Carbon Sequestration, Greenhouse Gas Emissions, and Nebraska Agriculture – Background and Potential

A Report Relating to the Requirements of LB 957 of the 2000 Session of the Nebraska Unicameral and Containing the Recommendations of the Carbon Sequestration Advisory Committee

A Report of the Nebraska Department of Natural Resources
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Scientists believe that rising levels of carbon dioxide and other greenhouse gases are contributing to global warming, although to what extent is difficult to determine. While limiting fossil fuel consumption is one method of reducing emissions of carbon to the atmosphere, another is sequestering carbon sources on the land. Carbon sequestration is the use of practices, technologies, or other measures that increase the retention of carbon in soil, vegetation, geologic formations, or the oceans with the effect of offsetting carbon dioxide emissions from other sources.

Nebraska's agricultural producers can help address greenhouse gas concerns by implementing practices that cause the land to act as a sink for carbon, by decreasing emissions of greenhouse gases from agricultural production activities, or by participating in other activities such as biofuels production (which can provide a substitute for fossil fuel use). Many of the activities that increase the organic content of soils, and thus sequester carbon, also increase agricultural productivity as well as improve soil, air and water quality.

With Nebraska's large agricultural land base, the state's landowners could potentially profit from carbon sequestration if certain types of carbon trading or other financial incentives are put in place. Yet there are very significant questions about whether substantial carbon trading markets will develop in the United States and, if so, what form they might take. At this point in time there has been no federal government action that would result in development of strong carbon markets in this country.

An agreement on rules for implementing an international agreement, the Kyoto Protocol to the United Nations Framework Convention on Climate Change, was reached in Marrakech, Morocco in November 2001. The agreement would restrict future greenhouse gas emissions by industrialized countries and provide for trading of credits by countries to offset greenhouse gas emissions. However, the Protocol has not yet been ratified by the requisite number of nations for it to take effect and is opposed by the President of the United States. Would the United States be able to participate in the potential resulting carbon market if it was not party to the Kyoto Protocol? International developments bear monitoring as they continue to unfold.

The United States currently contributes over 18% of the world's emissions of the three major greenhouse gases in global warming potential, while only having about 5% of the world's population. U.S. Department of Agriculture estimates have indicated that cropland has the

potential to sequester about 154 million metric tons of carbon per year, or about 8.4% of total U.S. emissions. Another source indicates that cropland could sequester as much as 123 to 295 million metric tons annually, including potential offset from use of biofuels, reduced fuel usage, and reduction of eroded sediments. Nebraska cropland management practices currently sequester about 1.7 million metric tons of carbon per year. It is estimated that this level of sequestration can be maintained and increased to 2.3 million metric tons if all cropland is converted to a no tillage management system. Agroforestry in Nebraska has an estimated potential to sequester 82 to 165 million metric tons in carbon storage value at a point 40 years after planting. Forestry in Nebraska has an estimated storage potential of almost 50 million metric tons at that 40-year point.

A number of practices can help sequester carbon, including:

1. Conservation tillage, buffers, conservation reserve
2. Soil erosion management
3. Conversion of marginal agricultural land to grassland, forest, or wetland
4. Wetland restoration
5. Irrigation
6. Elimination of summer fallow
7. Use of biomass or energy crops to substitute for fossil fuels
8. Use of biogas from liquid manures to substitute for fossil fuels
9. Improved fertilizer use and efficiency
10. Rangeland and pastureland management
11. Agroforestry
12. Forestry

When considering the above practices, it should be kept in mind that there are practical limits to the capacity to store carbon in a given area of land and that later changes in land management could, in a short time, release carbon back into the atmosphere that had taken years to store. Measurement of carbon storage is also one of the challenges likely to be a factor in implementation of many potential international or national options. Potential approaches include: direct in-field measurement, indirect remote sensing techniques, and default values for land/activity based practices.

Nebraska could consider a number of options that might address carbon/greenhouse gas concerns. These include:

1. Provide additional funding for basic carbon sequestration related research relevant to Nebraska
2. Develop a state greenhouse gas inventory

3. Complete a carbon sequestration baseline survey and update periodically
4. Create a permanent carbon sequestration committee
5. Sponsor a carbon sequestration pilot/demonstration project
6. Enact legislation requiring those seeking to negotiate carbon related contracts to register with the state. The state could also provide a clearinghouse of carbon market information.
7. Grant a government entity the power to enter into contracts on behalf of landowners
8. State incentives or programs for actions that result in additional carbon sequestration
9. Continue or expand state incentives for bio-fuels programs. Examine biomass options.
10. Initiate livestock waste / methane reclamation programs
11. No new action

Recommendations of Carbon Sequestration Advisory Committee

Sequestration of more carbon in the soil and vegetation is one of the activities that can be used to address atmospheric carbon levels and the global warming issue. If policies encouraging more carbon storage were to be put into force at the national or international level, that could create opportunities for Nebraska agriculture. Those opportunities might conceivably come in the form of conservation incentives or in the form of markets to sell credits for carbon stored in the soil or vegetation.

Significant uncertainties exist about the potential effect of an as yet unratified international accord and about what national policies may be adopted and when. Therefore, our most important recommendation is that Nebraska maintains a Carbon Sequestration Committee to respond to changing conditions. That committee could be either a continuation of the current Carbon Sequestration Advisory Committee created under LB 957 or a newly created committee.

Whatever form the committee takes, we believe it should have additional duties and support beyond those LB 957 identified for the current committee. The committee would need to play a leadership and organizational role in carbon related issues. It would also need to monitor and highlight developing national and international actions that could affect Nebraska agriculture. It could help to guide or implement the other recommendations found in the following paragraphs, including a pilot project, funding for research, or a greenhouse gas inventory. Although the committee should primarily centered on carbon sequestration, it could also make recommendations about or provide guidance for potential related activities, such as a state climate action plan. A major activity of the committee should be to monitor federal funding opportunities to assure that Nebraska carbon sequestration related activities can take advantage of available programs.

The overall goal of the committee would be to see that Nebraska is able to fully and efficiently take advantage of any opportunities that might arise from evolving national or international efforts to address greenhouse gas issues. Doing this would require a funding source. We recommend a cash fund be created to support committee activities. Ideally, a staff position to support activities would also be created. To add committee coordination, issue monitoring, and other duties on to those of any existing agency without further support would likely make it more difficult to fulfill that agency's current mission while still not providing the type of support a carbon sequestration committee would need.

Our second recommendation is that additional funding be provided for basic research relevant to Nebraska. Currently the University of Nebraska and its Institute of Agriculture and Natural Resources are among the leaders in national and international carbon sequestration research. Nebraska would be well served to see those efforts continue. That research should extend not only to the physical aspects of carbon sequestration, but also to the administrative and economic aspects. In many instances information needed to answer basic questions is unavailable. In other instances available information was developed recently and should be used with caution until further research occurs. All of this underscores the need for research.

Our third recommendation is that funding be provided to help support a carbon sequestration pilot project in Nebraska. A pilot project could conceivably show the physical effects of sequestration measures in a specific area, demonstrate carbon measurement techniques, and even show how administrative mechanisms, incentives or market mechanisms might work. Federal funding levels for such efforts appear to be partially dependent upon pending legislation. Ideally state and/or local support could provide match should adequate outside funds become available.

Our fourth and final recommendation is that Nebraska develops a greenhouse gas inventory. As of July 2001, thirty-four states and Puerto Rico had completed inventories and another two states had inventories underway. Nebraska was not among those states. Greenhouse gas inventories identify major sources of greenhouse gas emissions and create a baseline for further action.

In summary our four major recommendations are:

1. **Maintain a Carbon Sequestration Committee to respond to changing conditions**
2. **Provide additional funding for basic research relevant to Nebraska**
3. **Provide funding to support a carbon sequestration pilot project in Nebraska**
4. **Develop a state greenhouse gas inventory**

I. Introduction

Legislative Charge

The Nebraska Legislature (LB 957), asked the Director of the Department of Natural Resources, in consultation with the Carbon Sequestration Advisory Committee, to prepare a report by December 1, 2001 analyzing carbon sequestration and emissions trading. The Legislature directed that the following topics be addressed:

- *"The potential for, and potential forms of, greenhouse emissions regulation;*
- *The potential for development of a system or systems of carbon emissions trading or markets for carbon sequestered on agricultural land;*
- *Agricultural practices, management systems, or land uses which increase stored soil carbon and minimize carbon dioxide or other greenhouse emissions associated with agricultural production;*
- *Methods for measuring and modeling net carbon sequestration and greenhouse emissions reductions associated with various agricultural practices, management systems, or land uses occurring on agricultural land;*
- *Areas of scientific uncertainty with respect to quantifying and understanding greenhouse emission reductions or soil carbon sequestration associated with agricultural activities; and*
- *Any recommendations of the Carbon Sequestration Advisory Committee …"*

This report addresses the legal framework and potential market approaches to carbon sequestration, the types of agricultural practices that have the potential to store carbon, and discusses the problems associated with measurement and modeling of carbon sequestration from different agricultural practices. This report was funded in part through a grant from the Nebraska Environmental Trust. The Legislature has also asked the Director of Natural Resources, in consultation with the Carbon Sequestration Advisory Committee, to publish a report assessing the carbon sequestration potential of Nebraska agricultural land. That separate report is scheduled to be available by March 1, 2002. Reports on potential forms of greenhouse gas regulation, and the potential for development of a market system were developed separately as background material to assist in compiling this report, and are separately available through the University of Nebraska Public Policy Center's website at http://ppc.unl.edu/ or through the Nebraska Carbon web-site at http://www.carbon.unl.edu/

Carbon Sequestration and Nebraska

Scientists believe that rising levels of carbon dioxide and other greenhouse gases (see next section) are contributing to global warming, although to what extent is difficult to determine. While limiting fossil fuel consumption is one method of reducing emissions of carbon to the atmosphere, another is sequestering carbon sources on the land. Carbon sequestration is the use of practices, technologies, or other measures that increase the retention of carbon in soil, vegetation, geologic formations, or the oceans with the effect of offsetting carbon dioxide emissions from other sources.

Agricultural producers can help address greenhouse gas concerns by implementing practices that cause the land to act as a sink for carbon, by decreasing emissions of greenhouse gases from agricultural production activities or by participating in other activities such as biofuels production (which can provide a substitute for fossil fuel use). Many of the activities that increase the organic content of soils, and thus sequester carbon, also increase agricultural productivity as well as improve soil, air and water quality. A number of activities that store carbon, such as agroforestry, can also increase wildlife habitat and its diversity. One of the challenges in selecting measures to sequester carbon or limit greenhouse gas emissions is to find which measures may have the highest level of those related benefits in a given situation.

With Nebraska's large agricultural land base, the state's landowners could potentially profit from carbon sequestration if certain types of carbon trading or other financial incentives are put in place. Yet there are very significant questions about whether substantial carbon trading markets will develop in the United States and, if so, what form they might take. Development of a substantial carbon trading market is dependent upon international agreements that are still evolving and on various national and international initiatives At this time there has been no federal government action that would result in development of strong carbon markets in this country. Neither has the U.S. government done anything to prohibit American citizens and companies from participating in carbon sequestration activities. In any event, the potential for Nebraskans to profit could conceivably be enhanced if the state takes actions to ensure it can act quickly should significant carbon markets develop. A separate assessment of how management decisions involving cropping and tillage systems affect soil organic matter is being developed in connection with LB 957 may help provide the needed baseline data. If a carbon storage market does not develop, the benefits of increased conservation and improved land management related to carbon sequestration may still provide a long-term economic benefit to the state.

Another advantage of carbon sequestration to Nebraskans is that it may contribute to curbing global warming and the negative climate related impacts that such warming could have to the state. However, it is not the purpose of this report to discuss the impact carbon sequestration may have on global warming. Rather, this report focuses on the potential for greenhouse gas regulation, carbon sequestration markets and other greenhouse gas measures related to agricultural activities.

Despite the potential advantages of carbon sequestration, another note of caution is in order. Soils have limited capacity to store carbon and activities such as plowing a field can release a great deal of stored carbon in a short period of time.

Predictions of future political actions are beyond the scope of a state agency report. The current U.S. administration has indicated it does not intend to sign the Kyoto protocol but has remained involved in monitoring global warming issues and carbon sequestration. The timeframe over which major changes, national or international, may occur is speculative. Action by other nations and continued anticipation of future political action may result in some cross-border marketing or attempts to buy carbon rights in anticipation of future laws. There may also be some carbon purchase by firms for public relations reasons. However, the nature and strength of any carbon market that might develop without a U.S. emissions limitation is uncertain.

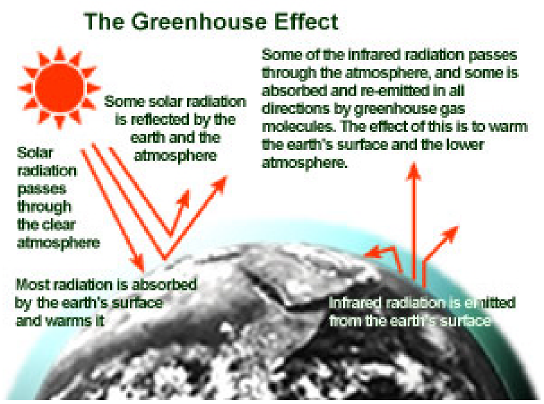
The potential international and national law changes that would have the most relevance for Nebraska agriculture (should they occur) would be national carbon emissions limitations and action making carbon sinks including cropland/grazing land soils eligible for credits. The level of the emissions limitations and nature of any carbon credit allowance would likely determine the market value of carbon sequestration for Nebraskans. Incentives for activities that sequester carbon are also a possibility.

Background -The Greenhouse Effect and Human Induced Changes

Earth’s climate is warmed and moderated by gases in the atmosphere that trap the sun’s heat, notably water vapor and carbon dioxide. These gases allow radiant energy from the sun in the form of visible light to pass through and reach the earth’s surface where it is converted into heat. Some of this heat is reflected from the earth’s surface in the form of infrared radiation.

Certain gasses, including carbon dioxide, absorb a portion of this heat energy and reradiate it back toward the surface of the earth, much as a greenhouse allows sunlight to enter and heat the interior, but then the roof and walls retain the heat. The greenhouse effect is critical to maintaining life on the planet. Absent greenhouse gasses, heat energy would be reflected back into deep space and average planetary temperatures would be some 60 degrees Fahrenheit colder than they are today. Figure 1 illustrates the greenhouse effect.

Figure 1-1



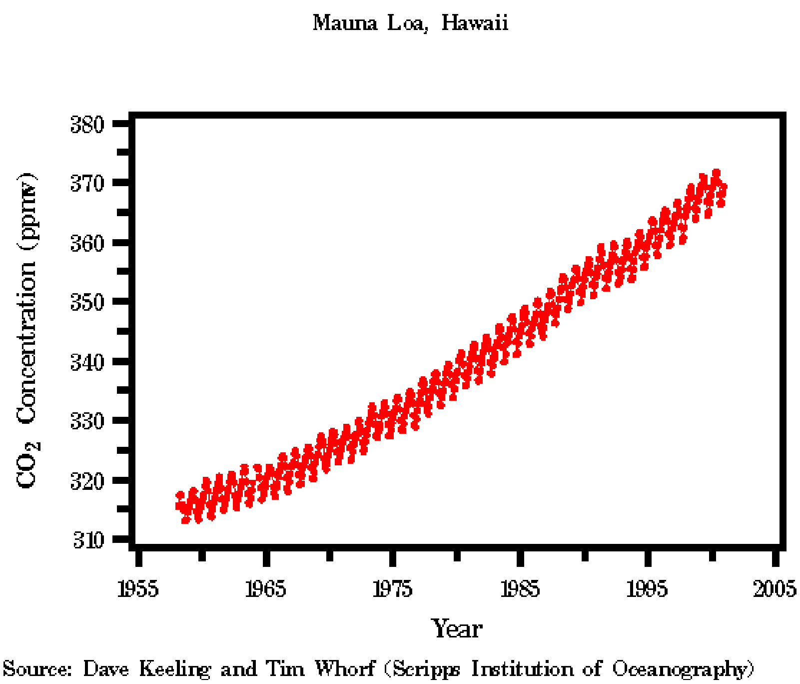
From US Environmental Protection Agency, 2001

The discovery that so-called greenhouse gases play a significant role in moderating earth's climate is not recent. The ability of certain atmospheric gasses to form a heat-retaining dome around the planet was first hypothesized by the noted chemist Fourier. Fourier began musing about the ability of the planet to retain heat when he accompanied Napoleon's forces to Egypt in 1798, and he had fully developed his theory by 1820. The greenhouse effect was thus discovered coincident with the advent of the industrial revolution in Europe. In 1896, the Swedish chemist and Nobel Prize winner Arrhenius first advanced the theory that carbon dioxide emissions from the combustion of coal could cause the earth's climate to warm. Building on the work of Fourier, Arrhenius noted that combustion of coal and other fossil fuels releases large amounts of carbon dioxide into the atmosphere. Since carbon dioxide is a greenhouse gas, Arrhenius hypothesized that humans might alter the earth's climate by burning fossil fuels such as coal.

Today, there is no dispute about the fundamental science of heat retention and reflection by atmospheric gasses. Nor is there any dispute that the concentration of greenhouse gasses in the atmosphere has been increasing. Measurements taken on Mauna Loa in Hawaii (FIGURE 2) beginning in the 1950's, and from polar ice cap samples (FIGURE 3) confirm that the concentration of greenhouse gasses in the atmosphere has increased dramatically over preindustrial revolution levels. Moreover, there appears to be a correlation between an increase in greenhouse gases and an increase in global temperatures in the last 100 years. (FIGURE 4). A warming trend of about 1degree Fahrenheit has been recorded since the late 19th century (EPA 2001). The EPA Global Warming Website states: "In short, scientists think rising levels of greenhouse gases in the atmosphere are contributing to global warming, as would be expected, but to what extent is difficult to determine at the present time" (EPA, 2001).

FIGURE 1-2

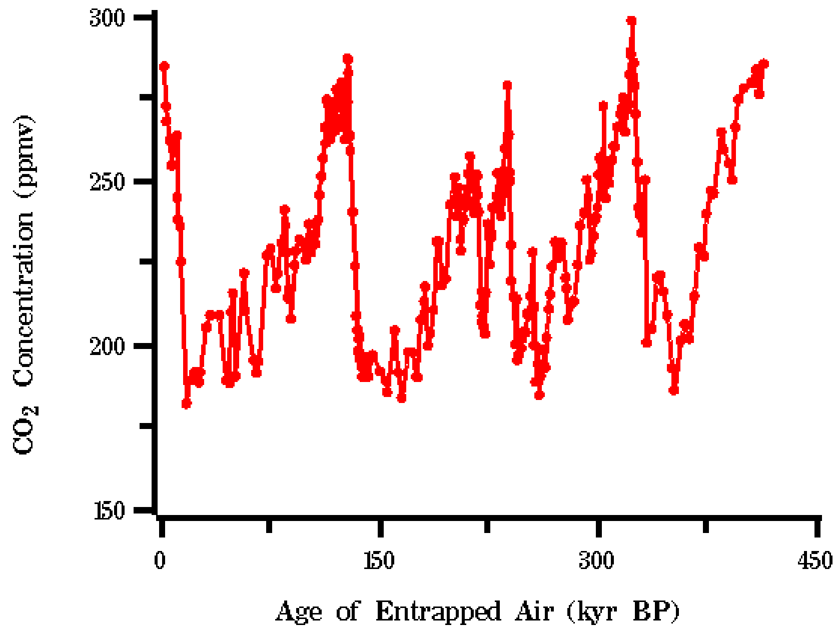
Carbon Concentrations Since 1955 as Measured at Mauna Loa, Hawaii



From Oak Ridge National Laboratory

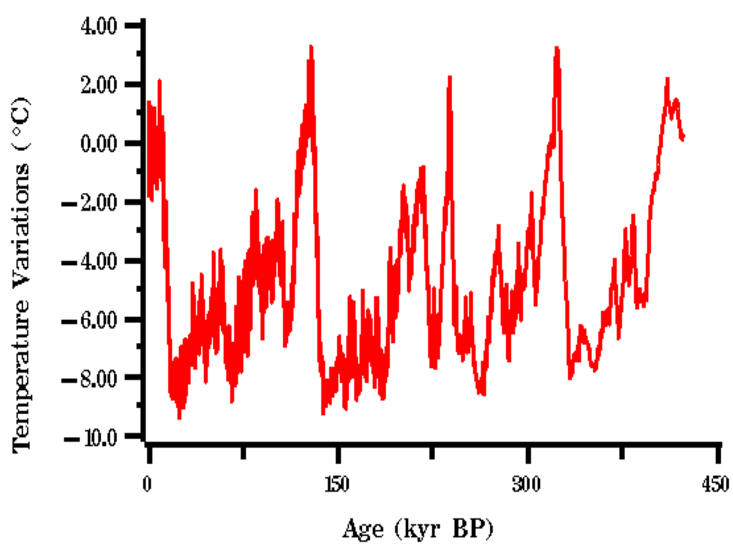
FIGURES 1-3 and 1-4

Vostok, Antarctica Ice Core Atmospheric Carbon Dioxide Record



Source: Jean–Marc Barnola et al.

Historical Isotopic Temperature Record from the Vostok Ice Core



Variation with time of the Vostok isotope temperature record as a difference from the modern surface temperature value of –55.5 °C.

Source: Petit et al.

Figures 1-3 & 1-4 From Oak Ridge National Laboratory and Oak Ridge National Laboratory Carbon Dioxide Information Analysis Center

Because global atmospheric carbon levels and temperatures fluctuated significantly prior to major human influences on the carbon cycle, there is discussion about the role human activity has played in this increase. However, the Intergovernmental Panel on Climate Change (IPCC, 1996) found that carbon dioxide concentrations have increased 31 percent since 1750 and that current concentrations have not been exceeded in the last 420,000 years and perhaps not in the last 20 million years. They also noted that the current rate of increase is unprecedented during at least the last 20,000 years. More recently the IPCC indicated that "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities" (IPCC, 2001).

The consequences of global warming are somewhat speculative, but potentially severe. Among the possible impacts of global warming are rises in ocean and sea levels, altered marine ecosystems, destruction of coral reefs, spread of disease vectors, especially for insect born infectious diseases, more intense and severe weather patterns, regional changes in agricultural production potential, altered patterns of precipitation and other changes in the hydrologic cycle, increased desertification, increased forest loss, and substantial loss of biodiversity. Moreover, small changes in average temperature can have a dramatic impact. Atmospheric chemistry, however, is exceedingly complex. In particular, the capacity of the planet to adapt to increasing concentrations of greenhouse gasses is not clearly understood. Global warming, for instance, can be expected to increase cloud cover. Water vapor in clouds is itself a greenhouse gas that contributes to global warming. At the same time, enhanced cloud cover exerts a cooling effect by preventing some of the sun's radiant energy from striking the surface of the planet. Determining the precise impact of these, and other, feedback loops is a matter of continuing study.

Implications of the Carbon Cycle

Carbon is an essential element for all life on earth. It is found in the atmosphere in various forms; it is dissolved in the oceans; and it is a major component of many soils and rocks. Carbon is cycled continuously through the biosphere, the atmosphere, the soils and the oceans as a result of natural forces. Understanding the carbon cycle is essential to understanding the causes and cures of climate change.

One implication of the carbon cycle is that humans can alter the natural flows of carbon through the carbon cycle in a way that causes a disproportionate amount of carbon to be stored in the atmosphere, thereby accentuating the greenhouse effect. The principle human activity that alters the carbon cycle in a way that increases carbon dioxide concentrations is the combustion of fossil fuels.

A second implication of the carbon cycle is that atmospheric concentrations of carbon also can be affected by activities, such as deforestation, that reduce the capacity of the planet to absorb additional greenhouse gasses. Tropical rain forests, for instance, have the capacity to capture and remove significant quantities of carbon from the atmosphere by storing it in vegetation. Processes and mechanisms capable of removing greenhouse gases from the atmosphere are known as sinks. Converting tropical rain forests to farmland eliminates the carbon sink and, if the forest is burned, releases additional CO_2 to the atmosphere. Alternatively, if the wood residue is allowed to decay, another greenhouse gas, methane, will be released to the atmosphere from termites that assist in the decomposition process. Other human activities that contribute to increased concentrations of greenhouse gases in the atmosphere include various agricultural cropping practices, the production of livestock, and the use of internal combustion engines.

Sources of Greenhouse Gas Emissions

Greenhouse gases whose concentrations can be affected by human activity are known as anthropogenic greenhouse gasses. Other significant anthropogenic greenhouse gases besides carbon dioxide include methane (NH_4), nitrogen oxides (NO_x), and chlorofluorocarbons (CFC's). Although the primary focus of this paper is on carbon, the other anthropogenic gases play a significant role in global warming because greenhouse gasses vary in their global warming potential and in their persistence. Carbon dioxide, the most important by volume, is less potent than other gasses. Methane has approximately 20 times the global warming potential of carbon dioxide, nitrous oxides have approximately 300 times the global warming potential of carbon dioxide, and CFC's have global warming potential thousands of times greater than that of carbon dioxide. Despite its relative lack of potency, carbon dioxide has been viewed as the most significant anthropogenic greenhouse gas because of its abundance. Carbon dioxide emissions are expected to contribute approximately 50 percent of the increase in global temperatures expected during the next 60 years (Justus, 2001). Greenhouse gasses also vary as to how long they persist in the atmosphere. Carbon dioxide, for instance, has an atmospheric life of 50 to 100 years. In contrast, methane persists for only 12 years, but some other anthropogenic greenhouse gases may persist for thousands of years.

The differences in persistence and global warming potential of the various greenhouse gases have important policy implications. First, a common unit of currency must be found. To account for varying potencies, it is common practice to refer to greenhouse gases in terms of carbon equivalents. Second, persistence of greenhouse gases in the atmosphere means that the climate is currently affected by activities that occurred generations ago and stabilizing greenhouse gas emissions will not prevent the further buildup of greenhouse gas concentrations in the atmosphere. Tables 1 and 2 summarize the major greenhouse gases that have been affected by human activity.

Human induced greenhouse gas emissions are attributable to three general primary factors: fossil fuel combustion/transport, agricultural and land use changes, and chemical use. Burning of fossil fuels is responsible for about 80% of global carbon dioxide emissions and 20% of global nitrous oxide emissions. In the U.S. fossil fuels also account for about 25% of methane emissions (EPA, 1998). United States emissions of carbon dioxide, methane and nitrous oxide contribute over 18 percent of total global emissions based on global warming potential (U.S. Dept. of Energy, 1999), while the U.S. has only about 5 percent of the world's population. This has caused some concern that there may be an increase in the greenhouse gas emissions rate as development occurs in areas that are currently economically less developed.

Table 1-1 Selected greenhouse gases that have been affected by human activity

	Carbon dioxide	Methane	Nitrous oxide
Preindustrial concentration*	278 ppmv	700 ppbv	275 ppbv
Concentration in 1994	358 ppmv	1720 ppbv	312 ppbv
Percent change from Preindustrial times to 1994	29%	146%	13%
Rate of concentration change**	1.6 ppmv/yr 0.4%/yr	8 ppbv/yr 0.6%/yr	0.8 ppbv/yr 0.25%/yr
Global emissions to the atmosphere by human activity, 1992	26,033 MMT	375 MMT	6 MMT

From: U.S. Department of Energy, "Emission and Reduction of Greenhouse Gases from Agriculture and Food Manufacturing – A Summary Whitepaper," December 1999

Source: Intergovernmental Panel on Climate Change (IPCC 1996a), U.S. Department of Energy/Energy Information Administration (DOE/EIA 1998), and Lal et al. 1998. 1 ppmv = 1 part per million by volume of gas 1 ppbv = 1 part per billion by volume of gas 1 MMT = one million metric tons of gas (10^{12} grams of gas) * Prior to 1850 ** Averaged over the decade 1984-1994

Table 1-2. Human-caused greenhouse gas emissions from global, U.S., and U.S. agricultural sources for three greenhouse gases, 1997

	All Sources	US Sources	US Agricultural Sources	
Emissions, percent of total global carbon equivalent*				
Carbon Dioxide	72.8	15.4	0.45	
Methane	22.0	1.84	0.55	
Nitrous Oxide	5.20	1.12	0.79	

From: U.S. Department of Energy, “Emission and Reduction of Greenhouse Gases from Agricultural Food Manufacturing – A Summary Whitepaper,” December 1999.

* Carbon dioxide equivalent is the concentration of carbon dioxide that would cause the same amount of radiative forcing as a given mixture of carbon dioxide and other greenhouse gases. Carbon dioxide equivalents are computed by multiplying the amount of the gas of interest by its estimated global warming potential. From the carbon dioxide equivalent it is possible to define a “carbon equivalent,” which is the carbon dioxide equivalent multiplied by the molecular weight ratio of carbon to carbon dioxide (i.e., 12/44).

The above tables indicate that carbon dioxide accounts for about 73 percent of the contribution to worldwide global emissions with most of that coming from fossil fuel combustion. Carbon dioxide accounts for over 83 percent of the United States greenhouse gas emissions (in carbon equivalents). Methane accounts for about 22 percent of global greenhouse gas emissions with flooded rice production and animal husbandry being prime sources. However, in the U.S. methane accounts for only about 10 percent of national emissions and 70 percent of that is from non-agricultural energy use and waste management. Finally, nitrous oxide (which includes natural and fertilizer derived nitrous oxide from the soil surface as well as nitrous oxide from biomass burning and biotic processes in forest soils) accounts for only about 5 percent (6 ½ percent in the U.S.) of human induced greenhouse gas emissions. Some chemical use from synthetic compounds has also resulted in increased greenhouse gas emissions. However, concentrations of one of the major chemical products, chlorofluorocarbons, decreased steadily in the 1990s following international action. The Environmental Protection Agency indicates that "since the pre-industrial era atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more that doubled, and nitrous oxide concentrations have risen by about 15%" (EPA, 1998).

Data on Nebraska greenhouse gas emissions is at best only partially available. Thirty-three states have completed greenhouse gas inventories and another two have inventories underway. Nebraska is not among those states. However, some limited comparative carbon dioxide emissions data is available. The U.S. Energy Information Agency provides estimated data on carbon dioxide emissions from fossil fueled steam-electric generating units in the United States. In 1999 Nebraska ranked 35th in those emissions Nebraska was 38th in population in the 2000 census. U.S. Department of Energy Data indicates that in 1990 Nebraska ranked 21st out of 51 states and U.S. territories in carbon dioxide emissions from fossil fuel use. At that time Nebraska accounted for 0.67% of U.S. Fossil fuel emissions (U.S. Dept. of Energy, 1995, 1995). In 1990 Nebraska accounted for .634% of U.S. population. However, states with more dispersed populations are generally significantly less efficient on a per capita basis.

II. LEGAL, POLICY, AND ECONOMIC ISSUES: POSSIBILITIES, BARRIERS, AND UNKNOWN FACTORS

An article in *Newsweek* (Foroohar, 2001) during the summer of 2001 noted:

> there is a new multinational business: trading in pollution. Under the Kyoto Protocol on global warming, endorsed by 178 nations last month, many nations would have to cut their greenhouse-gas emissions to certain target levels. If their own pollution levels remain too high, they can trade for credits from countries that beat their targets--or they can earn credits by performing good green works abroad. This so-called emission trading turns greenhouse gases into a commodity that can be bought and sold, just like gold, soybeans or pork bellies. “If you can trade corn, you can trade carbon,” says economist and veteran trader Richard Sandor. He's in on the ground floor of what he says will become “the biggest commodities market in the world. (p. 36)

If Dr. Sandor is correct, if rights to emit carbon are to be traded like commodities, will there be a need for government action? Apparently, some governments already are acting to establish formal mechanisms to facilitate trade.

The *Newsweek* article continues:

> Governments are getting in the act, too. Denmark has established the first national trading scheme, aimed at the utilities industry. In May the EU announced plans for a European scheme to be launched in 2005. Last week the U.K. Emissions Trading Group, a joint venture between the British government and industry, announced the launch of a national trading market for greenhouse gases. Under the plan, British companies will be invited to set their own targets for emissions reduction, then bid for carbon allowances with other firms. The British government is offering a substantial perk--215 million of subsidies over five years for companies that meet their quotas. But according to John Craven, head of the Emissions Trading Group secretariat, there's an even more important benefit. “Companies that join early will get voluntary experience doing something that will eventually become mandatory under Kyoto,” says Craven. "Those that practice now will have an advantage in the future.” (p. 36)

However, it is companies, not governments, which will do the trading in the emerging carbon market.

> Why are major organizations like the World Bank, which recently launched a $145 million fund to invest in carbon-emission-reduction projects, willing to place their bets now? “Because everyone knows that a carbon-constrained future is inevitable,” says Steve Drummond, managing director of the London-based online greenhouse-gas-trading firm, CO2e.com. . . . “Whether or not the U.S. signs up for Kyoto, multinationals know that emission legislation will affect them in some market,” says Drummond. (p. 36)

The Cantor Fitzgerald group in association with Price Waterhouse Coopers formed CO2e.com. As noted at the site (http://www.co2e.com/trading/MarketHistory.asp), several companies are already in the market, and

> trading greenhouse gas emission reductions, not carbon credits. "Credit" denotes accreditation or formal recognition by an empowered regulatory body. No such entity exists for greenhouse gas reductions at this time. Reductions may refer to reductions in actual emissions, avoidance of potential emissions, or the removal of atmospheric carbon and storage in a sink (e.g., carbon sequestration in a tree farm).

This is to say, trading in reductions, also sometimes referred to as carbon equivalent offsets, has already started. Trading in carbon emissions credits and/or in allowances (such as in the sulfur market), which require recognition by a regulatory body, is still to come.

This chapter examines the legal, economic, and policy issues that have motivated the international community to address the problem of climate change. Generally this chapter addresses the likelihood that trading in carbon equivalent offsets will be part of the international response to global warming. More specifically, it addresses how the potential for carbon sequestration in Nebraska, -- that is, removing atmospheric carbon and storing it in Nebraska -- might generate economic benefits for the state while contributing to the solution of a global problem. This chapter draws on the background papers on law and regulation by Thorson (2001) and emissions and storage (sequestered carbon) markets by Lynne and Kruse (2001).

General Background

Although there are a great many policy and practical issues to be considered as nations formulate the role that carbon sequestration should play in efforts to address human induced climate change, relatively few legal issues are raised at the state or local level. Most of the legal issues that would accompany development of an economic market in carbon emission allowances or offsets– for example, the enforceability of contracts, business relations in an international context, securities laws, and so on – are already developed areas of law. Neither carbon sequestration nor the marketing of carbon emission allowances is likely to present legal concerns that are going to require the development of a new area of law or will require legal analysis that is idiosyncratic to carbon issues. Nothing precludes a state from acting to provide incentives or other opportunities for participation in sequestration activities.

Regulation of greenhouse gases, on the other hand, may prove to be a more complex matter. Part of the complexity stems from the fact that climate change is a global problem, not a national or local one. The problem also is complex because anthropogenic greenhouse gases are emitted as a consequence of activities that generally are conceded to be essential to economic activity and development. Furthermore, the problem is complex because greenhouse gas emissions are widely scattered across the planet.

The fact that climate change is a global issue means that no nation can capture the benefits of regulation for its own citizens absent cooperation of the international community. A nation has no incentive to engage in costly regulatory programs if the purported benefits of the program can be thwarted by another nation that increases its emissions of greenhouse gases. Conversely, even if general international cooperation is achieved, relatively small emitters have an incentive to sidestep costly regulatory measures because they can benefit from the collective action of others without having to bear any of the costs of those actions, a classic free-rider problem. Finally, the impacts of global warming are not spread equally across the planet. Some low-lying island nations face the prospect of becoming submerged if sea levels rise even modest amounts. On the other hand, some nations would probably benefit from global warming in the short run as growing seasons and precipitation patterns change. The problem is one that cannot be resolved without achieving general consensus, but general consensus will be extraordinarily difficult to achieve.

The fact that greenhouse gas emissions are associated with economic activity means that the cost of greenhouse gas abatement could well be significant. It also brings into sharp focus the differences between the developed world and the developing world. The world's developed economies are highly dependent on energy consumption, much of it derived from fossil fuels. Developing countries are poised to greatly increase their consumption of energy, and hence their contribution of greenhouse gases to the atmosphere, as they strive for economic equality with the developed world. Developing nations like China have an enormous potential to increase emissions of greenhouse gases as their economies grow; understandably, such nations are unwilling to forgo growth to contribute to a solution to a global warming problem that they see being caused largely by consumption of energy in the developed world. Other developing nations see their economic future tied to conversion of forestland to agricultural land, much as occurred previously in Europe and North America. This potential loss of sinks has the same impact as increasing emissions from burning fossil fuels. Still other nations have economies that are almost entirely dependent on providing the fossil fuels that fuel the development of the world, but which cause so much of the buildup of greenhouse gasses in the atmosphere.

Finally, the fact that greenhouse gas emissions are widely dispersed across the planet means that one cannot achieve success solely by forging an agreement between, say, the 10 or 12 largest emitters, particularly when so many developing countries have the potential to greatly increase their contribution to the buildup of greenhouse gases in the atmosphere. The international agreements that have been negotiated to date, and the national programs that have been proposed, are all of recent vintage and all reflect the difficulties discussed above. The legal environment is necessarily evolving as nations struggle with the complexities of global warming. Not surprisingly, many of the emerging legal rules are frustratingly vague and incomplete.

International Law and Policy Context: Preliminary International Consensus

The Framework Convention

In 1988, the United Nations Environmental Program and the World Meteorological Organization created the Intergovernmental Panel on Climate Change (IPCC). The IPCC is organized into three working groups that focus respectively on the science of the climate system, the impacts of climate change and policy options for response, and the economic and social dimensions of climate change. One of the IPCC's first tasks was to assess the scientific, technical and economic basis of climate change policy in preparation of the United Nations Conference on Environment and Development, the so-called "Earth Summit" held in Rio de Janeiro in 1992. In 1990, the panel recommended a climate change convention modeled after the Vienna Convention for the Protection of the Ozone Layer.[1] The goal was to draft a document that would gain the largest number of adherents. Many of the difficult issues were put aside to be addressed in subsequent annexes and protocols.

The Framework Convention on Climate Change was one of the landmark agreements in international environmental law that was adopted at the Earth Summit. The United States signed the Convention on June 12, 1992, together with 153 other nations. The United States Senate consented to ratification on October 7, 1992, and President George H. Bush signed the instrument of ratification on October 13, 1992. The United States thus became one of the first nations to ratify the Convention. The agreement entered into force on March 24, 1994, having been ratified by the requisite 50 nations. Currently, the convention has been ratified by 186 nations.

A framework convention sets out general objectives, principles, and commitments made by parties to the convention, but it lacks the level of detail that will be required to solve the problem addressed by the agreement. Framework conventions are flexible documents; they are intended to be modified or supplemented by protocols as additional information becomes available. Ongoing research efforts and regular meetings are typically a feature of framework conventions.

The general objective of the climate change agreement is to achieve "stabilization of greenhouse gas concentrations in the atmosphere at the level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within the time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."[2] In their actions to achieve the objective of the convention, parties are to be guided by five principles: 1) developed country parties should take the lead in combating climate change;[3] 2) special circumstances of developing country parties should be given full consideration;[4] 3) parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate adverse effects;[5] 4) economic development is essential for adopting measures to address climate change;[6] and 5) measures taken to combat climate change should not constitute a means of arbitrary or unjustifiable discrimination against or a disguised restriction on international trade.[7]

The framework convention achieved remarkable international consensus on a wide variety of issues. First, parties agreed on the need to stabilize the amount of greenhouse gases in the atmosphere. To accomplish their goal, there are two choices. Either man- made emissions of greenhouse gases must be reduced or the ability of the planet to remove and sequester greenhouse gases from the atmosphere must be enhanced, or both strategies must be pursued simultaneously. The framework convention repeatedly recognizes management of emissions, sinks, and reservoirs as crucial to the successful resolution of climate change issues.[8]

Second, climate change is a global issue. An increase in carbon sequestration anywhere on the planet or a reduction in carbon equivalent emissions anywhere on the planet will have a positive effect on stabilizing the level of greenhouse gasses in the atmosphere. Consequently, there are many efficiency gains to be achieved from collective action.

Third, the agreement recognizes that a significant political split exists between developing countries poised to greatly increase their carbon emissions, and developed countries whose economies already depend on consumption of fossil fuels. In many ways this split reflects a fundamental difference of opinion in how the planet's capacity to absorb greenhouse gases ought to be allocated. Developing countries argue for an equitable allocation of this capacity;[9] some developed countries essentially argue that capacity has already been allocated under principles of prior appropriation. The Convention, however, makes it clear that developed countries must take the lead in efforts to stabilize greenhouse gas concentrations in the atmosphere. At the same time, the convention recognizes that greenhouse gas controls must be adopted with economic sensitivity. The fact that climate change is a global problem and the resolution of the problem must proceed in a way that does not destroy the world economy, or individual national economies, suggests that markets may play a significant role in solutions.

Fourth, the convention recognizes that the impact of implementing response measures, as well as the impact of anticipated global warming, will vary from nation to nation. Among the groups of nations facing special problems, the convention identifies a) small island countries; b) countries with low-lying coastal areas; c) countries with arid and semiarid areas, forested areas and areas liable to forest decay; d) countries with areas prone to natural disasters; e) countries with areas liable to drought and desertification; f) countries with areas of high urban atmosphere pollution; g) countries with areas with fragile ecosystems, including mountainous ecosystems; h) countries whose economies are highly dependent on income generated from the production, processing and export, and/or on consumption of fossil fuels and associated energy intensive products; and I) landlocked and transit countries.[10]

Finally, the convention recognizes that implementation measures must be developed at national, regional, and local levels. To date, most of the legal activity with respect to greenhouse gas abatement has been at the international level. The United States, for instance, does not regulate greenhouse gas emissions.[11] In other countries, however, momentum to minimize greenhouse gas emissions is mounting.

Adding Details: The Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change[12] was an attempt to enact binding emissions limitations for a group of 38 industrialized nations identified by the Framework Convention.[13] Although the United States signed the Kyoto Protocol, it has not been submitted to the United States Senate for its consent to ratification. In fact, a Senate resolution adopted without dissent makes it clear that the Senate will not be receptive to a submission in its current form, and President Bush has indicated that he opposes the Kyoto Protocol.[14] The protocol remains important, however, because it is the first attempt to craft detailed commitments within the Framework Convention, and because any future international efforts are likely to embody many of the principles of the Kyoto agreement. The limits set out in the Kyoto Protocol apply to emissions of fixed greenhouse gases measured over the period from 2008 to 2012.[15] Affected parties are required to demonstrate progress toward meeting commitments by 2005.[16] The net changes in greenhouse gas emissions by sources and removals by sinks are used to meet commitments under the protocol.[17] In other words, a commitment reduction can be met by reducing emissions or by engaging in activities that enhance removals of greenhouse gasses from the atmosphere by sinks.[18]

Because greenhouse gas emissions cause global impacts, it does not matter, from an environmental perspective, where reductions in emissions or removals from sinks occur. This would suggest that least cost removal and reduction activities should be pursued without regard to national borders, and points to the possibility of using both emissions and storage markets to achieve the potential cost savings while addressing climate change issues.

The protocol contains three regulatory mechanisms designed to allow parties to reduce the cost of complying with emissions limits, joint implementation,[19] a clean development mechanism,[20] and international emissions trading.[21] A fourth mechanism, joint fulfillment,[22] allows affected parties to enter into agreements that redistribute total reduction commitments among themselves. The four mechanisms thus are designed to reduce the cost of complying with national commitments without loss of any environmental benefits associated with the overall cap on emissions.

Joint fulfillment was initially included in the Protocol to allow the European Union to redistribute commitment obligations among member states as long as total emission reduction commitments are satisfied. The effect of joint fulfillment is to place a bubble over contracting states with compliance satisfied as long as net emissions from the bubble are within limits specified by the protocol. However, once the joint fulfillment contract is deposited with the Secretariat, the obligations contained in the contract become binding on individual nations under the protocol.

Joint implementation allows affected parties, or authorized legal entities such as brokers or corporations,[23] to transfer to or acquire from other parties' emission reduction units derived from specific projects designed to reduce emissions or enhance sinks of greenhouse gases.[24] For example, an acquiring party might agree to finance a project that produces greenhouse gas reduction benefits in exchange for some or all of the greenhouse gas reduction benefits that can be derived from the project. The precise allocation of reduction benefits is a matter for contractual allocation among the participating states. The party acquiring emission reduction units can increase carbon equivalent emissions above its cap determined in the Kyoto commitments, or, alternatively, sell emission allowances to some other party.

The clean development mechanism authorized by the protocol parallels joint implementation described above, except that reductions in greenhouse gas emissions are achieved by sponsoring projects in specified countries. The goal of the clean development mechanism is to promote sustainable development in developing countries while assisting developed countries in meeting their commitments under the Kyoto protocol.[25] Certified emission reduction units obtained from clean development mechanism projects can be used by certain countries to help meet their reduction commitments.[26]

Emissions trading, in contrast to joint implementation and the clean development mechanism, are not project based. Rather, it permits parties to buy and sell the right to emit greenhouse gases, with only the overall cap on emissions affecting how many allowances can be held in total.[27] For instance, a party in a position to reduce greenhouse gas emissions at relatively low-cost might undertake projects that generate more reductions than would be required under the Kyoto obligations. Those excess credits could be sold to other parties that face greater economic challenges in meeting the Kyoto commitments. The effect of emissions trading would be to reduce emissions in the selling country below the level anticipated by the Kyoto agreement or to permit emissions in the purchasing country to exceed the level anticipated in the Kyoto agreement

There are many contradictions and unanswered questions in the Kyoto mechanisms. Some of these questions have been addressed in negotiations that concluded in Marrakech, Morocco in November 2001. The Marrakech clarifications of the Kyoto Protocol apparently liberalized both the use of carbon sinks and the use of emissions trading to achieve emissions reduction targets. As of the time of this writing, however, there has not been sufficient time to analyze the Marrakech clarifications to ascertain whether a country can get credits for trading with a nation, such as the U.S., that has not ratified the Protocol. Similarly, do the Marrakech agreements clarify the extent to which land use changes and other carbon sink enhancing activities can serve as the basis for satisfying the various trade mechanisms? Removals by sinks are specifically mentioned with respect to joint implementation in Article 6.[28] In contrast, the clean development mechanism authorized in Article 12 makes no mention of sinks. Articles 6 and 17 provide that transfers of emission credits must be supplemental to domestic actions taken to meet protocol commitments.[29] Similarly, Article 12 provides that certified emissions reductions can only be used to meet part of the protocol commitments.[30] With respect to joint implementation and clean development mechanism projects, parties are required to demonstrate that the projects produce emissions reductions in excess of those that would have occurred absent the project.[31] Are these demonstrations now required, and if so, how are they measured? Additional questions that needed to be answered included how the commitments under the protocol are to be enforced, penalties for failure to achieve commitments, and who bears the risk of nonperformance when part of the nation's performance depends on reductions generated within the borders of another emission.[32]

Even without a detailed analysis of the newest modifications, a general outline of the process to be used in regulating emissions can be discerned. First, caps are placed on net emissions of greenhouse gas on a country-by-country basis with the cap based on historical experience caps. Second, emissions allowances are determined based on the net emissions measured as the difference between the amount of greenhouse gasses emitted and any new removal by sinks. Consequently, emissions controls and land use measures may each be valid ways of achieving emissions reduction goals. Third, net emissions within any one country may be increased or decreased by purchase or sale of emission allowances. Fourth, precisely how a nation chooses to meet its emissions reductions commitments is a matter of domestic, not international, law. Finally, and very controversially, emissions caps have not been placed on developing countries, an issue that makes it unlikely that the United States will ratify the Kyoto Protocol.

Kyoto's Accounting Procedures for Permitted Greenhouse Gas Emissions

To fully appreciate the complexity of the emissions capping mechanism incorporated into the Kyoto agreement, it is useful to examine the accounting procedures in more detail. The Kyoto Protocol sets qualified emission limitations for individual developed countries.[33] These limitations are calculated as a percentage of the emissions that occurred during a base year, generally 1990.[34] The United States, for instance agrees to cap its emissions at 93% of the amount that was emitted in 1990; most European nations are capped at 92% of the base year emissions.[35] Qualified emissions limitations can be viewed as (initial) emission allowances. To give parties time to implement measures that will permit reductions in emissions, for example, to the 93% level, the allowances do not become binding until the first commitment period, which extends from 2008 to 2012,[36] although parties are expected to demonstrate progress toward meeting the reduction goals by 2005.[37] To provide additional flexibility, parties are given a bulk allocation of allowances during the five-year commitment period, calculated by multiplying the annual qualified emission limitation by five.[38] This allows a party's emissions to vary from year to year during the commitment period without a nation falling out of compliance as long as the total aggregate amount of emissions allowances are not exceeded by the end of the five year commitment period. A party can increase its emissions beyond the qualified emissions limitations by securing emission reduction units as part of a joint implementation project;[39] certified emissions from a clean development mechanism project;[40] or by purchasing surplus emission allowances from willing sellers, or by reducing the amount of emissions by using less (lower demand for) fossil fuel.[41] Conversely, any party transferring emission reduction units as part of a joint implementation project or any party selling surplus emission allowances will have their permissible allowances reduced by the amount of the transfer.[42] If emissions during the commitment period are less than a nation's assigned allowance, the surplus can be carried forward to future commitment periods.[43]

Domestic Implementation of International Commitments

Once a nation has committed to capping greenhouse gas emissions at certain prescribed levels, it is expected to adopt domestic programs to achieve those goals. Apart from the emissions caps contained in the Kyoto Protocol, countries like the U.S. have an independent duty under the Framework Convention to limit emissions of greenhouse gases and protect and enhance sinks.[44] A wide variety of alternative approaches can be hypothesized. They can be divided into two groups, policies designed to reduce emissions of greenhouse gases and policies designed to protect and enhance sinks, and thus creating the potential for offsets being available for transfer.

Policies Designed to Reduce Emissions

Nations have a variety of strategies that they might pursue in attempting to discourage the emission of greenhouse gases. Because fossil fuel consumption is the greatest source of greenhouse gas emissions, emissions control strategies will likely be directed toward the energy sector. Several options are available. A nation might enact a carbon tax that would be assessed on the basis of carbon emissions. To avoid or minimize the tax owed, emitters would have an incentive to switch fuel sources, to improve efficiency, and to adopt conservation measures. Historically, the United States has been reluctant to implement pollution taxes. A nation might also choose other tax and subsidy mechanisms, for example, it might subsidize mass transit and tax private automobiles.

As an alternative, a nation might adopt technology forcing emissions standards that would apply to classes and categories of emitters. This is the strategy used in the United States to control conventional pollutants under the Clean Water Act. A variation on the theme requires that products manufactured for resale attain certain specified efficiency standards. Examples include efficiency standards for appliances, water use standards for toilets, and CAFE standards for automobiles. Closely related to efficiency standards are command and control regulations that mandate the use of certain technologies to minimize emissions. Examples could include a requirement that landfills or large confinement feedlots capture and reuse methane generated from normal operations. The difficulty with command and control regulations is that they tend to be inflexible and are often inefficient. At least some command and control regulation, however, is likely to be a feature of domestic greenhouse gas legislation.

A third alternative approach is a cap and trade system where the emissions of individual emitters are capped at some level that forces an aggregate decrease in emissions, but where parties are allowed to trade allowances among themselves. The United States has had great success with such a program with respect to sulfur dioxide under the Clean Air Act. Despite significant differences between sulfur and carbon and the ways to counter their adverse environmental impacts (e.g., the numbers of people and entities who conceivably could sequester carbon is extremely large, unlike the sulfur case), the sulfur model may influence the way that a cap and trade system develops for carbon. Thus, to the extent that caps are placed on greenhouse gas emissions by particular emitters, emissions allowances might be created that can be freely traded permitting reductions to occur at least cost. Another set of alternatives involves public efforts to make fundamental changes in the sources of energy used in a country. A nation might choose to invest in or subsidize the development of energy sources that don't result in significant net emissions of greenhouse gases. Hydropower, nuclear power, and power from various renewable energy sources such as solar power and wind power and biomass would be favored. A nation might also increase research efforts designed to develop alternative sources of energy such as hydrogen fuel cells or fusion power.

Policies Designed to Protect and Enhance Sinks

A nation might also attempt to meet its commitments by undertaking activities that enhance the ability of sinks to remove greenhouse gases from the atmosphere. Most of these efforts involve land use choices or restrictions, as well as changes in the way land is managed, for example, in technologies and farming or ranching practices. Historically, in the United States, most land use regulatory decisions have been deemed to be within the purview of state and local governments, rather than the federal government. Although there would be a clear constitutional nexus for regulating land uses to achieve greenhouse gas abatement goals at the federal level, it seems likely that states will play a greater role in such efforts than they would with respect to emissions policies.

To date, most of the attention regarding enhancement of sinks has been directed toward forestry practices. That is not surprising because forests have a great potential to sequester carbon. Nations that are engaged in deforestation by, for instance, converting forestland to agricultural land, are contributing to the buildup of greenhouse gasses through their land use policies. Moreover, the Kyoto Protocol specifically refers to deforestation, reforestation, and afforestation, although the terms are not defined.[45] Generally, deforestation is the permanent removal of the forest, reforestation is replanting a forest where one previously existed (or perhaps, in a more limited sense, replanting a forest immediately after harvest), and afforestation is a change in land use from non-forest to forest. Nebraska's Halsey National Forest would be a clear example of an afforestation project. A nation might attempt to gain credit for sink enhancing activities by mandating sustainable forest practices, by subsidizing tree planting efforts, or by regulating or otherwise discouraging the conversion of forestland to non-forestland.

The Kyoto Protocol also recognizes that non-forest related sinks, including other land use changes and removals by agricultural soils, might also be enhanced in ways that help stabilize the level of greenhouse gases in the atmosphere.[46] As discussed in greater detail elsewhere in this Report, studies suggest that agricultural cropland[47] and rangeland[48] have great potential to sequester carbon. The United States Department of Agriculture estimates that the total carbon sequestration and fossil fuel offset potential of U.S. cropland is estimated at 154 million metric tons of carbon per year or 133% of the total emissions of greenhouse gases by agricultural and silvicultural activities.[49] Policies other than market-like carbon trading that might be adopted to enhance the potential of agriculture to sequester carbon include subsidizing, encouraging, or mandating farming practices that encourage carbon retention in soils, or by mandating or subsidizing conservation activities, such as minimum tillage or no tillage, that produce greenhouse gas abatement benefits.[50] Farmers could be asked to adopt such practices as a condition of participating in the farm program or they could be encouraged to engage in such practices as voluntary transactions with emitters who are seeking carbon sequestration offsets for planned emissions. Additional benefits could be gained from preventing or discouraging the conversion of grasslands to croplands. In many cases, carbon sequestration benefits could be achieved by returning marginally productive lands to other uses such as wildlife habitat, by restoring degraded soils, by preserving wetlands, and planting windbreaks. A number of existing USDA conservation programs produce carbon sequestration benefits including the Conservation Reserve Program and the Conservation Buffer Strip Initiative. The Wetland Reserve Program may also provide such benefits, although increased carbon sequestration in wetlands must be balanced against increased methane emissions.

In the United States, federal agricultural conservation programs have a long history. Conservation subsidies or payment for service programs currently under consideration could have an influence on carbon sequestration. With bi-partisan support from members of Congress, including Sen. Sam Brownback (R-Kan.), Sen. Tom Harkin (D-Iowa), Rep. Jerry Moran (R-Kan.), and Sen. Ron Wyden (D-Ore.), among others, there is independent legislation that will allow for carbon sequestration and/or provisions of other statutes under discussion, such as the Farm Bill, that might involve carbon sequestration options.

The Conservation Reserve Program (CRP) is a program of this nature. Its original purpose was to enhance wildlife habitat while enhancing long term soil productivity by taking highly erodible cropland out of production, and thus creating a reserve of land (and soil) that could be cropped if needed at some later time. Farmers and ranchers can bid land into the program with bids accepted at mutually agreed to prices to maintain the land in grass rather than cropland for a certain number of years, with payments made each year over the duration of the contract. Due to its focus on moving cropland back into grassland, CRP works to sequester substantive amounts of carbon, suggesting perhaps that the CRP program could be shifted to a carbon sequestration program as the CRP contracts reach their end.

A recently proposed act would establish a voluntary incentive program based on payments as high as $50,000 per farm per year to implement and continue conservation practices and systems (Conservation Security Act of 2001, S. 932 and H.R. 1949). The bill focuses on land currently being farmed and ranched in contrast to set aside programs such as the CRP program. Generally, it proposes to pay farmers and ranchers to practice a wide array of conservation practices leading to enhancements in soil and water quality; air quality; biological diversity; and, for the purposes of understanding how it relates to the carbon question, "reduction of greenhouse gas emissions and enhancement of carbon sequestration" (S. 932, Section 1240Q(10)).

It is likely that most nations would pursue a variety of approaches in attempting to minimize the emission of greenhouse gases, although it is too early to anticipate specific programs.[51] Given the potential significant economic impact of controls, particularly carbon controls, it is likely that nations will search for innovative, cost effective measures.

Land use measures have two principle advantages as a tool for addressing climate issues. First, land use measures may be a least cost alternative to meeting emissions reduction goals, at least in the short term. Second, land use measures produce synergistic benefits in the form of enhancing biodiversity, enhancing water quality by reducing runoff and maintaining wetlands, and preserving landscapes. At the same time, use of sink enhancements to meet greenhouse abatement goals has been controversial. Some feel that too liberal use of sinks would make it possible for governments to claim credit for policies that they would have pursued even in the absence of global warming concerns. Others raise a series of technical objections.

A number of issues need to be resolved before carbon sequestration can properly be accounted for in climate change programs. On the other hand, to ignore the potential benefits of sink enhancement is to ignore the fact that substantial amounts of carbon are sequestered in soil and biomass and that those numbers can be affected by policies that are adopted. Moreover, sinks can be an attractive way of meeting emission reduction commitments, especially in the short run.

Potential for Developing Markets for Carbon Sequestration Benefits

The range of possible strategies that a nation might employ to achieve greenhouse gas reduction commitments is almost limitless. Presumably most nations will pursue multiple options. The extent to which a nation chooses to rely on voluntary measures to achieve reduction objectives, including free market transactions, as opposed to command and control regulations, is largely a matter of public policy. Some believe there is little that can be done by voluntary action that could not be compelled constitutionally by government fiat. Some believe there are an advantage to voluntary action in easier public acceptance and the potential for greater economic efficiency in achieving environmental goals. At least in the United States, it is likely that any significant greenhouse gas abatement program would incorporate market mechanisms in conjunction with government setting bounds and helping the market operate in equitable and just ways.

As noted earlier, it appears that no legal impediments prevent the development of markets for carbon sequestration benefits. In fact, a number of examples of early attempt to acquire carbon sequestration offset or, more often, options for carbon sequestration offsets can be found. In some cases corporate emitters are positioning themselves to respond to regulation that they feel will be imposed on them in the near future. In other cases, corporations are merely responding to the fact that consumers in some countries have demonstrated an interest in purchasing products that are produced in an environmentally friendly manner, even if the products are offered at higher prices. Eventually, however, markets will not flourish unless there is an appropriate legal and institutional infrastructure to support them.

The carbon offsets (storage) market is of special interest. At a minimum the following structures are probably necessary for such a market. First, there must be an effective way to measure or verify the amount of carbon sequestered in the place in question. Second and closely related, there must be a means of enforcing commitments made in private offset contracts short of litigation. Third, there must be a means of minimizing transaction costs. One possibility is to pool individual landholdings for negotiation purposes. The pool could be privately operated through a broker, organized locally, or, with an appropriate grant of authority, organized through such entities as a Natural Resources District. Finally, there needs to be some way of discovering what is a fair market price for a carbon offset representing carbon in storage, which requires a substantive number of transactions each year in order that price can evolve and a good database on transactions becomes available Currently, carbon offset markets are in their infancy, with very few transactions to date. It is difficult to predict the fair market value of such offsets.

In part, this is because the regulatory programs that would generate much of the economic value of potential carbon offsets have not yet been enacted. In part, it is a function of difficulties in measuring the amount of carbon in place, and, when the market operates on the basis of best management practices, knowing the amounts of carbon storage that ought to be associated with each practice. Equally important, however, is lack of a clearinghouse that reports information on trades. Individuals, in particular, have little basis to decide whether a particular contract for carbon offsets is a good or bad bargain. The fact that the market for carbon stored is clearly (eventually) an international one both enhances the potential value of carbon offsets and adds to the complications of determining a fair price. In the final analysis, the value of carbon offsets will depend on the cost of achieving the same carbon reduction benefits at any location on the globe.

Also, in particular with respect to the offsets market, the matter of incentives, as related to the kind of offsets that will be traded, will need to be resolved. It seems that at least two kinds of offsets might be considered in market trading, that of carbon offsets in flow (COIF) and carbon offsets in stock (COIS). The former represents the rate at which carbon might be sequestered in any given year, for example, perhaps something on the order of say 0.2 tons per acre per year, while the latter represents the total amount of carbon sequestered at the site, for example, 70 tons per acre in place in that particular year. Intriguingly, if the market evolves only in the flow, the COIF, this would likely create a perverse incentive to reduce the stock in place, because then more flow can be added to the now smaller stock. This perhaps cannot be emphasized enough, and points to developing markets in stock, and to trade in a kind of certificate represented by COIS. Trade might commence, for example, in 1-ton certificates, with each certificate representing 1-ton of carbon stored in a particular acre in that specific year. With the focus on how much is actually stored in place, the incentive will be to maintain the stock, and thus to accomplish the real objective of the carbon sequestration approach: Holding carbon in place, and out of the atmosphere. Paying for best management practices also holds the potential for equally perverse incentives, in that such practices relate primarily to flows in any given year, and not to overall stocks in the soil.

Focusing on the stock in place also points to the reality that eventually a particular place, a certain acre in some site, will be filled to capacity. Once filled to capacity, the incentive to maintain it at full capacity needs to be in place. Again, focusing on trading in COIS, perhaps a 1-ton certificate, holds the potential to provide this incentive, and helps ensure the stock is maintained. If this incentive is not provided, it will be advantageous to first fill a particular site to capacity while receiving a price or payment for the flows or the practice, and then go out of the flows (or best management practices) market, and mine it out. This would position the manager to re-enter the flows (or best management practices) market and receive a price (or payment) for building the stock again.

Examples of Market Place Activity Currently Taking Place

Global companies and organizations of various kinds are being positioned to participate in trading in light of the international efforts to address greenhouse gasses. Some are focusing on emissions trading, others on offsets, and most on both kinds.

One example is the International Emissions Trading Association (IETA). It proposes to provide an ongoing overview of the status of trading by countries and global companies (see http://www.ieta.org/). It is based on the premise that it is in the interest of all involved that an international trading scheme emerge, leading to the lowest overall abatement cost possible. The association is built on the premise that trading will likely be more prominent after the second commitment within the Kyoto Protocol in 2008, but it can also help during the preceding years. The national trading approaches that emerge will all have their unique characteristics. There could be elements that emerge which make them incompatible at an international level. In order for these national markets to be working together efficiently by 2008, the "bugs" must be worked out before then. That is why this time period leading to 2008 can prove to be quite valuable, and perhaps explains why we are seeing emergence of groups like the IETA. Facilitating these national schemes to work together will enrich all involved by bringing together the diversity of all involved. This will enable the elements that need to be standardized to become so, while at the same time preserving the distinctiveness of each individual approach (see http://www.ieta.org/).

Carbon offset markets are evolving in several places, with special attention being paid to the rainforest areas of central and South America. Countries such as Costa Rica, El Salvador, Guatemala, and Honduras see the potential to profit from the capability of said areas to sequester more carbon at a faster pace and to hold large quantities of carbon in place for an indefinite period. The focus is on sustainable development (Stewart and Tirana, 1999) and using carbon offset markets to enhance the environmental and profit opportunities in such regions.

Certification companies are also emerging to help the offset markets, for example, SGS Société Générale de Surveillance, an inspection, testing, monitoring, and enforcement organization with offices in more than 140 countries. SGS was recently employed by the Costa Rican government to certify the carbon stored in a rainforest area, with the intent that Costa Rica could eventually sell such carbon offsets on the world market (see http://www.sgsgroup.com/SGSGroup.nsf/pages/costarica.html). The certification of this carbon offset program could help ensure that over 1.25 million acres of Costa Rican forests are preserved. This SGS certification is the first under the terms of the Kyoto agreement on climate change, and it offers the possibility that these forests will remove more than 1 million metric tons of carbon equivalent from the atmosphere. These offsets could then be sold to companies in industrialized countries whose emissions exceed the agreed upon limits in the Kyoto Protocol.

This kind of activity is also ongoing in the U.S., as represented in the Montana Carbon Offset Coalition. The Coalition is a quasi-public entity created with the help of the Montana Legislature. Landowners can receive complete cost sharing to plant trees on land that is not naturally regenerating to trees. In turn, they receive payments to store carbon in the land and the trees. Contracts are signed for upwards of 100 years with the carbon offsets transferred to Montana Watershed, Inc., the private entity associated with the Coalition that actually holds the offsets. The idea is to help corporations mitigate their carbon emissions through purchasing the carbon offsets associated with the now forested land (see http://www.digisys.net/mwi/Welcome.html and http://www.carbonoffset.org/eligible.html).

As a case in point, through the negotiating help of the Chicago-based firm of Environmental Financial Products, LLC (an investment bank and consultancy, who specializes in the design and implementation of market-based environmental protection programs), the Coalition was able to help the Confederated Salish and Kootenai Indian Tribes of northwestern Montana sell carbon offsets to the Sustainable Forestry Management (SFM) group through their London, U.K. office (see http://www.envifi.com/News/sfm_SandK.htm). A total of 47,972 tons of CO_2 equivalent will be sequestered over an 80-year period through reforestation of 250 acres of pineland forest. An investment by SFM will fund the reforestation of the land that was lost to fire. The trade will be monitored by tribal foresters to ensure carbon storage is maintained for a 100-year period. This Chicago firm also proposes to trade in emission (allowances) once this market emerges.

The Pilot Emission Reduction Trading (PERT) program in Ontario, Canada is an industry-led organization that lays claim to memberships by many businesses and industries, as well as some government agencies and universities. PERT operates as a think tank on issues relating to emissions trading especially in the Windsor-Quebec corridor. It works at suggesting and designing emission (allowance) trading rules that might work. As noted on the PERT website, it sees the mission “to help shape future legislation and commitments on emissions (see http://www.pert.org/pert.html).” The Canadian government rewards private business and industry for participating in PERT. This kind of an approach is also spreading to other parts of Canada, for example, in the Greenhouse Gas Emission Reduction Trading Pilot (GERT) in Saskatchewan. The GERT Pilot is a "baseline and credit" mechanism, in the main privately operated, in contrast to a “cap and trade” mechanism where government plays a more direct role in setting limits on emissions. Each site or project starts with a certified base of emissions, and then earns credits from reducing said emissions below the baseline by avoiding increases in emissions that would have otherwise occurred, or perhaps actually reducing current emissions. The resulting credits (i.e., the company now needs fewer allowances to cover the reduced emissions) can be sold to other companies (see http://www.gert.org/faqs/#gert). Private businesses in Canada have been assured by the Canadian Government that credits (reductions) certified now will be recognized in the future. A multi-stakeholder technical committee reviews each project and trade to assess whether it has resulted in actual emissions reductions that are measurable and verifiable at levels above what is already required by law. Again, a project such as GERT will provide practical experience for companies and industries so that they will be in a better position to contribute to future full-scale GHG emissions trading programs (http://www.gert.org/background/#ghgert). Evolution in such approaches to managing emissions, and giving credits for reduced emissions, will ultimate affect offset markets and prices as well. Emissions markets and offsets markets would likely be highly interrelated.

In fact, a consortium of power companies in Canada has been actively searching for carbon offsets that they might apply against their baseline emissions. In particular, a consortium of 10-power utilities that are responsible for 25% of Canada's GHG emissions and 55% of stationary point source emissions are negotiating payments with groups of farmers for installing an appropriate mix of best management practices that increase the carbon stored on the farms within the tract of land associated with the group over several years. Payments would be made each year during the time practices are in place. The idea is that the contracts would perhaps run for 10-20 years, with projections that payments of $0.50 to $1.50 per ton per year will bring farmers to shift to carbon sequestration practices. Some U.S. farmers apparently are already participating in this initiative. The IGF Insurance Company, the fourth largest crop insurer in the U.S. with widespread operations in Iowa, has created a partnership with CQuest, a firm that helps implement carbon credit trading, to sell carbon emission reduction credits (CERCs). A CERC is the equivalent of one metric ton of atmospheric carbon dioxide reduced from an agreed-upon baseline (Zeuli, 2000, p. 244). These two companies have initially solicited options on carbon credits from farmers and other landowners in Iowa by working through IGF's crop insurance agents' network. The companies use formulas developed by the USDA Natural Resource Conservation Service to calculate the amount of carbon that is sequestered under alternative conservation practices. Price is negotiated independently for each contract. According to one news release (PRNewswire, cited in Zeuli, p. 245), 2.8 million metric tons of carbon credits have already been sold to the Canadian consortium (although we have not been able to confirm that this event actually has occurred or that any money has actually changed hands). Also, it seems that IGF was negotiating options to buy carbon credits, rather than buying actual credits, and offering quite modest option payments. Despite these uncertainties, interest remains high, and farmers across the nation are poised to participate if the opportunity arises (e.g., McRoberts, 2001).

Several global firms are now positioned, and some are already involved in carbon trading. These companies have been actively helping, or, more commonly, positioning themselves to help, companies to trade in carbon reductions (offsets) and eventually in emissions. The activity by Cantor Fitzerald in association with Price Waterhouse Coopers in reductions was alluded to earlier, and is detailed at the CO2e.com website. Another example is the collaboration among Arthur Anderson, Credit Lyonnais, and Natsource, who "have teamed ... to create an international carbon repository to serve the developing market in emissions trading" (Mortished, 2000). The Chicago Climate Exchange has also emerged as a pilot project for trading of greenhouse gases in the mid-western region of the U.S. Led by Richard Sandor, known as the "father of futures," the efforts includes the participation of nearly 30 corporate partners, including British Petroleum, Dupont, Ford, and the Wisconsin Energy Corporation. (McRoberts, 2001). The initial proposition is for phased-in commitments, starting with a target of 2% below 1999 baseline emission levels during 2002 and gradually declining by 1% per year thereafter. Monitoring, verification, tracking, and reporting requirements will be implemented, and credits will be given for domestic and foreign emissions offset projects as well as certain carbon sinks (see http://chicagoclimatex.com). The expectation is that trading in the U.S., Canada, and Mexico will be ongoing by 2003 (Phase 3 of the pilot project). Environmental Financial Products, LLC of Chicago is also involved in this pilot project funded by the Joyce Foundation in a contract with the Kellogg Graduate School of Management at Northwestern University.

Innovest, an internationally recognized investment advisory firm, recently created the Innovest Carbon Finance Practice. The Carbon Finance Practice provides clients with clear, company specific research into the business risks and opportunities that global climate change presents at the corporate level. Their primary objectives are to: (1) understand and quantify the potential financial liabilities associated with carbon emissions generated through industrial processes and energy consumption; (2) benchmark corporate emissions profiles, financial exposure, and climate change strategy relative to industry standards; (3) optimize corporate greenhouse gas mitigation strategies; (4) identify hidden carbon-related assets and liabilities; and (5) stay abreast of strategic and operational best practices by tracking policy developments. Current analyses do not include a company's potential carbon risk exposure, which could represent as much as 40% of an energy-intensive manufacturing firm's entire market capitalization (see http://www.innovestgroup.com/carbonpractice.pdf).

In response to this market void, Innovest offers services including company-specific carbon risk profiles, custom portfolio analysis, reviews and analyses of policy developments, and custom advisory and consulting services. When creating a carbon risk profile, Innovest rates a company's current carbon management practices, potential carbon risk, and potential carbon profit opportunities. With these profiles, companies have a unique opportunity to be visionary and to act more efficiently toward the emerging carbon market. Innovest has teamed with leading law firms, global energy brokers, carbon commerce service providers, and energy future speculators in order to be as well rounded as possible when offering their services. The target clients for Innovest's Carbon Finance Practice package are investment banks, insurance companies, industrial corporations, strategic investors, and pension fund managers (http://www.innovestgroup.com/carbonpractice.pdf).

Carbon banks are also emerging. The International Carbon Bank and Exchange (see http://www.carbonexchange.com/about/) "provides a platform that enables individual and corporate clients to keep track of Greenhouse Gases in a secure environment." Emission baselines and emission reduction credits (ERCs) can be established and then banked, retired, or made available on the market to consumers or industry. A firm, for example, may start using wind energy in an action that produces ERCs, which can then be banked or sold. Even individuals can cover their emissions through the Bank. For example, a typical sports utility vehicle may emit 7-8 metric tons of carbon per year. A consumer owning such a vehicle can voluntarily buy ERCs to cover these emissions through the Climate Safe program (used for consumers). A firm within an industry can similarly buy and sell ERCs through the Carbon Exchange program (used for industry). These offsets can be bought and sold in real-time on this website. The ICBE uses the revenue from this program to finance renewable energy systems in home and community systems (http://www.carbonexchange.com). This Bank and Exchange is operating under the "baseline and credits" notion, helping an individual, firm, or industry verify and certify the baseline emissions and the changes made in the emissions leading to marketable credits. The baseline and credits idea may involve government agencies (as in the Canadian GERT project), but does not necessarily do so, with the baseline and credits evolving mainly in the private sector.

Conclusion

Climate change is a serious problem that will be addressed by the United States, though perhaps not through the Kyoto Protocol. Both the President and Congress have suggested that climate change is an issue that merits serious attention. For example, on March 29, 2001 President Bush noted, "Our economy has slowed down in a country – our country. We also have an energy crisis. And the idea of placing caps on CO2 does not make economic sense for America." On July 13, 2001 he indicated, "my administration's climate change policy will be science based, encourage research breakthroughs that lead to technological innovation, and take advantage of the power of markets". On June 11, 2001 the President stated, "We all believe technology offers great promise to significantly reduce emissions – especially carbon capture, storage and sequestration technologies" (http://www.whitehouse.gov/).

Despite the concern over climate change problems, there is not a consensus about how best to handle the problem politically and practically. President Bush has indicated that he opposes the Kyoto Protocol. The U.S. was not a party to a recent agreement on rules to implement the Kyoto Protocol. In November 2001, 165 other nations did reach an agreement on those rules. However, an accord has not yet been ratified by the requisite number of nations for it to take effect.

The emerging regulatory structure in the U.S. will necessarily be proceeding in a top down manner with the international commitments driving domestic commitments and domestic commitments eventually impacting on particular firms and individuals. Intriguingly, however, private companies are also often leading the efforts to bring about emissions and offset trading. It seems reasonable to consider that eventually the more top down regulatory approaches could meet the more grassroots market approaches, and emerge on a joint path.

Footnotes for *Legal, Policy and Economic Issues*

[1] 26 I.L.M. 1529 (1987). International efforts to address ozone depletion have been remarkably successful. The potential role that CFC's play in ozone depletion was first raised in 1974. The Vienna Convention, opened for signature in 1985, was a modest document in which the parties agreed to take "appropriate measures" to prevent ozone depletion and to cooperate in the conduct of research and scientific assessments. Shortly after the Vienna Convention adjourned, British scientists reported discovery of an "ozone hole" over Antarctica. Two years later, parties negotiated the Montreal Protocol to the Convention, and parties agreed to first freeze, and then significantly reduce CFC consumption. As additional information was generated from research, subsequent Conferences of the Parties further amended the protocol to first accelerate planned reductions in consumption, and later to ban consumption of some substances entirely. Additional ozone depleting substances were also identified and made subject to regulation. The international response to the ozone problem is widely hailed as a triumph of modern diplomacy, and consequently, it is no surprise that drafters sought to model the Framework Convention on Climate Change after the Vienna Convention. In many ways, however, ozone depletion was an easier problem to come to grips with than climate change. First, no one benefits from ozone depletion, although some are harmed more than others. Second, replacements for CFC's were soon developed, so economic impacts of regulation were minimized. Third, production was concentrated in a way that permitted successful actions in the short run if agreement could be reached among a relatively small number of parties.

[2] UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, *supra* note 1, art. 2.

[3] *Id*. art. 3 .1.

[4] *Id*. art. 3 .2.

[5] *Id*. art. 3 .3.

[6] *Id*. art. 3.4.

[7] *Id*. art. 3.5.

[8] *See, e.g., id. Preamble*; arts.3.3; 4.1(b),(d); 4.2 (a)-(c).

[9] What constitutes an equitable allocation is also not free of controversy. An equitable allocation of absorption capacity might be calculated on a per capita basis, a per acre basis, or on a per unit of GDP basis.

[10] UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, *supra* note 1, art. 4.8.

[11] Although the United States does regulate emissions of nitrogen oxides and ozone depleting substances, both are regulated for reasons other than their global warming potential. Carbon dioxide, however, is not currently regulated as an air pollutant.

[12] KYOTO PROTOCOL TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, FCCC/CP/1997/L.7/Add. 1 (open for signature December 11, 1997, not yet entered into effect).

[13] *Id*. art 3.1. Reduction commitments embodied in the Kyoto protocol are specified in Annex B and range from a decrease of 8 percent from the 1990 base year levels for most European countries, to an increase of 10 percent over the 1990 levels for Iceland. The United States agreed to reduce its greenhouse emissions by seven percent from 1990 levels. *Id*., Annex B.

[14] The so-called Byrd-Hagel resolution, Sen. Res. 98, was passed the United States Senate on July 25th 1997 by a 95-0 vote. In the resolution, which had 64 co-sponsors, the Senate states that the United States should not be a party to any protocol that fails to apply emissions limitations to developing countries as well as developed countries. It also calls for an economic impact statement to accompany in the submission of a protocol to the Senate for ratification.

[15] Emission limitations contained in the protocol are intended to be met during a five-year commitment from 2008-2012. KYOTO PROTOCOL, *supra* note 12, art. 3.7.

[16] *Id*. art. 3.2.

[17] *Id*. art. 3.3. The Protocol authorizes only a limited number of land use related activities that qualify for removal credits. They are afforestation, reforestation, and deforestation (a negative removal credit) since 1990. *Id*. Unfortunately, the terms *afforestation*, *reforestation*, and *deforestation* are not defined in the Protocol. The Conference of the Parties to the Protocol, however, is authorized to decide on rules and guidelines that would allow other human induced sink enhancement activities, including removals by agricultural soils and land use changes, to qualify for credits against emission limitation commitments. *Id*.

art. 3.4. The extent to which nations can claim credit for carbon absorbed by forests and agricultural lands has been a contentious issue at subsequent Conferences of the Parties, with the issue often pitting the United States against the European Union. *See generally* S. Fletcher, *RL30692: Global Climate Change* 4-7 (Congressional Research Service, Library of Congress, 2001).

[18] The goal of the Protocol is to reduce the net discharge of greenhouse gasses to the atmosphere. This can be accomplished by reducing the direct emission of greenhouse gasses from sources or by engaging in activities that enhance the ability of sinks to remove greenhouse gasses from the atmosphere. For example, if a forest were planted where none existed before (afforestation), the net carbon removal from the atmosphere by the biomass of the trees would be credited against emission reduction commitments.

[19] *Id*. art. 6.

[20] *Id*. art 12.

[21] *Id*. art 17.

[22] *Id*. art. 4.

[23] *Id*. art.6.3.

[24] *Id*. art 3.1. The transfer of emission reduction units is contingent on project approval by both parties, on the project providing reduction or enhancement benefits that otherwise would not occur, and on the acquiring party being in compliance with other responsibilities under the protocol. The acquisition of emissions reduction units must also be supplemental to domestic actions taken to comply with the emission limits specified in the protocol. *Id*.

[25] *Id*. art. 12.2.

[26] *Id*. art. 12.3(b).

[27] No details of a permissible trading regime were included in the draft of the Protocol. The Protocol provides that the Conference of the Parties will develop principles, modalities, rules and guidelines. *Id*. art. 17.

[28] *Id*. art. 6.1.

[29] *Compare id*. art 6.1(d) *with* art. 17.

[30] *Id*. art. 12.3(b).

[31] *Compare id*. art. 6.1(b) *with* art. 12..5(c).

[32] For an analysis of the risk of nonperformance, see D. Goldberg, S. Porter, N Lacasta & E. Hillman, *Responsibility for Non-Compliance under the Kyoto Protocol's Mechanisms for Cooperative Implementation* (Center for International Environmental Law, 1998).

[33] These are set forth on a country-by-country basis in Annex B of the Protocol.

[34] KYOTO PROTOCOL, *supra* note 12, art. 3.7. Transitioning economies, notably the nations of the former Soviet Union, were permitted to select an alternate base year. *Id*. art. 3.5. Any party can use 1995 as a base year for certain enumerated tract greenhouse gases. *Id*. art 3.8.

[35] *Id*., Annex B.

[36] *Id*. art. 3.1. 2008 to 2012 is the first commitment period. By implication, additional commitment periods with new, and presumably more stringent, reduction goals would follow.

[37] *Id*. art. 3.2.

[38] *Id*. art. 3.7.

[39] *Id*. art. 3.10.

[40] *Id*. art. 3.12.

[41] *Id*. art. 3.10.

[42] *Id*. art. 3.11.

[43] *Id*. art. 3.13.

[44] FRAMEWORK CONVENTION, *supra* note 1, art. 4.2(a).

[45] KYOTO PROTOCOL, *supra* note 12, art. 3.3.

[46] *Id*. art. 3.4.

[47] See R. LAL, J. KIMBLE, R. FOLLETT & C. COLE, THE POTENTIAL OF U.S. CROPLAND TO SEQUESTER CARBON AND MITIGATE THE GREENHOUSE EFFECT (1999).

[48] See R. FOLLETT, J. KIMBLE & R. LAL, THE POTENTIAL OF U.S. GRAZING LANDS TO SEQUESTER CARBON AND MITIGATE THE GREENHOUSE EFFECT (2001).

[49] *Soil Carbon Sequestration: Frequently Asked Questions*, USDA Global Change Fact Sheet, USDA 2001.

[50] In addition to conservation tillage, other beneficial management practices include optimum management of crop residues and application of manures, soil fertility optimization through site specific management, elimination of summer fallow, and use of winter cover crops. *Id*.

[51] For a summary review of emerging plans from the EU, Denmark, France, Germany, the Netherlands, Norway, the United Kingdom, Australia, and Canada see J. Cameron, D. Robertson & P Curnow, *Legal & Regulatory Strategies for GHG Reductions—A Global Survey*, 15 NAT. RESOURCES & THE ENVIRON. 176 (2001).

III. Carbon Sequestration and Agricultural Greenhouse Gas Emissions Reduction – Potential State Level Options

General

Nebraska could consider a number of options that might potentially: 1) better position the state to take advantage of carbon markets, if they should develop, 2) increase knowledge of carbon sequestration and greenhouse gas emissions, 3) better understand Nebraska greenhouse gas and carbon sequestration related options, 4) tend to better manage existing carbon, 5) expand the storage of carbon, or 6) use bio-mass to substitute for existing energy intensive activities. The following paragraphs, with one exception, provide an overview of potential state level options. The exception involves options related to non-agricultural greenhouse gas emissions reduction. There is a wide range of options that could result in reductions in emissions of non-agricultural greenhouse gases. However, those options are considered to be beyond the scope of this report. Finally, it should be noted that the order in which options are numbered is not a function of the importance or desirability of the option.

OPTIONS DESIGNED TO PROVIDE ADDITIONAL INFORMATION

Option #1 – Provide additional funding for basic carbon sequestration related research relevant to Nebraska.

Description: This could conceivably include research on a variety of topics, including potential methods of measuring/accounting for sequestration and emissions reduction in Nebraska, cooperative efforts with researchers in other states or nations, including research into how government programs and/or marketing might increase sequestration or reduce emissions in the state. In some instances state or local research monies might be used to leverage funds from outside the state.

Option #2 - Develop a state greenhouse gas inventory.

Description: Greenhouse gas inventories identify major sources of greenhouse gas emissions and create a baseline for future action. They generally present annual greenhouse gas emissions by sector (e.g. energy, agriculture, waste), by gas, and by source (transportation, etc.). As of July 2001, thirty-four states and Puerto Rico had completed inventories and another two states had inventories underway. Nebraska was not among those states. A greenhouse gas inventory is a significant source of information for a greenhouse gas action plan. The EPA has specific guidance for estimating greenhouse gas emissions.

It should be noted that as of May 2001 twenty-five states had also completed state climate action plans (showing how a state could reduce its greenhouse gas emissions). Those plans are not included as a specific separate option here because this report is focused on options related to carbon sequestration and agricultural greenhouse gas emissions reduction.

Option #3 – Complete a carbon sequestration baseline survey for both soil and vegetation on all remaining land uses and update on a periodic basis.

Description: A baseline survey for cropland and grassland is being completed as part of the LB 957 planning effort and should be available by early 2002. However, that does not include other land uses. In addition there is not a current plan to update that material on a periodic basis. It is possible that some subsidiary material, such as keeping a tabulation of acres in the Conservation Reserve Program might also be helpful. Up to date information might assist in quick response should national or international policy change.

OPTIONS DESIGNED TO PROVIDE NEW ORGANIZATIONAL MECHANISMS

Option #4 - Provide a permanent carbon sequestration committee or council to monitor ongoing developments.

Description: Recent international action on climate change and carbon sequestration has been very significant, even during the course of writing this report. The potential market implications of international action are not yet fully known. A permanent carbon sequestration or climate change/greenhouse gas task force could respond quickly to international or national legal changes and changing market conditions. It could also provide guidance/input to any continuing program development or research/emissions inventory work. In addition it could work to maintain high visibility for state level greenhouse gas and carbon sequestration issues as changes occur. If funding, staffing, or reporting requirements were to be mandated it would help to assure continued activity on the issue. This option could include designation of a state agency as a lead agency.

Establishing a single point of state government contact for carbon sequestration information is also a potential option.

LB 957 did not provide an ending date for the Carbon Sequestration Advisory Committee that provides the recommendations contained in this report. There might need to be some consideration of whether the charge for that committee might meet any needs identified for the future or whether those needs could be better met by adding a new charge or creating an entirely new committee.

Option #5 - Sponsor a carbon sequestration pilot/demonstration project. Consider including marketing, emissions reduction and biofuel elements.

Description: A pilot project could be used to demonstrate the technical, administrative, legal and economic facets of how carbon sequestration management and marketing could work in Nebraska. The project (or projects) could show how new technology or governmental/administrative approaches could be used to reduce greenhouse gases in a real world setting. In Nebraska, agriculturally related carbon sequestration may make particular sense for a project. At some point, federal funds might be made available. The U.S. Environmental Protection Agency has shown interest in state greenhouse gas related activity and President Bush recently announced the formation of the National Climate Change Technology Initiative. Potential project scope and Nebraska pilot project areas would need to be identified. This could conceivably include marketing, emissions reduction, and biofuel or methane recovery elements in addition to carbon sequestration. The project could also be used to leverage outside funding into Nebraska.

Option #6 – Research and consider legislation that requires brokers or others seeking to negotiate carbon offset or option contracts to register with the state and provide sample contracts with the Department of Agriculture or the Department of Natural Resources. The State could also enact legislation to provide a central clearinghouse of market information.

Description: This option would allow the state to review contracts and take action in cases where activity looked legally questionable or deceptive. Conceivably it could be expanded to allow the state to monitor acres and dollar volume of such activities and provide such information to policy makers and the public. Such information could conceivably be provided via the internet. To the degree this helped encourage marketing activity it might help inject funds into agriculture.

Option # 7 - Grant some government entity the power to enter into contracts on behalf of landowners and/or the power to ensure enforcement of the obligations contained in carbon offset contracts or options.

Description: If significant carbon markets were to develop, a governmental entity might be used both to monitor compliance with carbon contracts and/or to act a broker/consolidator for local carbon sequestration activity. This might reduce confusion and the potential for problems that could occur if multiple entities were to enter into separate contracts with a variety of landowners. The need for these types of authorities might depend upon the strength and specific requirements of any carbon markets that would develop. There may be significant questions as to whether public or private consolidation or brokering of carbon sequestration credits would work best if markets were to develop.

OPTIONS DESIGNED TO PROVIDE STATE INCENTIVES/PROGRAMS FOR ACTIONS THAT RESULT IN ADDITIONAL CARBON SEQUESTRATION

Option #8 - State incentives or programs for actions that result in additional carbon sequestration. Potential actions include:

a) ***Increased incentives to landowners for no till and other conservation measures that sequester carbon. Spot checks to ensure compliance and measure sequestration levels.***

b) ***Incentives for forestry and agroforestry***

c) ***Tree planting programs for public lands***

d) ***Urban forestry campaign***

e) ***Buffer and tree planting programs for streambanks and public areas where eroded sediments occur***

f) ***Public rangeland conservation programs and requirements***

g) ***Provide additional public information on Carbon Sequestration***

Description: There are a wide variety of existing and potential state and local level programs that can increase carbon storage. A few of them are listed above. In the case of existing programs, current levels of funding could be increased. The programs listed above are primarily incentives, with a few information/education or administrative types of activities. Although none are listed, regulatory programs are technically an additional possibility.

However, such programs would appear to have limited current relevance given today's federal legal framework.

It is significant that many of the current incentive options (such as the conservation reserve program) are delivered through federal funds and may be most appropriately funded from that level. However, the conservation benefits of many carbon sequestration incentives can also provide a rationale for state and local funding.

OPTIONS THAT PROVIDE STATE INCENTIVES FOR AGRICULTURAL GREENHOUSE GAS EMISSIONS REDUCTION ACTIVITIES

Option # 9 - Continue or expand state incentives for bio-fuels programs. Examine biomass options.

Description: Biofuels have the major benefit of coming from plant material that pulls carbon from the atmosphere as part of its growth process. Alternatively, fossil fuel burning releases carbon that was previously sequestered in the ground. Biofuels can also release fewer greenhouse gases on a per-mile traveled basis. Nebraska currently provides significant tax credits for ethanol production. The state government automobile fleet is also operated with alternative fuel vehicles.

Option # 10 – Initiate livestock waste / methane reclamation programs

Description: High livestock numbers may give Nebraska particularly significant opportunities for recapture of methane and other greenhouse gas contributions from livestock waste.

OTHER OPTIONS

Option # 11 – No New Action

Description: No further action is one of the options that can be considered.

IV. Practices and Land Uses That Increase Carbon Storage and Minimize Greenhouse Gas Emissions

General

When discussing the potential of agricultural practices to sequester carbon, two very significant factors should be kept in mind: (1) the practical maximum limits of the sequestration potential (i.e., the capacity to store carbon) on a given area of land and (2) the potential for carbon stored over a number of years to be released back into the atmosphere over a relatively short period of time. Best management practices allow soil to annually store carbon over a significant amount of time and achieving the practical upper limit on carbon sequestration on cropland may require at least 50 years. However, at some point the management needed to add still more carbon to land that already has high carbon levels may become cost prohibitive. Also, if no program is in place to ensure proper conservation measures are continued, the higher levels of stored carbon can also result in larger emissions should proper conservation measures be discontinued.

Some agricultural practices such as tillage have historically released carbon into the atmosphere. However other practices can substantially improve carbon sequestration and have substantial side benefits for producers, the environment and the public at large. Most of those practices have in fact been the subject of government programs or support due to their conservation values alone without strong regard to their additional carbon sequestration benefits. In that sense carbon sequestration programs may sometimes be viewed as a previously largely unrecognized benefit to already worthwhile conservation efforts. Agriculturally related practices, land uses and management techniques that can increase soil carbon sequestration, sequester carbon in vegetation, or minimize agricultural greenhouse gas emissions generally include:

1. Conservation tillage, buffers, CRP
2. Soil erosion management
3. Conversion of marginal agricultural land to grassland, forest, or wetland
4. Wetland restoration
5. Irrigation
6. Elimination of summer fallow
7. Use of biomass or energy crops to substitute for fossil fuels.
8. Use of biogas from liquid manures to substitute for fossil fuels.
9. Improved fertilizer use and efficiency
10. Rangeland and pastureland management
11. Agroforestry
12. Forestry

The overall potential to sequester carbon from the above agricultural practices is significant. For example, the potential benefits from combined total cropland and grazing land related emission reduction and sequestration practices may range from about an estimated 152.5 to 405 million metric tons (MMT) of carbon per year or about 8% to 22% of annual U.S. greenhouse gas emissions (If sum of estimates from Lal et. al., 1999 and Follett et. al., 2001 are used). However, there is not total agreement on sequestration potential from various practices, especially on such topics as grazing land. Current data are best used with caution. In addition the amount of new or additional carbon sequestered may begin to decline as a soil reaches its capacity. Furthermore, several uncertainties exist with respect to how these practices or the sequestration that results are to be accounted for in a national or international market. If practices themselves are accepted as a surrogate for sequestration, it is unknown which, if any, might be accepted as a marketable carbon sequestration practice.

Although U.S. cropland and grazing land have considerable potential to sequester more carbon, they are far from the only source of carbon storage. Currently the U.S. has only about 7% of the world's land area and 13% of the world's cropland (United Nations, 1994). Cropland overall accounts for only 5.3% of the world's land carbon in storage down to a depth of 1 meter.

Table 1 provides additional information on current global land carbon stocks down to a depth of 1 meter by land use. It should be noted that the amount of carbon in storage and the potential for additional carbon storage do not necessarily correspond. One of the key questions in carbon storage is not just how much carbon is stored by a land use, but how easy it is to either lose that carbon through emission to the atmosphere or gain additional carbon storage. In other words movement through the carbon cycle is as important as the size of the carbon stock. Another question revolves around whether currently existing stocks of carbon may be credited under new carbon management systems versus crediting only gain or loss of carbon stocks.

Table 4-1. Global carbon stocks down to a depth of 1 m.

		Carbon Stocks			
Land Use	Land Use Area, 10^9 hectares	Vegetation	Soil	Total	Percent Of Total Carbon Stock
		Giga Metric Tons			
Boreal Forests	1.37	88	471	559	22.6
Tropical Forests	1.76	212	216	428	17.3
Tropical Savannas	2.25	66	264	330	13.3
Temperate Grasslands	1.25	9	295	304	12.3
Wetlands	0.35	15	225	240	9.7

Deserts & Semideserts	4.55	8	191	199	8.0
Temperate Forests	1.04	59	100	159	6.4
Croplands	1.60	3	128	131	5.3
Tundra	0.95	6	121	127	5.1
Sum	15.12			2477	100.0
Source: Modified from Intergovernmental Panel on Climate Change, 2000, "IPCC Special Report-Land Use, Land Use Change and Forestry-Summary for Policymakers," World Meteorological Organization and United Nations Environment Program, 22 p.					

Soil Conservation Benefits of Carbon Sequestration Techniques to Nebraska

Regardless of whether carbon sequestration benefits are involved, there are a number of reasons for implementing many of the conservation techniques that result in carbon storage. One of the most important of these is to protect and maintain the long-term productivity of the soil in the state through reduction in soil erosion. For example, quality criteria in the NRCS Field Office technical guide generally allows a soil loss of 5 tons/acre/year (0.032 inches/year) which is 16 times faster than an average rate of soil formation (estimated at .002 inches per year). Although the rate varies with individual soils, 5 tons/acre/year is generally close to "T" (tolerable level of soil erosion that maintains soil productivity). 1992 data indicates that 21.4% of U.S. cultivated cropland was eroding at greater than "T" as a result of sheet and rill erosion, and 16.1 % was eroding at greater than "T" from wind erosion (USDA, 1996). The negative yield impacts due to soil erosion are felt on cropland as well as pasture and rangeland. Other additional benefits of conservation practices, especially conservation tillage, are a decrease in fossil fuel use, time savings for operators, moisture conservation with resulting yield increases, better water quality, and a reduction in off-site sediment damages.

Estimated average annual sheet and rill erosion on nonfederal land in Nebraska has decreased for all types of land use as reported in the 1997 National Resources Inventory summary report (USDA, 2001). Since 1982 the erosion rate on cultivated cropland has decreased from 4.8 tons/acre/year to 2.9 tons/acre/year. On non-cultivated cropland the change was from 0.7 tons /acre/year to 0.5 tons/acre/year. Much progress has been made in the reduction of soil erosion, and if "T" is used as the standard, average soil erosion in the state is well within tolerable limits. However, a portion of the state's cultivated cropland has still not reached "T", and there may be some who would argue for the stricter soil formation rate as a sustainability standard.

Cropland

USDA estimates from 1998 indicate a U.S. cropland soil sequestration potential of 154 MMT or about 8.4% of U.S. emissions annually. Another source indicates improved management of U.S. cropland has an estimated potential to sequester between 75 and 208 MMT of carbon per year. This figure rises to 123 to 295 MMT when the potential offset from use of biofuels, reduced fuel use, and reduction of eroded sediments are added (Lal, et. al., 1999). Table 2 presents cropland soil sequestration data by management type both for the U.S. overall and on a sequestration per hectare (ha) basis, and provides an indicator of the relative potential importance of various types of management.

There is some evidence that soil organic content is likely to increase in dry areas when soil is irrigated, since most soils in dry areas have naturally low levels of soil organic content. Table 2 indicates irrigation water management has significant carbon sequestration potential. Nebraska currently ranks second in the nation in total irrigated acreage and has continued to experience a trend of some additional irrigation development. However, the extent to which fuel consumption required by irrigation may offset the carbon storage benefits of irrigated land needs to be considered.

Nebraska's soil stored significantly more carbon prior to sodbusting in the 1800's, although adoption of conservation measures, especially minimum tillage, in recent decades has likely resulted in increased soil carbon storage versus previous decades. Nebraska cropland management practices are estimated to currently sequester about 1.7 MMT of carbon per year based upon climate, soils and management factors. It is estimated that this level of sequestration can be maintained and increased to 2.3 MMT per year if all cropland is converted to a no tillage management system (Brenner et. al., June 2001). This would represent about a 35% increase in carbon sequestration over current levels. However, at some point in time the amount of new or additional carbon stored may begin to decline as the soil reaches its capacity.

Other areas of potential greenhouse gas emissions reduction from cropland are improved fertilizer management, which can account for reduction in nitrous oxide emissions, reduction of soil erosion, which can account for an estimated reduction of 12 to 22 MMT of carbon emissions per year (Lal et. al., 1999); and reduced fuel usage due to conservation tillage. Another major cropland activity that can help reduce greenhouse gas emissions is biofuels production. Because biofuels are grown on the land, they can pull carbon from the atmosphere while growing and their use can partially supplant use of fossil fuels and the resultant release of that stored carbon. With predicted increases in U.S. and world energy demand, biofuels provide one method of meeting that demand without significantly increasing atmospheric carbon levels. Although it is not an objective of this report to address market or economic factors related to biofuels production, the potential role of biofuels should be noted. Potential U.S. biofuel production could result in a reduction of about 5.3 percent of U.S. carbon equivalent emissions via replacement of fossil fuels (U.S. Dept. of Energy, 1999).

Grazing Land and Livestock

The conversion, restoration, and management of U.S. grazing lands, including pasture and range, are estimated by one source to have an additional total carbon sequestration potential of about 29.5 to 110 MMT per year with improved management practices accounting for much of that potential. After accounting for carbon losses from grazing lands they are estimated by that source to have a net potential of sequestering about 17.5 to 90.5 MMT annually (Follett et. al., 2001). (Table 3). This compares to 123 to 295 MMT for cropland soil sequestration and fossil fuel offset / emission reduction potential. However, grazing land potential sequestration figures are still subject to discussion. Recent research conducted in Kansas's grasslands, however, indicates that for most or normal grazed or ungrazed grasslands the net carbon flux is zero. That source indicated that grazing lands aren't generally accumulating carbon and that the only way sequestration is likely to occur on a given pasture is if it has been abused and land management is changed (Owensby, Personal Communication, 2001). In Nebraska rangeland and pastureland account for about 51% of land use while cropland accounts for about 40 % of land use (NRCS 1997). No figures have been developed for potential sequestration from grazing land in Nebraska. Given current research, some caution seems in order when considering carbon sequestration potential on grazing land.

Methane

Another important component of greenhouse gas emissions related to grazing and livestock is methane production. Methane is produced by internal fermentation of cellulose from low quality forage to high quality protein. Methane production increases as the quality of the diet decreases. Livestock practices that can reduce methane emissions include the following:

1. Improvement of diet (may be limited to around 5%).
2. Changes in herd management including: reduction of cow numbers/amount of beef produced, increasing the percent of calf crop, increased weaning weights, and reduced time to weaning.
3. Improvement in milk production per cow as the result of continued improvements in management and genetics. By increasing milk production per cow, methane emissions per unit of milk produced declines.

4. Refinements to the marketing system for the beef industry as well as improved cow-calf sector performance.
5. Improvement in the quality of grazing lands which would ultimately promote better digestion and therefore decreases in methane emissions.

Given Nebraska's large livestock population, methane reduction techniques seem likely to have particular relevance for the state. A 1993 estimate indicated that a 23% reduction in U.S. methane emissions from livestock was possible by 2010 and a 17% reduction in methane emissions from livestock waste was also possible (EPA, 1993).

Table 4-2. Estimated U.S. Carbon Sequestration Potential through Improved Cropland Management

By Management Measure-Modified from Lal et al. 1999

Scenario (MMTC/yr)	Area (10^6 ha)	C sequestration potential (MTC/ha/yr)	Total potential (MMTC/yr)	Mean of the Potential (MMTC/yr)	Mean Potential as % of Total
Residue management	----	----	11-67	39	27.5%
Conservation tillage	100	0.24-0.40	24-40	32	22.6%
Eroded lands restoration	28.6	0.3-0.7	9-20	14.5	10.2%
Fertilizer management	117.5	0.5-0.15	6-18	12	8.5%
Rotation with winter cover crops	51	0.1-0.3	5-15	10	7.1%
Conservation Reserve Program	16.2	0.3-0.7	5-11	8	5.7&
Organic manures and by-products	----	----	3-9	6	4.2%
Supplemental irrigated water mgmt.	21	0.1-0.3	2-6	4	2.8%
Sub-irrigation water management	43.4	0.7-0.12	3-5	4	2.8%
Idle land management	20	0.15-0.25	3-5	4	2.8%
Summer fallow elimination	9.4	0.1-0.3	1-3	2	1.4%
Salt affected soils restoration	19.6	0.05-0.15	1-3	2	1.4%
Conservation buffers	3.2	0.3-0.7	1-2	1.5	1.1%
Mine lands restoration	0.63	1-3	0.6-2	1.3	.9%
Management of rice straw	1.3	0.4-1.15	0.5-1.5	1	.7%
Wetland Reserve Program	2.0	0.15-0.35	0.3-0.7	.5	.4%
Improvement in crop yields	117.5	0.004-0.006	0.5-.07	.06	>.1&
			75 - 208		
Total potential = area x rate of sequestration					
Source: Modified from R. Lal, R.F. Follet, J. Kimble and C.V. Cole “Managing U.S. Cropland to Sequester Carbon in Soil,” Journal of Soil and Water Conservation, First Quarter 1999					

Table 4-3. Estimated Potential CO_2 Sequestration Losses and Benefits from Conversion, Restoration, and Intensified Management of U.S. Grazing Lands Adopted/Modified From Follett, Kimble, Lal, 2001

	Area (Mha*)	Mean of Estimated Range For Quantity Sequestered (MMTC/yr)**	Mean as % of Total
Land/Soil Restoration	123.63	16.65	23.9%
Grazing Management on Pasture	15.3	12.25	17.6%
Conservation Reserve Program	14.73	11.05	15.8%
Improved Rangeland Management	107.00	10.70	15.3%
Improved Pastureland Management	40.85	10.15	14.5%
Non Intensively Managed Grazing Land	329.16	4.90	7.0%
Land Conversion from Cropland and Forest to Pasture	5.31	3.98	5.7%
Nitrogen Fertilizer of Mountain Meadows	.48	0.15	.2%
Emissions Losses from Grazing Lands	239.00	-15.75	
Net Gain (Range)		17.5 to 90.5	

Source: Modified from Follett, R.F., J.M. Kimble, and R. Lal, 2001, "The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect," CRC Press

*Area figures combine multiple management subcategories from original text in some instances. The area in some categories includes both current area and land that may be potentially converted to the management/use. **. Note: The original data in Follett et al. was for a range of quantity sequestered. This table has combined information into a mean.

*** See text discussion for alternate view on grazingland sequestration potential

Reductions in methane emissions are also possible through improved manure handling. U.S. Department of Energy estimates indicate that a 15 to 25% reduction in methane emissions is possible from improved manure handling, including capturing emissions and generating power from lagoons, and applying manure to cropland through injection in the soil. Methane recovery systems collect the methane produced by liquid manure management systems and use the captured methane as a fuel. Through use of methane recovery systems, it is technically feasible to reduce total methane emissions from livestock manure by 80 percent. Although methane recovery systems are technically feasible for virtually all farms using liquid-based manure management systems, methane recovery systems tend to only be profitable for large farms in warm climates.

Agroforestry

Agroforestry practices leave the bulk of the land in agricultural production, while integrating trees into the ongoing farm or ranch operation. Agroforestry practices can accomplish a multitude of objectives. Among these are the reduction of water stress to improve crop yield and quality, reduction of soil erosion, snow management, livestock protection and odor control, provision of wildlife habitat, and energy conservation around farmsteads. Although there are numerous agroforestry practices, a few hold especially strong promise for storing carbon in Nebraska. These include field windbreaks, living snow fences, riparian forest buffers, pivot corner plantings, and short rotation woody crops. The potential for agricultural lands in Nebraska to store carbon through the increased adoption of these agroforestry practices is estimated to be substantial. However, biomass equations for trees and shrubs grown in agroforestry practices must be generated for a range of age, soil, and climate conditions. While biomass equations based on stem diameter and height already exist for most tree species, almost all of these equations have been generated from data gathered on forest grown trees. These forest-derived equations have been shown to severely underestimate the biomass of windbreak trees by as much as 100 percent.

Field Windbreaks

These windbreaks reduce evaporation and plant transpiration rates such that per field crop yields are typically improved, even though a portion of the field has been converted to windbreaks (Kort and Turlock, 1999). These yield increases, along with reduced input costs, more than economically justify planting a portion of the land to trees, however, windbreaks are a long-term investment that can take 7 to 10 years to become fully effective (Brandle et al. 2000).

Windbreaks typically function effectively for 50 to 70 years and would continue to accumulate carbon over the life of the planting. Most of the windbreaks in the North Central U.S. were planted in the 1930's in response to the dustbowl and most of these have reached the end of their functional life and are in dire need of replanting or rehabilitation.

Living Snowfences

In North and South Dakota, Nebraska, Minnesota, and Iowa there are over 460,000 miles of roadway. In these states and others in the North Central region many roads would benefit from protection with a living snowfence. Properly designed living snowfences can dramatically reduce the need to plow and re-plow roadways and improve safety.

Riparian Forest Buffers

Tree growth is accelerated in riparian zones due to favorable moisture and nutrient conditions. When agroforestry buffer systems that contain trees, shrubs, and grasses are designed and planted in these moist environments they can also filter out excess nutrients, pesticides, animal wastes, and sediments coming from agricultural activities.

Center Pivot Irrigation Corners

Center pivot irrigation systems are commonly installed on 160 acre, ¼ sections. However, most of these systems are unable to irrigate about 6 acres in each corner of the tract, resulting in about 24 non-irrigated acres per center pivot. These irregular shaped corners make maneuvering equipment difficult, but in areas where precipitation is adequate for crop production, farmers may still resort to dry land cropping of corn or soybean. However, where moisture is limiting these corners are often used for forage crops or simply left vacant. In the North Central region there are several million acres of center pivot corners that could be planted to trees and shrubs to provide wildlife habitat and crop protection, while storing carbon.

Short Rotation Woody Crops (SRWC)

Low prices for traditional crops have increased the interest of farmers in fast-growing woody crops, like hybrid cottonwood trees, for fuel and fiber. These trees can be planted in large blocks and provide a way of increasing on-farm income, while also being designed to accept agricultural, livestock, community, and industrial waste applications. The rapid growth of SRWC results in high rates of nutrient uptake and large amounts of carbon storage over rotation lengths as short as 5-15 years.

Table 4-4. Agroforestry potential to store carbon on Nebraska farmland. Storage values are calculated at 20 and 40 years following planting. However, depending on species and purpose, planted trees can live for many decades or more than a century.

Agroforestry Practice	**Stored CO_2 / Land Unit*** **At Age 20** ***metric tons (mt)***	**CO_2 Storage Potential for Nebraska** ***million metric tons (mmt)*** ***20 years***	***40 years***
Field Windbreak[2] **(planted on 5% of cropland)**	36 - 72 mt /mile *(20 ft width, 0.4 mi. = 1 ac.)*	11.7 - 23.4	23.4 - 46.8[1]
Living Snow Fence[3] **(high priority roadways)**	162 - 324 mt /mile *(50 ft width)*	5.4 - 10.8	10.8 - 21.6[1]
Riparian Forest Buffer[3]	426 - 852 mt /mile *(100 ft width, each side stream)*	9.2 - 18.4**	18.4 - 36.8
Pivot Irrigation Corners[4] **-pivots below 23 inch annual precipitation**	352 - 704 mt /pivot *(4 corners, each 6 acres)*	6.6 - 13.2***	13.2 - 26.4
-all corner pivots	" "	15.1 - 30.2	30.2 - 60.4
TOTAL		**41.4 - 82.8**	**82.8 - 165.6**

*Tree biomass and subsequent CO_2 storage estimates are based on volume tables derived from trees grown under shaded forest stand conditions. Recent research at the University of Nebraska (Zhou et al., *submitted)* has shown that tree biomass for green ash grown under windbreak conditions can be as much as 100% greater. This is attributed to the greater branch biomass and changes in the stem diameter to height relationship that occur in open grown, sunlit trees. Research is underway to determine if similar biomass patterns occur for other windbreak tree species. The upper bounds of the ranges reflect this possibility

**Riparian estimates are derived from the rate of trees growing in field windbreaks. Due to the more favorable moisture and nutrient conditions typical of riparian landscape positions, these estimates are likely to be conservative.

***1997 data show 42,940 pivots in Nebraska, and most of these are located on 160 acre ¼ sections. Only irrigation pivots on lands averaging 23 inches or less of precipitation would likely be available for tree planting (44 percent of pivots), as farmers could still plant the non-irrigated corners to corn or soybeans above this moisture level.

[1]Brandle et al 1992. [2]USDA, SCS. 1990. [3]Garrett, H.E., et.al., 1994. [4]Boellstorff et al.1997.

Forestry

Forest management for Nebraska farmers and other landowners on much of the Great Plains typically involves narrow tracts of land adjacent to rivers and streams and their associated upland sites. The surrounding agricultural lands and their related management activity significantly influence these forests. Much of the early forestland has been converted to row-crop agricultural use. Only occasionally are forests the dominant influence on the Nebraska landscape as in the Pine Ridge and along some portions of the Missouri River. Regardless of the size of the forest holding, the most common forest management practice is harvesting merchantable trees. Most often this harvesting occurs without any kind of management plan. Forest management activities that improve forest health and productivity such as forest stand thinning, pruning, and pest control are not commonly used.

Enhanced Forest Management

The 1994 U.S. Forest Service inventory documented 948,000 acres of timberland in Nebraska. Increased investments in management, primarily to improve stocking levels, reduce damage caused by over-grazing in forestland, and in conducting thinning and protection activities, offer the potential of significant increases in forest growth. With enhanced management the potential for increased growth has been estimated at about 330 percent higher than the average annual net growth measured over the last inventory cycle.

New Forest Plantings

There is an opportunity to establish new forest plantings on portions of Nebraska farms currently devoted to other land uses; however this potential is difficult to quantify. In 1997, 4.5 million acres of Nebraska cropland were not harvested and approximately 48 percent of Nebraska agricultural land was classified as pasture and rangeland. Opportunities for establishing new forest plantings exist on at least a portion of these lands.

Urban Forestry

Urban forestry projects are unique in that under some circumstances they can reduce energy consumption as well as sequester carbon. Shade trees planted near buildings reduce summer air conditioning requirements. In addition trees can act as windbreaks, reducing heating needs in winter. Although the emissions reduction associated with energy effects of urban forestry can be several times the sequestration benefits on a carbon dioxide basis, they are difficult to estimate.

Table 4-5. The potential in Nebraska of enhanced forest management on existing forestlands and new forest plantings to store carbon are estimated. Values for new plantings are estimated at year 20 and 40 although carbon would continue to increase for many more decades. Likewise, the full value of enhanced management would not be realized for at least 60 years.

Forestry Practice	Additional Stored CO_2 per Land Unit* *At Age 20* *metric tons (mt)*	CO_2 Storage Potential for Nebraska *million metric tons (mmt)* *20 years*	*40 years*
Enhanced Management Of Existing Forestland	1.8 mt/acre	1.8	7.1
New Forest Plantings (1,000,000 acres)	14.8 mt/acre	14.8	42.9

References

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V. Measuring and Modeling Carbon Sequestration and Agriculturally Related Greenhouse Gas Emission Reduction Techniques and Areas of Uncertainty

Measuring Carbon Levels

Two significant issues pertaining to the measurement and modeling of carbon sequestration are: 1) How can carbon sequestration best be measured on an individual field, and 2) What are the most effective techniques to apply measurements to large areas?

There are several challenges to accurately measuring the amount of carbon sequestered. First, the baseline carbon of existing fields must be measured in order to calculate the potential gains and losses from different land use activities. Second, measurements must be transferred into statewide or regional values. Third, baseline and changing carbon levels in other areas of the world (with a wide variety of soil types and land uses) must be accurately compared to the U.S. values.

From an economic viewpoint, the stored carbon must be measured in a readily understood and consistent manner so that potential buyers and sellers have a clear understanding of the product. A current method is to compare the amount of stored carbon in the soil to one metric ton of atmospheric carbon dioxide that has been removed from the atmosphere or avoided from an emission source. Such a unit is commonly expressed in terms of a carbon emission reduction equivalent. Another major concern is the cost effectiveness and accuracy of the various measurement techniques that might be preferred for different management and accounting systems. For instance, would the per acre cost of estimating the carbon sequestered on one landowner's farm for an individual credit be different than the per acre cost of simply doing a county wide or statewide estimate. In each case this may depend upon the accuracy desired.

On a statewide basis, one of the first items required is a baseline of current soil carbon levels. The assessment being conducted in conjunction with LB957 should help fill that role. Because carbon can rapidly be lost from soils that have had conservation measures removed, accounting systems would also likely require an accurate accounting on the debit side of the ledger.

At some point the amount of new or additional carbon sequestered may begin to decline as a soil reaches its capacity. Sequestration in the vegetation from conservation efforts such as agro-forestry will also need to be considered as well as emissions reductions from agricultural activities. There are several potential approaches to measuring the amount of carbon being stored from a particular land management practice. Generally these include:

1. Direct in field measurements of soil carbon, biomass or carbon flux;
2. Indirect remote sensing techniques;
3. Default values for land/activity based practices.

The answer to which method is adopted will depend upon the requirements of whatever accounting and management system is adopted. This in turn will depend partly upon the eventual stipulations in potential international agreements. The overriding question is how accurate an accounting of sequestration is needed and how expensive it is to conduct.

Direct Measurements

Direct methods include field sampling and laboratory measurements of total carbon in the soil. Changes in carbon content resulting from changes in land management are then expressed as the change in carbon amount on an area (kg m^{-2}) or volume basis (kg m^{-3}). The calculation is not difficult but requires awareness of the variability of soil properties. Another promising direct method is eddy covariance measurement of carbon dioxide fluxes. The vertical component of air movements (eddies) over a vegetated surface can be measured along with the carbon concentration associated with each eddy. By correlating vertical wind speed and carbon dioxide concentration for each upward and downward moving eddy, the net flux (uptake or release) of carbon dioxide by the ecosystem (vegetation plus soil) can be calculated. This method provides the net flux of carbon dioxide representative of a large area (landscape). It is being used at about 150 locations worldwide. The accuracy and precision of this method is improving as more experience is gained.

At this stage it is not known how accurately and efficiently a routine soil carbon field monitoring program can be implemented, but evidence suggests it can be done for a cost as low as a few dollars an acre, depending upon the degree of accuracy desired. Measurements may only need to be done once every 3 to 5 years, and combination with satellite imagery and computer modeling could result in efficiency gains. There has been little research on the optimum frequency for sampling of soil carbon levels. In addition to scientific considerations that optimum frequency may depend in part upon the type of accounting required by potential future national or international programs or agreements. It may also depend in part upon market concerns for accuracy or risk.

University of Nebraska scientists have initiated an interdisciplinary research program to investigate the carbon sequestration potential of major rainfed and irrigated agro-ecosystems in the north-central USA. They are investigating carbon sequestration within three major agro-ecosystems (a rainfed maize-soybean rotation, an irrigated maize-soybean rotation, and an irrigated continuous maize system). Their effort includes: (a) quantifying annual amounts of carbon sequestered and the associated inter-annual variability, at the landscape level, employing eddy covariance flux systems year-round, (b) quantifying soil C changes using geo-referenced soil samples, and (c) developing reliable, cost-effective procedures for predicting annual C sequestration and changes in soil C stocks at the scale of a single production field using detailed crop yield mapping.

Indirect Remote Sensing Techniques

Even if a field measurement program could be developed, agricultural practices are inherently dispersed over a wide geographic area. Staffing costs for monitoring and verification of land use practices over such a wide area could prove to be cost prohibitive. Because direct field measurements can be expensive, the use of indirect remote sensing techniques is being considered. High altitude or satellite imagery has been used to verify no-till conservation practices, cropping patterns, and biomass accumulation. In addition to cost, remote sensing may have several other advantages. For example, remote based data can be used for verification and comparison of carbon storage on a regional basis, while an individual inspection may see only a single field.

Default Values for Activity Based Practices

Another approach to estimating carbon storage is the use of default value for certain land-based activities. A land-use based accounting system would focus on the changes in carbon stocks on managed lands during a defined time period. Default values would be assigned to a particular tract of land based upon county or regional level research on the average sequestration likely to result from specific agricultural or conservation measures in that area. Various values could be assigned to such broad land management activities as forest, cropland, or grazing management. Such an approach, termed a land use, land use change, forestry (LULUCF) system has several advantages. For example, under a LULUCF approach, field measurement of carbon storage changes in individual fields would not be necessary. Rather verification would only require that a particular practice was used on the land in question. Land use verification can be readily measured by remote sensing techniques, eliminating the need for an army of field inspectors.

Measuring Agroforestry Carbon

A distinct advantage of agroforestry is the relative ease with which carbon accumulation can be measured and monitored. The baseline for agroforestry practices that involve tree planting can be assumed to be zero. Over time satellite imagery or aerial photos could be used to verify the continued presence and extent of a planting, such as a field windbreak. Statistical ground sampling methodology could be designed to document the amount of carbon accumulation over time for representative agroforestry practices across a range of site conditions.

There is one urgent technical need. That is for the development of biomass equations for trees and shrubs grown in agroforestry practices. Equations must be generated for a range of age, soil, and climate conditions. While biomass equations based on stem diameter and height already exist for most tree species, almost all of these equations have been generated from data gathered on forest grown trees. Research conducted on several tree species grown in windbreaks confirms that these forest-derived equations severely underestimate the biomass of windbreak trees by as much as 100 percent (Zhou et al., *submitted*). The need to mathematically account for differences in the relationship of tree crown biomass to stem diameter was previously demonstrated by Geron and Ruark (1988). The crowns of open grown trees and forest grown trees develop differently in response to light and available moisture regimes. For example, the lower branches of forest grown trees are shaded and in many species are self pruned. The stem tends to be long and straight with a relatively narrow crown structure. In contrast, open grown trees receive light from all sides and thus tend to have shorter, stockier stems and bigger crowns and numerous large, low branches. Bratton et al (1995) were unable to identify any equations in the peer-reviewed literature that were constructed from trees grown in linear arrangements in the Great Plains.

Additional Information

There is a variety of research underway on the science of carbon measurement. A full discussion of all techniques is beyond the scope of this report. One good source of further information for those interested is *"Monitoring and Verifying Soil Organic Carbon Sequestration"* (Post et. al.) in "*Carbon Sequestration in Soils: Science, Monitoring and Beyond (Rosenburg, et. al.).*

Modeling Soil Carbon

Numerous soil carbon models have been developed. Two of the more well known are the Century Model and the CQESTR model and are used as examples. The ongoing assessment of Nebraska soil carbon being conducted in conjunction with the LB 957 process is using the Century EcoSystem Soil Organic Matter Computer Model developed by the Colorado State University Natural Resources Ecology Laboratory and the USDA Agricultural Research Service. The model has provided reliable estimates of soil carbon changes and in the Nebraska case local data will be providing detailed inputs to the model. The model simulates dynamics of carbon, nitrogen, sulfur and phosphorous in the top 20 cm of the soil. Submodels simulate soil water balance, crop growth, dry matter production and yield. A variety of crop types and management options can be specified. More information on the model and its use is available in a Phase I progress report for the LB 957 related assessment (Brenner, et al., June, 2001).

The CQESTR model developed by the USDA-ARS specifically shows the impact that different farm management practices have on soil carbon. Soil organic matter change is computed by CQESTR by maintaining a budget of soil carbon (1) additions as a result of sequestering atmospheric carbon dioxide in soil or adding amendments like manure and (2) losses of organic carbon through decomposition by microbes. The model requires the initial soil organic matter content for each soil layer of interest. The budget and identity for each organic input is maintained over a 4-year period of “composting.” At the end of four years, the composted organic input loses its identity and is placed into the soil organic matter pool in an abrupt step function. Both the “composting” residues and the “mature” soil organic matter are decomposed daily using an exponential function driven by cumulative heat units with appropriate empirical coefficients for the type of residue, nitrogen content and incorporation into the soil by tillage. The model uses daily time steps to calculate heat units that are initiated for each organic input, typically after harvest of the crop. Other soil amendments are tracked similarly. When soil carbon is decomposed in soil to carbon dioxide, it is normally transported out of the soil in the gaseous phase by dispersion/diffusion and advection in air.

Other Greenhouse Gases

Human induced increases in atmospheric methane concentrations come primarily from ruminant livestock such as cattle, sheep and goats and from waste storage lagoons. Nitrous oxide emissions come from the conversion of soil organic nitrogen and nitrogen fertilizer to the nitrate ion and from the conversion of the nitrate ion to nitrogen gas. Well over half of the nitrous oxide emissions in the world come from cropland soils. The sources of this nitrous oxide are commercial fertilizer and legume crops that convert nitrogen in the atmosphere into soil organic nitrogen. Anhydrous ammonia is the primary source of nitrous oxide among the commercial fertilizers. Obviously, the more anhydrous ammonia applied to a field, the more nitrous oxide that is emitted.

The basic approach used to measure other greenhouse gasses such as methane and nitrous oxide is not dissimilar to the approach taken for carbon and carbon dioxide. Direct measurements of nitrous oxide emissions from cropland, and methane emissions from cattle, swine, and waste lagoons are collected and analyzed. Individual field measurements are then converted to equivalent tons of carbon dioxide emissions. (For example, methane has 21 times the global warming effect per metric ton of carbon dioxide and nitrous oxide has 310 times the effect. Therefore, one metric ton of methane equals 21 metric tones of equivalent reductions in carbon dioxide and nitrous oxide 310 times). The net reduction in carbon emissions resulting from changes in operations is then calculated.

Although the reduction in methane and nitrous oxide emissions from specific agricultural activities emissions, such as reducing the amount of anhydrous ammonia used, covering waste lagoons, or using higher fiber cattle feed can be quantified, verification of these types of emission reductions can be problematic. Changes in agricultural practices that reduce emissions are not easily verified by remote sensing techniques and may require on site observation. The actual amount of emission reduction achieved is often farm specific and development of default values for these types of activities on a statewide or regional basis is difficult.

VI. Abbreviated Questions and Answers on Carbon Sequestration and Nebraska

Following are some questions and abbreviated answers related to topics of concern in this report.

1) ***How much carbon sequestration potential is there for Nebraska lands? How do current carbon sequestration levels in Nebraska compare to pre-sodbusting and to other states? How does Nebraska's carbon sequestration potential compare to other areas of the nation and world?***

Nebraska *cropland* management practices are estimated to currently sequester about 1.7 MMT of carbon per year based upon climate, soils and management factors according to a recent study. According to the research, that level of sequestration can be maintained and increased to an estimated 2.3 MMT per year if all cropland is converted to a no tillage management system. That would represent about a 35% increase in carbon sequestration over current levels. Significantly that study does not account for some conservation practice factors that will be examined in a related assessment due by January 1, 2002.

USDA estimates from 1998 indicate U.S. cropland soil sequestration potential of 154 MMT or about 8.4% of U.S. emissions annually (not including biofuels, fuel offset or eroded sediments). However, these figures are not likely strictly comparable to the Nebraska figures.

At age 40 following planting *agroforestry* in Nebraska has a carbon storage potential of 82.8 MMT to 165.6 MMT. Averaged over 40 years this amounts to 2.07 MMT to 4.14 MMT annually. At age 40 following planting *forestry* would have a carbon storage potential of 50.0 MMT (7.1 MMT for enhanced management of existing forest and 42.9 MMT for 1,000,000 acres of new forest plantings. Averaged over 40 years this amounts to 1.25 MMT annually. Each of the above estimates was based upon a variety of assumptions. There are no estimates for *grassland* carbon sequestration potential in Nebraska.

Cropland accounts for only about 5.3% of world land/vegetation carbon vegetation storage to a depth of 1 meter. Nebraska's land very likely stored significantly more carbon prior to sodbusting in the 1800's. Some sources indicate that soil carbon levels in the central U.S. cornbelt began dropping with conversion to agriculture, probably stabilized by around the late 1940s, and began rising around the 1970s with the advent of conservation tillage and higher yielding crop varieties which produce more residue. There has not been an analysis of Nebraska's total carbon storage potential in relation to other states and countries. In general countries with large land bases and lower population densities would have relatively more to gain from international agreements that count carbon credits than countries with high population densities and a small land base.

Finally, it should be noted that potential sequestration rates have a time factor involved. At some point the amount of new or additional carbon sequestered may begin to decline as a soil reaches its capacity.

2) ***How do current international treaties or federal and state laws address carbon emissions, carbon credits trading, or carbon sequestration?***

Federal and Nebraska state laws do not currently specifically address carbon sequestration. Some individual countries have unilaterally placed restrictions on carbon emissions. At the international level, the U.S. has ratified a framework convention on climate change. However, the U.S. Senate has, never ratified the Kyoto Protocol to that convention, while signed by the U.S.. In 1997 it adopted without dissent a resolution that made clear it would not have been receptive to its submission in that form. President Bush has indicated his opposition to the agreement. The Kyoto Protocol places greenhouse gas emissions restrictions on certain developed countries including the United States. Emissions laws in some countries and anticipation of some type of international action on rules to implement the Kyoto Protocol have led to some limited international marketing attempts to sequester carbon and document reductions to secure possible future credits. At Marrakech, Morocco in November 2001, 165 countries agreed to rules for putting the Kyoto Protocol into action. Noteworthy is the fact that the U.S. was not a part of that accord. The Marrakech agreements clarify the ability of countries to offset emissions limitation requirements by properly managing forests and farmlands that absorb carbon dioxide. Rules for trading emissions credits apparently have been liberalized. The Marrakech agreement/Kyoto Protocol could have future market implications for the United States. However, there are problems even beyond the U.S.'s reluctance to enter into the agreement: To go into force the accord must be ratified by 55 countries responsible for 55% of global greenhouse gas emissions. Whether there will be a finalized treaty remains to be seen.

3) ***What is the likelihood of changes in current international treaties and federal or state law related to carbon emissions, carbon credit trading, or carbon sequestration? What changes are most likely? Over what timeframe are changes likely to occur? What potential changes would have the most relevance for Nebraska landowners?***

Predictions of future political action are beyond the scope of a state agency report. The current U.S. administration has indicated it does not intend to sign the Kyoto protocol but has remained involved in global warning issues. In a March 13, 2001 letter to Senators Hagel, Helsms, Craig and Roberts President Bush indicated: "As you know, I oppose the Kyoto Protocol because it exempts 80 percent of the world, including major population centers such as China and India, from compliance and would cause serious harm to the U.S. economy". On March 29, 2001 the President indicated "Our economy has slowed down in a country – our country. We also have an energy crisis. And the idea of placing caps on CO2 does not make economic sense for America." However, the President has formed a Cabinet-level climate change working group. In the earlier mentioned March 13, 2001 letter he said, "I am very optimistic that, with the proper focus and working with our friends and allies, we will be able to develop technologies, market incentives, and other creative ways to address global climate change". On July 13, 2001 he indicated that "… my administration's climate change policy will be science based, encourage research breakthroughs that lead to technological innovation, and take advantage of the power of markets". On June 11, 2001 he stated, "We all believe technology offers great promise to significantly reduce emissions – especially carbon capture, storage and sequestration technologies"(www.whitehouse.gov). Potential international action and treaties are still under discussion . The timeframe over which major changes, national or international, may occur is speculative.

Action by other nations and continued anticipation of future political action may also result in some cross-border marketing or attempts to buy carbon credits in anticipation of future laws. There may also be some carbon purchase by firms for public relations reasons. However, the nature and strength of any carbon marketing that might develop without a U.S. emissions limitation is uncertain.

The potential international and national law changes that would have the most relevance for Nebraska agriculture (should they occur) would be national carbon emissions limitations and action making carbon sinks including cropland/grazing land soils eligible for credits. The level of the emissions limitations and nature of carbon credit allowance would likely help determine the market value of soil carbon.

4) How might a carbon trading system work and what might be the size of payments to participating Nebraska landowners? Have there been any payments in Nebraska or in surrounding states to date*?*

The size of payments to Nebraska landowners would likely depend on whether U.S. emission caps were in place, the levels at which they were set, the basis of carbon credits (total carbon stored or only increases above a baseline), and the expense of administering the chosen carbon credit system. If no U.S. emission caps were in place payment size would likely depend upon the rules other countries followed in emission laws and agreements as well as the levels of expectation regarding future government action. Some academic estimates have been made of potential payment size given set assumptions and there have been some limited carbon trading transactions in the U.S.

5) What should Nebraskans do to prepare for potential carbon sequestration opportunities?

The recommendations of the Carbon Sequestration Advisory Committee are found in this volume and provide one set of answers to the above question. Another answer is that some actions already have been taken. In conjunction with the effort to produce this report a statewide carbon assessment is nearing completion. A separate report on that effort is to be issued March 1, 2002 and will provide the basic data to let Nebraska respond quickly should significant carbon markets develop. It could also play a role in helping the state respond to the spectrum of carbon management initiatives that could conceivably come about. In addition the University of Nebraska plays a significant role in national level carbon sequestration related research.

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