Soil Carbon Sequestration and Greenhouse Gas Mitigation:

A Role for American Agriculture

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March 2007

TABLE OF CONTENTS

Executive Summary

Agriculture is beginning to play an important role in reducing greenhouse gas (GHG) emissions, and in doing so is generating new sources of income for producers. However, U.S. agriculture faces its own challenges in today's economy. Among the challenges facing agricultural producers are profitability, high energy costs, soil erosion and soil quality, water quality, and water use efficiency. It is possible for agricultural producers to earn money as they reduce emissions of greenhouse gases and sequester carbon from the atmosphere; however, the most effective policy to allow U.S. farmers to provide maximum GHG mitigation and earn the greatest value is through a mandatory nationwide cap on greenhouse gas emissions. A mandatory nationwide cap creates a larger and more profitable market for agricultural carbon credits by creating demand and value for emission reductions. The U.S. policy should be designed to ensure that soil and crop management systems that can mitigate greenhouse gas emissions simultaneously enhance agricultural sustainability and increase profits.

Policies have recently been enacted that are proving beneficial to agricultural producers by increasing the demand for ethanol and other renewable fuels. Enactment of the Renewable Fuels Standard in the 2005 Energy Policy Act has boosted the demand for renewable fuels from biomass, such as ethanol from corn and other agricultural crops. In much the same way that these policies or incentives can help drive production of renewable fuels, and thus the demand for agricultural crops, a national policy or regulation that establishes a mandatory limit on greenhouse gas emissions can further drive demand for agricultural products. A nationwide cap on U.S. GHG emissions will provide certainty and predictability to businesses, including agriculture, of the value of carbon well into the future. This market certainty will encourage investments by producers in biofuel feedstocks, methane digesters, and no-till equipment, since such practices will be rewarded by the new carbon credit market.

Markets for soil carbon credits are in the very early stages of development in the U.S., hampered mostly by the lack of a market signal or a mandatory nationwide cap on GHG emissions. In the absence of such a signal, various instruments for reducing GHG emissions have emerged, including voluntary markets, regional and state mandatory reduction programs, and voluntary, private agreements between buyers and sellers of carbon reduction credits. The uncertainty regarding future federal legislative approaches to deal with the problem of climate change has created multiple and diverse approaches. The patchwork of approaches has many businesses worried about the need to comply with varied regulations in different states or regions, and about whether emissions reduction activities undertaken now will be recognized or rewarded in future federal policies. A nationwide mandatory cap should build on the successes of these efforts, and help establish a single, consistent approach to reducing greenhouse gas emissions.

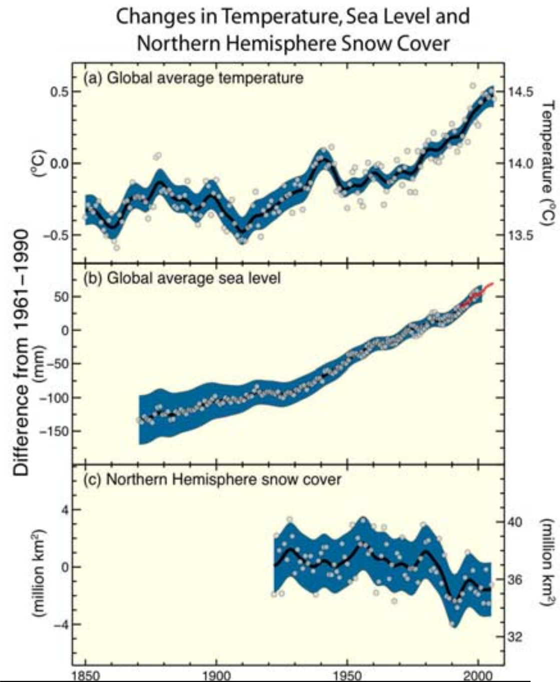
Specific policies to reward agriculture for emissions reductions must be included in any federal legislation or regulations to address global climate change. The European Union, in setting up its rules for crediting emissions reductions activities under its mandatory climate change program, excluded agricultural and forestry emissions reductions from receiving credit. The U.S. should not repeat this mistake, and should instead award top value for agriculture's highly-beneficial "charismatic carbon credits."

To insure proper reward for soil carbon credits, in particular, standardized, cost-effective protocols for measuring or estimating GHG emissions reductions from agriculture are critical for future mandatory carbon markets. Agricultural-based emissions reduction credits in the marketplace will require certainty that the credits represent true emissions reductions, whether for soil carbon or methane from animal manure. Fortunately, credible methodologies for estimating soil carbon exist. These methodologies are being improved, and new direct and indirect measurement technologies are also under development. Certified protocols should be developed immediately, with revisions and enhancements at regular intervals, as appropriate.

The 21st Century Farm delivers more than food and fiber: it provides energy security and valuable, low-cost emissions reductions to combat global warming, while enhancing agricultural sustainability and profitability. Agricultural emissions reduction techniques can be deployed now, while other methods of reducing GHG emissions from cars and power plants are developed, demonstrated, and deployed in the future. Agriculture is the bridge to a low-carbon future. Properly crafted market-based policies to combat global warming will reward these agricultural products and contributions, increasing market prices for carbon credits from $3-$4 per ton today to as much as $10-$20 or more per ton in the future.

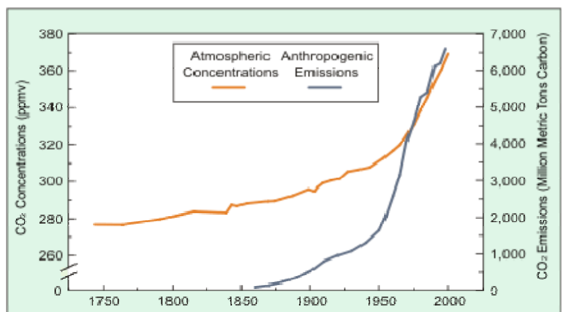
Global Climate Change

Global temperatures have been increasing over the past 150 years. There are fluctuations from year to year, but the clear trend is definitely upward. This warming trend is generally referred to as the greenhouse effect. The International Panel on Climate Change (IPCC), in its latest assessment of the scientific data on climate change, recently announced that: "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." (IPCC, 2007). Additionally, 11 of the last 12 years rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850)" (IPCC, 2007). Moreover, according to the IPCC most of the observed warming since the mid-20th Century is very likely due to anthropogenic increases in GHG emissions.



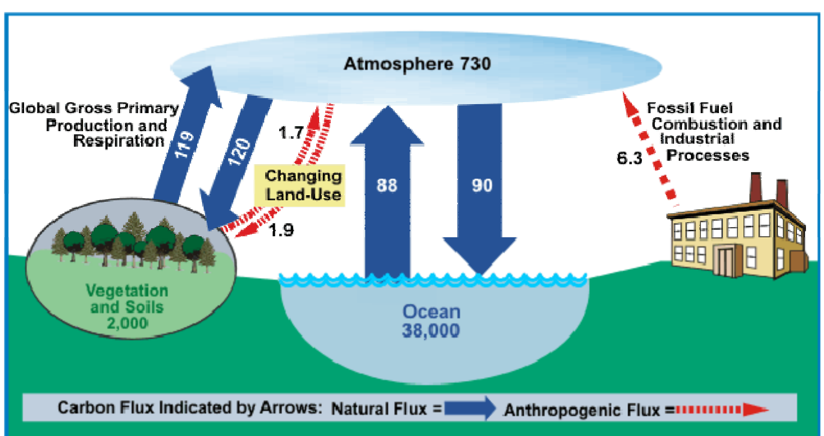
Source: Climate Change 2007: The Physical Science, Summary for Policy Makers, Report of the Intergovernmental Panel on Climate Change

The rise in global temperatures corresponds with and is attributed to increased levels of several important greenhouse gases (GHG), including carbon dioxide (CO_2), the most prevalent greenhouse gas, methane, and nitrous oxide. CO_2 concentrations have increased by about 35 percent since large-scale industrialization began around 150 years ago. During the past 20 years, about three-quarters of human-made CO_2 emissions were produced from burning fossil fuels.



Source: Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center, http://cdiac.esd.ornl.gov/.

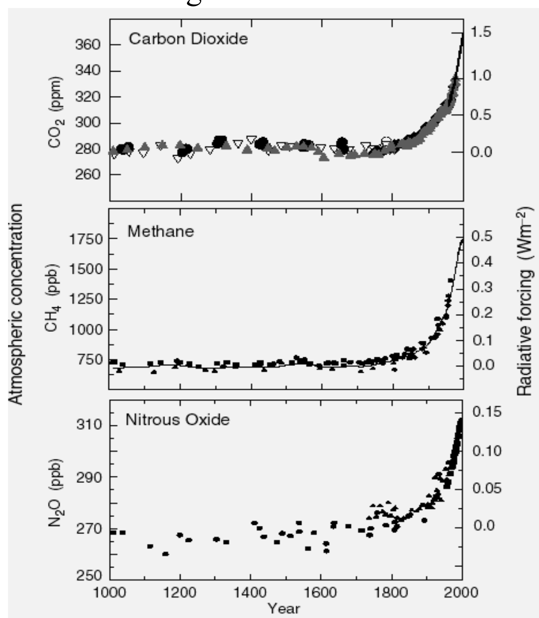
CO_2 in the atmosphere is in a constant state of flux among its repositories, or "sinks"; this is called the *Carbon Cycle*. The movement, or "flux," of carbon between the atmosphere and the land and oceans sinks is dominated by natural processes, such as plant photosynthesis. While these natural processes can absorb some of the net 6.3 billion metric tons of human-produced CO_2 emissions emitted each year (about 2 billion metric tons are absorbed by the ocean and 1 billion by terrestrial systems, including soils), that leaves an estimated 3.2 billion



Source: Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (U.K., 2001) metric tons that are added to the atmosphere annually. The Earth's positive imbalance between emissions and absorption of GHG has resulted in the increased concentration of greenhouse gases in the atmosphere. This causes global climate change.

Greenhouse Gases and American Agriculture

The impacts of human activities on the global climate through the emission of GHG into the atmosphere are becoming better known. Agricultural activities can have a significant impact on both the release and uptake (or removal) of certain GHG. The three major GHG where agriculture has a role in global climate change include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The atmospheric concentrations of these three GHG have increased over the past 100 to 150 years (IPCC, 2001). Since the late 1800's, fossil fuel use, expansion of cultivated agriculture, and forest clearing have led to an increase in atmospheric CO_2 from 260 parts per million (ppm) to current levels >370 ppm (IPPC, 2001), as depicted in the graphic at right. In 2004, total U.S. GHG emissions were 7,074 Teragrams CO_2 equivalents (Tg CO_2 eq.). This represents a 15% increase in U.S. GHG emissions since 1990 (USEPA, 2006). Most of the recent increase in CO_2 has been attributed to combustion of fossil fuels.



Source: Climate Change 2001: The Scientific Basis, Report of the Intergovernmental Panel on Climate

Sources of CH_4 include natural sources such as wetlands and termites and also anthropogenic sources such as natural gas leakage, coal mining, rice paddies, enteric fermentation, animal wastes, and landfills. Sources of N_2O include natural ecosystems as well as industrial combustion and manufacturing, biomass burning, and agricultural practices, such as emissions from chemical fertilizers (Paustian et al., 2004). In the United States, emissions from agriculture and forestry represented approximately 440 Tg CO_2 eq., or 6% of the U.S. total GHG emissions. In 2004, U.S. agriculture represented 27% of the anthropogenic CH_4 emissions and 68% of the N_2O emissions.

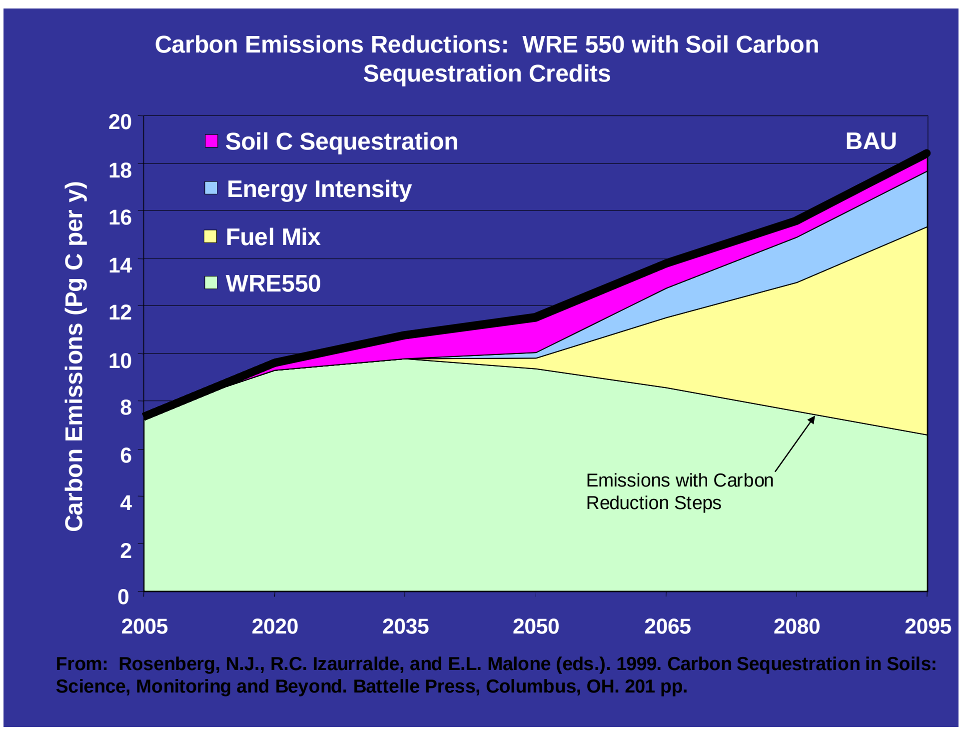
Globally, agriculture accounts for about 14% of the total GHG emissions (Bouwman, 2001; Rice, 2006), including 47% of the CH_4 emissions and 84% of the N_2O (USEPA, 2006). Global agricultural emissions increased by 14% from 1990 to 2005 (US-EPA, 2006a). N_2O from soils (21%), N_2O from manure management (18%), and CH_4 from enteric fermentation (12%) represent the agricultural sources showing the greatest increase in emissions during that period.

The Role of Agriculture in Combating Rising Greenhouse Gas Emissions and Climate Change

While agriculture contributes to GHG emissions, agriculture and forestry currently help to reduce a portion of total U.S. GHG emissions. Land use, land use change, and forestry (which, as a category, includes forests, trees in urban areas, agricultural soils, and landfilled yard trimmings and food scraps) represented a small but significant sink of 780 Tg CO_2 eq. (USEPA, 2006). Agriculture and forestry thus *reduce* U.S. GHG emissions by 11% of the total emissions (USEPA, 2006).

Agricultural soils alone currently sequester or store about 46 Tg CO_2 eq. per year (USEPA, 2006). With increased use of practices that enhance soil carbon sequestration, such as conservation tillage, that total could be increased to about 200 Tg per year. This value can be enhanced by CH_4 capture from animal agriculture, energy savings from reduced tillage, and the use of agricultural feedstocks for bioenergy. Thus production agriculture has the potential to reduce its own emissions and significantly offset the net U.S. GHG emissions from other sectors of the economy.

Economic analyses suggest that soil carbon sequestration is among the most beneficial and cost effective options available for reducing GHG, particularly over the next 30 years (Calderia et al., 2004). However, soils do have a finite capacity to store carbon, and thus cannot entirely solve the problem of increased GHG emissions. In the long-term, reductions in carbon emissions must inevitably come from changes in energy technologies. What soil carbon sequestration offers is the potential to reduce U.S. emissions and to help slow the increase in atmospheric GHG during the next 20 to 30 years while other, more effective technologies to reduce GHG emissions directly are developed and implemented.



Source: Adapted from Rosenberg et al., Pacific Northwest National Laboratories/Battelle.

The graphic above depicts an approach to reducing U.S. greenhouse gas emissions, utilizing various achievable methodologies, including soil carbon sequestration. The top line of the graphic represents the current U.S. GHG emissions path ("BAU", or "business as usual") showing how it is predicted to rise well into the future unless policies are enacted to reduce emissions. The various colored "wedges' each represent a technology or suite of methods that can be employed to reduce U.S. GHG emissions in order to combat global climate change. Soil carbon sequestration represents the top, red wedge, indicating its importance in helping to begin to reduce emissions in this country, and its significance as a first-step technology. The bottom line represents a global emissions reduction path targeted at atmospheric GHG concentrations of 550 ppm – a level at which it is believed to be highly likely (71% mean probability) that a warming of 2^{o} C will be exceeded (Meinshausen, 2005).

While agriculture as a mitigation option offers a short-term solution to help avert climate change, the practices that lead to soil C sequestration and reduced GHG emissions can have long-term and permanent benefits for improving agricultural sustainability and public impacts, such as improved air and water quality, improved soil fertility and productivity, reduced soil erosion, enhanced water retention, and improved wildlife habitat, among others. Few if any other means of reducing atmospheric carbon emissions have so many co-benefits. Because of these associated co-benefits of soil carbon, they are sometimes called "charismatic carbon" reductions. There are no known negative impacts or environmental consequences associated with soil carbon sequestration, as with some other proposed mitigation options. As discussed later in this report, charismatic carbon reductions from agriculture can have great appeal in the global carbon markets that are arising to combat global climate change.

Agricultural Practices that Combat Climate Change

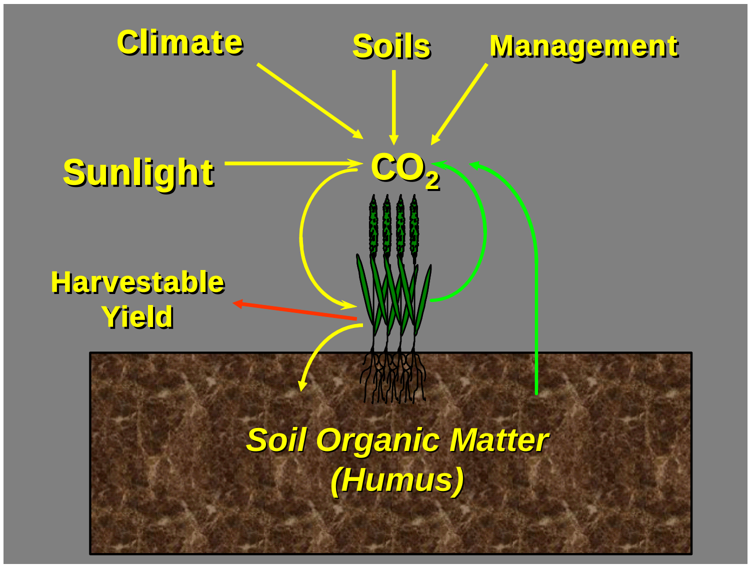
Agricultural land use options can play an important role in mitigating the increase of GHG emissions. Contributions of agriculture and forestry to mitigation of GHG can be achieved by (1) decreasing emissions of GHGs; (2) sequestering carbon derived from atmospheric CO_2 within the ecosystem; and (3) avoiding or displacing emissions.

Decreasing emissions: GHG emissions can be reduced by efficiently managing carbon and nitrogen in agricultural systems. For example, more efficient use of fertilizer often reduces N_2O emissions (Bouwman, 2001), and increasing the efficient use of feeds for livestock may reduce CH_4 emissions (Clemens and Ahlgrimm, 2001). The capture and destruction or use of methane emissions from animal waste management offers another opportunity for decreasing agricultural emissions (Clemens and Ahlgrimm, 2001; Paustian et al., 2004). The approaches that best reduce emissions in any geographic area, farm, or even field, depend on existing management practices and local conditions.

Enhancing sinks: Agricultural systems hold large reserves of carbon (IPCC, 2001), mostly in the form of soil organic matter and inorganic carbon. Agricultural soil carbon sequestration involves the long-term net accumulation and storage of carbon in the soil, known as the "soil sink". The effect of this storage capacity is to reduce the amount of carbon dioxide in the atmosphere while also improving soil quality and productivity. In crop production and grassland agriculture, plants absorb carbon dioxide from the atmosphere through the process of photosynthesis. Some carbon dioxide is released backed into the atmosphere through soil microbial respiration and plant root respiration. In all plant-based systems, carbon is constantly being cycled back and forth between the atmosphere, living tissue, soil organic matter, and soil microbes. It is the net result of this cycle that is of interest for climate change mitigation.

During the first half of the 20th century, much of the cropland in the U.S. was tilled constantly and intensively, and the result was a loss of net carbon from cropland soils and into the atmosphere. Historically, agricultural soils have lost 50% of their original soil C content before they were cultivated (Paustian et al., 1998; Lal, 1999, 2004a). Consequently, much of this lost C can be recovered through improved agricultural management activities. Replacement of some of the lost soil organic carbon levels over the next 50 years would represent a large net gain of carbon in the soil sink, and a significant reduction in the rate of CO_2 increase in the atmosphere.

The C in soil is a balance of inputs and outputs. Increasing inputs (i.e. increasing plant growth) or decreasing outputs or losses of C result in increasing soil C, called soil C sequestration or building C 'sinks'. The amount of C that is stored in soils is a function of climate, precipitation and temperature, and soil properties, principally clay content. Many studies have shown that significant amounts of soil C can be stored through a range of management practices (Lal, 2004a). Land use systems are complex, however, and a full accounting must be taken of the energy used in the inputs of different agricultural land use systems and the limits inherent in agricultural soils and ecosystems to mitigate GHGs. The effects of changes in agricultural land use on GHG mitigation must be more accurately measured both in terms of permanence in time (short-term, medium-term, and long-term effects) and landscape (local, regional, national, and global scales). Overall, however, agricultural soil sinks are an available and promising short-term means of reducing U.S. GHG emissions.



Displacing emissions: Crops and residues from agricultural lands can be used as a source of fuel, either directly or after conversion to transportation fuels such as ethanol or diesel (Schneider and McCarl, 2003; Cannell, 2003). The C from bio-energy feedstocks is from recently derived C through photosynthesis of CO_2 in the atmosphere, rather than from fossil C. The net benefit of these bioenergy feedstocks is equal to the amount of fossil-derived emissions displaced less emissions from production, transport and processing of the biofuel (Smith et al., 2007).

An example of a policy that can help displace GHG emissions from transportation fuels is the recently announced Low Carbon Fuel Standard (LCFS) in the state of California. The California LCFS is the worlds' first global warming standard for transportation fuels, and establishes an initial goal of reducing the carbon intensity of passenger fuels in the state at least 10 percent by 2020. The standard will require fuel providers in the state to reduce the average emissions of GHG associated with the fuels they sell, beginning at the end of 2008. The standard will decline over time, and is expected to reduce GHG emissions and triple the size of California's renewable fuel market. The agricultural sector can help to meet this mandate by providing low-carbon fuels. Fuel producers can reduce the average GHG emissions of fuels by blending or selling more low-carbon fuels, such as E10 and E85 ethanol.

[NOTE: I suggest incorporating the highlighted text into a multi-page spread, with different page or background colors, to emphasize the content.]

How American Agriculture Can Reduce U.S. GHG Emissions and Combat Climate Change

Building Carbon Sinks: Soil Carbon Sequestration

Cropland

Recent models of land use suggest terrestrial systems can mitigate the increase of atmospheric CO_2 by sequestering C into vegetation and soils. The estimated amount of C stored in world soils is about 1100 to 1600 Petragrams (Pg), more than twice the C in living vegetation (560 Pg) or in the atmosphere (750 Pg) (Sundquist, 1993). Carbon sequestration in vegetation and soils is an acknowledged global warming mitigation technology (IPCC, 2000). Caldeira et al (2004) categorized several mitigation options. Agricultural soil C sequestration is identified as a mitigation option that is immediately available to reduce large amounts of atmospheric CO_2. Other technologies such as new coal technology, hydrogen fuels, and geologic storage are identified as requiring further development before they can be widely implemented. Thus, agriculture is an identified primary mitigation option for reducing GHG emissions, with no known associated negative environmental or other impacts.

Current estimates of soil C sequestration are 40 to 77 million metric tons of CO2 (MMT CO_2) per year, primarily due to conservation set-aside, reduced tillage and increased crop productivity (Lokupitiya and Paustian, 2006). The potential for U.S. cropland to sequester C ranges from 275 to 760 MMT CO_2 per year (Lal et al., 1998) and another 66 to 330 MMT CO_2 per year for grazing lands (Follet et al., 2001). This amount is significant for the development of future U.S. policies to combat global climate change. For instance, if the U.S. had opted to participate in the global treaty to reduce GHG emissions (known as the Kyoto Protocol) soil carbon reductions could have met 20% or more of targeted GHG emission reductions to be made by the U.S. at a cost lower than other methods of GHG mitigation.

Mitigation practices in cropland management include the following four categories (Smith et al., 2007):

(1) Agronomy: Improved agronomic practices that increase crop yields and generate greater returns of plant residue can lead to increased soil C storage (Follett, 2001). Such practices include: improved crop varieties; crop rotations, to include crops which allocate more C to the roots (e.g. forages); and avoiding or reducing use of bare (unplanted) fallow (West and Post, 2002; Lal, 2003; 2004). Adding more nutrients, when deficient, can also promote soil C gains (Alvarez, 2005), but the benefits from N fertilizer can be offset by higher emissions of N_2O from soils if the N fertilizer is not managed properly (Schlesinger, 1999; Robertson and Grace, 2004; Gregorich et al., 2005).

(2) **Nutrient management:** Improving N use efficiency of fertilizer and manure can reduce emissions of N_2O (Robertson, 2004; Paustian et al., 2004). Practices that improve N use efficiency include: adjusted application rates based on improved estimates of crop needs (e.g. precision farming); improved timing of N applications and plant N uptake; and improved placement of N to increase plant uptake (Robertson, 2004; Paustian et al., 2004).

(3) Tillage/ residue management: Advances in weed control methods and farm machinery now allow many crops to be grown with reduced tillage or no-till. Since soil disturbance often stimulates soil C losses through enhanced decomposition and erosion, reduced- or no-till agriculture often results in soil C gains, though not always (West and Post 2002; Ogle et al., 2005; Gregorich et al., 2005; Mikah and Rice 200x). Adopting reduced-till or no-till may also affect emissions of N_2O, but the net effects are inconsistent and not well-quantified globally (Li et al., 2005; Cassman et al., 2003). Systems that retain crop residues also tend to increase soil C because these residues are the precursors for soil organic matter.

(4) Land cover/land use change: One of the most effective methods of reducing emissions is to allow or encourage the reversion of cropland to another land cover. The conversion can occur over an entire field ('set-asides'), or in localized spots, such as grassed waterways, field margins, or shelterbelts (Follett, 2001; Lal, 2004a; Ogle et al., 2003). Such land cover change often increases soil C storage; for example, converting cropland to grassland typically results in increased soil carbon. The Conservation Reserve Program (CRP) is one example of a set side program that has multiple benefits -- one of which, increased soil carbon -- was not the original intent of the program. Because land cover (or use) conversion comes at the expense of lost agricultural productivity, it is usually an option only on surplus agricultural land or on croplands of marginal productivity.

Grazing land management and pasture improvement

Grazing intensity: The intensity and timing of grazing can influence the growth, C allocation, and plant species of grasslands, thereby affecting the amount of soil C (Conant et al., 2001; 2005; Conant and Paustian, 2002; Reeder et al., 2004). Increased soil carbon on optimally grazed lands is often greater than on un-grazed or over-grazed lands (Rice and Owensby, 2001; Liebig et al., 2005). The effects are variable, however, due to type of grazing practice and plant species, soils, and climates (Schuman et al., 2001; Derner et al., 2006).

Increased productivity (including fertilization): As with croplands, soil C storage in grazing lands can be improved by those practices that increase productivity. For instance, alleviating nutrient deficiencies by fertilizer or organic amendments increases plant growth and, hence, soil C storage (Schnabel et al., 2001; Conant et al., 2001). Adding nitrogen, however, may stimulate N_2O emissions (Conant et al., 2005) thereby offsetting some of the benefits. Irrigating grasslands, similarly, can promote soil C increases (Conant et al., 2001), though the net effect of this practice depends also on emissions from energy used to pump the water and other related activities on the irrigated land (Schlesinger, 1999).

Nutrient management: Practices that tailor nutrient additions to plant uptake, as described earlier for croplands, can reduce emissions of N_2O (Dalal et al., 2003; Follett et al., 2001). Management of nutrients on grazing lands, however, may be complicated by deposition of faeces and urine from livestock, which are not as easily controlled nor as uniformly applied as nutritive amendments in croplands (Oenema et al., 2005).

Fire management: In native tallgrass prairie, proper burning management can enhance plant production. This enhanced plant growth can result in increased soil C. Research has shown a 5% increased in soil C with annual burning, compared to unburned tallgrass prairie (Rice and Owensby, 2004).

Restoration of degraded lands

Agricultural lands degraded by erosion, excessive disturbance, salinization, acidification, or other processes that curtail productivity can be at least partly restored by practices that reclaim productivity, often resulting in increased soil C storage (Lal, 2001; 2003; 2004b). These practices include: revegetation (e.g. planting grasses); nutrient and organic amendments to improve fertility and soil quality; reduced tillage and retention of crop residues; and water conservation (Lal 2001, 2004b; Bruce *et al*. 1999; Paustian *et al*. 2004).

Decreasing GHG Emissions: Manure management

Animal manures can release significant amounts of N_2O and CH_4 during storage. Methane emissions from manure stored in lagoons or tanks can be reduced by cooling or covering the sources, or by capturing the CH_4 emitted (Clemens and Ahlgrimm, 2001; Paustian et al. 2004). The manures can also be digested anaerobically to maximize retrieval of CH_4 as an energy source (Clemens and Ahlgrimm, 2001; Clemens et al. 2006).

Displacing GHG Emissions: Biofuels

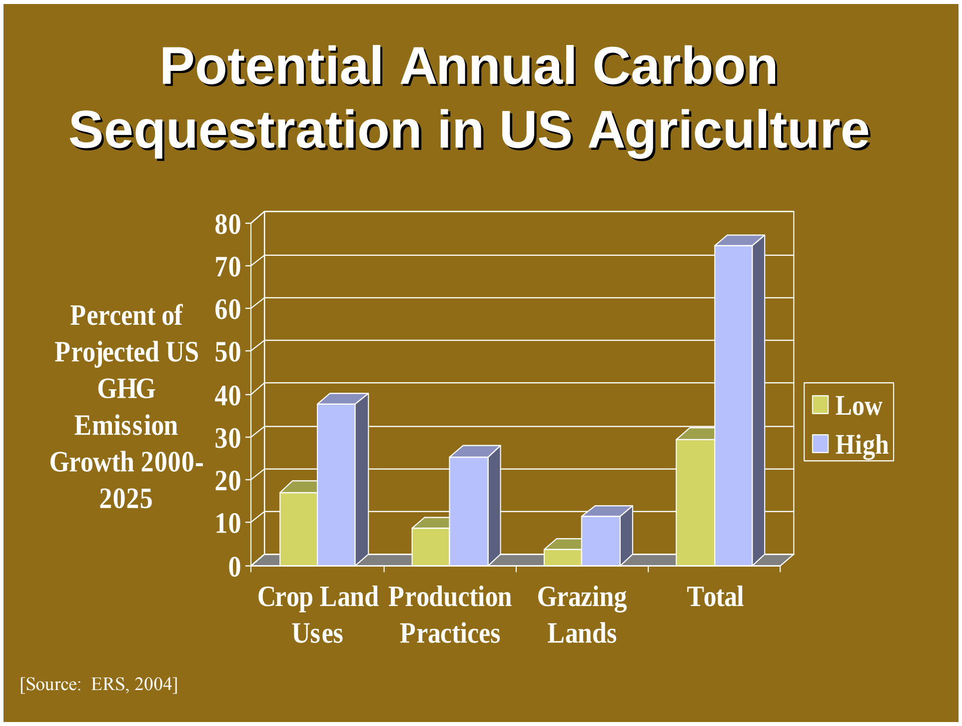
Agricultural crops and residues can be sources of feed stocks for energy, to displace fossil fuels. A wide range of materials have been proposed for use, including grain, crop residues, cellulosic crops (e.g. switchgrass), and various tree species (Edmonds, 2004; Paustian et al., 2004). These products can be burned directly, or processed to generate liquid fuels such as ethanol or biodiesel fuel (Richter, 2004). These fuels release CO_2 when burned, displacing CO_2 which otherwise would have come from fossil C and is recycled into new plant growth. The net benefit to atmospheric CO_2, however, depends on energy used in growing and processing the bio-energy feed-stock (Spatari et al., 2005). Full life-cycle analyses of net GHG impacts are needed to determine the GHG displacement levels. Removal of residues should not come at the expense of lost soil C and sustainability.

Table 1. Estimates of Potential Carbon Sequestration of Agricultural Practices

Agricultural practice	Tons C/acre/yr	MT CO_2/acre/yr	MT C/hectare/year
No-till	0.15-0.30	0.45-1.05	0.30-0.70
Summer fallow elimination	0.05-0.15	0.15-0.5	0.10-0.35
Use of cover crops	0.05-0.15	0.15-0.5	0.10-0.35
Grazingland management	0.015-0.03	0.06-0.1	0.03-0.07

The table above shows a range of estimated annual potentials for carbon sequestration on agricultural and grazinglands. However, the potential to achieve these reductions will be governed by the extent to which these practices are adopted by the producer, which in turn will be governed by markets and policy forces, including the rules that will determine whether and how much agricultural emissions reductions will be credited (McCarl and Schneider, 2001). Smith et al (2007) estimated that approximately 30% of this technical potential would be realized at a price of \$20 per ton of CO_2-eq., and increases to 75% at a price around \$100 ton CO_2-eq. In other words, in a functioning carbon market, the higher the price per ton of CO_2, the more farmers will participate and contribute to GHG emissions reductions.

The potential for agricultural practices to sequester carbon relative to the predicted growth in U.S. GHG emissions out to the year 2025 is shown in the graphic, below. The bars represent low and high estimates of reductions from agricultural sequestration, and show that agricultural sequestration can offset from 30 to over 70 percent of the growth in U.S. emissions until 2025.



Source: Environmental Defense, 2007.

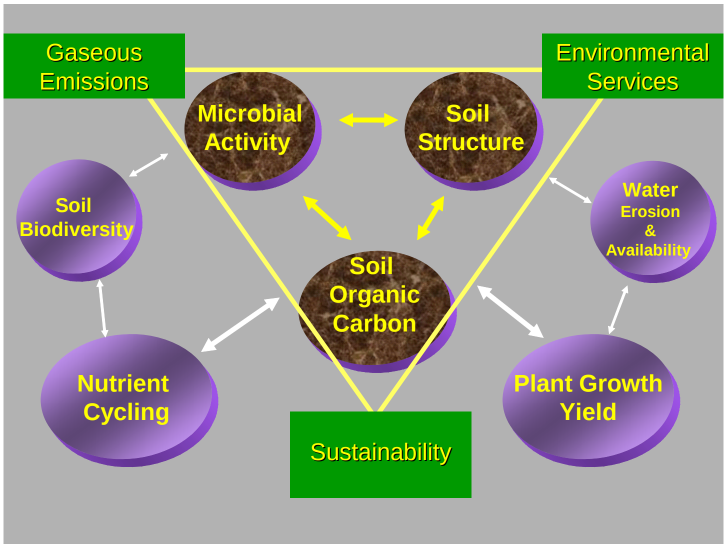
Economic Benefits of Conservation Tillage and No-Till Systems

Often no-till systems have higher net returns than conventional tillage systems due to lower overall costs. This is illustrated in an analysis comparing no-till corn production to tilled corn production systems in northeast KS (Table 1)(Williams et al., 2006). One of the major benefits of adopting less intensive tillage systems is the reduction in fuel use. Emissions from direct energy use in the KS study were nearly 40% lower for no-till compared to tilled systems due to reduced trips over the field. The lower trips over the field in no-till systems also reduce labor requirements and wear-and-tear on machinery, which can reduce equipment maintenance costs.

Table 2. Change in yield, net dollar returns, emissions, and soil carbon when converting from conventional tillage to no tillage corn production in northeast KS (Pendell et al., 2006)	
Mean Yield (bushels per acre) 86 CT	87.7
ΔNet Return ($ per acre)	+26.50
ΔDirect Emissions MT CO_2/acre/year	-0.03
Δ Soil Carbon (MT CO_2/acre/year)	-1.60

Co-benefits of Soil Carbon Sequestration: "Charismatic Carbon"

Several of the agricultural and forestry GHG mitigation options provide ancillary co-benefits to the agricultural sector and to society, making them somewhat unique in their ability to address climate change simultaneously with other pressing social and environmental issues. This has earned these reductions the title of "charismatic carbon credits."



Increased soil C content improves soil structure (McVay et al., 2006), increases soil fertility, soil biodiversity (Schnürer et al., 1985; Hooper et al., 2000), and water availability (Peterson and Westfall, 1997), all of which are beneficial to agriculture and to society. In addition, retention of residues on the soil surface reduces soil erosion, thus improving air and water quality. Better N management in agriculture and forestry has the potential to improve water quality and N use efficiency.

Increasing soil C also increases available plant nutrients; considering the nutrient supplying capacity of just N, P, S, a1% increase in soil organic matter content (equivalent to 21 Tons of CO_2) would translate to 75 lb N, 8 lb P and 8 lb of S per acre (Table 2) (Rice et al., 2007). Given current prices this is equivalent to a fertilizer value of $101 per acre per % organic matter or value of nearly $5/metric ton of CO_2 sequestered, which does not include savings from application costs.

Table 3. Plant nutrients supplied by soil organic matter (SOM) (adapted from Rice et al., 2007).

Nutrient	Value	Supplied by SOM	Savings
	$ lb^{-1}	*lb (% SOM)*$^{-1}$ *ac*$^{-1}$	*$ (% SOM)*$^{-1}$ *ac*$^{-1}$
Nitrogen (N)	1.1	25-75	28-68
Phosphorus (P)	3.3	2.5-8	8-26
Sulfur (S)	0.9	2.5-8	2-7
Total	**5.3**		**38-101**

Additionally, adoption of conservation tillage in lieu of traditional tillage is associated with reduced use of fuels and fertilizers, and reduced labor, resulting in cost-savings as well as additional reductions to GHG emissions, as discussed earlier.

New Technologies to Further Enhance Soil C Storage

Biochar: A promising technology to boost the charisma factor of soil carbon sequestration while also producing bioenergy involves recreating a process developed 2,000 to

2,500 years ago in the Amazon basin of South America (Lehmann, 2006). The process involves the pyrolysis of forest or agricultural biomass to form a charcoal product known as biochar, or agrichar. Under proper production conditions, 30-50 percent of the biomass carbon is retained in the porous biochar structure. The biochar is highly recalcitrant in soils, and can sequester the carbon for thousands of years. Use of the biochar as a soil amendment has also been shown to boost plant growth and improve water retention of soils, reminiscent of the highly fertile Terra Preta ("dark earth") soils of the Amazon region, also created with biomass char. In soils, the biochar also appears to improve nutrient retention and reduce nutrient leaching. Much of the biomass carbon can be captured during the pyrolysis as bio-oils or bio-gases for on- or off-site energy needs. The production of portable pyrolysis systems to utilize on-farm biomass and co-produce energy could offer much promise for agricultural sustainability and enhanced, stable soil carbon sequestration. Collaborative efforts to commercialize the biochar and bioenergy production technology are underway in several countries, including the U.S.

Modifications of the plant-soil system: A better understanding of the biological mechanisms and controls on belowground C flux and retention could lead to knowledge that would enhance soil C sequestration (Rice et al., 2004). Plant residues vary in their inherent decomposability due to differences in their chemical characteristics. Alterations in plant residues also alter the soil microbial community. For example, an increased in plant lignin content favors soil fungi and thus leads to enhance soil C storage (White and Rice, 2007). Thus conventional plant breeding or other biotechnological approaches to plant improvements could lead to enhanced soil C storage. (Rice and Angle, 2004).

Biochar and plant modifications are just two examples where research could lead to expanded capacity for soils to retain carbon and further its contribution to mitigation capacity. Both of these examples maintain soil in production and lead to enhanced sustainability.

Meeting the Climate Challenge: The Role of Carbon Markets

Governments around the world are facing the challenge of global climate change and how to slow, stop, and reverse atmospheric concentrations of GHG emissions to prevent costly and sometimes irreversible impacts. Most industrialized countries, with the exception of the United States and Australia, are acting through the international Kyoto Protocol, which offers a market-based framework to begin addressing the climate challenge. The United States has declined to participate in the Kyoto framework, and until now has chosen instead to pursue voluntary approaches to try to reduce GHG emissions. U.S. GHG emissions have continued to rise despite these voluntary measures, however, and have increased 16% since 1990 (USEPA, 2006). Recently, however, momentum has shifted in favour of mandatory policies, and it is likely that in the foreseeable future, the U.S. will adopt a mandatory nationwide cap on GHG emissions.

Citing the failure of voluntary U.S. emissions reductions policies and growing evidence of the dangers of unmitigated global climate change, increasing numbers of major U.S. businesses, policymakers, and states and regions are demanding that the U.S. undertake mandatory policies to combat climate change. In 2005, 53 U.S. senators voted in favour of a non-binding Sense of the Senate Resolution calling for the eventual adoption of mandatory limits on greenhouse gases. In February 2007, a coalition of large U.S. businesses and NGO's joined to call for immediate action on mandatory, flexible U.S. policies to deal with climate change. The companies in the partnership, called the United States Climate Action Partnership, include General Electric, Lehman Brothers, Caterpillar, Inc., Alcoa, Duke Energy, and others. In the

U.S. Congress, dozens of bills on global climate change have been introduced since the January 2007 start of the 110th Congress, many to mandate policies to reduce U.S. GHG emissions. Both the U.S. House of Representatives and the U.S. Senate are holding hearings on various approaches to cap GHG emissions. Most U.S. business leaders and policymakers acknowledge that mandatory policies are now inevitable.

It often is recognized that market-based emissions trading systems offer the least-cost method for reducing emissions. The environmental and economic success of the U.S. sulfur dioxide allowance trading program to reduce acid rain, as well as other similar markets, provides evidence of the benefits of emissions trading as a tool to meet emissions reduction goals at the least cost. Carbon markets similar to the sulphur dioxide trading market have arisen to deal with climate change.

Mandatory v. Voluntary Carbon Markets

Two types of carbon markets have emerged, globally and in the U.S.: regulated or mandatory markets, and voluntary markets. An example of a regulated or mandated global market is the market established by the Kyoto Protocol, a "cap-and-trade" system which seeks to reduce global emissions of GHG by 5.2% between 2008 and 2012. Under Kyoto, each participating country accepts a "cap" or limit on its GHG emissions. Participating countries generate and accumulate "credits" based on reductions of GHG emissions. A credit is awarded for each ton of carbon dioxide reduced, or the equivalent amount of other GHG. The "trade" refers to the use of markets to allow members to meet their cap at the lowest price possible, either by reducing emissions from a source or through a sink, or by buying or trading credits from another member country that has extra emissions reductions to sell. Countries that have ratified the Kyoto Protocol can participate in the Kyoto carbon markets that have developed under this framework.

The European Union Emissions Trading Scheme: The European Union (EU) established the first mandatory carbon market under Kyoto. The EU Emissions Trading Scheme (EU ETS) began in January 2005, and saw an estimated $40 million in trading in its first month (Ecosystem Marketplace, 2006). According to the World Bank, an estimated $22 billion worth of carbon trading occurred in the EU ETS in the first 9 months of 2006, alone. Prices per ton of CO_2 in the European market have been somewhat volatile, reaching a high of US $39 per ton CO_2 in April, 2006, and dropping 50% shortly thereafter. In February, 2007, prices per ton were at a low of US $1.37, prompted in part by reports that EU member countries had awarded too many emissions allocations to emitting sectors, thus reducing the demand for emissions credits

The EU ETS is a means for EU member countries to comply with treaty obligations under the Kyoto Protocol, and also to meet deeper emissions reduction mandates adopted by the EU. The EU ETS allows the participation of all its member countries in the market, all of whom have ratified the Kyoto Protocol. The ETS is the first regulated GHG market in existence, but Japan, Canada and other countries are working to begin similar markets in their own countries to help meet their Kyoto commitments. Market analysts have predicted that the Kyoto GHG markets will reach US $40 billion annually by 2010 (Point Carbon, 2006).

Chicago Climate Exchange: An example of a voluntary carbon market is the U.S.-based Chicago Climate Exchange (CCX). CCX describes itself as the world's first, and North America's only, voluntary, legally-binding GHG emissions trading market. CCX was initially established in 2001 as a pilot trading system for emission reductions, but has grown to a full-fledged and operational market. CCX has nearly 200 member companies, which include the

Ford Motor Company, Motorola, Inc., IBM, and the Bayer Corporation. Members agree to reduce their GHG emissions six percent by 2010, from a baseline average from 1998 to 2001. CCX points out that its members gain valuable market experience through participation – experience that will prepare them for future regulations or mandates to reduce GHG emissions.

An important distinction between mandatory and voluntary carbon markets is the difference in price signal that each generates. Mandatory markets create demand, and thus value, for the commodities being traded – in this case, carbon and other GHG. The value and price signal is a function of many factors, and is determined by the market and the level of supply and demand of the commodity at any given time. For businesses, mandatory markets remove risk by creating certainty and assurance that investments in the commodity will have value for as long as the policy exists. Voluntary markets lack such certainty, and without it, investments in the commodity carry more risk. Demand for the commodity (carbon credits) in voluntary markets is thus lower, and hence, the price signal or value will be lower, on average. According to a May 2006 report, the total value of carbon markets in 2005 was over US $10 billion (IETA/World Bank, 2006). The value of transactions in just the first quarter of 2006 was $7.5 billion. These values were driven by the mandatory EU ETS system.

The Role of Agriculture in Carbon Markets

Based on the recommendations of the science-based International Panel on Climate Change (IPCC), The Kyoto Protocol recognizes agricultural and forestry sinks as accepted forms of emissions reductions credits for participating countries. Carbon sequestration in vegetation and soils is an acknowledged global warming mitigation technology (IPCC, 2000). Despite this, the European Union does not allow agricultural soil and forestry reductions credits to be traded or sold within the EU ETS market. Some member countries and industries have argued for their inclusion, and discussions are underway for the consideration of forestry credits.

Despite this exclusion, the EU's own experts have acknowledged the potential value of agricultural soil sinks in helping to reduce GHG emissions and in helping the EU to achieve its obligations. The European Climate Change Programme (ECCP) commissioned an expert group of scientists to assess the potential for agricultural soils in the EU to reduce GHG emissions. That group determined in a 2003 report that agricultural soil sinks could contribute annual reductions of 60-70 metric tons of CO_2 per year in the EU, or 19-21% of the total emission reduction obligations the EU is committed to from 2008-2012 under the Kyoto Protocol. The EU can still decide in the future to accept soil sink credits in its emissions reduction scheme, but would have to overcome opposition from environmental groups and other critics. It is not known whether future Kyoto markets in other countries will include or exclude agricultural and forestry credits. In the proposed Canadian system, soil-derived C credits would be allowed for emission reductions.

In the US, scientists and soil experts have completed assessments of the potential for U.S. soils to reduce GHG emissions, and have determined that soil sinks can reduce U.S. emissions 15-20% annually. It is important for the agricultural sector to be recognized and rewarded for its role in reducing GHG emissions in future U.S. policies to combat climate change. The U.S. should not repeat the mistake of the EU by excluding these low-cost, high value "charismatic carbon credits" from being rewarded in the marketplace. Additionally, if the U.S. joins an international emissions reduction framework in the future, as many believe it will, it is equally important that certified agricultural and forestry reductions of GHG be awarded credits by the federal government within that future system.

The U.S.-based voluntary market established by the Chicago Climate Exchange has embraced the value of agricultural GHG emissions reductions for credits or value within its system. Agricultural and forestry credits are a prominent feature of the CCX market.

Agricultural Carbon Credits in the Chicago Climate Exchange

CCX awards GHG emissions reduction credits, which are called "offsets", to practices that sequester carbon, including agricultural and forestry practices. Within the CCX system, participating members who cannot meet their emissions reduction commitments internally can purchase "offset" credits generated by approved forestry and agricultural GHG emissions reductions, including for methane collected from animal manure, carbon sequestered in cropland soils by conservation tillage, conversion of croplands to grasslands, and forest sinks. CCX allocates emissions reduction credits at the following rates for agricultural and forestry offset projects:

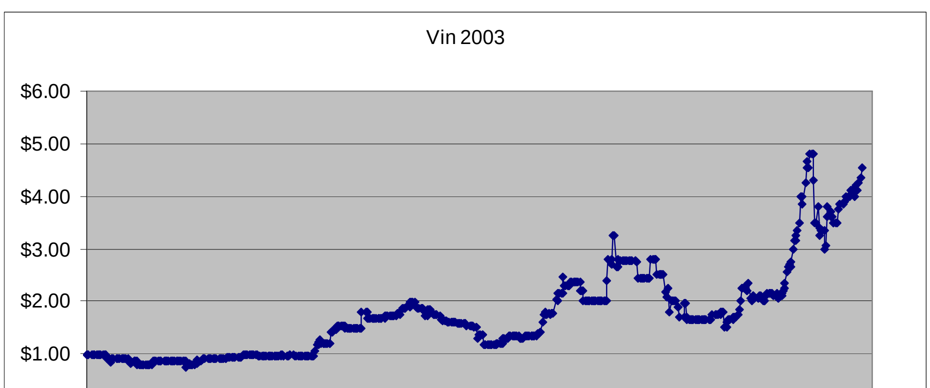
- *Soil carbon credits* – farmers who undertake continuous conservation tillage on croplands can earn credits of 0.5 MT of CO_2 per acre per year. For cropland planted to continuous grass cover (on or after January 1, 1999), the owner can earn credits of 0.75 tons of CO_2 per acre per year.

- *Methane credits* – farmers who capture and combust methane from livestock manure management using anaerobic methane digestors can earn credits of 18.25 MT of CO_2 per ton of methane combusted. (Since methane is a GHG that is 21 times stronger than CO_2, many more credits are awarded per ton of methane reduced than per ton of CO_2.

- *Forestry credits* – landowners can earn credits for emissions reductions accumulated by afforestation or reforestation projects on their lands. The amount of credit varies with the region of the U.S., the species of tree, and the age of the tree, or years since the trees were planted.

Aggregators for Agricultural Offset Projects: Offset projects involving less than 12,500 MT of CO_2 equivalents per year are sold through an aggregator, or a group certified by CCX to "bundle" credits for sale in the CCX market. Aggregators are generally needed for agricultural soil carbon offset projects since, while the number of traded agricultural offsets or credits within CCX are significant, the volume of emissions reductions credits per farm is relatively low. The role of the aggregator is to collect and bundle a sufficient volume of credits from agricultural operations be efficiently traded in the market. In the CCX system, approved aggregators include many agriculture organizations such as the Iowa Farm Bureau, the North Dakota Farmers Union, and the National Farmers Union.

CCX has shown the ability of a GHG market to take advantage of and reward agricultural emissions reductions. To date, one of CCX's approved aggregators, the Iowa Farm Bureau, has



CCX price $/MT of CO_2 from 2004-2006.

signed up 900,000 acres in 12 states to receive GHG credits for carbon sequestered via no-till on cropland and on cropland converted to grass plantings. At the current CCX average market price of \$4.00 per ton CO_2, this would equate to a value for no-till of \$2.00 per acre per year, or about 7% additional income based on the Kansas example discussed on page 12 (Table 2)(Williams et al., 2006). The North Dakota Farmers' Union, another aggregator under CCX, has signed up roughly 1 million additional acres for credit. That equates to participating farmers receiving \$2.00-\$2.50 per acre for continuous no-till for soil carbon credits sold in the CCX market, and from \$3.00-\$3.75 per acre for cropland converted to grass plantings, such as on CRP lands (less a 10% fee for the aggregators). According to CCX, registered offsets for 2006 totalled 1.5 million tons. At \$4.00 per ton, that translates to \$6 million (CCX, 2007).

Because methane and nitrous oxides are much stronger GHG than CO_2, projects that reduce emissions of these GHG from animal manure, for instance, can generate many more credits per ton of GHG reduced. Anaerobic methane digesters are not widely in use in this country (US EPA reports that there are just 80 digesters in use, nationwide: 62 on dairy farms, and 8 on hog farms). The digesters capture methane gas, which can be used to power generators for on-farm energy needs, or fed into the electrical grid. The methane gas can also be piped elsewhere for other uses. One dairy farmer in Minnesota who installed a methane digester on his farm sold his GHG emissions reduction credits to CCX in 2005 for about US \$10,000.

Enrolling in the Chicago Climate Exchange: To enrol in CCX, individual farmers must register with an aggregator, such as the Iowa Farm Bureau or the National Farmers Union. The role of the aggregator is to 'bundle' together carbon credits to provide a large enough quantity of credits to be tenable on the market. The minimum eligible quantity for a CCX project is 12,500 MT CO_2 equivalents per year. To enrol, a farmer needs an enrolment form, which can be obtained from an approved CCX aggregator; a legal description of the acreage to be enrolled, and a description of management practices to be employed (from the list of CCX-approved practices). Farm Service Agency maps and crop reports (CCC-578) are acceptable for these requirements. The farmer must also certify annually that the practice for which the credits are awarded is maintained. CCX also utilizes independent third party verifiers to conduct in-field inspections (compliance checks).

Who can enroll in CCX?: The CCX offsets program which awards credits for agricultural and forestry emissions reductions projects is not currently nationwide, but is being expanded. The CCX market for soil carbon credits is centered primarily in the Midwest, and agricultural producers in many counties in 17 Midwestern states have enrolled agricultural and forestry projects to date. To determine eligibility on an individual basis, contact CCX (wwww.chicagoclimatex.org) or one of CCX's more than 20 approved aggregators (listed on the CCX website).

Future Additional Opportunities in CCX: CCX is currently seeking to expand the geographic range of eligible agricultural projects for its offsets program, and to add rangeland sequestration activities for credit. Agricultural soils in the northeastern and southeastern U.S. are not currently eligible to receive CCX offset credits for emissions reductions, but the Exchange is seeking to expand agricultural offset credits to these areas. It must first determine standard sequestration rates in those areas. To establish these rates, the CCX relies on its Scientific Advisory committee to examine the existing research database and to establish recommended rates for those regions. CCX is also currently developing protocols to credit emissions reductions for soil management on rangelands. The rangeland areas being considered for eligibility will be an expansion of the current eligible soil credit areas, with some limitations regarding annual precipitation levels. When completed, the protocols will likely include counties in California, Idaho and Washington states, the Rocky Mountain Range, the Northern, Western, and Central Great Plains Regions, and additional selected areas.

Beyond CCX

Other business entities have been formed expressly to produce and sell agricultural GHG reduction credits in existing and future markets. AgCert International, based in Dublin, Ireland, has offices in the U.S. and five other countries. AgCert helps create emissions reductions projects on livestock farms, and has developed a UN-approved methodology for GHG emissions reductions from animal waste management systems. AgCert improves manure handling on farms, resulting in reduced emissions of the potent greenhouse gases methane (CH_4) and nitrous oxide (N_2O), for which they gain credit in mandatory carbon markets. AgCert installs anaerobic methane digesters on farms, or other means of containing and removing the GHG emissions associated with manure management ,

UN approval of AgCert projects means the GHG credits generated can be traded in Kyoto markets, provided the projects are located in participating "Kyoto countries". To date, AgCert has generated 118,560 Certified Emissions Reductions Credits (CERs) under the Clean Development Mechanism (CDM) of the Kyoto Protocol. The CDM was designed to encourage emissions reductions projects between industrialized and developed countries, to effectuate "clean" development projects involving technology transfer from the industrialized country partner. The CDM credits generated by AgCert can be sold or traded in the EU ETS.

Below is a diagram of the anaerobic digestion process that AgCert employs for its GHG credit projects (AgCert, 2007).

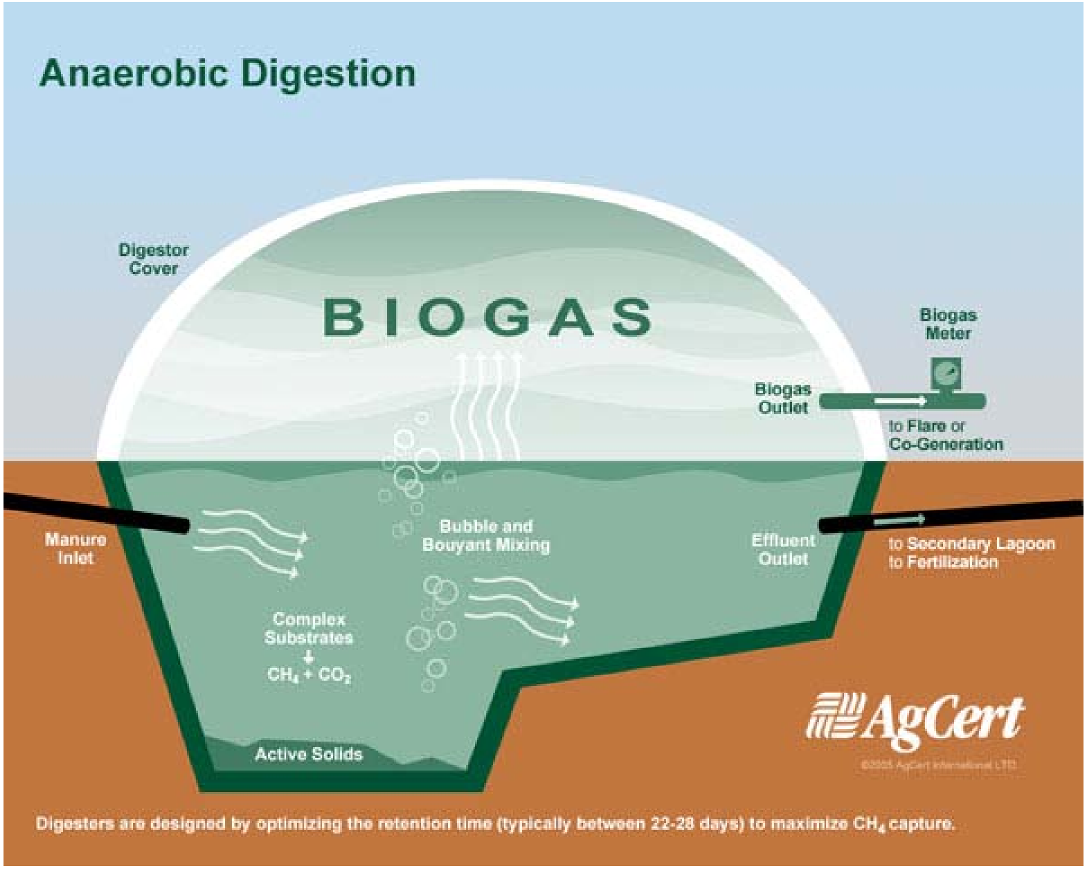


Diagram of Anaerobic Digester process. Source: AgCert, 2007.

AgCert currently focuses only on swine operations, but is condisering incorporating additonal livestock species in its projects. It may also develop emissions reductions credits under the Kyoto Protocol's Joint Implementation mechanism. This mechanism is similar to CDM, but promotes emissions reductions projects between industrialized countries as a means of sharing or trading technologies. Early in 2007 AgCert announced that it was working to aggregate project sites in the U.S. in anticipation of federal-level caps on GHG emissions.


On-farm anaerobic methane digester, at right, built by AgCert. Source: AgCert, 2007.

Organizations such as Environmental Defense (ED) also work to establish direct connections between voluntary buyers and sellers of carbon credits. ED arranged a trade in 2002 between Pacific Northwest Direct Seed Association (PNDSA), a no-till association, and Entergy Corporation, an energy holding company based in Texas. Entergy leased carbon credits for 30,000 tons of sequestered carbon dioxide from PNDSA over a 10-year period, in order to offset GHG emissions from power plants. Each participating farmer in PNDSA, who agreed to use no-till or direct-seed agricultural practices for at least 10 years, received payment from Entergy for the carbon credits. The agreement is providing marketplace experience in carbon trading for both PNDSA and Entergy in anticipation of mandatory carbon markets. Like CCX, the Entergy/PNDSA project establishes the value of businesses such as Entergy looking to the agricultural sector for valuable, low-cost "charismatic carbon" emissions credits. For credits that are negotiated privately between buyer and seller, there is no established price, but it is highly unlikely that the price will exceed that received in voluntary markets such as CCX, at least in the absence of mandatory GHG policies.

U.S. Regional and State Mandatory Carbon Markets: The Regional Greenhouse Gas Initiative (RGGI) enacted in 2005 represents the first mandatory "cap-and-trade" policy in effect in the U.S. RGGI sets a cap of current emissions by 2009, and 10% below that by 2019 for the nine Northeastern and mid-Atlantic states currently involved (Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont; Maryland is expected to join in 2007). Under RGGI, the first phase of the carbon market will involve only credits and emissions sources from within the utility sector. A later phase will develop protocols to allow other sources and sectors to participate in the carbon trading. This could conceivably allow agricultural credits to be traded in the market, but as in the experience in the EU, it cannot be assumed that these credits will be included without the engagement of the agricultural sector.

In September of 2006, the state of California enacted the first mandatory policy to regulate GHG emissions at the state level. The state-wide cap requires the state to reduce its emissions of GHG to 1990 levels by 2020. In June of 2007, the state will publish its first list of discrete activities that can receive credit for emissions reductions, through 2011. Among the agricultural activities being considered for credit is the use of anaerobic digesters to capture and reduce methane emissions from livestock manure management. Of the approximately 2,000 dairy farms in California, only about 1% currently utilize the digesters.

THE 21ST CENTURY FARM: C Credits and Income Generation

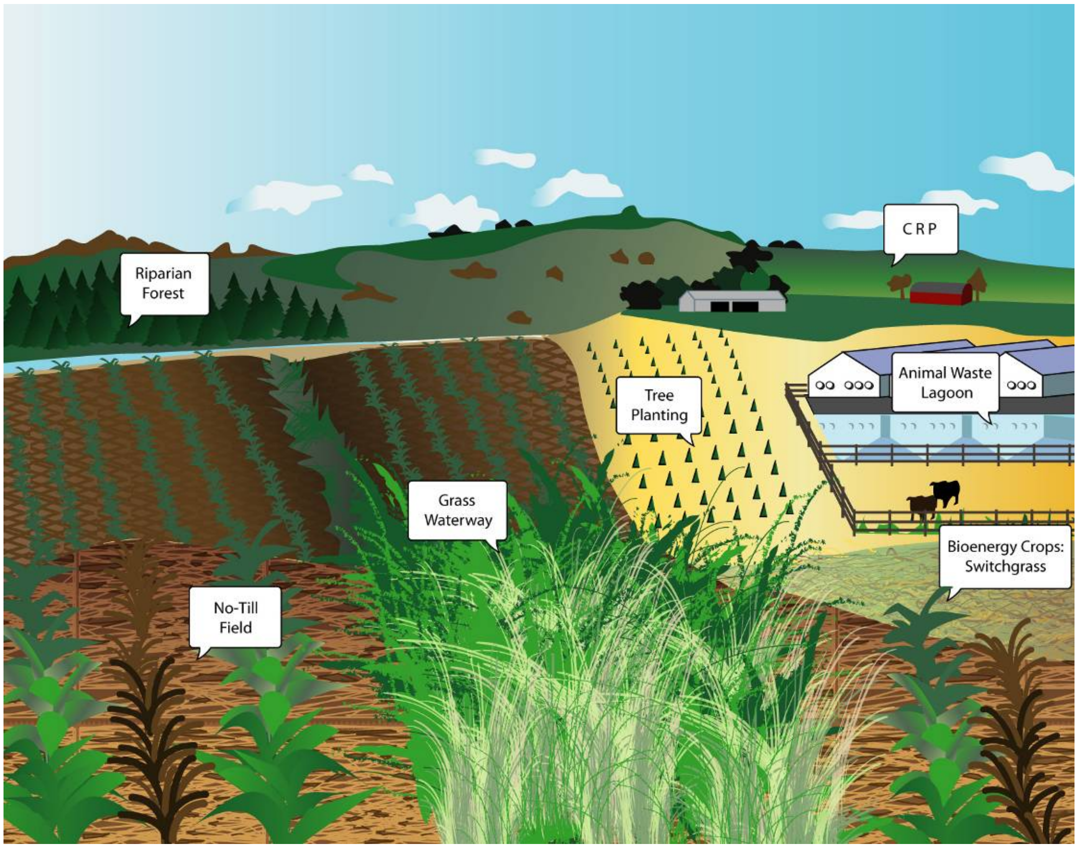


Table 4. The 21st Century Farm: Potential annual income generated from carbon credits on a "model" 1,000 acre farm.

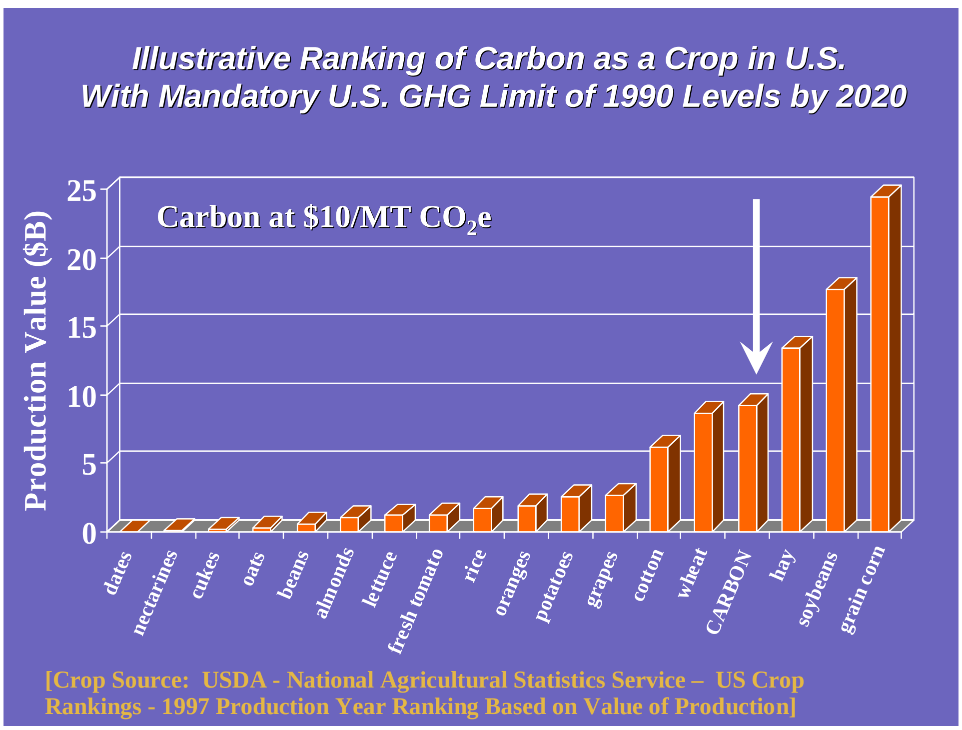
Practice	Soil MT CO_2/a/y	Area (acres) *	Total Soil Credit	Value $4/Ton	Value $10/ Ton	Value $20/ Ton	Other Credits[1] MT CO_2/a/y	Value $10/ Ton
Riparian Forest	NA	40					0.70?	
Grass Waterway	3.00	50	150	600	1500	3000		
Tree Planting[2]	0.45	100	45	180	450	900	0.70	700
CRP	3.00	100	300	1200	3000	6000		
Bioenergy grass crop	0.20	200	40	160	1600	3200	5.0	10000
No-till Field	0.75	500	375	1500	3750	7500		
Anaerobic Methane Digester for Animal Manure Treatment	NA	50*[3]		300	750	1500	1.5*[3]	750
Total		1000		3940	11050	22100		

*Figure reported as head of cattle, rather than in acres.

[1] Other credits generated could include: carbon accumulation in woody biomass (Heath et al., 2003a) and from the use of perennial grasses for cellulosic ethanol production, with the ethanol substituting for fossil fuel use (Nelson personal communication), and methane credits (per head

of cattle) from managing an animal waste lagoon, with the installation of an anaerobic methane digester.
[2] (Heath et al., 2003b)
[3]The amount of credits awarded by CCX in association with use of an anaerobic methane digester to handle cattle manure is approximately 1.5 MT CO_2/head/year (Personal communication with Dave Miller, Iowa Farm Bureau, 2007).

The 21st Century Farm could deliver substantial benefits for mitigation offsets and income for the farm. Based on a farm of 1,000 acres with a diversified land use, the farm could generate \$20,600 based on a \$20/ton value just in soil carbon credits; that is an additional income of over \$20 per acre. Nearly 40% of the income comes from soil C credits generated from no-till crop production, which also is generating food and income. Under the current voluntary trading mechanism offered by CCX, at \$4.00/ton CO_2, the income is 3 to 6 times less than an anticipated value under a cap and trade system. Additional income would be derived from energy offset credits for the energy crops, offset credits in wood, and methane destruction from the animal waste lagoon if an anaerobic methane digester is installed. This scenario does not include additional offset credits that can potentially be generated for reduced on-farm fuel use, which can generate additional income and reduce farm inputs. All these extras could double or triple the income from the farm.



Source: Adapted from Environmental Defense, 2007

Ensuring That Agricultural Emissions Reductions Are Credited and Rewarded in Future Mandatory U.S. Carbon Markets

Most large U.S. businesses and policymakers agree that mandatory policies to reduce GHG emissions that cause climate change are inevitable in this country, likely within 3-5 years. As evidenced by the European Union's decision not to accept agricultural and forestry sink credits in their Emissions Trading System, it cannot be assumed that credits will be granted to agriculture in U.S. markets, either. The agricultural sector must engage in the policy debate to ensure that GHG emissions reductions are credited and viable in future mandatory markets in this country.

Existing voluntary and mandatory markets have provided valuable experience regarding the issues that need to be addressed to create full market value for agricultural credits. Many of these issues involve the concept of soil carbon sinks, including for example, how to measure, monitor and verify increased levels of soil carbon; how to ensure the longevity or permanence of soil carbon; and how to assure the "additionality" of credits – a term used to denote that sequestered tons are above "business-as-usual", or are additional to what would have occurred in the absence of the regulation or policy. Determination of project baselines (temporally and geographically) is also important for proper crediting, to accurately determine net GHG emissions reductions achieved by a project or activity. These issues are all important to ensure that a GHG emissions reduction market achieves actual emissions reductions. Each is also readily addressed in the context of the policies that will be enacted to govern those future carbon markets.

Measurement, Monitoring, and Verification of Soil Carbon Credits

Carbon dioxide is a colorless, odorless gas that is not visible to the naked eye. In soils, carbon content is accurately measured by defined protocols on soil sampling and having the soil analyzed in a laboratory for carbon content. This methodology, called core sampling, is the "gold standard" of soil carbon measurement, and is the method used by researchers and scientists to verify the carbon content of soils. CASMGS (Consortium for Agricultural Soils Mitigation for Greenhouse Gases) has also drafted a protocol for soil sampling procedures. However, soil sampling and soil carbon analyses can be relatively expensive, invasive, and time-consuming. This method if done on every field is not cost-effective for voluntary carbon markets. The cost of such measurement procedures would likely exceed the market value of the credits. However under a higher value ($36.60 to $366/ton CO_2) measurement costs can be 3-10% of the value of the credit (Mooney et al., 2004)

Currently in the U.S., soil carbon credits are awarded based on estimates of sequestration associated with a certain practice in a given geographic area. Under CCX, for example, farmers in the Midwest who enrol their no-till acres with an aggregator for a certain time period will receive payments for carbon sequestration based on the number of acres enrolled, rather than on a direct measurement of added carbon in the soils. The default value of 0.5 tons of CO_2 per acre, per year is used for no-till practices in the CCX system. CCX derived the default value for awarding soil credits from scientific data collected by land-grant universities and USDA-ARS to obtain an average soil sequestration rate in the Midwest. A discount is included in the default value to provide assurance that the number of credits awarded is not overestimated. The use of practice-based default values is acceptable in voluntary markets, and CCX is to be commended for developing a science-based methodology for developing its default values. However, mandatory markets may require more robust soil carbon measurement methodologies to award full market value to soil carbon. Future markets that include measures of nitrous oxide (N_2O) and methane (CH_4) will also require more robust methodologies and research.

Standardized Measurement Protocols for Market Certification of Agricultural Credits

The U.S. Department of Agriculture should immediately establish standardized protocols to ensure that agricultural carbon credits can be certified and authorized for market trading at top value in future mandatory markets. The protocols should provide adequate assurance to potential buyers that the credits are real and can be verified. Different standards might appropriately be developed for different agricultural activities, since measurement technologies for soil carbon are different than for methane reductions in anaerobic digesters. While there are many potential methodologies and technologies in use and in development across the federal government and in the private sector, it will be essential for the government to designate an acceptable level of performance that a technology must meet to award certification and credit to agricultural emissions reductions. In this way multiple methodologies may be acceptable, provided they meet the minimum requirements designated by the government. The standard can be revised as technologies improve and as methodologies are further tested in the marketplace.

In determining a soil carbon measurement protocol, USDA should include the expertise of CCX, universities, the Soil Science Society of American, and other appropriate entities in the determination. The Soil Science Society of American in early 2007 appointed an Adhoc Committee on "Standardization of Methods for Measurements, Monitoring and Verification of Carbon Sequestration in Agricultural Soils." The Committee's objectives are to recommend methods of determining soil carbon sequestration rates for the express purpose of trading these credits in carbon markets. The Committee is including considerations of credibility, economics, and ease of use by aggregators as part of their decision-making.

Some Methodologies and Technologies for Soil Carbon Measurement

A description of some available measurement methodologies and technologies under development follows, but this list is not exclusive; there are many more methodologies that are not described here. Each of the technologies under development has key capabilities that can help to answer the question of just how much agriculture can help society by reducing or removing GHG. Not all of the technologies in use and under development are user-friendly for farmers and ranchers; accessibility, utility and cost are important determinants for future programs, however, and should be taken into account when standardized protocols are established.

Model-based Estimates of Soil Carbon

COMET-VR (Voluntary Reporting of Greenhouse Gases-CarbOn Management Evaluation Tool): The USDA Natural Resource Conservation Service (NRCS) and Colorado State University (CSU) Natural Resource Ecology Laboratory (NREL) have jointly developed a model-based approach to estimate soil carbon inventories based on changes in management practices. COMET-VR is a web-based application linked to the CENTURY model and to land use datasets. The Century Model is an ecosystem model that simulates carbon, nitrogen, and other nutrient changes on cropland, grasslands and forests. COMET-VR is user friendly: it is accessible to all users via the internet, and was developed to allow farmers and ranchers to estimate soil carbon inventories for registration in the Department of Energy's voluntary GHG emissions registry, known popularly as the 1605(b) program. Continued enhancements to the underlying datasets can make the soil carbon estimates more robust. USDA is currently working on some enhancements to COMET-VR, such as adding more crops and crop rotations to the options available for producers to choose from when entering their individual information into the program. The Department should continue to invest significant resources to further develop the program for future mandatory market use.

<u>Direct Measurement of Soil Carbon</u>

Besides the "gold standard" methodology of core-sampling, a range of high-technology, non-invasive instruments for direct measurement of soil carbon are in various stages of development. For example, the Department of Energy (DOE), as part of is Terrestrial Carbon Processes Program, has developed hand-held, laser technologies, such as the Laser-Induced Breakdown Spectroscopy (LIBS) instrumentation, and instruments that use infra-red light beams and neutrons to measure soil carbon (Izaurralde and Rice, 2006)

Together with the methodologies described above, these higher-technology methodologies should be calibrated and validated to maximize the value of soil carbon credits for market trading. USDA should work with DOE and with other appropriate federal and private entities, such as CCX, to evaluate and compare measurement technologies, and where possible, link and calibrate them at various scales. Some of the technologies work best at national scales, rather than at the farm of field scale. Also, some include measurements or estimates of more than one GHG, while others account for just changes in carbon content. The CENTURY model data, used in the COMET-VR program, has good estimates of soil carbon changes at national scales. The data in the CENTURY model should be continuously improved to enhance its estimates at all regional and local scales, and should be compared with other instruments and methods, such as the DOE instruments and core-sampling methodologies employed by soil scientists. The goal should be to, over time, ensure that the national-level modelling data correlates with the finer-resolution core-sampling data at the field scale, and that the methodologies can be linked (aggregated and disaggregated) to ensure greater accuracy and resolution at different scales.

Permanence

Soil carbon can remain sequestered for thousands of years, but it can also be lost due to practices that disturb the carbon. Intensive tillage practices tend to disrupt soil carbon, and cause its loss to the atmosphere, whereas conservation and no-till practices allow soil carbon stores to remain undisturbed, and even to grow as more carbon is sequestered. Policies to reduce GHG emissions can take the permanence characteristic of soil carbon into account while still fully awarding soil carbon credits. CCX, for instance, deals with the issue of permanence in at least two ways. First, farmers who enrol lands with CCX for carbon credit must annually certify that they continue to follow management practices that sequester rather than disturb soil carbon. CCX uses third-party verifiers to undertake compliance checks. Additionally, CCX keeps a reserve pool of soil carbon credits, equivalent to 20% of enrolled soil carbon credits in each year, to insure against potential losses of soil carbon from some of its projects. The reserve tons are released for trade or sale on the market only at the end of the enrolment period, provided that they are not needed to 'make up' for lost tons elsewhere.

Another way that a regulatory policy could deal with the soil carbon permanence characteristic would be to require direct testing on an interim basis – for example, every 5 or 10 years, to verify that the sequestered carbon remains in the soil at the credited levels. If the carbon is not there at levels credited, the difference would need to be replaced with new credits.

Additionality

A major criticism of the CCX carbon offsets program relates to the issue of additionality. CCX awards credits for carbon sequestration for projects and practices that were already occurring, and that would have occurred even in the absence of the CCX emissions reduction program. Farmers who have been no-tilling for years can enrol their no-till acreage in CCX and get paid for the carbon reductions, despite the fact that they are doing nothing new to benefit the atmosphere or to combat global warming. CCX representatives defend the practice, arguing that it is important to reward "good actors" regardless of when they instituted their beneficial practices. This notion does avoid creating a perverse incentive that might tempt a farmer to plow up soil carbon in order to re-sequester that carbon for money in the CCX voluntary market, or a future mandatory market. Additionally, it does not penalize farmers for being early adopters and for utilizing beneficial management activities even in the absence of a requirement or incentive to do so. In devising future mandatory GHG emissions regulations, policymakers will have to resolve the issue of additionality by establishing rules to equitably address who is rewarded and who is not for the same actions or activities.

Baselines

A baseline refers to the 'starting point' from which emissions reductions are measured for credit. The term baseline may be temporal, as in, a 1990 baseline determines that all new emission reductions after 1990 will be awarded credit. Alternatively, a project baseline may determine the geographic area in which changes in GHG will be measured for credit. No-till acreage in the CCX program, for instance, will have both a temporal and a geographic baseline upon which credits are based. As is the case for additionality, baseline issues in the context of mandatory GHG regulations will be determined by establishing rules for implementation.

What is Needed In Carbon Markets to Reward Agricultural Emissions Reductions?

To take advantage of the GHG emissions reductions that the agricultural sector has to offer in the U.S., regulatory policies or mandates at all levels (state, regional, federal) that seek to reduce GHG emissions must include the following:

- Provisions that expressly define the role of agricultural mitigation options as a bridging technology to future, more costly, not-yet-available emissions reductions technologies. These should include soil carbon credits; biofuels replacement credits; methane emissions reduction credits from methane capture and combustion from manure storage systems, methane enhancement in an anaerobic digester, and burning of the methane for heat or electricity; and nitrous oxide emissions reductions from reduced use of chemical fertilizers.
- Recognition of the greater value of "charismatic carbon credits" to society. Soil carbon sequestration can help combat global warming, but multiple ancillary benefits of soil carbon sequestration exist for farmers and society, and should be acknowledged. Soil carbon sequestration improves air and water quality, improves soil fertility and productivity, and enhances agricultural sustainability and profitability, among other benefits.
- Standardized, approved protocols to measure, monitor, and verify agricultural emissions reductions are needed for mandatory carbon markets. These are particularly need for soil carbon sequestration emissions reductions, to ensure full market credit.

- Continued refinement of technologies to measure and monitor soil C sequestration rates and trace greenhouse gas emissions and reductions (N_2O and CH_4) across a variety of agricultural practices, climate, and soils.
- Better coordination among land grant universities (research and extension), USDA-ARS and USDA-NRCS to develop and deliver programs supportive of farmer participation and reward in carbon markets.

Conclusions

- Existing voluntary U.S. GHG markets have stimulated the participation and interest of the agricultural sector in GHG markets. Under the voluntary Chicago Climate Exchange, farmers generated an estimated $10 million in additional revenues in 2006 for soil carbon sequestration activities, alone. Additional income was generated for forestry and use of anaerobic methane digesters. When the U.S. inevitably adopts a mandatory, nationwide GHG emissions reduction program, the price per ton of CO_2 credits will likely be higher than the current CCX price of $4 per ton of CO2 eq. Depending on the policy adopted, and the extent to which agricultural practices are allowed to receive credits for GHG emissions reductions, prices may range anywhere from $10-20 per ton of CO_2, or more.

- This higher price per ton of CO_2 will dramatically improve income opportunities for the agricultural sector, and quite likely increase participation rates of farmers and ranchers, as well. As discussed in this report, the ancillary benefits to the agricultural sector and to society associated with soil carbon sequestration, in particular, has earned these carbon credits the designation of "charismatic" carbon credits.

- Inclusion of agricultural emissions reduction credits in a carbon trading market will help to keep the cost of credits lower than they would be without them. This is because agricultural emissions reductions activities are readily deployable now, at lower cost -- and with greater net societal benefits – than many other emissions reduction technologies, including geological sequestration. Agriculture's 'charismatic' carbon credits thus additionally benefit society by helping to keep the cost of compliance low for sectors and businesses that must reduce their emissions. In this way agriculture can provide the 'carbon bridge' to the future, enabling the U.S. to reduce its GHG emissions efficiently and effectively while technologies to reduce emissions from fossil energy are developed.

- Farmers and ranchers can begin to prepare for this market by contacting approved aggregators within the Chicago Climate Exchange, including the National Farmers Union or the Iowa Farm Bureau. Additionally, the Agricultural Extension Service of the USDA Natural Resources Conservation Service can provide information on agricultural management practices that reduce GHG emissions.

- Perhaps most importantly, the agricultural sector must ensure that agricultural emissions reductions are awarded credits within the context of all mandatory global warming policies enacted in this country. To exclude agricultural credits risks precluding the multiple benefits to society of these charismatic carbon credits, and a profitable income stream for agriculture.

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