CHAPTER 4

IMPACT OF GOLF COURSE CONSTRUCTION AND MANAGEMENT ON TURF SOIL QUALITY

4.1 ABSTRACT

A method for evaluating environmental quality of a large-scale landscape, such as golf courses, that bridge scientific research and public use is in great demand. A study was conducted to monitor soil quality criteria and devise a system to assess the long-term impact and sustainability of golf courses on the soil environment. Research was initiated in 1997-1998 at a time that a future golf course site was in a natural grassland condition. In 1998-1999 the course was in a construction phase with extensive modification of the original soil in all fairways.

During the next several years the same sites were sampled each spring and fall with the goal to quantify indicators of soil quality and follow their change during the construction and establishment of the golf course. Using a multiple indexing system, soil quality control charts were used to produce spider/radar graphs, which, in turn, were used to quantify numerous soil quality indicators. Since the completion of construction numerous changes to pre-construction conditions were observed. The 10^{th} and 18^{th} fairways contained excess carbonates, which resulted in high soil pH and high calcium saturation levels. Soluble salts were found to be within the control limits for sustainability, however, these levels were well above pre-construction conditions. Soil bulk density and porosity were also within the allowable control limits, however, the 13^{th} fairway had bulk density values below the lower control limit for turf grasses but similar

to pre-condition levels of natural tall and short prairie grasses. Aggregate stability was initially quite low after construction but over the course of two years gradually increased to levels near pre-construction conditions. Microbial properties fluctuated over the two years after construction. However, potentially mineralizable C and N, microbial biomass C and N, and total C and N were lower compared to pre-construction and undisturbed soil conditions. These properties may take years to recover or may never return to pre-construction conditions.

While numerous soil quality indicators did degrade over the course of construction and post construction, the use of a multiple indexing system proved useful in the composite evaluation of multiple soil quality indicators. Further research and data collection on these indicators will help to strengthen the use of spider/radar graphs as an index to measure multiple indicators of environmental quality and provide soil managers with a reliable view of their soils' quality status.

4.2 OBJECTIVE

The objectives of this study were to:

1. Monitor the change of numerous soil quality indicators before, during and after construction of a golf course on a natural grassland site.

And

2. Assess the combined status of multiple soil quality indicators by producing a soil quality index using spider/radar graphs.

4.3 MATERIALS AND METHODS

4.3.1 Site Description

The experimental site was located on the main course at Colbert Hills Golf Course in Manhattan, Kansas. Seven areas on the fairway of six different holes were monitored from pre construction, during construction, and a two-year period after construction. The fairway areas received extensive modification from native soil conditions. A base layer typically consisting of slightly weathered shale and fractured limestone was put in place to shape each fairway according to the course specifications. In some areas, the base layer consisted of materials quite high in silt and clay content. Topsoil was brought in from several areas around Kansas and a 15-30 cm layer of topsoil was placed above the base layer. The soil texture of the fairways is mainly silty clay loam, with a significant amount of silt loam and a few areas having a silty clay texture. The fairways were sodded with a warm season grass, Zoysiagrass. Zoysiagrass is known as a low maintence turfgrass with a high heat tolerance and low weed content (Brede, 2000). The seven research areas are on the fairways of the back 9 holes and are located on the holes 10, 12, 13, 14, 15, and 18. Two sampling sites are located on hole 12, one is near the tee box and is referred as CH-12T and the other is located in the middle of the fairway and is referred to as CH-12F in tables and diagrams. Figure 4.1 is a diagram of the Colbert Hills development site with the seven sampling sites identified by their ID number. The soil map of the original soils located on the Colbert Hills Golf Course

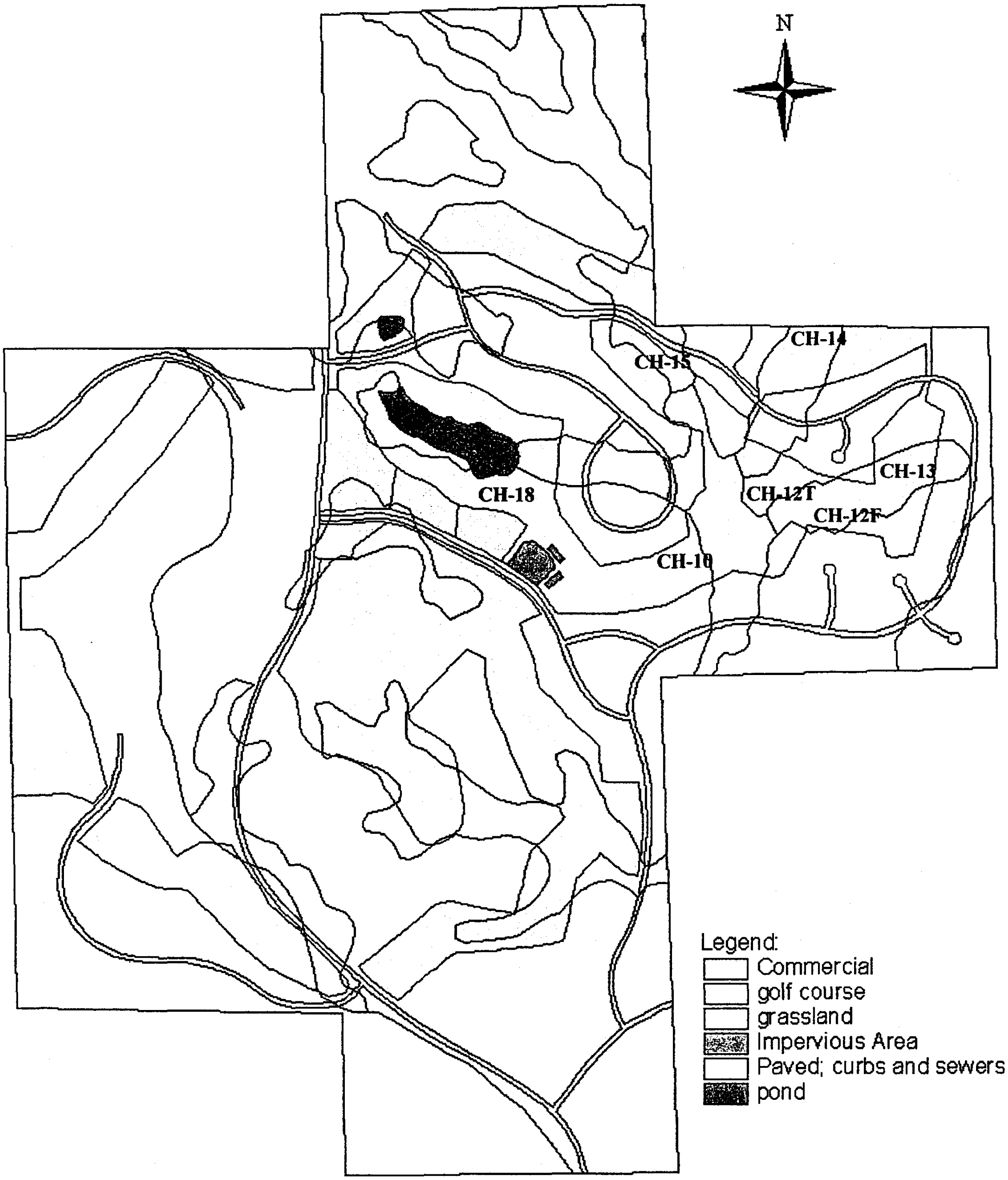

Figure 4.1. Land development breakdown and location of sampling sites for Colbert Hills Golf Course (modified from Su, 2002).

4.3.2 Soil Sampling and Analysis

Soil cores were collected before construction (1997), and every six months, during the months of May and October, from October 1999 to present (October 2001). An additional sampling was conducted in July 2000 in areas not disturbed by golf course construction. Three sets of 3 to 4 (9-10 total) 12 x 24 cm cores were removed from random locations in each area using a Giddings tractor mounted soil sampler. The thatch was removed and each core was divided into an upper and lower 12-cm sub sample cores. An additional three cores (5-cm x 5-cm) were removed for bulk density analysis. The sampling holes were filled with USGA standardized sand and covered with the thatch removed from the samples. Each of the three sets of soil cores were then split again into two sub-sets. One subset was sieved using an 8.00-cm and 4.75-cm sieve. Material collected on the 8.00-cm sieve and material that passed through the 4.75-cm sieve was dried and grounded for chemical analysis. The material collected on the 4.75-cm sieve was kept for aggregate stability. The other subset was sieved using a 4.75 mm sieve and kept in 5° C cold storage for later microbial analysis. Microbial analysis was performed within 10 days of sample collection. The soil analyses performed and methods used for each soil quality indicator are referenced in Table 4.1.

Table 4.1. Physical, Chemical, and Biological soil quality indicators measured on the fairway soils and the referred method.

Property	Method	Reference	Notes
Physical propterties			
Soil Texture	Pipet method	Kilmer & Alexander (1949); Soil Survey Laboratory Staff (1996)	
Bulk denisty	Core method	Blake & Hartge (1986)	
Porosity	Core method	Danielson & Sutherland (1986)	Calculated from bulk denisty and assumed particle density of 2.65 g cm-3
Aggregate Stability	Dry & Wet Disintegration	Kemper & Rosenau (1986)	6 sieves used for wet disintegration; 8.00 mm (No. 5/16), 4.75 mm (No. 4), 2.00 mm (No. 10), 1.00 mm (No. 18), 0.50 (No. 35), and 0.212 (No. 70)
Biological properties			
Microbial Biomass C & N	Chloroform Fumigation Incubation Method	Jenkinson & Powlson (1976); Rice et al. (1996) Anderson & Domsch (1978); Horwath & Paul (1994);	Field moisture content used
Mineralizable C & N	Chloroform Fumigation Incubation Method	Jenkinson & Powlson (1976); Anderson & Domsch (1978);Horwath & Paul (1994);	Field moisture content used
Potential Mineralizable C & N		Cabrera & Kissel (1988); Garcia (1992)	
Chemical properties			
Total C & N content	Dry Combustion	Nelson & Sommers (1996); Leco Corp (1995)	CNS-2000, Leco Corp., Furance temperature at 1350^{0} C
Electrical Conductivity	Saturated Paste Method	Whitney (1998); Rhoades (1996)	
Cation Exchange Capacity	Ammonium Ion Replacement	Chapman (1965)	Ammonia extract representing CEC of the sample was analyzed by colormetric procedure on the Rapid Flow Analyzer (RFA-300)
pH	1:1 Water Method 2:1 $CaCl_2$ Method	Thomas (1996); Watson & Brown (1998) Thomas (1996); Watson & Brown (1998)	
Extractable Mg, K, Ca, Na	Ammonium Acetate Method	Warncke & Brown (1998)	A low sodium filter paper was used and analysis of extracts diluted 1:8 was done by ICP