Carbon Sequestration:
An Overview of the Issues

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Abstract

In the face of uncertainty, soil carbon sequestration projects and carbon credit trading are beginning. Those firms that expect CO_2 emission controls to become mandatory or reductions in emissions to be valued by consumers of "green" products are looking for cost-effective means to offset carbon emissions. This paper provides an overview of the issues developing around carbon sequestration in soils on farms and carbon credit trading. Some of the questions discussed include: What Is Carbon Sequestration? Why the Concern about CO_2? What Is a Carbon Emission Reduction Credit? What Will Farm Managers Have to Do to Obtain Credits to Sell? What Are the Credits Worth? What Are the Risks?

What Is Soil Carbon Sequestration?

Fossil fuel combustion, expansion of cultivated agriculture, and forest clearing have lead to an increase in atmospheric carbon dioxide (CO_2) from 260 parts per million (ppm) to recent levels of greater than 370 ppm, Figure 1 (IPPC, 1995).

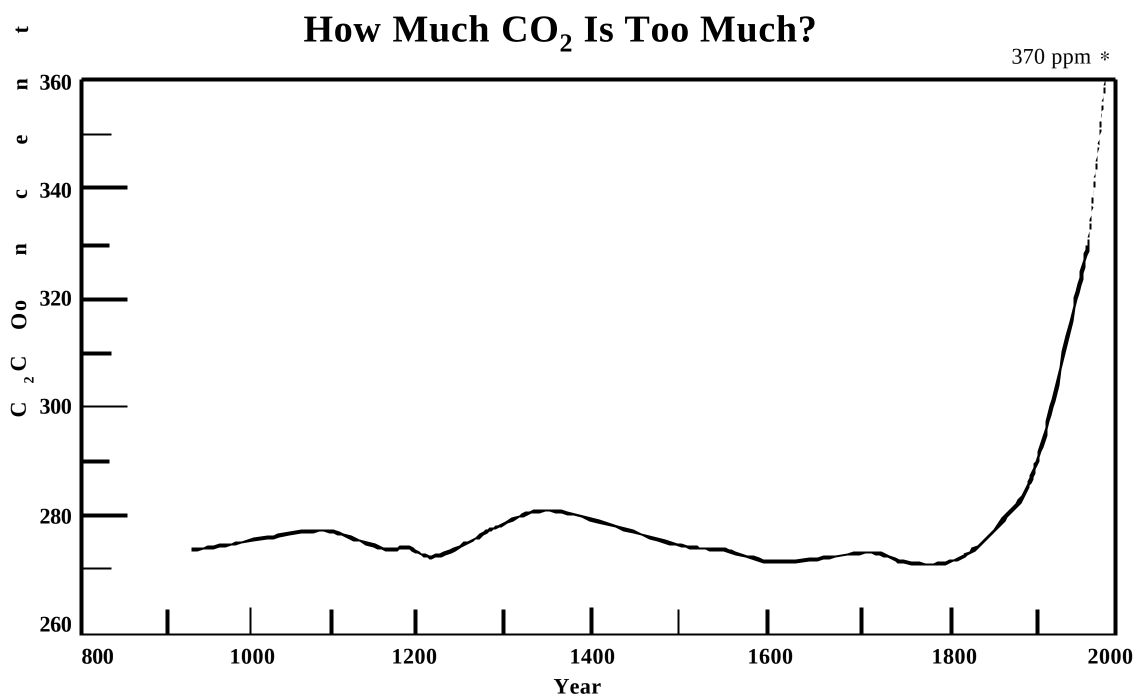


Figure 1. Temporal changes in atmospheric concentration of CO_2 (Intergovernmental Panel on Climate Change, 1995).
***(Rice, 2000)**

Cardon dioxide is one of three greenhouse gases that are receiving increasing attention. CO_2, methane (CH_4) and nitrous oxide (N_2O) are believed to trap heat in the atmosphere the same way glass does in a greenhouse. The accumulation of these gases in the atmosphere is likely to cause changes in climate (USDA, 2000). In 1996, U.S. agricultural activities contributed about 114 million metric tons of carbon equivalent to the atmosphere or about 6 percent of total U.S. greenhouse gas emissions (USDA, 1998). However, agriculture also can play a role in removing carbon dioxide from the atmosphere by storing carbon in a terrestrial sink such as soils, plant material, and trees. Soil conservation practices can be used to sequester carbon in the soil. The total carbon sequestration and fossil fuel offset by U.S. cropland is estimated to be 133 percent of the total emissions of greenhouse gases by agriculture and forestry activities (USDA, 1998). In other words, agricultural land possibly could be managed to increase carbon storage and reduce the carbon in the atmosphere.

Why the Concern about CO_2?

The accumulation of CO_2 in the atmosphere is believed to lead to a warming of the earth's atmosphere that could have serious consequences. Carbon dioxide accounts for about 86% of total greenhouse gas emissions in the U.S. (Goodin et al., 1998). Although the extent and impact of increasing atmospheric CO_2 on climate change are unknown and quite controversial, the Intergovernmental Panel on Climate Change (IPCC) reached an agreement in December, 1997, in Kyoto, Japan, to reduce greenhouse gas emissions. Under the Kyoto Protocol, the U.S. is requested to reduce net emissions of CO_2, $NH_{4,}$ and N_2O by 7 percent below 1990 levels by 2008-2012. Sequestration of carbon could be counted as well as reductions in emissions. Lal et al. (1998) reported that U.S. emissions of greenhouse gases may average 1,600 million metric tons of carbon equivalent per year and that the overall potential of U.S. cropland to mitigate CO_2 is 120 to 270 million metric tons of carbon per year or 7.5 to 16.9 percent of total emissions. If greenhouse gases need to be reduced by 7%, then agriculture may have an important short-term role.

What Are the Basics of Carbon Chemistry and the Carbon Cycle?

As reported by Schartz (2000), burning of fossil fuels releases carbon dioxide and water vapor to the air in addition to energy.

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$
$$CH_2 - \text{carbohydrate}$$

Alternatively, carbon is removed from the air by photosynthesis. Plants use CO_2 through photosynthesis, releasing oxygen and locking carbon in plant material, including roots, which decompose and store carbon in the soil. This natural process requires energy, which is obtained from solar radiation.

$$CO_2 + H_2O \rightarrow CH_2O + O_2$$

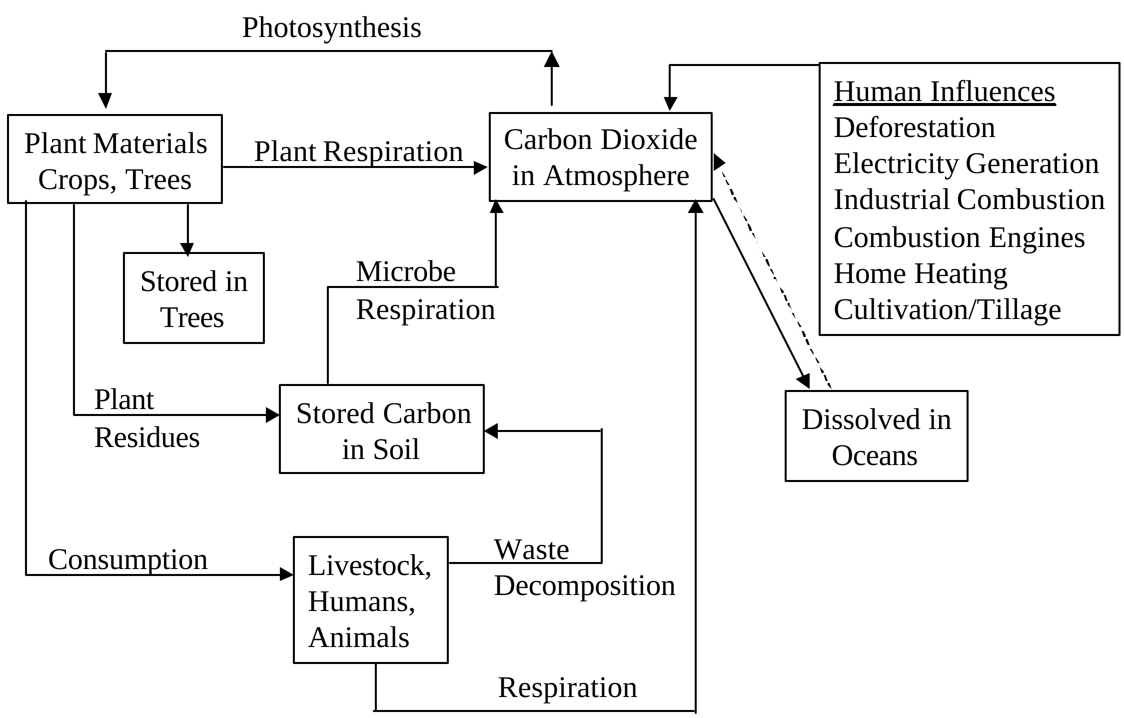


Figure 2. Carbon Cycle - Circulation of Carbon Atoms in the Environment

Figure 2 presents a basic diagram of carbon cycling through the environment. The left side of the diagram illustrates the carbon cycle, and the box in the upper right indicates how carbon is removed from storage by human influence as fossil fuels or as organic matter in soil. Removing carbon from fossil fuels in storage and combusting them adds carbon to the atmosphere. Major carbon sinks are soils, trees, and the oceans. Burning of forests and tillage of soils also add carbon to the atmosphere.

Why the Interest in Carbon Sequestration and Carbon Credit Trading?

There are two basic reasons for the increasing interest in sequestering carbon and carbon credit trading. The first is potential national and/or international regulation of greenhouse gas emissions, and the second is an increasing interest by consumers to purchase environmentally friendly, neutral, or "green" products.

The Kyoto Protocol, an unratified United Nations treaty on climate change, would require a U.S. reduction of CO_2 emissions by 7% below 1990 levels by 2008-2012. Although the U.S. is not likely to ratify this treaty in its current form, some other countries like Canada are moving ahead with the expectation that something like it eventually will be approved. One alternative for some countries and industries to reduce their share of greenhouse gases is to pay another industry like agriculture to either reduce theirs and/or to sequester carbon from the atmosphere. This process would involve selling and buying carbon credits and may involve other parties such as brokers or clearinghouses. Legislation has been introduced in Congress that would give credit for early reductions and grant emission credits if future domestic programs (regulations) are put in place to reduce greenhouse gases. <www.senate.gov/~epw/san_3.24.htm>

Consumer interest in having a cleaner environment and in purchasing environmentally friendly products also has been increasing. Carbon credit trading or trading of other greenhouse gas credits would facilitate these purchases.

What Is the Nonregulatory Interest?

Suppose a consumer products firm produces a product that contributes 20 lbs. of carbon to the atmosphere per unit of manufactured product. That is equivalent to 1/100 of a ton. Suppose it is willing to pay a holder of a credit $3.00 to $10.00 per ton to sequester carbon or reduce carbon emissions by 1 ton. That is a cost of $3.00 to $10.00/100 units or $0.03 to $0.10 per unit. Consumers may be willing to pay an additional $0.03 to $0.10 per unit, and the company may be able to gain market share by advertising that its product is neutral in terms of greenhouse gas emissions. In other words, for every ton of carbon the consumer products company creates, it will pay someone to reduce emissions by a ton if this is the most economical approach.

What Is Happening in the Legislative Arena?

Current legislation and regulatory measures have their roots in climate change challenges presented by the United Nations Framework Convention on Climate Change ratified by the U.S. in 1992 and the pending Kyoto Protocol introduced in 1997. These two proposals address international efforts to stabilize atmospheric concentrations of greenhouse gases and to formalize commitments by calling on industrialized nations to reduce national average emissions over the 2008-2012 period to about 5% below 1990 levels. Neither proposal specifically addresses agricultural contributions to atmospheric stabilization, but measures identified to reduce global warming include carbon sequestration options and energy conservation practices.

Recently, legislative measures have been introduced by Kansas Senators Brownback and Roberts. Senator Brownback's bill named "Domestic Carbon Storage Incentive Act of 2000" proposes financial incentives in the form of conservation payments to increase the storage of carbon in the soil, which would encourage use of no-till, biomass production, buffer strips, and other conservation measures. Senator Roberts' bill entitled the "Carbon Cycle and Agricultural Best Practices Research Act (1999)" provides research funding for carbon sequestration. Both of these bills have called attention to agriculture's potential to sequester carbon and to mitigate greenhouse gas effects. Further details of the two legislative acts can be found at
<http://thomas.loc.gov/cgi-bin/bdqu...@@@L&summ2-m&|/bss/d106query.html|> and
<http://thomas.loc.gov/cgi-bin/query/C?c106:/tem/~c106tzj82n>.

What Is a CERC?

CERC^{TM} is the acronym for Carbon Emissions Reduction Credit. It is a registered trademark of the CVision Corporation. One CERC is the equivalent of 1 metric ton of carbon dioxide not released to the atmosphere in carbon equivalents. These also are called offsets or credits. Farm managers eventually will be certified to sell CERCs based upon the quantity of carbon that can be sequestered in the soil and/or by following specific farming practices.

What Does Trading of Credits Do?

Trading of carbon credits establishes a market value or price received for reducing carbon, whether it is in a regulatory environment or not. Sellers of the credit will base their sale on the cost to reduce 1 metric ton of carbon. Buyers will buy based upon their own cost to reduce 1 metric ton of carbon. If it is cheaper for emitters of carbon dioxide to buy a credit rather than controlling their emissions, they will buy credits. Sellers will want to sell credits if they can reduce or sequester carbon at a cost less than the price or value of the credit.

Carbon credit transactions would involve the purchase of emission rights from those with ability to sequester carbon. Polluters with higher costs of emissions control than the value of the credits (pollution rights) could pay others who can more economically reduce carbon emissions. These firms essentially are paying to pollute, but the cost they pay creates incentives to reduce their emissions in the long run. The general idea is that those who can reduce emissions economically will receive permits and sell them to those who cannot. Emissions trading transforms the "right to emit a pollutant" into a scarce resource and creates economic incentives for innovations in emissions reduction. The permit sold to a utility by an agricultural producer may end up being sold to another utility, if reducing emissions eventually becomes less costly than the current value of the credit.

Have Any Credits Been Traded?

Cantor Fitzgerald, an environmental brokerage service in New York, worked with IGF Insurance Company and CQuest, Ltd. to transfer credits between farmers in Iowa and the Greenhouse Gas Emissions Management Consortium of Canada (GEMCo). GEMCo is a group of energy companies some of which are electric power suppliers. The three firms serve as the network of service providers that define, measure, verify, audit, transfer, deposit, register, and assure the creation and transfer of CERCs to GEMCo.

CQuest, Ltd., an international broker of credits in West Des Moines, Iowa, is serving as a clearinghouse for buying and selling of carbon credits between GEMCo and farm managers in Iowa.

The market for credits is still in its infancy, but CQuest tentatively has arranged for farmers in Iowa to sequester 2.8 million metric tons of carbon for GEMCo. Steve Griffin of CQuest indicated that farm managers have volunteered to sell credits to GEMCo, but they do not know yet the quantity that could be sold or the payment they would receive. GEMCo essentially has obtained an option to buy credits in the future without an option premium.

This trading has been done in Iowa because of previous work on the impacts of carbon levels in soils related to cropping and tillage rotations conducted by the National Soil Tilth Laboratory in Ames, Iowa. This information is needed to establish the protocols or agricultural practices for the credits.

What Will Farm Managers Have to Do in Iowa to Obtain Credits to Sell?

CQuest is having two protocols or general farm management practices certified by the National Soil Tilth Laboratory in Iowa. Specific details were not available from CQuest at the time this paper was prepared. It is important to note that although the USDA is providing information and education on carbon sequestration, it is not endorsing a carbon credit trading program at this time. Carbon sequestration is not official U.S. government policy, and the Kyoto Protocol in its current form has not been ratified by the U.S.

What Can Farm Mangers Do to Reduce Carbon Emissions and Sequester Carbon in the Soil?

The general answer is that increasing the efficiency of inputs produced from fossil fuels, decreasing the use of fossil fuels, and improving soil management to reduce erosion, such as with no-till cropping systems, will reduce carbon cycling to the atmosphere. Table 1 indicates sources of atmospheric carbon emissions associated with U.S. agricultural land.

Table 1. Sources of Annual CO_2 Emissions from U.S. Agricultural Land.

Source	MMTC/Year
Fertilizer and Pesticides	12.9
Fossil Fuels	15.0
Soil Erosion	15.0

MMTC is Million Metric Ton Carbon.
(Lal et al., 1998).

What Can Farm Managers Do to Sequester Carbon in Soil?

Several potential methods exist to increase carbon sequestration, but not all are compatible with each other.

1. Practice soil erosion management - reduced disturbance of soil with conservation tillage and no tillage. In addition, this may reduce overall carbon emissions from fossil fuel and chemical use. Kern and Johnson (1993) estimated that total fossil fuel emissions from tillage and herbicide use decrease with less tillage.
2. Enroll or stay enrolled in the Conservation Reserve Program (CRP).
3. Use conservation buffers - use vegetated or filter strips along streams to reduce soil erosion.
4. Restore wetlands, but this may cause a tradeoff with methane emissions.
5. Convert marginal land to grassland, forest, or wetland.
6. Reduce energy use with conservation tillage, implement no-tillage, improve efficiency of inputs like fertilizer and irrigation water, and utilize more efficient heating systems.
7. Improve soil fertility management and use organic manures.
8. Increase cropping intensity, such as changing to wheat-corn-fallow and wheat-sorghum-fallow

from wheat-fallow. Irrigation to increase cropping intensity would only partially offset the carbon emissions from increased energy inputs used for irrigation (Lal et al., 1998).

9. Leave more crop residue.

10. Reduce/eliminate fallow (moisture trade-offs).

11. Plant cover crops (moisture trade-offs).

12. Plant trees in riparian areas, on CRP, or as windbreaks.

13. Improve pasture and rangeland through improved grazing and fire management.

14. Produce and use biofuels (renewables) from biomass such as methanol and biodiesel. This reduces use of petroleum, which reduces release of stored carbon. The carbon not released from long-term storage is replaced by fuel generated by photosynthesis and solar energy, a renewable fuel. Many of the economic questions concerning biofuels at this time are unclear.

How Much Carbon Can Be Sequestered per Acre?

The answer to this will depend upon many site-specific factors, but some general ranges can be provided.

Table 2. Potential Soil Sequestration Rates for Carbon

Practice	MT/Ha/Yr	MT/Acre/Yr	Ton/Acre/Yr	Tons/Acre/10Yr
CRP	.30 - .70	.12-.28	.13 - .31	1.34 - 3.12
Conservation Tillage	.24 - .40	.10-.16	.11 - .18	1.07 - 1.78
Fertilizer Management	.05 - .15	.02-.06	.02 - .07	.22 - .67
Rotation with winter cover	.10 - .30	.04-.12	.04 - .13	.45 - 1.34
Summer Fallow Elimination	.10 - .30	.04-.12	.04 - .13	.45 - 1.34

Lal et al., 1999
1 Metric Ton (MT) = 1.1 U.S. Ton or 1 Short Ton = .909 metric ton
1 Hectare (Ha) = 2.47 Acres
To convert MT/Ha/Yr to Ton/Acre/Yr multiply by .4453.

Rice (2000) indicated that in Kansas, producers probably can increase carbon sequestration by about .5 metric ton/hectare/year, which is about 0.2 ton/acre/year of carbon in the upper 2 inches of soil by using no-till intensive farming. Additional credits eventually may be obtained if fuel use is reduced and manure application is managed to increase soil carbon.

What Will the Credits Potentially Be Worth?

Greg Lewis and Steve Griffin, both officials of CQuest, speculate that by 2002, the credits will be worth $3.00 - $10.00 per ton with a possible average of $5.00/ton. Carbon credits currently range from $0.30 to $3.50/ton. A GEMCo official stated in 1998 that the company would not be willing to pay more than $3.00/U.S. ton (Donnelly, 2000). Earlier trades between utilities and energy firms ranged from $2.70 - $20.00/metric ton.

According to CQuest, farms in Iowa may be able to store 0.5 to 1 ton/acre/year, but this is counting soil sequestration, reduction in fuel combustion from to no-till, and possibly better manure management practices such as soil injection to increase carbon. Soil injection also may reduce methane emissions, which potentially may be another source of greenhouse gas credits.

The (U.S. President's) Administration Economic Analysis (1998) estimated that the market price for carbon during the initial phase of the Kyoto Protocol would be $14.00 - $23.00/metric ton. At a sequestration rate of 0.5 MT/ha/yr., this would translate to $7.00 - $11.50/ha or $2.83 - $4.65/acre.

At 0.2 ton/acre/year, the range in values is $0.06/acre at $0.30/ton, $0.70/acre at $3.50/ton, and $4.00/acre at $20.00/ton.

In addition, the goal of the U.S. Department of Energy (2000) is to develop sequestration options with a cost objective of $10.00/ton of carbon equivalent, which is equivalent to adding $.002 per kilowatt-hour to the price of electricity. This information indicates what the upper bound on the value of cost of carbon sequestration eventually may be.

The International Emissions Trading Association lists trades, potential trades, and the value of the credits at <www.ieta.org>.

Do Trees Sequester Carbon and What Is the Cost of Carbon Offset Projects with Trees?

Trees also sequester carbon and do not release the sequestered carbon to the atmosphere unless burned. Some of the first projects to obtain credits for carbon sequestration have been undertaken with trees. Credits sold by those who plant trees and manage tree plantations or private forests will compete in the marketplace with those who wish to sell credits based upon soil sequestration. Therefore, the cost of sequestering carbon in trees is of interest. Sedo (2000) provided estimates of the cost of sequestration of carbon by trees in relatively small projects in the northwestern U.S. These costs ranged from $2.00 to $15.00/ton (Table 3).

Table 3: Cost of Carbon Storage by Trees in the Northwestern U.S.

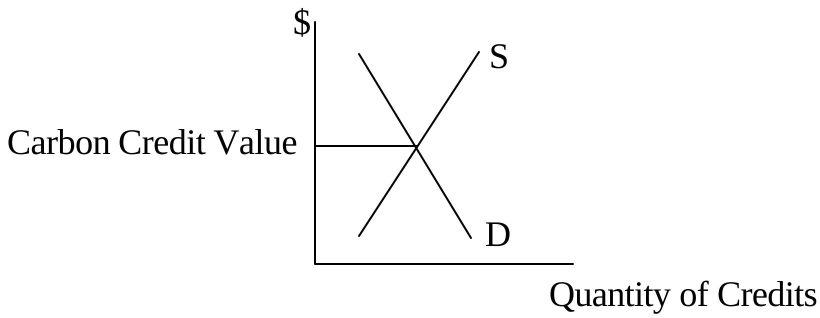
Project	Cost/Ton
Eastern Washington Reforestation	$2.00
Forest Resource Trust Project	$2.00
Southern Oregon Reforestation	$2.00 - 2.50
Salt Lake City Urban	$10.00 - 15.00
Western Oregon New Plantings	<$1.00

Source: Sedo (2000)

However, Moulton and Richards (1990) reported that the cost of more extensive programs to reduce CO_2 emissions by 10 to 20 percent with tree planting would range in cost from $16.90 - $20.90 per ton. They also reported that the sequestration rate for trees ranges from 0.40 to 2.84 tons per acre per year in the southern plains. Parks and Hardie (1996) indicated that the costs of expanding tree planting on CRP acreage would be even higher because of the opportunity costs associated with returns from other uses. In comparison, McCarl and Schneider (1999) reported that agriculture could reduce emissions or provide carbon sequestration at costs ranging from $10.00 to $25.00 per ton.

What Will Influence the Value of a Carbon Credit?

Demand and supply of carbon credits will influence the price or value of the credits.



The potential demand effects include the following. Regulations requiring the reduction of CO_2 increase demand and raise market price. Therefore, the extent or magnitude of the required reduction will have an impact on price. The greater the emission reduction required, the greater the demand and the higher the price. The greater the desire of emitters of CO_2 to offset it, the greater the increase in demand and the greater the increase in price. Some amount of increased demand for credits may occur in the absence of regulations, if the demand for environmentally friendly or “green” products increases. The larger the number of countries involved in international carbon emission reductions, the greater the demand and the higher the price.

The potential supply effects include the following. New and more economic ways to reduce or sequester carbon emissions would allow for certification of more credits. Therefore, an improvement in technologies to lower carbon sequestration costs would increase the supply of credits. This generally would have the impact of lowering the price of credits in the market. Alternatively, not allowing a particular sequestration technique to be used would decrease supply and raise the price of credits.

Can Sequestration of Carbon in the Soil Go on Indefinitely?

The amount of carbon that can be stored in the soil will plateau in a 40- to 50-year range. The time period depends upon the geographic site and specific practices followed. In other words, as much carbon will be released to the atmosphere from soil as is saved per year at some point. Some opposition and concern exists about allowing carbon to be sequestered in soil, because it can be released easily in the future with tillage or erosion. However, sequestration and carbon credit trading in the soil allow major emitters of CO_2 to buy time to reduce their emissions, while developing economical long-run solutions to greenhouse gas reduction by using more energy-efficient technology or renewable and carbon neutral energy sources.

How Will Soil Carbon Sequestration Be Monitored?

According to Rosenberg and Izaurralde (2000), one reason for some opposition to the use of soils for carbon sequestration is the difficulty associated with verifying soil carbon changes in the field. Current methods to obtain the accuracy needed are time consuming and expensive and do not lend themselves to measuring annual change. Initial practices will have to be established, certified with accurate models, and monitored, possibly with remote sensing techniques using satellites.

How Are Property Rights Issues Involved?

Environmental policies generally affect producers' property rights. However, we do not know what form greenhouse gas emission policy will take, so many questions remain. What will be done if some farmers get paid to adopt no-tillage and market forces cause others in other parts of the country or world to opt out and revert to more tillage, so the net effect is small? Will restrictions be imposed on those who do not choose to sequester carbon and sell credits?   How will soil sequestration be monitored? Will on-site visits or satellite photographs by a verification authority be required? Is this a concern for the landowner and manager? What will future restrictions be to maintain carbon in the soil once there is no financial incentive to do so? Will there be penalties for releasing carbon in the future? Who owns the carbon in the soil? The farm manager, buyer of the credit, or mineral lease holder? The holder of the credit may not be the person or company it was sold to originally. It could be an interest group that destroys the credit to remove it from resale in the marketplace. If producers get paid not to pollute, will they have to pay if they do pollute? What will be the impact upon the flexibility to choose farming techniques with broader greenhouse gas emission laws?

Who Might Benefit the Most from Carbon Credits?

Just as some areas of the country are more efficient at producing wheat or corn, some areas may be more efficient at sequestering carbon. The same case applies in other geographic locations around the globe. Similar crops may produce less biomass in drier areas than in wetter areas. Warmer areas may sequester more carbon, but soil microbes also may be more active over longer periods. Higher moisture and moderately cooler areas may be at an advantage. Cover crops used over winter in wetter regions may be advantageous to some. Farmers in areas that can efficiently produce trees also may hold an advantage over other tree farmers or agricultural commodity producers.

Are There On-Site Benefits of Soil Organic Carbon and No-tillage Systems?

Smith et al. (2000) reported that the on-site value of additional soil organic carbon ranges from \$1.00 to \$4.00/ton/hectare/year in Lethbridge, Alberta, Canada, because of increased productivity in wheat systems. Therefore, producers in some areas may see long-term productivity increase from carbon sequestration, which will be site-specific. Yields may be affected in some areas more than others by changes in tillage techniques and residue management. In any analysis of tillage and/or cropping system, this value of organic material, if any, would be in yield changes and reflected in net returns.

Substantial research has been conducted in Kansas for no-tillage cropping systems including economic analysis of university research trials. The majority of this research is summarized by Dhuyvetter and Kastens (1999). Enterprise records from north central Kansas farms show substantial net return variability across farms for no-till wheat and grain sorghum.

What Are the Risks to Farm Managers?

A question yet to be answered is what will the allowed emissions of CO_2 and other greenhouse gases be for agriculture? Will agriculture be viewed as a net sequesterer or as a net emitter or both? How will rules and regulation on other greenhouse gas emissions affect agriculture? Who will benefit, and who will pay the cost? When environmental policy is enacted or changed, there are usually both winners and losers from an economic perspective.

Many of the strategies to save carbon in the soil will require a capital investment (unless they already are being used) with an uncertain payoff. When will payments for carbon credits take place, and are they certain or uncertain? What will be the future value of carbon credits? Will their early volunteer action receive credit or will early adopters be penalized or go unrewarded?

Will soil sinks be accepted internationally? Soil sinks may provide a competitive advantage to the U.S. because of the high percentage of land in production compared to population to some parts of the world. Will the amount of carbon change be economically measurable and will it be as expected? Who owns the carbon in the soil once it is sequestered? If tillage occurs in the future, will producers be required to buy the credits back or just commit to restore the carbon content in the soil to the agreed-upon amount?

Has Any Research Been Conducted on the Farm Level Economic Impacts?

Hurley (1999) conducted a preliminary analysis of the impact of receiving $23 per metric ton of carbon sequestered by a 640 acre farm in Boone County, Iowa. The management practices evaluated included no-tillage for a corn soybean rotation on 418 acres, forages in rotation with row crops on 114 acres, 20 acres of windbreak, 80 acres of grasses for biofuel production, and 8 acres in miscellaneous uses. This system was estimated to sequester carbon at a maximum rate of 169 metric tons per year over the 640 acres or approximately .26 metric tons per acre. This maximum sequestration rate would result in a carbon credit value of $3,887 per year. However, the cost of establishing these practices, if any, also would have to be considered for an economic rationale.

What Are the Potential Impacts on Land Values?

Land allocation decisions in production agriculture depend highly on the land's ability to generate returns. Values for land are influenced heavily by its capacity to earn income either through sales of products it produces or payments associated with its use. The greater the relative net income generated, the higher the relative land value. Land will move into carbon sequestration programs based on net returns from commodity production, government payments, carbon credit values, and cost per ton sequestered. Land prices likely will change as a result of competition for land among commodity production, conservation set asides for carbon sequestration, and growing trees used directly for carbon sequestration. Competition for land for commodity production versus conservation uses raises concerns in developing countries. They are concerned about food security and, therefore, may not have the land resources to devote to conservation purposes such as reforestation. Converting productive or marginally productive lands used for commodity production to conservation projects may not be either economically or technically feasible. Controversial but legitimized conservation in developing countries could decrease production, increase prices for food and fiber, and change export earnings and import costs (Rosenberg and Izaurralde, 2000).

Carbon Sequestration by Agricultural Producers: A Diamond in the Rough?

Just as the farm manager plants a crop each year with optimistic but uncertain expectations about price and yield, carbon sequestration and credit trading are occurring with an unknown outcome. In the face of uncertainty, soil carbon sequestration projects are developing because of expectations that CO_2 emission controls eventually will become mandatory or that emission reductions will be valued by consumers of “green” products. Firms are looking for cost-effective means to offset their carbon emissions.

Measures undertaken to increase carbon sequestration will conserve soil and reduce erosion impacts on water quality, increase soil organic matter and water-holding capacity, increase wildlife habitat, and possibly reduce fertilizer use and its impact on water quality. However, conservation tillage usually requires additional herbicides and other chemicals, which may have negative impacts on water quality (Rosenberg and Isaurralde, 2000).

Further, how much will the credits be sold for versus the cost of supplying them to the market with alternative production practices? How will the value of the credits affect crop mix and production flexibility, and will they have negative or positive impacts on market prices for commodities and net income? The crops that sequester more carbon may increase in total acreage and supply, causing a decline in market price, whereas those crops that do not may cause the opposite effect.

Increasing fossil fuel prices in the marketplace (diesel) may encourage less tillage to lower energy costs and the generation of more credits, therefore causing the value of credits to fall.

The economic impacts at the farm level and at the broader national and international economy level are not well researched at this point. We have much to learn.

What Can Interested Farm Managers Be Doing?

Farm managers who have an interest in selling carbon credits could be making the following preparation:

1. Have a plan approved for your farm that describes the practices you will follow.
2. Have a baseline established that indicates how much carbon existed in the soil before changing or continuing practices. This will be needed to establish the additional amount of carbon sequestration.
3. Have documentation of your practices since 1990 with NRCS, Kansas Farm Management Association, or other independent party, if possible.
4. Be registered with a national or international group that keeps records of carbon inventory to establish the number of credits you can sell and have sold.
5. Consider creating a producer pool to deliver credits and share benefits. This could allow for annual flexibility in farming operations. It may be useful to have blends of management

practices approved for flexibility to reduce risk.

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Websites Related to Carbon Sequestration

The addresses for these sites are provided for information purposes only and do not imply endorsement of the sites or any products offered by them.

Agricultural Practices to Sequester Atmospheric Carbon In Soils
<www.oznet.ksu.edu/pr_smel>

Cantor Fitzgerald Environmental Brokerage Services
<www.cantor.com/ebs>

Emissions Marketing Association
<www.emissions.org>

Environmental Financial Products
<www.envifi.com>

Greenhouse Gas Emission Reduction Trading Pilot
<www.gert.org>

National Association of Conservation Districts
<www.nacdnet.org>

National Association of Resource Conservation and Development Councils
<www.RCDnet.org>

The Carbon Market News Service
<www.carbonmarket.com>

The Greenhouse Emissions Management Consortium
<www.gemco.org>

The International Emissions Trading Association
<www.ieta.org>.

USDA Global Change Program Office
<www.usda.gov/oce/gcpo/index.htm>

U.S. Senate Committee on Agriculture, Nutrition and Forestry Hearing on Carbon Cycle Research and Agriculture's Role in Reducing Climate Change.
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