications (water conservation, salinity, soil compaction)

The first step toward rapid spatial mapping of large, complex turfgrass areas is development of mobile platform equipment. We have developed two mobile devices each with GPS units. The first device is for use on non-saline sites with capability for: a) rapid measurement of surface zone volumetric water content (VWC). VWC data can be used to map spatial VWC, evapotranspiration (ET) patterns, and determination of Coefficient of Uniformity (CU) for VWC (Dukes et al., 2006); b) turf performance or stress by NDVI (normalized differential vegetative) using spectral reflectance; and c) penetrometer resistance (PR) for soil compaction mapping. A second device has the capability for: a) determination of apparent soil conductivity (ECa) using ER and 4-wenner probe array for multiple soil depths, and b) turf performance by NDVI by spectral reflectance. Within PA and PTM, ECa can be used to estimate soil texture and soil moisture on non-saline sites, and salinity on saline sites.

This equipment or similar spatial and temporal mapping devices developed by other scientists will provide the means to rapidly obtain spatial data on turfgrass sites and address the remaining protocols for the specific field applications previously noted in the water conservation, salinity, and soil compaction areas. Combining systematic protocols with real-world case studies for each of these field applications will be major steps toward implementation of the PTM approach for water, salinity, and soil compaction management.

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