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CARBON SEQUESTRATION BY AGRICULTURAL SOILS

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The Greenhouse Effect

Some gases in the atmosphere absorb heat and prevent long-wave radiation from reflecting back into space. This condition is similar to properties of glass in a greenhouse, hence the name "Greenhouse Effect." These gases, often referred to as "greenhouse gases," can be both natural and synthetic. The natural gases include carbon dioxide (CO_2), methane or marsh gas (CH_4), and many oxides of nitrogen, for example, nitrous oxide or laughing gas (N_2O).

Carbon dioxide in the atmosphere has increased from 280 parts per million (ppm) before 1850 to about 360 ppm today (IPCC, 1994). Burning of fossil fuels and changes in land use have contributed to this increase. As the CO_2 concentration increases, so does the possibility that the atmospheric temperature will also increase, causing a change in global climate (King et al., 1997; Schmandt and Clarkson, 1992; Schneider, 1989). Some scientists argue the atmosphere is so well buffered that the atmospheric CO_2 will not change (Anonymous, 1998). Another argument is that as air temperature increases, cloud cover will increase and more of the sun's energy will be reflected, resulting in no climate change (Anonymous, 1998). Although exact predictions can not be made at this time, there is agreement among most scientists that, if greenhouse gases continue to increase, climate will change. While the unusually warm summer of 1998 and the recent effects of El Niño might not be a product of a change in climate, they have increased the concern about possible global climate change.

Policy Concerns

Recently, the international community has been discussing ways to reduce greenhouse gases in the atmosphere. A straightforward, if not easy, approach would be to reduce the man-made production of these gases. Unfortunately, greenhouse-gas production is linked to industrial output or energy production, and any reduction will most certainly impact living standards. On November 11, 1998, the United States announced that it had signed the Kyoto Protocol, which provides legally binding commitments to the reduction of greenhouse gases. If ratified with the advice and consent of the U.S. Senate, the Kyoto Protocol binds United States to reduce greenhouse-gas emissions to seven percent below 1990 levels by the year 2012.

An effective strategy to comply with this protocol could be accomplished through flexible mechanisms such as carbon emission trading, tax incentives for new technology, encouragement of voluntary reductions, and providing a larger role for agriculture in emissions reductions through soil carbon sinks (Glasener and Nipp, 1999). However, some oppose the Kyoto agreement because they believe implementation of the agreement will put the U.S. at a comparative disadvantage to less-developed countries (Global Climate Coalition, 1999).

Some critics question the science supporting projections that global warming is a serious environmental threat, and have voiced objections that developing countries are exempt from reducing emissions of CO_2 and other greenhouse gases. The concerns raised by the critics are being examined by

ongoing atmospheric research conducted by several government agencies, including USDA-ARS and USDI-NOAA and many university scientists. As with many issues of this scale, it will take time to produce definitive answers.

At this time there are a number of solutions that might be used to meet our international commitment. One possibility is that industrial emitters of CO_2 could possibly purchase "credits" from farmers who sequester carbon in their soils. Also, government programs could be developed to provide incentives to encourage producers to sequester carbon in agroecosystems. Carbon sequestration would not only provide carbon credits, but would protect soils from erosion by wind or water. Thus, carbon sequestration would not only increase farm income; it would encourage agricultural practices that promote soil quality.

Soil Organic Matter and Carbon Sequestration

Preliminary estimates of overall CO_2 sources and sinks indicate that current agricultural activities constitute a net sink. Currently, the Kyoto Protocol recognizes forests as sinks but not agricultural croplands and grasslands. Two roles are distinguished for forests: the process of biomass build-up, e.g., fixation of atmospheric CO_2 into biomass, and carbon storage in wood and other biomass to be used as sinks. Increasing carbon sequestration in agricultural soils is a possible strategy in slowing or stopping the current increase in atmospheric CO_2 concentrations. Lal et al. (1998) estimate that U.S. cropland could potentially sequester 120-270 million metric tons of carbon per year. This potential sequestration could be accomplished through increasing productivity, decreasing tillage, and conversion of other land usage to agricultural production (Paustian et al., 1997).

The Intergovernmental Panel on Climate Change (IPCC, 1994) has estimated that in the next 50 to 100 years, between 40 and 80 gigatons of carbon might be absorbed in agricultural soils by using existing, generally accepted management practices. These practices involve reduced tillage or direct seeding, use of legumes in rotations, reduction of summer-fallow, and returning animal wastes or sewage sludge to the soil. When croplands are planted to perennial grasses, under the Conservation Reserve Program, or formerly cultivated land is planted to a biomass crop such as trees, between 0.5 and 1.5 tons per hectare of carbon are added to the soil annually.

Soil can be both a source and sink for carbon and nutrients. Soil organic matter (SOM) represents a major pool of carbon within the biosphere and is estimated to be roughly twice that in the atmosphere. Changes in land use and climate can change the amount of carbon held in soils and affect CO_2 fluxes between the atmosphere and the soil. Some agricultural management practices will lead to a net carbon sequestration in soils. Regional estimates of the carbon sequestration potential of these practices are crucial if policymakers are to plan future land use changes to reduce CO_2 emissions.

Pacific Northwest soils have a great potential to increase their carbon contents and contribute to carbon sequestration. Best management practices to sequester carbon may include reducing summer-fallow, increasing green manure use, improving erosion control, shifting from conventional tillage to minimal and no-tillage, reducing crop residue burning, and ensuring adequate fertilization. The reduction of summer-

fallow by conversion to annual cropping may be the more important management change to increase carbon sequestration.

In Europe, soil-carbon sequestration potential has been estimated using several mathematical models and data from the Global Change and Terrestrial Ecosystems Soil Organic Matter Network (Smith et al., 1997). Relationships between management practices and yearly changes in soil organic carbon were developed and used to estimate changes in the total carbon in European soils. At the Columbia Plateau Conservation Research Center in Pendleton, the residue decomposition model, D3R (Douglas and Rickman, 1992) is being modified to predict carbon sequestration (Rickman et al., this issue). The information generated from this carbon sequestration model could be used to assist producers in the Pacific Northwest as well as in other locations in their efforts to increase the carbon concentration in their soils. Also, this data could be incorporated into geographical information systems for use by producers or other agencies.

Conclusions

While the international controversy over carbon sequestration continues to be debated, and many policy decisions in this area are yet to be made, practical and economically viable agronomic reasons exist to increase the carbon content of soils. However, research is needed to develop methods that increase the soil carbon sequestration rate and the quantities that can ultimately be stored. Agriculture has a tremendous opportunity to contribute to the mitigation through improved practices that also provide other environmental and conservation benefits.

It is currently possible to monitor changes in soil-carbon content. However, data collection is expensive and results can be extremely variable. There is an urgent need to develop reliable, accepted methods that are economically viable to estimate soil C. There is also a need for continuous and direct measurements of CO_2 exchange between the atmosphere and terrestrial ecosystems.

Agriculture can play an important role in carbon sequestration. Initial equipment costs and reluctance to adopt reduced tillage technologies could impede widespread adoption of soil carbon sequestration practices. Developing technologies have the potential to increase the ability of agriculture to sequester carbon. Many producers are already implementing these technologies, not specifically for carbon sequestration but for increasing crop yields, agronomic sustainability and improved soil quality.

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