Soil Organic Matter Reaches Equilibrium

By *Yaling Qian and Tony Koski*

Soil organic matter (SOM) is recognized as having profound influences on soil fertility, especially in sand-based root zones. SOM is interesting to turf managers because changes in it influence air-filled porosity, water retention and percolation in sand-based root zones. SOM also serves as a major reserve of plant nutrients, especially nitrogen, phosphorus, sulfur and potassium. In addition, appropriate levels of SOM in sand-based root zones may increase surface stability for putting greens.

Excessive SOM accumulation (especially when an organic matter layer is formed), however, will result in slow oxygen diffusion into the root zone and slow water movement. As a result, disease, black layer and poor rooting may follow.

Major obstacle to SOM study

One major obstacle that has prevented researchers from addressing questions of SOM change in turf systems is that SOM change is a slow process, and annual changes are generally small. Long-term experiments (over years and decades) are often necessary to document these changes.

To overcome this obstacle, we designed a study to take advantage of the historic soil-testing results from golf courses with ages ranging from about 1 year old to about 45 years old. Many golf courses analyze soils (including SOM measurement) on a regular basis and possess long-term soil testing results. Documented management activities, and other site-specific data such as weather and soil texture, are also available for many well-managed golf courses. Such information is invaluable in revealing the dynamics of SOM, and interpreting SOM changes in golf courses.

The goals of this study were to conduct a survey to compile data on soil-testing results (including SOM) from different golf courses and generate regression models to predict the rate of SOM changes and to help identify factors important to SOM changes.

Compilation of soil-test data

During 2000, 12 golf courses around the Denver area; three courses around the Fort Collins and Loveland, Colo. areas; and one course in Saratoga, Wyo., were surveyed. All soil testing results were compiled (Table 1).

The oldest golf course was 45 years old in 2000; the newest golf course was 1.5 years old. We compiled the existing soil testing results, including mineral content, cation exchange capacity (CEC), SOM and pH.

Concurrent with our compilation of the soil data, we also collected information on prior land use, grass species and type, irrigation, mowing height and frequency, fertilization and other cultivation practices. Ten courses with ages ranging from 4 to 45 years were established on native prairie, five courses with age ranging from 1.5 to 35 years were established on agricultural land, and one 5-year old course was built on a mixture of native and agricultural lands.

Turfgrasses grown in putting greens were creeping bentgrass or a mixture of creeping bentgrass and annual bluegrass. Turfgrasses grown on fairways and tees were perennial ryegrass, Kentucky bluegrass or a mixture of both. At all survey sites, irrigation was provided at approximately 75 percent to 100 percent of evapotranspiration (ET) since turf establishment.

In the fairway sites, existing soils were subjected to shaping and topsoil replacement prior to establishment. Soil series, surface texture and taxonomic classification for the 14 sites used in the fairway data were obtained with the help of two people: Ron Follett, a researcher at Soil, Plant and Nutrient Research Lab of the U.S Department of Agriculture's (USDA) Agricultural Research Service; and Michael L. Petersen, an area soil scientist at the USDA's Natural Resources Conservation Service.

Most greens and tees were constructed using the USGA method or other sand-based methods. Exceptions were greens at Valley CC and the Olde Course at Loveland, where the greens were originally established on native soil. Approximately 6 inches of sand has been added to these native soil greens over time through topdressing.

A total of 690 data sets were compiled. Servi-Tech Laboratories in Dodge City, Kan., tested 26 samples; 90 samples from the Old Baldy GC in Wyoming were tested by the Soil, Water, and Plant Testing Laboratory at Colorado State University in Fort Collins, and 574 soil samples were tested by Brookside Laboratories in New Knoxville, Ohio. The soil-testing labs provided information on analytical methods. All labs used the Walkey–Black procedure to determine SOM. Soils were sampled to a depth of 4.5 inches to 6 inches. Data were reported as percent SOM by weight. Data were analyzed to evaluate the changes of SOM content over time after establishment of turf in putting greens and fairways and to relate SOM to other soil-test variables and management regimes.

TABLE 1

Description of golf courses that participated in the study

Golf Course	Years since establishment	Prior land use
Rolling Hills CC	31	Native grassland
Ptarmigan CC	13	Native grassland
Boomerang Links	10	Agricultural land
Valley CC	45	Native grassland
Inverness GC	26	Native grassland
Hiwan CC	38	Native grassland
Murphy Creek GC	2	Agricultural land
Boulder CC	35	Native grassland
Springhill GC	22	Agricultural land
The Olde Course at Loveland	35	Agricultural land
Cattail Creek GC	9	Native grassland
Plum Creek Golf and CC	16	Native grassland
Westwoods GC	8	Native grassland
River Valley Ranch GC	5	Agricultural land
Saddle Rock GC	5	Native or agricultural land
Old Baldy GC	37	Native grassland

The findings

A quadratic model with plateau best described the changes of SOM after turfgrass establishment. Before SOM reached equilibrium, SOM under turf increased quadratically. After reaching equilibrium, SOM did not change over time under continued turfgrass management.

Putting greens: The regression shows that SOM of putting greens was .6 percent at one year after turfgrass establishment, increased to 2.7 percent at 20 years after establishment, and to 3.4 percent at 30 years after establishment.

The increase in SOM was most rapid during 30 years after establishment, with SOM gradually reaching equilibrium thereafter. The rate of increase was about .09 percent SOM/year for the linear part of the curve that extends from one year to about 30 years.

If we assume a soil bulk density of 1.6 grams per cubic centimeter, then roughly about 160 pounds SOM is added by turf to a 5,000-square-foot putting green every year for up to 30 years.

Fairways: The average SOM of fairways was 1.76 percent at one year after turfgrass establishment, increased to 3.8 percent at 20 years after establishment and was 4.2 percent at 30 years to 45 years.

The increase in SOM appears to be most rapid during the first 24 years after fairway establishment, with SOM gradually reaching equilibrium thereafter. The rate of increase was about .1 percent SOM per year for the linear part that extends from 2 years to 24 years.

Assuming a soil bulk density of 1.5 g/cm^3, roughly 35 pounds SOM per thousand square feet is added annually to fairway soils by turfgrass for the first 24 years following establishment.

Putting greens are established on sand, which has lower initial SOM than in fairways (.6 percent vs. 1.76 percent). Although the increase in SOM continued for a shorter period, fairways accumulated a higher level of SOM at equilibrium than did putting greens

(4.2 percent vs. 3.9 percent). This indicates a higher capacity for carbon stabilization in the loams and finer textured soils of fairways, compared to sand used for putting green construction and topdressing.

More frequent core cultivation (with cores often removed) and addition of low SOM sand to greens will prevent higher accumulation of SOM (compared to fairway soils).

The characteristics of turf systems, including high production and high root turnover, may contribute to the high potential to build up SOM in comparison to soils in other agricultural systems.

SOM and previous use

To determine the effect of prior land use on SOM in turfgrass, comparisons were made for land converted to golf courses (during the past 10 years) from agricultural land vs. native grassland.

The previous land use of Murphy Creek GC, Boomerang Links, River Valley Ranch GC and parts of Saddle Rock GC was agricultural, whereas those of Plum Creek Golf and CC, West Woods GC and parts of Saddle Rock GC were native short-grass prairie.

The SOM of native grasslands and agricultural lands prior to golf course establishment was not measured, and SOM content in the surface was likely significantly changed due to golf course construction. However, our results indicated that fairways converted from agricultural lands exhibited 24 percent lower SOM than fairways converted from native grasslands within 10 years following establishment.

Thus, past land use imparted a strong control on the SOM baseline where fairways are built. Numerous studies have demonstrated that intensive agricultural practices result in oxidative losses of SOM.

For example, a Texas study showed SOM in the top 4 feet of agricultural soil to be 25 percent to 43 percent less than that of native prairie sites. The initial soil conditions in fairways built on previously native grasslands may be beneficial in terms of fairway management and fertility compared to fairways established on agricultural lands.

In contrast to fairways, prior land use had little influence on SOM in putting greens. This is not surprising because putting greens are built with non-native, sand-based soils.

SOM, soil mineral content and pH

Fairways. In addition to the change of SOM over time after turf establishment, our compiled data indicates that the level of SOM was influenced by soil pH, which ranged from 6.5 to 8.3.

When pH was more than 7.3, the level of SOM decreased as soil pH increased. When soil pH was less than 7.3, SOM level was not affected by pH. As SOM increased, soil potassium levels increased.

The relationships between SOM and magnesium, CEC and calcium were not significant in fairways.

Putting greens. SOM content in putting greens was influenced by soil pH, which for all soil samples in putting greens ranged from 5.9-8.0. When pH was more than 7.1, the level of SOM decreased as soil pH increased; but when soil pH was less than 7.1, SOM level was not affected by pH.

There is a strong linear relationship between CEC and SOM; the higher SOM, the higher CEC in the putting greens. Furthermore, soil SOM was also highly correlated with soil calcium, iron, sodium and potassium content in putting greens. This suggests that the higher the SOM, the greater potassium, calcium and iron levels will be available in putting greens.

Conclusions

The rate of increase in SOM was largely linear to about 20 years to 24 years in fairways and 25 to 30 years in putting greens. Soil organic matter gradually reached equilibrium thereafter.

Our study also found that past land use often controls the SOM baseline. Fairways converted from agricultural lands exhibited 24 percent lower SOM within 10 years after turfgrass establishment than fairways converted from native grasslands.

We concluded that SOM accumulation in turf soils occurs at a significant rate at first 25 years to 30 years after establishment. A rate is comparable to SOM accumulation rates reported for U.S. land that has been placed in the conservation reserve program.

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