Geophysical Research Abstracts,
Vol. 11, EGU2009-1110-2, 2009
EGU General Assembly 2009

Simulating Soil C Stock with the Process-based Model CQESTR

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The prospect of storing carbon (C) in soil, as soil organic matter (SOM), provides an opportunity for agriculture to contribute to the reduction of carbon dioxide in the atmosphere while enhancing soil properties. Soil C models are useful for examining the complex interactions between crop, soil management practices and climate and their effects on long-term carbon storage or loss. The process-based carbon model CQESTR, pronounced ‘sequester,’ was developed by USDA-ARS scientists at the Columbia Plateau Conservation Research Center, Pendleton, Oregon, USA. It computes the rate of biological decomposition of crop residues or organic amendments as they convert to SOM. CQESTR uses readily available field-scale data to assess long-term effects of cropping systems or crop residue removal on SOM accretion/loss in agricultural soil. Data inputs include weather, above- ground and below-ground biomass additions, N content of residues and amendments, soil properties, and management factors such as tillage and crop rotation. The model was calibrated using information from six long-term experiments across North America (Florence, SC, 19 yrs; Lincoln, NE, 26 yrs; Hoytville, OH, 31 yrs; Breton, AB, 60 yrs; Pendleton, OR, 76 yrs; and Columbia, MO, >100 yrs) having a range of soil properties and climate. CQESTR was validated using data from several additional long-term experiments (8 – 106 yrs) across North America having a range of SOM (7.3 – 57.9 g SOM/kg). Regression analysis of 306 pairs of predicted and measured SOM data under diverse climate, soil texture and drainage classes, and agronomic practices at 13 agricultural sites resulted in a linear relationship with an r2 of 0.95 ($P < 0.0001$) and a 95% confidence interval of 4.3 g SOM/kg. Estimated SOC values from CQESTR and IPCC (the Intergovernmental Panel on Climate Change) were compared to observed values in three relatively long-term experiments (20 - 24 years). At one site, CQESTR and IPCC estimates of SOC stocks were within 5% of each other for three rotations. At a second site, decreasing tillage intensity increased SOC stocks for winter wheat-fallow rotation for both observed and estimated values by CQESTR and IPCC. At the third site, CQESTR simulated an increase in SOC stocks with increased fertility levels, while IPCC estimates of SOC stocks did not reflect an increase. The CQESTR model successfully predicts SOM dynamics from various management practices and offers the potential for C sequestration planning for C credits or to guide crop residue removal for bio-energy production without degrading the soil resource, environmental quality, or productivity.