MONTANA STATE UNIVERSITY
EXTENSION SERVICE
MONTGUIDE

MT200404 AG issued **4/04**

Soil Carbon Sequestration in Agriculture: Farm Management Practices Can Affect Greenhouse Gas Emissions

Perry Miller, Rick Engel, and Ross Bricklemyer
Dept. of Land Resources and Environmental Sciences

The greater the tillage, the less soil carbon will be present. Soil organic matter is about 58 percent carbon.

The greenhouse effect is caused by heat from the sun that is trapped in the atmosphere by gases, much like the glass of a greenhouse traps the sun's warmth. Trapping the sun's heat allows fairly hospitable global temperatures and is essential to life. Without this natural greenhouse effect, Earth's average temperature would be below freezing and most life would be impossible.

But if the greenhouse effect becomes too intense, temperatures rise and have important environmental consequences. This is popularly known as "global warming," which scientists have stated is a leading global concern. Global warming is an increase in the earth's temperature caused by increased greenhouse gas concentrations in the atmosphere. As these gases increase, the 'greenhouse effect' intensifies, trapping more of the sun's heat.

Which Greenhouse Gases are Important to Agriculture?

The primary greenhouse gases: water vapor, carbon dioxide, methane, and nitrous oxide, with water vapor being the most common. Carbon dioxide, methane, and nitrous oxide result mainly from human activities. Carbon dioxide is released mainly due to combustion of fossil fuels such as coal, gasoline, diesel, and natural gas, and is also produced when solid wastes, wood, and wood products are burned. Carbon dioxide concentrations have increased from 270 parts per million in the mid-1800s to 370 parts per million in 2004. These increases have been implicated in a gradual increase in the earth's temperature.

All atmospheric gases contribute to global warming, but some gases like nitrous oxide and methane are more powerful than carbon dioxide due to their long duration in the atmosphere and strong absorption of long-wave radiation. Scientists sometimes use the term global warming potential to compare the heat-trapping ability of other greenhouse gases to carbon dioxide. Carbon dioxide is used as the baseline greenhouse gas and assigned a value of 1. Methane has 21 times and nitrous oxide 310 times the global warming potential of carbon dioxide. Thus, every ton of methane has the global warming potential of 21 tons of carbon dioxide and every ton of nitrous oxide warms as much as 310 tons carbon dioxide. These values are referred to as carbon equivalents.

What are the Consequences of Climate Change?

The potential consequences of climate change are not fully understood, but several adverse effects are likely. Some are predicted to be gradual, while others might be sudden if ocean currents become redirected. With an increase in the earth's temperature, moisture will evaporate more quickly causing some areas to be more arid and others to have more rainfall. Global weather patterns are strongly linked to ocean currents. If global warming causes a shift in ocean currents, we could have a sudden and long-lasting weather change. The continued addition of greenhouse gases to the atmosphere is predicted to raise the earth's average temperature by several degrees in the next century, especially in the more polar latitudes. This could have dramatic effects on polar ice melting, shifting shorelines, habitat range of plants and animals, and agricultural production. Most of the United States is expected to warm, although scientists are unable to determine which parts of the United States might become wetter or drier. Agriculture could probably adapt to slow gradual change but would probably suffer serious losses with sudden climate shifts.

How can Agriculture Affect Climate Change?

Agricultural activities serve as both sources and sinks for greenhouse gases, so specific agricultural practices could slow the pace of global warming. Methane dynamics are linked closely to livestock production practices and wetland agriculture, such as rice production. We focus on crop management in Great Plains agriculture in this note and so will ignore methane here. Carbon dioxide dynamics are related to energy use cycles on farms and more importantly, to soil management. Nitrous oxide dynamics are related to soil nitrogen management, including fertilizer nitrogen.

What is Soil Carbon Sequestration?

Carbon sequestration refers to the removal of carbon dioxide from the atmosphere into a long-lived stable

CASMGS — Consortium for Agricultural Soils Mitigation of Greenhouse Gases

This MontGuide is one in a series exploring the potential of agricultural sequestration of carbon. Soil carbon sequestration can be used to reduce the level of greenhouse gases in the atmosphere. Montana State University - Bozeman in collaboration with nine institutions will provide the data and analysis needed to explore the potential of this new market for agricultural producers. More information and accompanying publications can be found at **www.casmgs.montana.edu.**

form that does not affect atmospheric chemistry. Currently, the only viable way to trap atmospheric carbon dioxide is via photosynthesis, where carbon dioxide is absorbed by plants and turned into carbon compounds for plant growth. Carbon is considered sequestered if it ends up in a stable form, such as wood or soil organic matter. Soil carbon sequestration is an important and immediate sink for removing atmospheric carbon dioxide and slowing global warming.

What Management Practices Sequester Soil Carbon?

Practically, there are three areas of farm management that can affect soil carbon sequestration in the Great Plains: tillage, cropping intensity and fertilization.

Tillage and soil carbon are negatively related. The greater the tillage, the less soil carbon. No-till systems build soil organic matter, which is about 58 percent carbon. No reliable data exist in Montana regarding soil carbon accumulation rates due to no-till, but extensive research in nearby southwestern Saskatchewan shows that soils depleted of organic matter typically accumulate soil carbon at a rate of 0.1 tonne/ha/yr (~0.045 tons/ac/yr), but may vary from 0 to 0.2 t/ha/yr depending on soil type, soil management, local weather patterns and specific no-till systems.

Different no-till systems result in varying soil disturbance, but any system that reduces tillage substantially can increase soil carbon. Montana field research completed in 2001 showed carbon storage rate from no-till adoption similar to that in southwestern Saskatchewan, but with considerable farm-to-farm variability. That variability needs to be understood.

Cropping intensity and soil carbon are positively related. The more frequent the cropping and greater the biomass inputs, the more soil carbon. Summer fallow reduces cropping intensity. Reducing fallow typically increases soil carbon through greater annualized biomass inputs, but may be economically difficult. No Montana data exist on carbon storage rates due to cropping intensity, but data from southwestern Saskatchewan show average carbon storage rates of about 0.2 tonne/ha/yr (0.09 ton/ac/yr) when converting from 50:50 crop-fallow to continuous cropping. Field research began in 2003 in north central Montana to compare soil carbon accumulation due to no-till adoption and continuous cropping. We expect this research to provide important information about greenhouse gas emissions in the short term, and may serve as long term benchmark sites to support future carbon credit trading.

Fertilization affects soil carbon mainly through crop biomass. However the carbon:nitrogen ratio of soil organic matter results in stable organic matter typically within a range of about 8-10: 1. If insufficient nitrogen is present to permit stable formation of soil organic matter via soil microbial degradation of crop residues, then little carbon may be sequestered.

How are Soil Carbon and Nitrogen Related?

This 8-10:1 carbon:nitrogen ratio means that for every 8-10 lb of carbon sequestered in soil organic matter, 1 lb of nitrogen must accompany it. This tie-up of nitrogen reduces nitrogen for crops. For example, if a farmer adopted no-till that resulted in an increase of soil carbon of 0.45 ton/ac over 10 years, 0.045 t/ac (90 lb) of applied nitrogen would have been tied up in soil organic matter and would not have been available to his crops. Legume crops such as alfalfa, peas, lentils and chickpea could serve as alternative sources for nitrogen. Economic considerations of changing crop rotations should be considered carefully.

Is Nitrous Oxide an Important GHG in Montana?

Nitrous oxide can be emitted from the soil during both nitrogen mineralization and immobilization processes and is linked to fertilizer nitrogen. The Intergovernmental Panel on Climate Change uses a default value of 1.25 percent of fertilizer nitrogen inputs are lost as nitrous oxide. Since nitrous oxide has a global warming potential equivalent 310 times that of carbon dioxide, a loss of even one pound of nitrous oxide has a large impact, potentially canceling out carbon credits due to carbon dioxide removal. Marked differences in such losses likely exist in different climates, and research is underway to measure such loss in semiarid cropping systems. Indications are that the 1.25 percent used by the IPC carbon is too large for semi-arid environments and may overestimate nitrous oxide emissions from fertilizer applications in our region. Wet soils favor nitrous oxide losses. More intensive cropping by lowering fallow frequency, which reduces periods of high soil moisture, may minimize nitrous oxide emissions from soils.

Will It Pay for Farmers to Manage for Carbon Credits?

Since carbon credit markets in the United States are new and trading is light at this time, it is uncertain what the future value of carbon credits will be to Great Plains farmers. Farmers would be well advised to keep abreast of developing carbon credit markets, but to enter them cautiously. Other MontGuides provide additional information to assist producers in making decisions about entering the carbon market.

This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement No. 2001-38700-11092. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

File under: Marketing Management
E-9 (Strategies & Alternatives)
Printed April 2004
(10000304-CF)