FEATURE ARTICLE

Global Warming and Soil Carbon Sequestration

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There is worldwide concern regarding greenhouse gas emissions and their potential effects on global warming. The Soil Science Society of America (SSSA) has published a small book of 16 chapters entitled *Soil Carbon Sequestration and the Greenhouse Effect.* It is available from SSSA under the listing of Special Publication No. 57. Summaries are given in this publication of the global trends relative to the sources and soil processes associated with carbon (C) as it relates to the greenhouse effect.

In the chapter by Professor Rattan Lal of Ohio State University, **he indicates that the atmospheric concentration of carbon dioxide has increased by about 32% from 280 ppm in the year 1700 to 370 ppm in the year 2000.** The three principle sources of this atmospheric CO_2 increase are (a) **combustion of fossil fuels** such as coal, oil, and natural gas, which currently supply 85% of the world's total energy, (b) **the industrial production of cement, lime and ammonia,** and (c) **agricultural activities** such as deforestation and biomass burning that are involved in the conversion of natural to agricultural ecosystems. **Sequestration** is the process of being separated or removed, typically in an organic complex in soils. The carbon sequestered in soil is in two primary forms: soil organic carbon (SOC) and soil inorganic carbon (SIC), with the latter occurring principally as soil carbonates. The SOC pool comprises highly active humus and relatively inert charcoal carbon, with the soil organic humus encompassing a wide range of organic substances from plant and animal residues. The carbon in the form of carbonates is particularly significant in soils in the semiarid and arid climatic regions.

Certainly, the soil carbon pool is of importance in the global carbon cycle, but unfortunately this is not widely recognized as significant by many spokespersons. An analysis revealed that **the carbon in the upper 1 meter depth of the soil profile is 3.0 times greater than the carbon in the atmospheric pool and 4.1 times the carbon in the biotic pool involving trees and other living entities.** Typically, carbon constitutes approximately 58% of the total mass of soil organic matter. Activities that reduce the soil organic carbon (SOC) pool and accentuate emissions to the atmosphere include deforestation, biomass burning, plowing, drainage, and indiscriminate use of fertilizers and lime. **Soil carbon is the second largest source of carbon emissions into the atmosphere, ranking second to fossil fuels. It is estimated that cultivated soils have lost 50% of the original soil organic carbon pool and that severely eroded soils have lost 70 to 80% of the original soil organic carbon pool.**

Soil carbon is a large and active pool that often is overlooked in terms of its interaction with the atmospheric carbon pool. There are a number of common myths about soil carbon and its role in an accelerated greenhouse effect. These myths are being perpetuated and are leading to misunderstandings. Twenty-five myths are discussed in another chapter by Professor Rattan Lal, including the following seven:

- **Emissions from soils and biotic pools have made minor contributions to atmospheric carbon dioxide enrichment.** Actually a considerable amount of the 32% increase in the atmospheric carbon dioxide concentration is attributed to depletion of soil and biotic carbon pools and represents 50% of the CO_2 emissions from fossil fuel combustion since the dawn of settled agriculture.
- **Emissions of greenhouse gases from the soil and biotic pools have been significant only since the 1950s.** Actually soil carbon emissions to the atmosphere were most significant during periods of rapid expansion in agricultural cropland. In North America this period was from 1850 to 1950, and was much earlier in Europe and certain other portions of the globe.
- **The historic loss of soil carbon is too small to warrant strategic planning for carbon re-sequestration.** This assumption is refuted above.
- **Soil erosion merely leads to carbon redistribution over the landscape.** A substantial portion of organic carbon is concentrated in the surface soil layer, which also is the most prone portion of the profile in terms of soil erosion. In the erosion process, the soil organic carbon that was previously buried within the soil becomes exposed to microbial processes and climatic elements that result in emissions to the atmosphere.
- **Sediment deposition in depressional sites and aquatic ecosystems leads to carbon sequestration.** The state of soil organic carbon buried in depressional sites such as wetlands depends on the soil and hydrological characteristics. Thus, significant portions of the carbon car-

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manure-based fertilizers, and sites with a history of infestation. Preventively spot-treating such areas with imidacloprid (Merit®), either during or up to 2 weeks after the mating flights, will control young GJB grubs soon after egg hatch, before turf damage occurs. Halofenozide (MACH 2®) does not seem to be as effective against this particular grub species. Turf managers who treat with imidacloprid in June or July for preventive control of Japanese beetle, masked chafer, or other annual grub species will suppress GJB at the same time. Imidacloprid must be applied as a preventive—it is not effective as a curative treatment after the damage appears.

Alternatively, GJB can be effectively spot-treated with a short-residual insecticide, e.g., trichlorfon (Dylox®), carbaryl (Sevin®), or bendiocarb (Turcam®), after the eggs have hatched, but while the grubs are still small (i.e., before the mounds appear). As with all grub treatments, water-in the residues to move them into the soil. Presence of young grubs can be verified beforehand by sampling with a spade or golf hole cutter. Even small GJB grubs tend to be a few inches deeper than grubs of other species. **To confirm the identification, recall that GJB is the only species that crawls on its back**.

Your options are more limited once damage from the large grubs has appeared. Raking or sweeping down the soil mounds may be adequate with light infestations. Cultural practices that enhance turf vigor will help to encourage recovery from GJB damage. Overseeding thinned, damaged areas in the autumn helps to prevent weed encroachment the following spring.

Treating with a fast-acting, short-residual soil insecticide (e.g., Dylox®) will stop the mounding and burrowing, but almost certainly will result in piles of dead grubs littering the surface (see above). **Be prepared for a messy, morning-after cleanup**—indeed, I once saw a youth soccer game canceled because of the GJB grub kill on a playing field that had been treated the evening before. In such situations, the best strategy may be to wait, and then use a preventive approach the following summer.

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ried into these depressional areas may be emitted as CO_2 or CH_4, depending on the degree of anoxia. Under reducing conditions in wetlands, methanogenesis can lead to the emission of CH_4 to the atmosphere.

- **Subsistence farming and low-input or resource-based agriculture are environmentally friendly.** It should be recognized that agricultural practices that are based on mining soil fertility will produce low returns and adversely effect the environment. The risks of soil erosion are increased by management practices that produce less ground cover and return little, if any, biomass to the soil.
- **Application of nitrogenous fertilizer leads to carbon emission due to fossil fuel used in their manufacture, transport and application.** Countering this myth, studies reveal that judicious applications of nitrogen fertilizers can lead to positive carbon balances in commercial agricultural. In other words, soil carbon sequestration occurs if the nitrogen fertility program is soundly based and judicious.
- **The net effect of irrigation on soil carbon sequestration is negative because of the power use of lifting the irrigation water and the release of carbon dioxide and carbonates brought to surface from ground water.** Contrary to this theory, judicious irrigation increases the biomass by 2 to 3 times compared with rainfed production systems and leads to additional sequestration of soil organic carbon.

Turfgrass Aspects. The authors of this book did not include the value of turfgrass vegetation in terms of potential sequestration of soil organic carbon. However, as one reads the book and as summarized in this article, **it is obvious that a turfgrass vegetative cover can be very important, and offers significant potential for the sequestration of carbon that affects global warming.** This is especially true for irrigated, judiciously fertilized turfgrass areas at higher cutting heights that enhance the depth of root growth. It is also obvious that turfgrasses can play a significant role in the restoration of eroded or agricultural soils that have been depleted of organic matter. There is a need to better understand turfgrass-soil processes and properties that influence the soil carbon pool under turfs, as well as their changes as affected by cultural practices. Hopefully those scientists involved in the study of soil carbon sequestration will recognize this turfgrass dimension as an important component and develop specific science-based information for use.