Modeling Soil Carbon Sequestration with EPIC and the Soil Conditioning Index

Why does it matter?

- Carbon dioxide (CO₂) in the atmosphere has been increasing at a steady pace during the past century. This is a fact documented by repeated measurements taken in the Hawaiian Islands since 1958 (initiated by Dr. Charles Keeling).
- Increasing CO₂ in the atmosphere is a concern, because of its potential to warm the planet. CO₂ and other greenhouse gases act as a barrier to prevent heat escaping from the atmosphere.
- Prior to the industrial revolution, atmospheric CO₂ concentration was about 280 parts per million (ppm). A delicate balance in atmospheric CO₂ is maintained dominantly through photosynthesis by plants (input) and organic matter decomposition by microorganisms (output). The CO₂ output has been increased in the past century by burning of fossil fuels, leading to the rising atmospheric CO₂.
- Soils in the southeastern USA have been depleted of organic matter due to historical cultivation practices that encouraged decomposition of organic matter and that contributed to enormous erosion losses.
- Soil stores carbon as organic matter, which is essential to soil quality. Conservation tillage is a practice that can help restore organic C in soil.
- Long-term field experiments are needed to quantify how much soil organic C can be sequestered with conservation agricultural practices. However, results of long-term experiments are site and management specific, resulting in high cost of determination.
- Computer simulation models can be used as a low-cost method (but need testing) to predict changes in soil organic C sequestration with changes in management styles.

What was done?

- We tested the effectiveness of two models to predict soil organic C sequestration in three soils in the southeastern USA. The two models were EPIC (Environmental Policy Integrated Climate – a highly technical, process-based model) and SCI (Soil Conditioning Index – a relatively simple index to predict soil organic C and erosion).
- Three field experiments testing conventional and conservation tillage were used to compare with model predictions: (1) a wheat/sorghum-corn rotation with low and high fertilizer application in the Blackland Prairie of Texas, (2) a corn-cotton rotation with and without dairy manure in the Coastal Plain in Alabama, and (3) cotton monoculture in the Mississippi Uplands.
What was found?

• Soil organic C was predicted to be greater under no tillage (NT) than under conventional tillage (CT) at all three locations, i.e. TX, AL, and MS (see set of 5 figures below-right). Experimentally measured values of soil organic C sequestration (i.e., value at end of experiment minus value at initiation) were 3.4 ± 3.7 Mg C ha⁻¹ under CT and 5.5 ± 3.5 Mg C ha⁻¹ under NT. EPIC-predicted soil organic C sequestration values were 3.5 ± 3.0 Mg C ha⁻¹ under CT and 4.9 ± 3.7 Mg C ha⁻¹ under NT; overall a reasonably good fit.

• Rates of soil organic C sequestration during the course of 50 years would have been 0.13 ± 0.11 Mg C ha⁻¹ yr⁻¹ under CT and 0.19 ± 0.12 Mg C ha⁻¹ yr⁻¹ under NT across locations. These average values would be equivalent to 0.19 metric tons of CO₂ equivalence per acre per year under CT and 0.28 under NT.

• A limited number of sensitive parameters were optimized in EPIC v. 3060 for successful validation of surface soil organic C against soil organic C measured in 5- to 10-year long field experiments in TX, AL, and MS.

• Although simulated soil organic C using EPIC v. 3060 was only weakly related to predictions under the same conditions using the soil conditioning index (SCI), there was a positive trend between the two model simulations. When simulated data in this study were combined with simulated data from other locations in the southeastern USA, there was a strong nonlinear relationship between soil organic C simulated with EPIC and SCI (see figure below).

• Additional testing of SCI is needed against other long-term experiments throughout the USA to become a more robust tool.

What is the impact?

• This study showed that EPIC v. 3060 and the soil conditioning index (SCI) could be useful, relatively inexpensive, and expedient tools to determine soil organic C sequestration among different tillage and residue management systems in the southeastern USA.

• Routine use of the SCI in USDA – Natural Resource Conservation Service field offices with calibrated soil organic C estimates could help promote soil conservation and C offset trading.

• Further research is needed to determine applicability of approaches to a wider range of management situations.

For more information

Full-length article can be accessed at: http://www.jswconline.org/