CHAPTER 2

CONSTRUCTION OF A SOIL QUALITY INDEX FOR TURF GRASS ECOSYSTEMS

2.1 INTRODUCTION

Golf courses are highly managed ecosystems that can greatly impact our natural environment. With the recent boom in golf course construction (more than 400 new golf courses are built annually) the environmental impact from golf course management is a significant concern. More than 17,000 golf courses exist today in the United States, a 28 % increase since 1986, covering more than 1.2 million hectares (National Golf Foundation, 2002). Golf course managers use a significant amount of fertilizers and chemicals to keep the grass green and healthy. Improper use of chemicals in their intensely managed systems can have adverse impacts on environmental resources such as soil, water and wildlife, but little research exists on the impact of golf courses and their management on soil quality. Golf courses provide a unique, living laboratory for the study and monitoring of environmental sustainability (Thien et al., 2001). Golf course superintendents are constantly looking for ways to improve the aesthetics and performance of their golf courses, while being environmentally conscious and improving ecological sustainability.

The challenge has been and continues to be the development and implementation of a comprehensive all-encompassing soil quality index. Other resources such as air and water have established thresholds and standards that many wish to apply to soil science. However, while the thought of applying the same knowledge and standards to the soil resource is a bit naive, there are ways and methods of assessing soil quality and producing standards on a local scale. The recent construction of a new PGA golf course in Manhattan, KS provided a unique opportunity to monitor the impact of organic amendments on soil quality and to implement the use of spider/radar graphs to reflect the status of multiple soil quality indicators. The next two chapters will focus on monitoring changes in soil quality in a turf (golf course) ecosystem at Colbert Hills Golf Course. The goal will be to produce a comprehensive soil quality index for specific soils that are under similar management conditions.

The objective of the first study in chapter three is to quantify indicators of soil quality and monitor their change under application of swine and dairy compost on golf green and tee box soils. The application of organic composts on golf course fairways, greens, and tee boxes to improve environmental quality has been practiced since the early 1900's (Piper & Oakley, 1917; Welton, 1930). The disposal of animal waste compost can present problems and even cause significant environmental problems. However, if properly used, animal waste composts may offer a safe method of disposal while also supplementing fertilizer use and improving soil quality. A soil quality index will be utilized to analyze the status of numerous physical, chemical, and biological soil quality indicators and to monitor any changes from the application of animal waste compost.

The objectives of the second study in chapter four is to quantify indicators of soil quality and follow their change during the construction and establishment of a golf course on a natural grassland site. Little research has been conducted on the impact of golf course construction on the soil ecosystem. A suite of physical, chemical, and biological soil quality indicators were monitored and developed into a composite soil quality rating.

Both of these studies will use a multiple indexing system and the integration of a spider-radar graph to monitor and visually represent the status of numerous soil quality indicators.

2.2 CONSTRUCTING A COMPOSITE SOIL QUALITY INDEX

The soil quality index developed for the two studies conducted at Colbert Hills Golf Course will utilize control charts and their conversion to spider/radar graphs. The six-step approach to soil quality research explained in the previous chapter will be used to produce a soil quality index. These six steps have been outlined and diagramed in a flow chart presented in Figure 2.1.

2.2.1. Identification of Soil Functions.

The development of a soil quality index depends greatly on the function of soil that is being analyzed. The creation of a soil quality index for golf courses assesses the functions of the soil and how golf course management may impact soil and water resources. The first step, in the six-step approach to soil quality research described by Thien (1998), is to identify the appropriate soil functions for a given land-use. The soil functions identified with the growth and development of turf are (Thien, 1998):

1. Growth – provide nutrients, air, water, and root zone for grass growth
2. Compaction – withstand foot and vehicle traffic without deterioration of other soil properties and processes
3. Soil Life – provide for a healthy microbiological balance

4. Environmental Buffer – accommodate a variety of soil amendments without contributing to the pollution of air or water resources
5. Cycles – maintain natural participation in carbon (energy), nutrient and water cycles

This list provides a starting point for the identification and selection of key indicators to measure soil quality. Soil quality indicators are then chosen to reflect and measure the soils ability to carry out each function. Soil quality indicators are chosen from a wide array of biological, chemical, and physical soil properties. Some soil properties can be used as indicators for multiple soil functions. In Figure 2.1, this process is shown, as numerous soil properties are divided up to reflect the ability of the soil to carry out each function.

2.2.2. Selection of Appropriate Indicators to Evaluate Soil Quality

The next step is to select those soil properties that will reflect the quality of the soil based on the intended function. The minimal data set proposed by Doran and Parkin (1996) and the suggested additional indicators proposed by Sims and Pierzynski (2000) when compost is applied were considered in the selection process. The physical, chemical, and biological soil quality indicators selected for both studies are listed in Table 2.1. Other factors such as water content, fertilizer application, and herbicide application were also monitored and reported when relevant.

Table 2.1. Selected soil biological, chemical, and physical indicators to measure soil quality on turf soil

	---Soil Characteristic---	
Biological	**Physical**	**Chemical**
Microbial biomass C and N	Soil texture	Total organic C and N
Mineralizable C and N	Soil bulk density	pH (1:1 water method)
Soil respiration	Soil porosity	pH (2:1 $CaCl_2$ method)
Biomass C/Total org. C ratio	Soil temperature	Electrical conductivity
Biomass N/Total org. N ratio	Aggregate stability	CEC
Potential mineralizable C and N		Mg, K, Ca saturation
		Exchangeable Sodium
		Free $CaCO_3$

2.2.3. Measurement of Indicator Status

Data was collected over a six-month period for the focused compost study and two years for the broad turf ecosystem study. However, the creation of a soil quality index is a dynamic and changing system that should not be limited to short term data. The soil quality index strength lies within consistent data collection over a long period of time. With time new indicators may develop and long-term trends can be seen.

2.2.4. Assessment of Indicator Status

2.2.4.1. Establishment of Control Chart Indices

Control charts compare an indicator value to ranges that delimit sustainable and degrading conditions. Setting appropriate target boundaries delineating sustainability and degradation is key. In some cases only minimum or maximum control limits may be appropriate. Control limits can be established with the assistance of state extension services, literature surveys, management experience, model predictions, consultants, regulations, or other sources. In many cases more research is needed to establish appropriate boundaries. Control charts are presented in the results and discussion section for each study. The upper and lower control limits are summarized in Tables 3.3 and 4.2. The greatest limit to establishing a composite soil quality index lies in the determination of the upper and lower limits of soil quality for a particular indicator. Soil biological indicators as well as some chemical indicators such as exchangeable sodium have no determined upper or lower bounds or as the case with Ca:K ratio one of the limits may be easily established, however the other boundary may be more arbitrary.

2.2.4.2 Transformation of Multiple Indices into Environmental Quality Evaluation Graphs

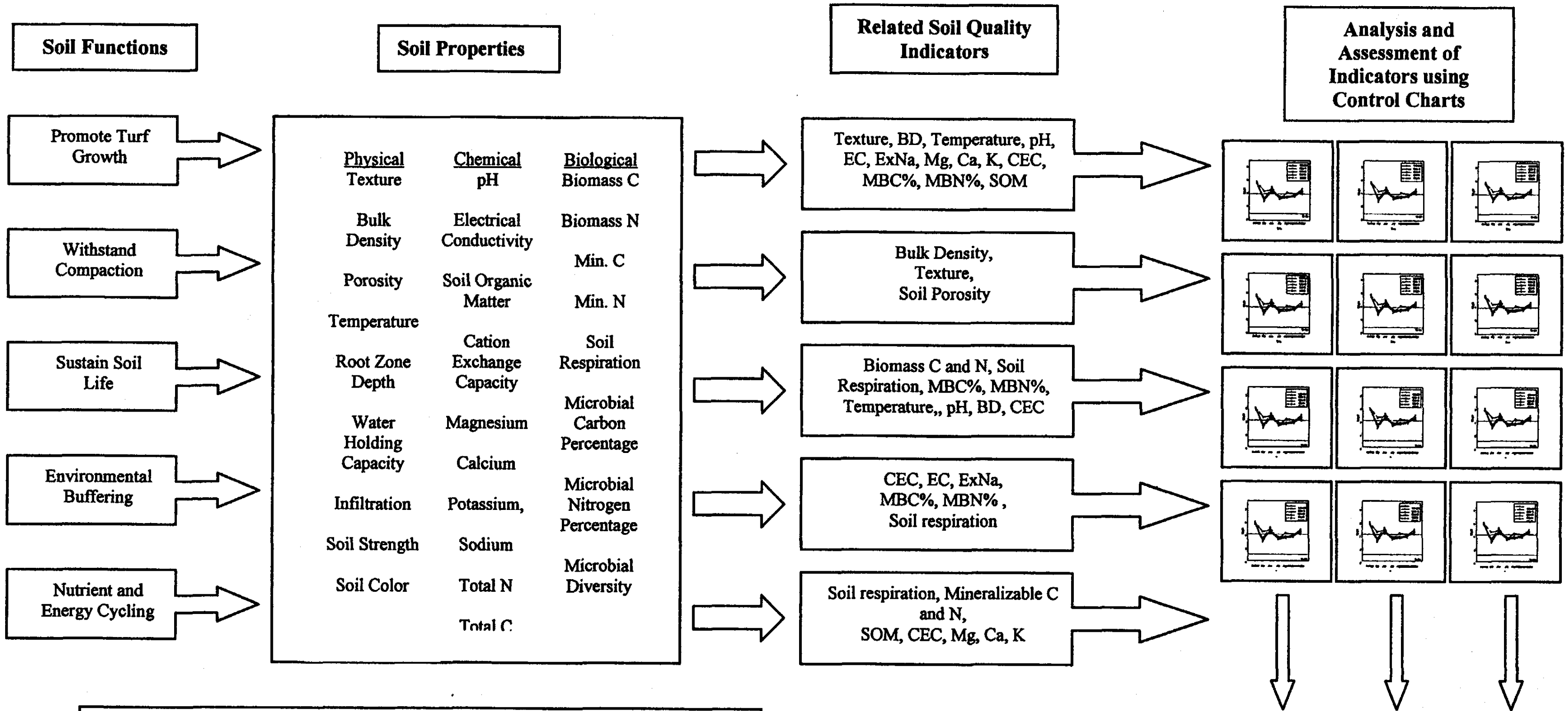
In this step, indices from any number of quality control charts are normalized onto a "spider radar" graph. This format produces an easy-to-understand, visual representation of environmental quality. The spider radar graph presented in Figure 2.2 illustrates how data from seventeen different control charts can be incorporated into one standardized index. These spider radar graphs give users a composite environmental quality evaluation by showing how well multiple indices conform to the limits of each indicator's sustainable range (as compared to scanning through many control charts). Indices (purple dots) that lie within their target range (zone between red lines) show soil indicators operating in a sustainable mode. Indices lying outside their target range represent an indicator in need of remediation. A high quality ecosystem would show a nearly circular radar image (colored area outline by purple dots) within the sustainable range. Degraded functions lying outside the sustainable range skew the radar image and alert the superintendent or manager to begin remediation. Outer arcs group indicators into various soil quality areas (physical, chemical, and biological).

2.2.5. Selection of Appropriate Remedial Management for Degraded Indicators

Based on which indicators are skewed for a given time, appropriate changes in management such as the application of fertilizers, additional irrigation, or reduction in pesticides may be needed to correct various soil parameters and to reach ideal or acceptable conditions. Golf course managers should not only base remedial management on values obtained for a given time, but also on trends observed for indicators over a period time. Monitoring trends in soil quality indicators over time can account for possible fluctuations in indicator values observed for a given time period.

2.2.6. Monitoring of Indicators Over Time

Successful remediation of soil degradation can be determined by continuous monitoring of soil quality indicators. Monitoring indicators over a long period of time will allow for better interpretation of spider/radar graphs that show changes in soil quality indicators over time. Additionally, monitoring over time may stress the addition of other soil or environmental parameters that need to be monitored.



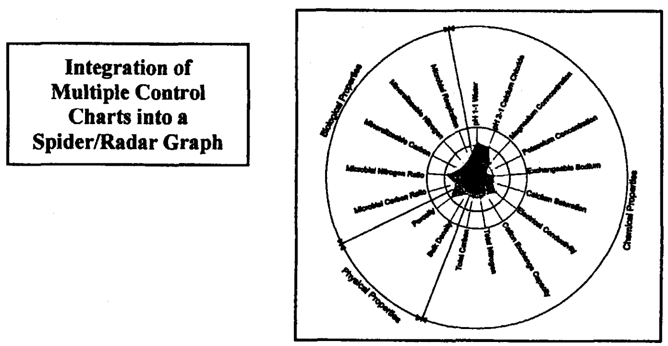


Figure 2.1 – Flow chart illustrating the stages of soil quality research. First, specific soil functions are identified. Next, appropriate soil quality indicators are selected and connected to specific soil functions. Then, indicators are measured and analyzed using control charts. Numerous control charts are then integrated into a spider radar graph to give a composite picture of soil quality.

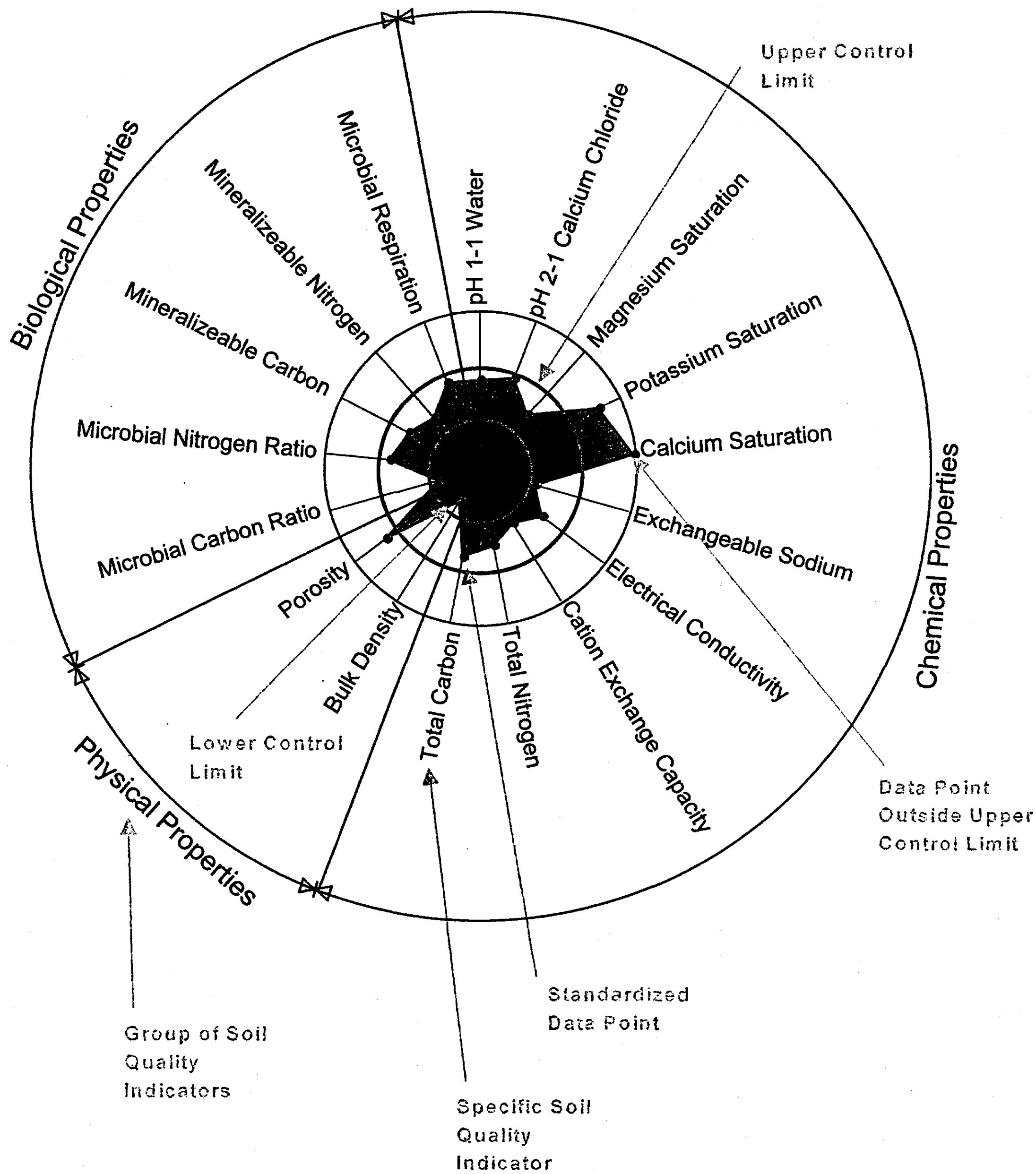


Figure 2.2. The use of a spider/radar graph to represent the status of numerous soil quality indicators.