CARBON SEQUESTRATION ON IDAHO AGRICULTURE AND FOREST LANDS

Idaho Soil Conservation Commission - Boise, Idaho - February, 2003

ACKOWLEDGMENTS

The author of this report is David F. Ferguson, Agricultural Program and Riparian Specialist of the Idaho Soil Conservation Commission. This report was printed in February of 2003.

This report was prepared with the support of many individuals and through a comprehensive literature review. Many references are cited, but numerous other reports were reviewed and credit is due and without the previous efforts of numerous states, this report would have been much more difficult to prepare.

The Carbon Sequestration Advisory Committee members are:

James Baker, Boise
Claude Bruce, Payette
John Carstensen, Boise
David F. Ferguson, Boise
Jodi Johnson-Maynard, Moscow
Kate Kelly, Boise
Thomas Lamar, Moscow
Ladd Livingston, Coeur d'Alene
Paul Mann, Caldwell
Charley McKetta, Moscow
John Remsburg, Rupert
Charlotte Reid, Firth
Julie Shain, Boise
David Shropshire, Idaho Falls
Delbert Winterfield, Swan Valley
Russ Zenner, Genesee

Some individuals contributed a substantial amount of support in the preparation of this report and are very much appreciated:

James Baker – Idaho Department of Agriculture
Brian Kummet – Nez Perce Tribal Forestry
Ladd Livingston – Idaho Department of Lands
Paul Mann – J.R. Simplot Company
Charley McKetta – Forest Econ. Inc.
David Shropshire – Idaho National Engineering and Environmental Laboratory

Other individuals that have attended meetings and provided input in the preparation of this report:

Mike Bowman, Lewiston
Ron Rickman, Pendleton
Ralph Fisher, Boise
Dan Pierce, Moscow
Stu Goldstein, Moscow
Ken Stinson, Moscow
Jerry Hanson, Coeur d'Alene
Marla Trible, Idaho Falls
David Huggins, Moscow
Roger Veseth, Moscow
Diane Leone, Moscow
Robert Wilkosz, Boise
Ivan Permann, Idaho Falls
Zach Willey, Bend, Oregon
Ron Blake, Boise
Pat Clark, Boise
Ervin Cowley, Boise
Jim Stewart, Nampa
Jere Stewart, Nampa
George Davis, Caldwell
Jim Schmollinger, Caldwell
John Gleim, Nampa
Glenn Shewmaker, Mountain Home
Duane LaFayette, Nampa
Jim Entry, Kimberly

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EXECUTIVE SUMMARY

Idaho Law 22-5103 (enacted on July 1, 2002) instructed the Idaho Soil Conservation Commission (SCC) to prepare a report exploring the potential for carbon sequestration on agricultural and private, non-industrial forest lands. This report was to also explore the production and use of biofuels, ethanol and biodiesel. This law, which originated from Senate Bill (S) 1379a, instructed the SCC to prepare a report by February 1, 2003, with input from a Governor appointed Carbon Sequestration Advisory Committee. Numerous individuals and this Committee met three times to provide review of critical elements of this report. Two technical papers have been produced to assist in the preparation, presentation, and discussion of this report, and are located in the Appendices. This report will address the following:

1. The potential for development of a system or systems of carbon emissions trading or markets for carbon sequestered on agricultural and forest land;
2. Agricultural and forestry practices, management systems or land uses, and biofuels production which increase stored soil carbon (and/or offset greenhouse emissions);
3. Methods for measuring and modeling net carbon sequestration associated with various agricultural and forestry practices, management systems or land uses occurring on agricultural and forest lands and legislation, if any, to define and protect property rights in and attendant to carbon sequestration;
4. Areas of scientific uncertainty with respect to quantifying and understanding carbon sequestration associated with agricultural and forestry activities; and
5. Recommendations of the carbon sequestration advisory committee developed pursuant to section 22-5103, Idaho Code.

There is a concern that the use of non-renewable fuels and other human activities are increasing greenhouse gases in the atmosphere, contributing to global warming. The latest assessment by the United Nations Intergovernmental Panel on Climate Change (IPCC, 2001), a body of 1500 scientists from throughout the world, concludes that the threat of climate change is very real. Sea surface temperatures and sea level are rising, continental glaciers are melting worldwide, and carbon dioxide concentrations in the atmosphere continue to increase. So far, the increase in global mean surface temperature has not been great, a little more than 1 ^{o}F during the past 100 years. However, IPCC concludes that the 21st century will be much warmer, an increase of 2.5-10.4 ^{o}F in average surface temperature during the next 100 years (IPCC, 2001). Large reductions in greenhouse gas emissions, possibly up to 70%, may be needed to stabilize the atmospheric concentration of carbon dioxide.

Currently, Idaho emissions seem to be relatively low compared to most other states. Carbon sequestration and other related greenhouse gas activities could offset emissions from sources located outside of the state. These practices or activities, such as those that sequester (store) carbon in forested or agricultural soils and croplands, and the production and use of biofuels, can create additional jobs and diversify agriculture; and conserve and protect existing natural resources, assisting the state in meeting natural resource objectives.

There are many agriculture, forestry, biofuels, and bioenergy practices that could be implemented within the state of Idaho. The Carbon Sequestration Advisory Committee is recommending ‘whole-farm’ evaluations utilizing case studies, state-wide economic analysis, and research activities. Some of these practices seem acceptable to landowners, effective in carbon sequestration, and/or reducing on-site emissions.

The following practices and activities have been evaluated for the purpose of exploring the potential for Idaho landowners to sequester carbon on and/or reduce greenhouse gas emissions related to their operation:

High potential for state-wide carbon sequestration:

- Afforestation (new forest) on poorly stocked forest lands,
- Nutrient management,
- Biomass (cropland residues) energy source
- Afforestation on marginal cropland,
- Ethanol production and use,
- Residue management (no-till, direct seed),
- Biogas recovery, digesters,
- Afforestation on non-stocked forest land,
- Reduced methane emissions from dairy livestock,

Moderate potential for state-wide carbon sequestration:

- Short rotation woody crops,
- Prescribed grazing on rangeland,
- Cropland residue burning alternatives or techniques,
- Land conversion to permanent grass cover (similar to CRP),
- Rangeland planting,
- Windbreaks & shelterbelts,
- Afforestation on marginal pastureland,
- Riparian conservation/restoration on private land,
- Reduced methane emissions from non-dairy livestock,

Low potential for state-wide carbon sequestration:

- Cover crops,
- Pastureland planting,
- Prescribed grazing on pasture land,
- Afforestation on pivot corners,
- Riparian forest buffers on non-forested land
- Riparian conservation/restoration on state land,
- Biodiesel production and use,
- Grassed waterways,
- Wetland construction and enhancement

The most effective practices increase above- and below-ground carbon, such as in forest plantings, no-till, and the conversion of marginal cropland and pasture land to trees, where new forest lands can sequester a large amount of carbon. Ethanol production could be very effective in reducing Idaho's transportation related greenhouse gas emissions. Biodiesel is not as effective compared to ethanol, mostly due to available acres of canola. Methane emission reductions from animal waste storage ponds seems promising, but acceptability may be low and installation costs high. If funding became available, the 'digester' technology may become more feasible to install on confined animal facilities, especially with operators being faced with odor regulations. Alternatives to burning crop residues can result in significant emissions reductions as well.

Idaho has the ability to sequester and/or offset nearly 15 million metric tons of carbon dioxide equivalents lo(CO_{2e}) per year. Afforestation, biofuels production, biogas recovery, nutrient management, no-till, methane reductions and agriculture energy sources could provide most of the state's sequestration and emission offsets. If public lands were to be included in a state-wide estimate, there could be a significantly greater amount of carbon sequestration and/or offsets.

Idaho's potential to increase stored carbon and reduce agricultural related emissions indicates a potential for carbon market activity. Potential purchasers of carbon 'credits' are likely to come from outside of the state, while Idaho's greenhouse gas emissions are low. The state would need to provide landowners a process to create carbon credits and an avenue for buyers to purchase those credits. Some carbon market activity has started in the state. There seem to three important elements missing or yet to occur that would kick-start a carbon market in the U.S. and Idaho. 1) Regulatory CO_2 emission reductions on point sources, such as electrical producers, 2) Public acceptance of carbon markets, allowing emission offsets, and 3) Carbon market and trading rules. Upon regulatory action, likely first by the U.S. Congress and EPA, carbon market development is sure to progress at a much faster pace.

The Pacific Northwest Direct Seed Association (PNDSA) has entered into an agreement with a southeastern U.S. company (ENTERGY) to purchase carbon 'credits' created from direct seed operations in north Idaho. Direct seeded acres have been estimated to sequester 0.55 metric tons of carbon dioxide per acre, per year (MT CO_2/y). The Nez Perce Tribe has been in negotiations with potential carbon credit buyers to sell credits generated from newly forested croplands in Northern Idaho.

Numerous ancillary benefits might be resultant of practices evaluated within this report:

- Water quality improvements (surface and ground waters),
- Total Maximum Daily Load (TMDL) targets could be met,
- Threatened and endangered species could be conserved,
- Air quality and odor problems may be resolved.

Economic benefits may be greatly appreciated as well. On-farm net returns may increase, local economies may be improved through increased employment and revenue, and programs may benefit from funding coming from sources outside of the state, which could reduce the demand for state funding.

A landowner actually producing a carbon credit, will consider the actual carbon sequestered and the emissions associated with the land use activities, a process that determines their baseline carbon and greenhouse gas emissions level. There are a number of methods used to verify an amount of carbon sequestered or reduction of greenhouse gas emissions that may be acceptable to carbon market participants. Further work is needed, however, to better predict and measure a 'whole-farm' net credit. The methods are key in predicting the potential for carbon markets in Idaho, which then predicts the benefit to the state. Sequestered carbon and greenhouse emissions relative to the land use activity will need to be calculated to determine a true credit, which is then potentially available for purchase.

If the state were to become active in carbon markets, great opportunity exists to partake of significant funding, which would enhance local economies, improve agriculture and forestry production, and net profits. In addition local economic enhancements relative to farm and forest operation, numerous environmental improvements might be achieved. Most practices that sequester carbon have a direct benefit to natural resources. Funding generated through carbon markets may range from \$8 to \$146 million, if greenhouse gas sources are mandated to reduce emissions. Emission sources might face reduction costs of \$20 to \$200 per metric ton initially. To meet anticipated regulations, greenhouse gas sources would need to reduce their emissions and/or purchase carbon offsets (credits) for some period of time.

Carbon sequestration on forest and agricultural lands seems to be much less expensive, where Ney et. al, 2000 estimates the rate for one metric ton of carbon sequestered is valued around \$1 - \$2. If greenhouse gas emissions become regulated, the carbon offset value will certainly increase, overcoming implementation costs. Assuming that greenhouse gas emission sources become regulated, a conservative estimate for carbon credits could be approximately \$10 per ton of CO_2 offsets. This would indicate that the potential annual inflow to the state could be in the millions, upwards of \$146 million. Current carbon offset prices in Oregon, for example, are currently much less than the \$10 per-ton carbon offset. Oregon regulations have set a per-ton carbon offset rate at \$0.57, to be paid by new utilities that cannot meet a CO_2 emissions cap at the plant. At the current Oregon carbon offset rate, Idaho could see about \$8 million come into the state, though dependent on carbon market participation. Regardless of the price of carbon offsets, there can be a substantial amount of funding come into the state through a carbon market.

There are numerous issue related to climate change and carbon sequestration. Within each of these issues are many uncertainties. Some of the uncertainties follow:

- Predicting and quantifying soil carbon, above- and below-ground biomass (vegetation) stored carbon
- Predicting and quantifying methane emissions from animal waste storage ponds and livestock enteric fermentation
- Predicting and quantifying nitrous oxide emissions from agricultural activities,
- Calculating a whole-farm, field, or project's net carbon sequestration level, which discounts land use related greenhouse emissions
- The potential quantity of agricultural products that are available and could be made available for biofuels production
- The potential quantity of agricultural products that are available and could be made available for bioenergy production, such as in co-fired facilities
- The potential effects of local climate change, weather, and catastrophic events on practice performance
- The potential future electrical demand in the state, from coal-fired electrical facilities
- Legal ramifications of long-term contracts between buyers and agricultural and forest landowners
- Landowner costs and benefits while implementing practices and participating in carbon markets
- Statewide costs and benefits while implementing practices and participating in carbon markets

Upon considerable review, the Advisory Committee has developed the following recommendations:

- Maintain the carbon sequestration advisory committee to monitor ongoing developments, facilitate economic analysis, facilitate research activities, and provide information to landowners
- Initiate a carbon market pilot project
- Improve landowner's understanding of carbon sequestration and climate change
- Enhance carbon sequestration research relevant to Idaho
- Complete carbon sequestration and greenhouse gas baseline analyses to prepare for future carbon sequestration markets
- Further study the potential economic benefits to Idaho landowners and the state through carbon markets
- Explore requiring carbon participants to be registered with the state
- Explore avenues to increase carbon sequestration in the state
- Explore the potential for improving the production and use of biofuels in the state, and their economic benefit

The Soil Conservation Commission and the Carbon Sequestration Advisory Committee is prepared to assist the state in enhancing its carbon market potential, increase carbon sequestration knowledge, and seek funding to carry out these recommendations. There is a substantial amount of work yet to be done before the state can fully engage and benefit from carbon market activities.

1 INTRODUCTION

According to scientists throughout the world, human activities are increasing atmospheric greenhouse gas (greenhouse gas) concentrations. An expected result of these increased greenhouse gases is higher global temperatures, higher sea levels, and increased climatic variability, including changes in precipitation patterns and magnitudes. These changes may affect agriculture by making some crop and animal production operations difficult or infeasible in parts of the world, but possibly enhanced in others. Slowing the rate of emission losses will require efforts in most every sector of the economy, from all parts of the world. Agriculture and forestry can make important contributions to these efforts, and can benefit by doing so. Agricultural and forestry practices that sequester carbon or reduce or offset greenhouse emissions can increase landowner income, improve productivity, and result in improve related natural resource conditions, such as water quality and wildlife habitat.

The state of Idaho could play an important role in providing carbon dioxide offsets through carbon sequestration and/or related greenhouse gas emissions through voluntary carbon markets. State-level organization and guidance in the development of carbon markets will be essential for enabling agriculture and forestry to offset greenhouse gas sources if necessary and feasible. The circumstances surrounding climate change is a complicated and has many uncertainties that are not easily dealt with just from within this state. This report is intended to help the state of Idaho, not to address climate change, but understand carbon sequestration and how its participation carbon markets that can offset greenhouse gases that seem to be impacting climate change. The Idaho Soil Conservation Commission (ISCC) is dedicated to providing technical and financial support to Idaho agricultural in the wise use and enhancement of soil, water, and other related natural resources. Any activity that can be utilized to accomplish the SCC's and the state's objectives should be explored. Carbon sequestration markets, which in reality includes greenhouse gas emissions trading, should benefit Idaho's economy, landowner's productivity, and natural resources through the application of numerous conservation practices and related activities.

1.1 SENATE BILL 1379A – IDAHO LAW 22-5201

Initiated by Senate Bill 1379a, now Idaho Law 22-5201, the ISCC has prepared this report to present the complexities of carbon sequestration which can address climate change issues and benefit the state:

1. The potential for development of a system or systems of carbon emissions trading or markets for carbon sequestered on agricultural and forest land;
2. Agricultural and forestry practices, management systems or land uses which increase stored soil carbon;
3. Methods for measuring and modeling net carbon sequestration associated with various agricultural and forestry practices, management systems or land uses occurring on agricultural and forest lands and legislation, if any, to define and protect property rights in and attendant to carbon sequestration;
4. Areas of scientific uncertainty with respect to quantifying and understanding carbon sequestration associated with agricultural and forestry activities; and
5. Any recommendations of the carbon sequestration advisory committee developed pursuant to section 22-5103, Idaho Code.

A 16 member advisory committee, appointed by the Governor of Idaho, provided a comprehensive review and valuable guidance in the development of this report. Their primary responsibilities included:

1. Advise and assist the chairman of the soil conservation commission in preparing this report;

2. Recommend policies or programs to enhance the ability of Idaho agricultural and nonindustrial private forest landowners to participate in systems of carbon trading. Such recommendations shall include potential policies or programs designed to optimize economic benefits to agricultural producers and nonindustrial private forest landowners participating in carbon trading transactions. Such policies or programs may include, but are not limited to, identifying existing or the potential of creating nonprofit organizations or other public or private entities capable of serving as assemblers of carbon credits or as intermediaries on behalf of producers in carbon trading systems;
3. Encourage the production of educational and advisory materials regarding carbon sequestration on agricultural and forest lands and participation in systems of carbon or greenhouse emissions trading;
4. Identify and recommend areas of research needed to better understand and quantify the processes of carbon sequestration on agricultural and forest lands;
5. Research the development of a greenhouse gas inventory and a mitigation action for the state of Idaho and;
6. Review the carbon sequestration programs and policies of other states.

The information presented here in this can help Idaho prepare a practical and comprehensive plan for promoting carbon sequestration activities and other related greenhouse gas emissions reductions. A state-wide plan that encourages and provides guidance in carbon sequestration is needed prior to landowners and the state participating in carbon markets. There are many legal, scientific, social, and economic uncertainties that should be addressed and overcome first, before the state can enjoy the benefits of carbon markets.

This report will introduce the reader to the basic science of global warming, climate change, the related greenhouse gases, and the international, national, and state's political and physical position regarding climate change. Carbon sequestration and its potential to offset greenhouse gases will then be explored. Idaho's demographics will be briefly discussed to better understand the physical capability to sequester carbon and eventually provide greenhouse gas offsets within a carbon market. Numerous agriculture, forestry, livestock, and biofuels alternatives will be explored that landowners and other interests can adopt. The actual measurement, monitoring and verification methodology of carbon sequestration and related greenhouse gases will be explored. The typical characteristics of carbon markets and other supporting programs will then be presented. After presenting the numerous aspects of potential state-wide participation in carbon markets, the state-wide benefit is limitedly explored. The uncertainties related to many aspects of carbon markets are briefly discussed and then the Carbon Sequestration Advisory Committee presents some recommendations to the state of Idaho. Many supporting papers, data, and references are included at the end of this report.

2 CLIMATE CHANGE

If the state of Idaho was to initiate a carbon market or a climate change program, it will require a basic understanding of the underlying scientific, technical, organizational, and political issues. The purpose of this section is to explore the current scientific understanding of global climate change and greenhouse gas reduction and carbon sequestration and offset measures. The first step introduces the greenhouse effect and the changes in climate expected to result from increasing atmospheric concentrations of greenhouse gases. The second step is to describe international and national responses to climate change to help Idaho understand the current global-wide position on climate warming. Upon gaining an understanding of global-wide activities and policies, a discussion regarding the alternatives Idaho may choose to address climate change and carbon markets are presented.

2.1 THE SCIENCE

The Earth's climate is maintained or affected by many factors, including radiant energy from the sun, volcanic activity, and other natural phenomena. Human activities, specifically those that result in emissions of greenhouse gases, may affect the climate system by altering its self-maintenance by interjecting an increased level of specific gases. Even though the atmosphere's natural "greenhouse" effect is relatively well understood, there are uncertainties regarding the effects of increased concentrations of greenhouse gases.

2.1.1 The Basis for Climate Change

Energy from the sun drives the earth's weather and climate. Atmospheric greenhouse gases (water vapor, carbon dioxide, and other gases) trap some of the energy from the sun, creating a natural "greenhouse effect." Without this effect, temperatures would be much lower than they are now, and life as known today would not be possible. Instead, the earth's average temperature is a more hospitable 60°F. However, problems arise when the greenhouse effect is altered by human-generated emissions of greenhouse gases.

Global warming could do more than add a few degrees to today's average temperatures. Cold spells still would occur in winter, but heat waves would be more common. Some places would be drier, others wetter. Perhaps more important, more precipitation may come in short, intense bursts (e.g., more than 2 inches of rain in a day), which could lead to more flooding. Sea levels would likely be higher than they would have been without global warming, although the actual changes may vary from place to place because coastal lands are themselves sinking or rising.

The climate of the Earth is affected by changes in radiative forcing attributable to several sources including the concentrations of radiatively active (greenhouse) gases, solar radiation, aerosols, and albedo reflection factors. Greenhouse gases in the atmosphere are virtually transparent to sunlight (shortwave radiation), allowing it to pass through the air and to heat the Earth's surface. This process, similar to what occurs in greenhouses, where solar radiation enters through the glass, but opaque to terrestrial infrared radiation, in which heat is trapped in the greenhouse. The term greenhouse has been used to a great extent by the media and has stuck, though greenhouses are generally heated from an internal source, generally warmer than the outside air when necessary.

The Earth's surface absorbs the sunlight and emits thermal radiation (longwave radiation) back to the atmosphere. Because some gases, such as carbon dioxide (CO2), are not transparent to the outgoing thermal radiation, some of the radiation is absorbed, and heats the atmosphere. In turn, the atmosphere emits thermal radiation both outward into space and downward to the Earth, further warming the surface.

This process enables the Earth to maintain enough warmth to support life: without this natural "greenhouse effect," the Earth would be approximately 55^{o} F colder than it is today. However, increasing concentrations of these greenhouse gases are projected to result in increased average temperatures, with the potential to warm the planet to a level that could disrupt the activities of today's natural systems and human societies.

2.1.2 **Carbon Dioxide and other Greenhouse gases**

Since the beginning of the industrial revolution, human activities have been adding measurably to natural background levels of greenhouse gases. The burning of fossil fuels (coal, oil, and natural gas) for energy is the primary source of emissions. Greenhouse gases are emitted by virtually all economic sectors, including residential and commercial energy use, industrial processes, electricity generation, agriculture, and forestry.

Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Some human-made compounds, including chlorofluorocarbons (CFCs), partially halogenated fluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and perfluorinated carbons (PFCs), are also greenhouse gases. In addition, there are photochemically important gases such as oxides of nitrogen (NOx) and volatile organic compounds (VOCs) that, although not greenhouse gases, contribute indirectly to the greenhouse effect by influencing the rate at which ozone and other greenhouse gases are created and destroyed in the atmosphere.

Energy burned to run cars and trucks, heat homes and businesses, and power factories is responsible for about 80% of global carbon dioxide emissions, about 25% of U.S. methane emissions, and about 20% of global nitrous oxide emissions. Increased agriculture and deforestation, landfills, and industrial production and mining also contribute a significant share of emissions. In 1994, the United States emitted about one-fifth of total global greenhouse gases. Idaho has not done an official greenhouse emission inventory, thus is not ranked or compared by EPA officially. However, initial estimates by EPA (http://yosemite.epa.gov/globalwarming/greenhouse_gas.nsf) rank Idaho 48 out of 51 in carbon dioxide emissions from fossil fuel combustion based on 1990 energy data. Likely, due to its low population, Idaho ranks low in emissions when compared to the rest of the nation. Its potential to offset other state's emissions through carbon sequestration and other related activities, however, could be high.

Since the pre-industrial era, atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%. These increases have enhanced the heat-trapping capability of the earth's atmosphere. Sulfate aerosols, a common air pollutant, cool the atmosphere by reflecting incoming solar radiation. However, sulfates are short-lived and vary regionally, so they do not offset greenhouse gas warming.

Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and institutional developments. Several emissions scenarios have been developed based on differing projections of these underlying factors. For example, by 2100, in the absence of emissions control policies, carbon dioxide concentrations are projected to be 30- 150% higher than today's levels.

2.1.2.1 CARBON DIOXIDE (CO_2)

Carbon dioxide, likely the most important of these gases, is involved in a complex global cycle, released from the interior of the Earth via volcanic eruptions, and by respiration, soil processes, combustion of carbon compounds oceanic evaporation. The combustion of liquid, solid, and gaseous fossil fuels is the major anthropogenic source of carbon dioxide emissions. Some other non-energy production processes (*e.g.*, cement production) also emit notable quantities of carbon dioxide. CO_2 emissions are also produced by forest clearing and biomass burning. Atmospheric concentrations of carbon dioxide have been increasing at a rate of approximately 0.5 percent per year (IPCC, 1996). Conversely, it is dissolved in the ocean and consumed during plant photosynthesis. There is approximately 359 parts per million by volume (ppmv) in the atmosphere, which scientists claim to be rising due to human related emissions from burning fossil fuels and forests.

In nature, carbon dioxide cycles between various atmospheric, oceanic, land biotic, and marine biotic reservoirs. The largest fluxes occur between the atmosphere and terrestrial biota, and between the atmosphere and surface water of the oceans. While there is a small net addition of CO2 to the atmosphere from equatorial regions, oceanic and terrestrial biota in the Northern Hemisphere, and to a lesser extent in the Southern Hemisphere, act as a net sink of CO_2 (IPCC, 1996).

2.1.2.2 METHANE (CH_4)

Methane is produced primarily by anaerobic (lack of oxygen) process such as in rice cultivation, ruminant animal digestive processes, decomposition of municipal and animal solid wastes. Methane is also emitted during the production and distribution of natural gas and oil, and is released as a by-product of coal production and incomplete fuel combustion. Methane is removed from the atmosphere reacting with the hydroxyl radical (OH) and is then converted to CO_2.

Increasing emissions of methane reduce the concentration of OH, a feedback which may increase methane's atmospheric lifetime (IPCC 2001).

2.1.2.3 NITROUS OXIDE (N_2O)

Nitrous oxide is produced by both biological mechanisms in the oceans and soils, and by human related activities, such as industrial combustion, vehicle exhausts, biomass burning and fertilizer use. It is destroyed in the upper atmosphere (stratosphere) photochemical reactions involving sunlight.

2.1.2.4 HALOCARBONS (CFCS, HCFCS, HFCS, PFCS)

Halocarbons are compounds containing carbon, halogens, such as chlorine, bromine, and fluorine, and sometimes hydrogen. Chlorofluorocarbons (CFCs), such as halons, methyl chloroform, carbon tetrachloride, methyl bromide, and hydrochlorofluorocarbons (HCFCs), are entirely human produced by aerosol propellants, refrigerator coolants and air conditioners. They are slowly destroyed by photochemical reactions in the stratosphere.

These compounds contribute to stratospheric ozone depletion. Normal processes in the atmosphere both produce and destroy ozone. Approximately 90 percent of atmospheric ozone resides in the stratosphere, where it regulates the absorption of solar ultraviolet radiation; the remaining 10 percent is found in the troposphere and could play a significant greenhouse role. While ozone is not emitted directly by human activity, anthropogenic emissions of these gases influence its concentration in the stratosphere and troposphere.

Under the *Montreal Protocol* and the *Copenhagen Amendments*, which controls the production and consumption of these chemicals, the U.S. phased out the production and use of all halons by January 1, 1994 and phased out CFCs, HCFCs, and other ozone-depleting substances (ODSs) by January 1, 1996.

2.1.2.5 CARBON MONOXIDE (CO

Carbon monoxide (CO) is created when carbon-containing fuels are incompletely burned. Carbon monoxide elevates concentrations of methane and tropospheric ozone through chemical reactions with atmospheric constituents that would otherwise assist in destroying methane and ozone. It eventually oxidizes to CO2.

2.1.2.6 OXIDES OF NITROGEN (NOX)

Oxides of nitrogen (NO, NO_2) are created from lightning, biomass burning (both natural and anthropogenic fires), fossil fuel combustion, normal metabolism, and in the stratosphere from nitrous oxide. They play an important role in climate change processes because they contribute to the formation of tropospheric ozone.

2.1.2.7 VOLATILE ORGANIC COMPOUNDS (VOCS)

Nonmethane Volatile Organic Compounds (NMVOCs) include compounds such as propane, butane, and ethane. Volatile organic compounds participate along with nitrogen oxides in the formation of ground-level ozone and other photochemical oxidants. VOCs are emitted primarily from transportation, industrial processes, forest wildfires, and non-industrial consumption of organic solvents.

2.1.3 Global Warming Potential (GWP)

The potential contribution to radiative forcing of the various greenhouse gases differ dramatically. Accurately calculating the amount of radiative forcing attributable to given levels of emissions of these gases, over some future time horizon, requires a complex and time-consuming task of calculating and integrating changes in atmospheric composition over the period. There is a need for an index that translates the level of emissions of various gases into a common metric in order to compare the climate forcing effects without directly calculating the changes in atmospheric concentrations (Lashof and Tirpak, 1990). This information can be used to calculate the cost effectiveness of alternative reductions, *e.g.*, to compare reductions in CO2 emissions with reductions in CH4 emissions to N2O emissions.

There are indices that account for the direct effects of carbon dioxide (CO2), methane (CH4), chlorofluorocarbons (CFCs), nitrous oxide (N2O), hydrofluorocarbons (HFCs), and perfluorinated carbons (PFCs). One of these indices is called Global Warming Potential (GWP) indices, has been developed in recent years. This also estimates indirect effects on radiative forcing due to emissions of gases that are not themselves greenhouse gases, but lead to chemical reactions that create or alter greenhouse gases.

The concept of global warming potential, which was developed by the Intergovernmental Panel on Climate Change (IPCC), compares the radiative forcing effect of the concurrent emission into the atmosphere of an equal quantity of CO2 and another greenhouse gas. Each gas has a different instantaneous radiative forcing effect. In addition, emissions of different gases decay at different rates over time, which affects the atmospheric concentration. In general, CO2 has a much weaker instantaneous radiative effect than other greenhouse gases; it decays more slowly, however, and hence has a longer atmospheric lifetime than most other greenhouse gases. While there is relative agreement on how to account for these direct effects of greenhouse gas emissions, accounting for indirect effects is more problematic GWPs are used to convert all greenhouse gases to a CO_2e (equivalent) basis so that the relative magnitudes of different quantities of different greenhouse gases can be readily compared. The GWP potential will be an important concept for states in determining the relative importance of each of the major emissions sources and in developing appropriate mitigation strategies. Table 1 shows the IPCC calculated global warming potentials for numerous greenhouse gases.

Table 1. Global Warming Potentials (GWP) and Atmospheric Lifetimes (Years

Gas	Atmospheric Lifetime	50-Year GWP	100-Year GWP	500-Year GWP
Carbon dioxide (CO_2)	50-200	1	1	1
Methane (CH_4)	12+/-3	21	56	6.5
Nitrous Oxide (N_2O)	120	310	280	170
HFC-23	264	11700	9100	9800
HFC-125	32.6	2800	4600	920
HFC-134a	14.6	1300	3400	420
HCF-143a	48.3	3800	5000	1400
HCF-152a	1.5	140	460	42
HFC-227ea	36.5	2900	4300	950
HCF-236fa	209	6300	5100	4700
HCF-4310mee	17.1	1300	3000	400
CF_4	50000	6500	4400	10000
C_2F_6	10000	9200	6200	14000
C_4F_{10}	2600	7000	4800	10100
C_6F_{14}	3200	7400	5000	10700
SF_6	3200	23900	16300	34900
Source: IPCC 1996				
The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and statospheric water vapor. The indirect effect due to the[production of CO2 is not included.				

The Kyoto Protocol, the international agreement yet to be ratified by enough developed countries, would require substantial greenhouse gas emission reductions in participating developed countries, which would focus on all of these gasses listed in the previous table. Land-based activities would primarily focus on CO_2, CH_4, and N_2O.

2.1.4 <u>Potential Climatic Changes</u>

According to current available temperature data over the last 100 years, global mean surface temperatures have increased 0.6-1.2°F between 1890 and 1996. Several pieces of additional evidence consistent with warming, such as a decrease in Northern Hemisphere snow cover, a decrease in Arctic Sea ice, and continued melting of alpine glaciers, have been corroborated.

For a given concentration of greenhouse gases, the resulting increase in the atmosphere's heat-trapping ability can be predicted with precision, but the resulting impact on climate is more uncertain. General circulation models are complex computer simulations that describe the circulation of air and ocean currents and how energy is transported within the climate system. While uncertainties remain, these models are a powerful tool for studying climate.

Some of the modeled, potential global impacts due to global warming:

- Sea levels raising by 15 centimeters by year 2050, 34 centimeters by 2100,
- Loss of coastal dry land due to rising ocean levels
- Loss of wetland, wildlife habitat,

- Increased coastal erosion, flooding,
- Increased salinity of rivers, bays and aquifers,
- Impact sewage disposal capabilities along coastal areas,
- Affect drinking water aquifers along coastal areas
- Increased precipitation and evaporation, altering existing local climates,
- Decline of freshwater quantities,
- Wetter winter, drier summers, increase frequency of intense rainstorms,
- Insufficient water for navigation; lower production of hydroelectric power; impaired recreational opportunities along rivers and lakes,
- Poor water quality; and decreased availability of water for agriculture, residential, and industrial uses.

Agriculture is expected to be affected by global climate changes, where yields of many crops are likely to be affected by changes in average temperatures and precipitation as well as by changes in climate variability and the frequency of droughts and floods (USEPA 1997). Climate change may also affect availability of irrigation water, the prevalence of pests, and soil erosion. Increased CO_2 levels may increase yields (the "CO_2 fertilization effect"). Most projected impacts in the agriculture sector involve considerable uncertainty; different assumptions generate very different results that range from net benefits to net losses for US agriculture.

2.1.5 Potential Climate Change in Idaho

Over the last century, the average temperature near Boise, Idaho, has increased nearly 1°F, and precipitation has increased by nearly 20% in many parts of the state, and has declined in other parts of the state by more than 10%. These past trends may or may not continue into the future but over the next century, Idaho's climate may experience additional changes. Some examples of potential changes to Idaho's climate include:

- A warmer climate could mean less snowfall, more winter rain, and a faster, earlier snowmelt, which could result in lower reservoirs and water supplies in the summer and fall,
- Additionally, without increases in precipitation, higher summer temperatures and increased evaporation also would contribute to lower stream flows and lake levels in the summer,
- Lower streamflows and runoff could reduce rates of groundwater recharge and exacerbate water supply problems
- Warmer climates and less soil moisture due to increased evaporation may increase the need for irrigation, however, these same conditions could decrease water supplies, which also may be needed by natural ecosystems, urban populations, industry, and other users,
- Climate change could increase wheat yields by 9-18%, barley and hay could increase by 12%, and potato yields could fall by 18% under severe conditions where temperatures rise beyond the tolerance levels of the crop,
- If conditions also become drier, the current range and density of forests could be reduced and replaced by grasslands and pasture,
- Hotter, drier weather could increase the frequency and intensity of wildfires, threatening both property and forests,
- Although Idaho is in compliance with current ozone air quality standards, increased temperatures could make remaining in compliance more difficult
- If conditions become warmer and wetter, mosquito populations could increase, thus increasing the risk of transmission of this and other diseases are introduced into the area. Even in areas that generally are dry with a river water source, the mosquito populations may be expected to increase.

See the EPA report titled "Climate Change and Idaho", for additional information, found at http://yosemite.epa.gov/oar/globalwarming.nsf/content/Impacts.html

2.2 INTERNATIONAL, NATIONAL, AND STATE RESPONSES TO CLIMATE CHANGE

The scientific evidence seems to indicate that continuing emissions of greenhouse gases are altering global climate. In response, governments at the international and national levels are taking action to reduce emissions of greenhouse gases. Many individual countries and states have also recognized the potential dangers that global climate change presents to both current and future generations.

2.2.1 International Responses to Climate Change

The international community has coordinated efforts to address the potential impacts of climate change, particularly within the last decade. Some of the more important events are listed below:

- *Villach and Bellagio Workshops* - assessed the role of carbon dioxide…
- *The Montreal Protocol on Substances That Deplete the Ozone Layer* - 47 nations reached agreement on a set of CFC control measures in September 1987.
- *Toronto Conference* - focused on the implications of climate change for world security…
- *The Intergovernmental Panel on Climate Change* - was formed in 1988 to conduct studies on global warming.
- *The International Geosphere/Biosphere Program* - facilitate understanding the present state of the earth and the potential impacts of global climate change.
- *Noordwijk Conference on Atmospheric Pollution and Climate Change* - encouraged the IPCC to include in its First Assessment Report an analysis of quantitative targets to limit or reduce CO2 emissions, and urged all industrialized countries to investigate the feasibility of achieving such targets…
- *Hague Declaration* - This conference and Declaration (signed by 23 nations) established support for new principles of international law.
- *Cairo Compact* - calls on affluent nations to provide developing countries with the technical and financial assistance to address global climate change.
- *United Nations World Climate Conference:* The IPCC reported the findings of the IPCC Working Groups to the United Nations (Scientific Assessment, Impacts Assessment, and Response).
- *Intergovernmental Negotiating Committee (INC)* - the U.N. General Assembly established the INC to prepare an effective framework convention on climate change…
- *United Nations Conference on Environment and Development (UNCED)* - On June 12, 1992… signed the U.N. Framework Convention on Climate Change... commits the world's governments to voluntary reductions of greenhouse gases…
- *Bilateral Sustainable Development Accord Between Costa Rica and the U.S.* - the U.S. and Costa Rica signed a bilateral accord intended to facilitate developing joint implementation projects.
- *1995 First Conference of the Parties(COP)* - delegates agreed on a mandate to establish appropriate action for the period beyond the year 2000…
- *Ad hoc Group on the Berlin Mandate* - delegates to AGBM -1 began the process of drafting a protocol on new commitments for the post-2000 period.
- *1997 Third Conference of the Parties (COP-3)* - the parties agreed to an historic protocol to reduce global greenhouse gas emissions and set binding targets for developed nations – Initiated

the Kyoto Protocol.
- *IPCC 2001 Report.* This report concluded a firmer association with human activities and climate change. It reported a higher range of temperature increases over the next 100 years than what was previously reported.
- *COP-6 Bonn Germany*. Many issues presented by the U.S. in earlier COP meetings, were discussed and basically finalized. Mechanisms. Carbon sinks, Compliance, and Financing issues, which provided more flexibility to developed countries, such as the U.S. to fund developing countries projects and receive credit, allow for carbon sinks in forests and soils under practice initiated after 1990, with some stipulations. Operational details were to be finalized at COP-7.

2.2.2 National Responses to Climate Change

The United States has undertaken actions to address climate change, including scientific and economic research, policy analysis, and program development. Some of these actions are:

- *Climate Change Action Plan* (CCAP) by the Clinton Administration in October, 1993 . The CCAP presented the U.S. strategy for reducing greenhouse gas emissions to 1990 levels by the year 2000. The CCAP called for voluntary measures by industry, utilities and other large-scale energy users. CCAP stressed energy-efficiency upgrades through new building codes in residential and commercial sectors. Large-scale trees planting and forest reserves were encouraged to enhance sequestration of $C0_2$ and to conserve energy. The CCAP avoided mandatory command and control measures.
- The Bush administration has developed a U.S. Climate Change Research Initiative, and a National Climate Change Technology Initiative.
- In February of 2002, President Bush announced a U.S. Policy for climate change, a new approach for meeting the long-term challenge for climate change. The reduction of greenhouse gas intensity of the U.S. economy would be 18% over the next 10 years. Greenhouse gas intensity measures the ratio of greenhouse gas emissions to economic output, which has been declining over the past several years. The goal, to be met by voluntary action, was to reduce emissions the 183 metric tons per million dollars of GDP to 151 in 2012. If not on track by 2012, and sound science justifies further policy action, the U.S will respond with additional measures that may include a broad, market-based program and other incentives and voluntary measures to accelerate technology development.
- Funds for carbon related research and agricultural activities in the Farm Bill were proposed under H.R. 2646.
- S. 769 proposed the establishment of a carbon sequestration program, as well as S. 785.
- S. 1293 was presented to amend Internal Revenue Code to allow for incentives for voluntary reductions of emissions and sequestration activities.
- S. 1781 was proposed, which would require the Secretary of Commerce to establish a voluntary system for trading for industrial greenhouse gases. Other similar bills have been introduced in the U.S. Congress with much support for continued research.

2.2.3 Other State Responses to Climate Change

Many individual states and localities have also initiated independent climate change responses. At the state level, many have developed a state-level greenhouse gas inventory, and many have developed or committed to develop a state-level action plan to reduce greenhouse gas emissions. Some are listed below that may be applicable to Idaho:

- The Iowa State Energy Bureau's Building Energy Management Program promotes cost-effective energy management improvements in state buildings, schools, hospitals non-profit organizations, and local government facilities (Wells, 1991).

- In Minnesota, more stringent energy standards have been adopted for the new construction of residential dwellings and government offices.
- Oregon has increased the weatherization standards in the construction of low income homes.
- New York has recently established a public-private partnership to encourage and support schools in making their facilities more energy efficient (*Energy Smart Schools*).
- Colorado has established the *Colorado Green Program*, which assists builders and honors residents who construct homes that conserve natural resources and increase energy efficiency.
- Mecklenberg County, North Carolina all school buses have been converted to CNG vehicles.
- Maryland, the Department of Transportation has replaced its fleet of diesel fuel shuttle buses at BWI with 20 new CNG vehicles. Also, the governor signed an executive order which formally expressed Maryland State Government's commitment to improve air quality and to comply with the clean fuel provisions of the *Clean Air Act Amendments of 1990* (CAAA of 1990) and the Energy Policy Act of 1992 (EPAct).
- *The Georgia Governor's Office of Energy Resources* is increasing energy and agricultural efficiency by facilitating six programs targeted to crop, poultry, and livestock producers. These programs conserve energy and save money in addition to reducing greenhouse gas emissions.
- *The Missouri Department of Natural Resources* has created a reforestation program designed to reduce heating and cooling needs with strategic landscaping, to arrest soil erosion, enhance natural water filtration, and remove carbon dioxide from the atmosphere. The program coordinator of this multifaceted project, called Operation TREE, must work to involve every division of the Department of Resources and encourage cooperation among other state agencies (Wells, 1991).
- *The Alabama Broiler Litter Program*, co-sponsored by the Science, Technology and Energy Division of the Alabama Department of Economic and Community Affairs and the USDA's Tennessee Valley Resource Conservation and Development Council, addresses energy conservation, reduces the landfill waste stream, promotes recycling, and improves agricultural productivity. In this program newspaper is shredded and blown over the poultry house floor, where it becomes matted and slick from droppings and moisture content. When the litter and paper is gathered from the floor, it is spread on crops as fertilizer, or is mixed with feed and is fed to livestock. The paper also acts as an insulator for the poultry house, thereby reducing energy needs (*Conservation Update*, September 1994).

These state activities listed above demonstrate how Idaho can implement programs to address climate change and benefit the state. Because Idaho is more attuned to local public sentiment than are their federal counterparts, a state planning process can incorporate localized public input and priorities. Federal agencies, however, must craft programs that cover larger regions of the country. As a result, state and regional priorities may be overwhelmed by national interests during federal planning. By initiating its own programs, Idaho can make adjustments according to their own needs, allocate resources as they see appropriate, and complement other state policy goals in ways that the federal government may not consider.

2.2.4 Idaho Activities

Some activities related to climate change are already occurring in Idaho. Cropland and forestry research, carbon sequestration on agriculture and forest-lands, and negotiations between energy companies and farm organizations are attempting to offset emissions is or has occurred. Some of these activities are summarized below.

2.2.4.1 PACIFIC NORTHWEST DIRECT SEED ASSOCIATION AGREEMENT WITH ENTERGY

The Pacific Northwest Direct Seed Association (PNDSA) is a grower-based organization committed to increasing direct seed farming systems in the Pacific Northwest. The primary goal of PNDSA is to increase the number of direct seeded acres from over 650,000 to 1 million by 2005. Direct seed is a tillage system that reduces soil disturbance while planting a crop, rewarding farmers with less inputs and reducing field erosion significantly, improving multiple natural resource conditions. Carbon sequestration also occurs under a direct seed system, which PNDSA has been working with researchers on the estimate an amount of carbon stored over a period of time.

PNDSA has recently negotiated an agreement with Entergy, a company from the Southeast, which will lease 30,000 tons of CO2 offset credits from the organization, fulfilled through its membership. Bt agreement, credits are generated by growers who have agreed to use direct seed agriculture methods for at least 10 years; direct seed cultivation avoids soil losses from oxidation associated with using traditional tillage techniques, and also reduces the growers' fuel use and soil erosion.

PNDSA is the aggregator and administrator of each 10 year lease. The eligible members are those that have ground direct seeded before 2002 that will be direct seeded for the next ten years. Annual or perennial crop production is acceptable. The actual number of tons will be calculated when total number of acres used in the contract are known. Verification will occur with the best available technology. Entergy and PNDSA will jointly seek development of verification models useable by all growers and energy companies for the future.

2.2.4.2 NEZ PERCE TRIBE - TRAMWAY CARBON SEQUESTRATION AND CRP PROJECT

The Nez Perce Tribe - Tramway Carbon Sequestration Project will sequester atmospheric carbon dioxide (CO_2) by planting trees on non-stocked agricultural land in north central Idaho that otherwise would not naturally regenerate and would not otherwise be planted. Ponderosa Pine seedlings are to be planted on the site. The Nez Perce Tribe will grow crop trees for a minimum of 80 years and to engage in sound forest management practices that will aid in attaining the maximum potential growth of crop trees.

The Nez Perce Tribe must meet several criteria to ensure that the Tramway – Agricultural Conversion Carbon Sequestration Project does not plant trees that otherwise would have been planted using other funds. The project area has been cultivated for agricultural production on forest soils for approximately 70+ years. The site would not regenerate naturally and planting tree seedlings is the best option for establishing trees on the site. The total area to be planted is about 400 acres. Anticipated benefits derived from the above ground biomass of wood alone is estimated at 46,859 metric tons of carbon or 171,974 metric tons of CO_2 equivalents over the 80 year period. An additional 9,044 metric tons of carbon or 33,192 metric tons of CO_2 equivalents is anticipated to be sequestered on site as soil Carbon. The approximate total of all carbon anticipated to be sequestered on site is 55,903 metric tons of carbon or 205,165 metric tons of CO_2 equivalents over the 80 year period.

2.2.4.3 EXISTING AND PROPOSED ETHANOL PLANTS

There are currently two small fuel grade ethanol plants owned by the J.R. Simplot Company producing fuel grade ethanol from potato peel and chips. These plants having been producing ethanol since the mid-80's. There are other entities considering building several large modern ethanol plants in the near future. A proposed ethanol plant in Payette County has received funds from the USDA Value Added Agriculture Product Market Development Grant to help launch the plant (Idaho Statesmen, 10/25/02). Local farmers and business leaders have been contributing money for the plant. Local farmers would provide grain, enough to run the plant, to market the ethanol in Idaho and other Northwest states.

2.2.4.4 RESEARCH ACTIVITIES

Some agricultural related soils, carbon and related research activities have been ongoing by organizations such as the University of Idaho and the USDA Agricultural Research Service:

- The USDA Agricultural Research Service, Northwest Watershed Research Center (NWRC) began deployment and testing of Eddy Covariance instrumentation to monitor canopy-scale water and carbon flux at the watershed. These data will complement the existing hydrologic-data collection network and will add a carbon flux component to the research program. After a period of testing, and development of a telemetry and database management system for these instruments, they will also be used to collect data in collaboration with the ARS Rangeflux network. This network was established in 1996 to monitor CO2 flux over unmanaged native rangeland in 9 western states.

- The USDA Agricultural Research Service, of Kimberly Idaho (NWISRL) has looked at dissolved organic carbon from the soil rooting zone, where little or no published information is available describing drainage losses of dissolved carbon (DOC) from furrow-irrigated calcareous Portneuf silt loam to the vadose beneath. Studies have determined that there is an annual mass loss of from one field was 56.4 kg/ha/y, or about 0.1% of the organic carbon present in soil (0 to 120 cm).

- The USDA Agricultural Research Service, of Kimberly Idaho and the University of Idaho Research & Extension Center in Parma, Idaho is conducting studies on manure/compost application effects on sugar beet establishment, N uptake, yield, and quality, topsoil and subsoil chemical and physical properties. The purpose of the study is to determine the effect of manure and compost application rates on N uptake and sugarbeet production, soil nutrient status, organic matter and soil carbon /changes, and soil physical and structural properties.

- Studies at the University of Idaho include:
  Variation of Fragipan Depth, Above-Ground Biomass, and Soil Carbon in a Small Grass Watershed. The research objective was to develop relationships between subsurface morphology and C movement at the subwatershed scale. The study site is a 1.7-ha subwatershed located in the eastern Palouse region of northern Idaho. Biomass was measured at points throughout the watershed. Preliminary data indicate that fragipan characteristics may be the best predictor of C accumulation in the watershed. This data will be useful in refining C cycling models for use in areas where water restrictive horizons are present.

  Evaluation of soil properties and management on decomposition of a common wood substrate. The objective of this study is two-fold. The effects of various forest management practices (e.g. timber harvesting, site preparation, fertilization) are compared on the decomposition of wood stakes at nine sites located across the Inland Pacific Northwest region. The effects of soil moisture, texture, volcanic ash influence, temperature, O_2/CO_2 levels, and microbial biomass and functional diversity on wood decomposition rates are evaluated. It is hoped that this decomposition information will give an integrated assessment of soil type and forest management impacts on soil biological properties, and can ultimately be tied to soil productivity and sustainability on managed forest sites.

  Supercritical Fluid Conversion of Biomass into Chemicals and Fuels. The aim and rationale of this project is to utilize lignocellulose products to produce chemicals and liquid fuels by using a "supercritical fluid" (SCF) treatment. SCF (either water or methanol) conversion of biomass is a relatively recent technology that is capable of depolymerzing lignocellulose derived materials to monomers, yielding similar results as with acid hydrolysis, but without the drawbacks set forth by these technologies. The outcome of this project is to establish the viability of supercritical fluid processing of biomass to fuels and chemicals (biorefinery). In addition, develop a biobased-chemical economy from renewable resources.

Non-thermal Residue Management in Kentucky Bluegrass Seed Production Systems. The overall goal of this project is to determine the effectiveness and sustainability of non-thermal residue management practices to maintain this perennial crop that protects against soil erosion and therefore can improve water quality. Preliminary data from Lewis indicate that the yield improves (due to savings in soil moisture) enough to make up for the loss of a crop in the fallow year. Preliminary data on residue levels indicate that chemical suppression, along with mechanical treatment is relatively effective at reducing residue levels at the Lewis Co. site. Data indicates that the practices of bailing and burning may not be necessary in all Kentucky bluegrass seed production systems. The sustainability of non-thermal systems will likely depend on the variety planted and site-specific environmental conditions. Non-thermal management practices developed based on this research has the potential to lead to improved soil, water, and air quality, while providing an opportunity for growers to participate in developing C markets.

Metabolic engineering of Lactobacillus for ethanol production. The long-range goal is to generate the ideal microbial biocatalyst for lignocellulosic biomass-to-ethanol conversion. The objective of this research proposal, which is the next step toward attaining our long-range goal, is to metabolically engineer *L.* MONT4 for ethanol production.

Other U of I research include measurements of C levels in CRP, and conventional and no-till agricultural systems; use of remote sensing to track long-term and current land use changes in Idaho; quantification of organic matter decomposition in forested systems; nitrogen availability in manure and composted amended soils and determination of credits to inorganic N fertilizer application; quantification of soil organic matter under various types of urban plantings; improving the efficiency of ethanol production from agricultural products through the use of unique microorganisms; isolation and generation of microorganisms for use as "biocatalysts" in the conversion of off-grade potatoes and potato processing waste to lactic acid; viability and optimization of supercritical fluid processing of biomass to fuels and other value-added products; use of Brassica species as natural pesticides, organic fertilizers, and biodiesel production.

The University of Idaho Department of Biological and Agricultural Engineering has been investigating the feasibility of utilizing plant-derived oils as fuels in compression ignition engines. Demonstration projects have ranged from using raw unrefined oil as fuel to ASTM grade biodiesel powering an 18-wheeler with a 50:50 blend of biodiesel and No. 2 diesel for 200,000 miles.

2.2.5 Future State Action

While Idaho's emissions are low when compared to other states, it can adopt strategies to provide offsets through carbon sequestration and/or agricultural related emission reductions, for specific greenhouse gases elsewhere in the U.S. or anywhere in the world. These offsets would primarily come from carbon sequestration or reduced emissions from agricultural or forestry activities. While global warming is likely to be addressed through cooperative national and international efforts, many actions can be initiated locally. The state might find it wise to take action prior to national legislation, where regulations may not be beneficial to the state. There are some reasons that Idaho may wish to take definitive action to increase stored carbon and offset greenhouse gas emissions from other source around the world. One reason may simply be to increase the state's economy through carbon markets. Another reason is simply to utilize an effective means to reaching the state's own natural resource objectives. Many recommendations are presented in Chapter 9.

3 STATE-WIDE CARBON SEQUESTRATION

A state-wide inventory of existing and potential carbon sinks and greenhouse gas emissions is a useful tool both for establishing a baseline level in which to measure future state-wide carbon sequestration and emission reductions. In addition to preparing an inventory of current carbon levels and greenhouse gas emissions, Idaho may wish to forecast *future* levels of stored carbon and greenhouse gas emissions in the absence of state policies to reduce emissions. Such a forecast could serve as a benchmark against which future activities could be measured. Idaho will also need to establish a current level of sequestration of carbon and predict a potential level to determine its capability of participating in any future programs or markets.

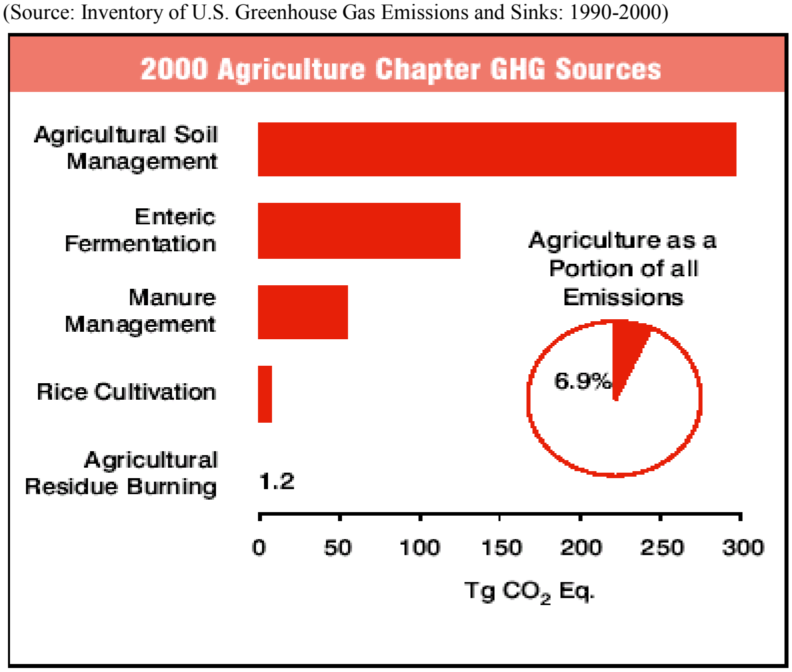
3.1 STATEWIDE CARBON LEVELS

The first step in a state's effort to encourage carbon sequestration and greenhouse gas emission activities is to identify all source categories in the state of those sinks and emissions. Site specific baselines will need to be determined before a landowner could sell carbon credits within a carbon market. The current (or past) level of stored carbon and emission levels establishes a baseline in which future practices will accrue "carbon credits". By developing an inventory, thus establishing a baseline, it can also identify those source categories that contribute the most in offsets or reductions of greenhouse gases. This identification of low soil carbon areas, for instance, would lead the state towards practices or activities that would provide the highest carbon sequestration within that area. Agricultural greenhouse gas emissions, where found to be high, could be similarly addressed .

3.1.1 Current State-wide Carbon Levels

Currently Idaho does not have a good baseline estimate of carbon sinks or a complete greenhouse gas inventory. EPA has provided an estimate of carbon dioxide emissions simply based on fossil fuel use which is estimated at about 3 million metric tons carbon equivalent (MMTCE) for 1990 and 4.1 for 1999. The majority has been estimated to be coming from industrial and transportation sources. (http://yosemite.epa.gov/OAR/globalwarming.nsf/content/EmissionsStateEnergyCO2Inventories.html)

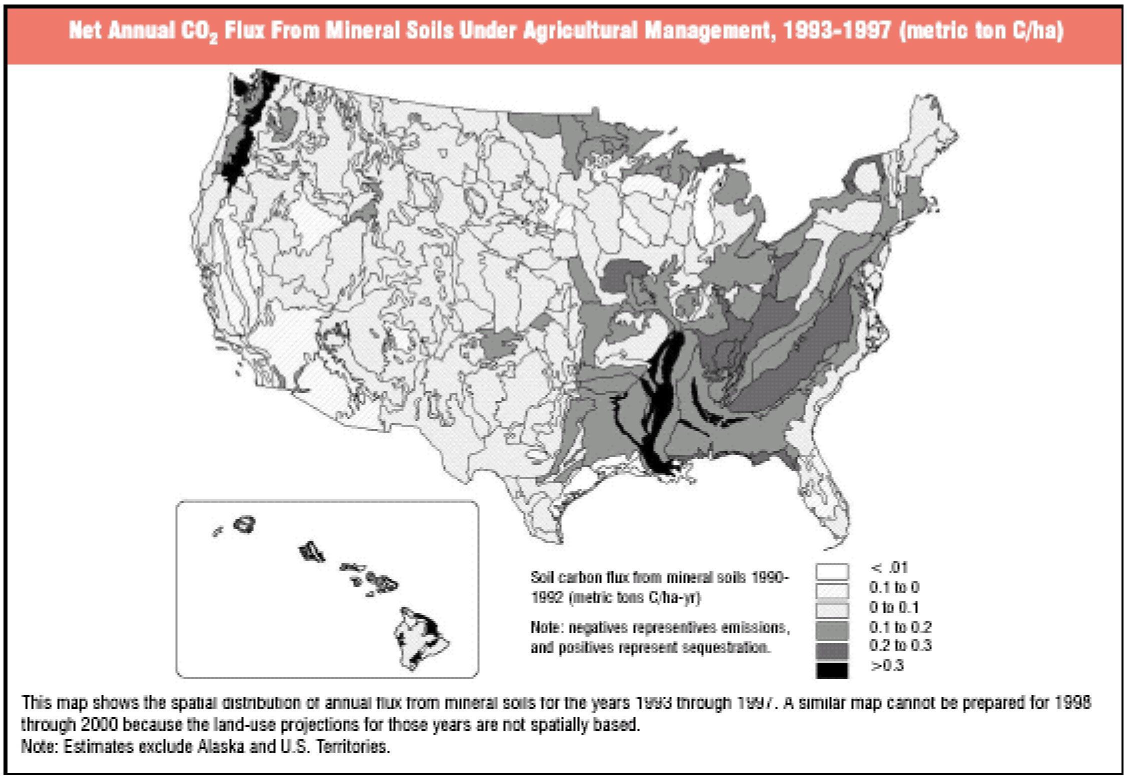
Figure 1. U.S. Agriculture Greenhouse Gas Sources
(Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000)



Initial U.S. estimates in carbon losses on agricultural croplands ranges from 30 to 50% of its soil organic carbon just in the conversion of native soils to cropland over the last 100 years. With nearly 292 million acres of existing cropland in the U.S., improved management, primarily conversion to direct seed or no till, could sequester near pre-agricultural levels of soil organic carbon (Lal et al. 1998). In Idaho, with about 4.5 million acres of cropland, there could be a significant amount sequestered in Idaho. Of the 292 million acres in the U.S., Idaho croplands constitute about 2% of the total, thus might only sequester 2% of the total potential on croplands in the U.S.

It has been has been estimated that in 2000, agricultural activities were responsible for 485 MMT CO_2 Eq., approximately 7% of the total U.S. emissions (EPA, 2002, Figure 1.). The majority of the agricultural emissions are nitrous oxide (65%), primarily from agricultural soils due to fertilization and other practices. Methane emission from enteric fermentation and manure management were near 26% and 8% respectively, primarily from beef and dairy cattle.

Figure 2 – (Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000)



Carbon flux (sequestration) was estimated for national agricultural soils have also been completed from 1990 through 2000. Mineral soils sequester carbon, whereas organic soils and liming practices emit carbon. Year 2000 carbon flux levels were estimated at 67 MMT CO_2 Eq. and 37 MMT CO_2 Eq. in 1990. The estimated net annual carbon dioxide flux from mineral soils from 1993 to 1997 in Idaho range basically 0 to 0.1 metric tons/hectare, whereas Eastern U.S. and western Washington and Oregon state soil ranged from 0.1 to >0.3 metric tons/hectare (Figure 2). Increased conservation efforts, primarily the adoption of no-till and conversion to perennial pasture and hay land, have caused an increase of sequestration, which then would then decrease the estimated net emissions. Idaho may also see increased sequestration if its upward trend of no-till and other management factors continue. Idaho's pre-irrigated calcareous soils along the Snake

River plain in southern Idaho had lower soil organic matter than what they are today. In contrast, pre-cropland soil carbon levels within high-precipitation areas generally have lower soil carbon levels today. Just looking at these differences between two cropland areas makes it difficult to estimate a state-wide average soil carbon level.

There are approximately 747 million acres of forested lands in the U.S., which has remained fairly constant during the last few decades. The approximate 23 million acres of forest lands in Idaho constitutes 3% of the total. Total U. S. net carbon flux in 2000 was about 903 million metric tons of carbon dioxide (MMT CO_{2e}) (EPA, 2001). Idaho and Montana were combined for the national estimate, constituting about 7.6% of the total U.S. carbon stock. By this estimate, Idaho would have about 2-3% of the total carbon flux in the nation. Simply estimating Idaho forest flux by percentage of its total in the U.S. would estimate Idaho's forests sequestering approximately 27 MMT CO_2 Eq. These estimates include the trees, understory, forest floor, forest soils, logging residues, harvested wood products, and land filled wood. To properly estimate Idaho's forest flux, further analysis and adjustments would likely need to be made in some or all of the categories which can sequester carbon. 1990 estimates were at 1097 MMT CO_2 Eq. for the entire U.S. forests, 33 MMT CO_2 Eq. for Idaho if the same logic is used for the estimate.

Estimating active carbon sequestration rates may be accomplished through a land-based inventory with existing data, where general land management and ownership, and current activities are described. Assigning some general estimates of carbon sequestration rates, which may vary widely depending on land use and practice, can provide a current baseline amount of carbon storage. The baseline year, which seems to be a based on international consensus, is 1990. If Idaho continues to establish state-wide carbon sequestration rates, 1990 may likely be the year in which to compare a current sequestration. This would provide an indication of an increase or decrease of the rate of sequestration state-wide. There would be, however, a wide range of sequestration. Policy decisions regarding carbon sequestration and related activities may be best made based on current trends in Idaho. If there is a downward trend in sequestration activities while there are increasing levels of emissions occurring within the state, it may choose to begin strategies to reverse the sequestration trends to begin to bring Idaho into a net reduction or offset of greenhouse gas emissions. If however, sequestration is increasing, then Idaho may choose to further evaluate to see if the trend will continue, and then ensure that a positive trend continues through policies and other strategies.

3.1.2 Forecasting State-wide Carbon Levels

Idaho may project the level of carbon sequestration rates and greenhouse gas emission reductions it will achieve through state-wide carbon markets and programs. That projection will need to refer back to the baseline discussed above to actually show a positive trend.

Projecting future carbon levels and emission reductions relative to a static baseline is less complex once the state greenhouse gas inventory is developed. However, to the extent carbon sequestration rates and greenhouse gas emissions are likely to grow with or without state policies, the use of a static baseline will likely understate future carbon sequestration rates and greenhouse gas emissions. If static data are used to estimate levels, the greenhouse gas reductions may be understated as well. For example, if a state plans to implement a carbon sequestration program that will include a certain percentage of all private forest landowners, and assumes the same number of land owners in 2010 as in 1990, the greenhouse gas reductions due to the program are likely not to be estimated correctly. With a transportation emission reduction strategy, for example, there will likely be more motorists and may skew analysis results if this increase is not accounted for.

An alternative approach is to project emission reductions relative to a forecasted reference case which accounts for projected changes in the state's population, economic activity, and other factors. This approach has the advantage of greater realism and thus greater accuracy. Another advantage is that if Idaho plans to achieve some set carbon sequestration and greenhouse gas emission levels, use of a forecasted reference case would allow the state to project whether its programs, policies and voluntary carbon market participation will achieve a target level.

Another approach would be to forecast carbon sequestration and greenhouse gas emission reductions only for those sectors in which the state plans to implement programs. This modified approach would enable the state to project with relative accuracy the offsets and reductions its program would achieve, in relation to future net carbon sequestration and greenhouse gas emission levels in the absence of programs. However, forecasting carbon sequestration (offsets) and greenhouse gas emissions for only some sectors would not enable the state to estimate total statewide levels in the absence of programs; thus the state would not know the total net greenhouse gas reductions needed to achieve some target level of carbon sequestration and/or greenhouse gas emissions.

Note that uncertainty is a significant concern when forecasting greenhouse gas emissions. To prepare reliable forecasts, Idaho should extend carbon sequestration and greenhouse gas emission forecasts only into the near future. Given the degree of uncertainty already associated with existing methodologies and available data, carrying projections beyond this point can undermine the usefulness of forecasts. The maximum time frame for projecting emissions in most situations is likely to be 15 to 20 years, which is the typical time frame for energy use projections. Beyond that, uncertainties in technological changes alone will likely call into question the accuracy of forecasts.

Forecasting can be complex because there are many factors that can affect future emissions, including population growth, economic growth, technological improvements, and degree of urbanization. Possible means of accounting for these external factors include expert judgment, content analysis, tending methods, economic forecasting, and end-use forecasting methods.

Some of the agricultural independent variables that may be used to estimate a carbon sequestration and greenhouse gas emission calculations are:

- Agriculture and forestland carbon sequestration by specific practices/activities,
- Greenhouse gas emissions from agriculture and forest land management
- Methane emissions from livestock, such as dairy and beef cattle, horses, and sheep,
- Methane emissions from livestock manure,
- Biofuels production and use.

3.1.3 Leakage of Greenhouse Gases During Implementation of Practices/Activities

When predicting carbon sequestration and greenhouse gas emission reductions, forecasts should take into account the possibility of "leakage" of greenhouse gas emissions. An example of such leakage of greenhouse gases is that during the implementation and operation of a practice or activity expected to increase carbon sequestration, there is an increase of greenhouse gases because of additional fossil fuel use through additional transportation and production activities. Another example is with ethanol production. Production related greenhouse emissions would likely need to be accounted for to estimate a net greenhouse gas emission reduction within the transportation sector. Many other examples of potential "leakage" could be identified; the challenge for state carbon sequestration and greenhouse gas planners is to identify areas where potential leakage may be significant, and to adjust their estimates of greenhouse gas reductions accordingly. This also shows that a "whole-farm" analysis is likely needed for a potential seller of carbon credits to encourage the actual sale of those credits.

3.1.4 Additionality

There is uncertainty regarding the acceptability of state or federal mandated practices or activities that are generating carbon credits with a carbon market. Where carbon sequestration practices and related activities are taking place, simply because of regulation or program incentives, those carbon credits produced may not be allowed to be sold or counted as greenhouse gas offsets. The potential expectation that some practices and activities may not be eligible for greenhouse gas offsets should not, however, dissuade the state from further exploring all potential practices and activities that may increase carbon sequestration and reduce greenhouse gases, regardless how they are implemented. It is not clear at this time is additionality will hinder carbon sequestration activities.

3.1.5 Future Activities

The initial estimate of current and potential levels of carbon sequestration looks positive. Further analysis is needed to determine what the state-wide potential of carbon sequestration might actually be in the near future, with or without carbon sequestration markets and state programs. Some future activities have been identified to better estimate and predict the physical capability of carbon sequestration in Idaho:

- Coordinate state-wide GIS (geographic information system) database development through the state GIS coordinator
- Prepare a state-wide GIS soils database that estimates current soil carbon levels
- Prepare a state-wide forestry based GIS database that estimates current carbon levels
- Improve the state-wide GIS based land use and ownership database
- Prepare a state-wide GIS based land management database
- Identify and further develop potential models to estimate current and future agriculture and forest soil/biomass carbon levels

3.2 IDAHO DEMOGRAPHICS

For Idaho to develop any climate change programs and policies, which may eventually be used help reduce greenhouse gas emissions, and/or provide offsets through agricultural and forest practices, a baseline amount of existing agricultural and forest related emissions and current sequestration levels must be established. These amounts will provide a "platform" in which potential amounts carbon sequestration or greenhouse gas emission reductions and offsets may be compared to determine its state-wide potential. Understanding Idaho's natural resource characteristics and current land use and management is the first step.

Table 2. Land Type

1997 Estimates for Idaho

Category	Acres	Percent
Federal Land (non forest)	33,563,300	62.7%
Rangeland	6,500,500	12.2%
Cultivated Cropland (62% irrigated)	4,541,300	8.5%
Forestland (federal)	3,947,800	7.4%
Pastureland	1,314,800	2.5%
Non-Cultivated Cropland	976,000	1.8%
CRP Land	784,800	1.5%
Other Rural Lands	552,500	1.0%
Large (Census) Water	471,700	0.9%
Urban Lands	425,200	0.8%
Rural Transportation	329,700	0.6%
Small Water	79,900	0.1%
Total Surface Area	53,487,500	100.0%

Source Data: USDA Natural Resources Conservation Service, Idaho 1997 NRI (Revised 12/2000) http://www.id.nrcs.usda.gov/nri/index.html

3.2.1 Land Ownership

Approximately 63% of Idaho's land are public land, managed by federal agencies. Bureau of Land Management (BLM) manages about 22%, the US Forest Service (FS) manages about 38%, and private lands consist about 38% of Idaho's lands. In the context of carbon sequestration on private lands, this would only constitute about 1/3 of the state, whereas, a large quantity of carbon sequestration is likely occurring on public and state lands. The potential for additional practices and improvements on these non-private lands may be great enough for the state to consider policies and programs to enhance sequestration activities beyond just its private lands.

Table 3 provides another categorization on lands in Idaho, broadening into some of the land use data. Where Table 2 and Figure 3 show ownership, Table 3. povides a better description of the diversity in the state. The NRI data and data obtained from the state's GIS data may not coincide exactly due to the differences in the methods of their production. However, the differences in the totals do not discourage the state-wide analysis and estimates on carbon sequestration potential.

Table 3. Land Owner/Manager

Owner/Manager	Acres	Percent
B.L.M.	11996648	22.3%
Bureau of Indian Affairs	687272	1.3%
Department of Energy	571744	1.1%
Forest Service	20743087	38.5%
Military Reservations	133301	0.2%
National Parks & Monuments	97509	0.2%
Open water	513682	1.0%
Private	16180017	30.0%
State of Idaho	2844964	5.3%
U.S. Fish & Wildlife Service	140909	0.3%
Total	53909133	

Source: idown.shp GIS shape file found at http://www.idwr.state.id.us/ftp/gisdata/shapefiles/statewid/
Acres may not be exactly the same as the NRI data

3.2.2 Land Use

According to 1997 NRI data, Idaho had about 19.4 million acres of nonfederal rural land in 1997. 35% of it is rangeland, 30% cropland, 21% forestland, and 7% pastureland. Harvested cropland acres are about 4.5 million acres (see also 2002 Ag statistics). The number of acres enrolled in the Conservation Reserve Program, over 790,000 acres as of 2003 (http://www.fsa.usda.gov).

Nearly 2.8 million cropland acres are considered "prime farmland." Prime farmland has the best combination of physical and chemical properties for producing food, feed, forage, fiber and oilseed crops and are also available for these uses.

About sixty-two (62) percent of Idaho's total cropland is irrigated, about 3.5 million acres. Idaho ranks 5th among states for the most federal land. Nonfederal land is about 19 million acres. Of these acres, nearly 4 percent, or 750,00 acres, are considered developed. Federal land totals about 33.5 million acres (63% of total land).

Private grazing lands total 9.4 million acres and include pastureland, rangeland, and grazed forestland. Grazing lands make up over 50% of Idaho's nonfederal rural land. Today, growth and prosperity are leading to expansion of small and mid-sized cities onto agricultural land. From 1982 to 1997, developed land has increased by 204,700 acres.

Land use is dynamic and therefore changes in use occur between each inventory period. The average annual rate of conversion to developed land in Idaho was 16,560 acres for the period 1992-1997. In the period 1982-1992 the average rate was 11,250 acres. This is an increase of 47 percent. The rate of increase was highest on rangeland, followed by pastureland, cropland, and then forestland. In terms of conversion rates, Idaho ranked 36th in the nation in 1997. Development, or urban built-up, increased by 91,900 acres in Idaho from 1992 to 1997. Sixty three (63) percent of this increase occurred in the following Idaho counties: Ada, Canyon, Kootenai, Twin Falls, Elmore, Bannock, and Bonneville.

3.2.3 Vegetative Cover

As shown in Table 4., the vegetation cover types on various lands owned or types of land have been estimated through geographical analysis, with multiple data and a simple query. The values within each category incorporates various land coverage, such as roads and other physical aspects, but given consistency in is development, the data can be used to compare cover types by ownership. Forested land, sagebrush, and croplands consist of the majority of the cover type. Within the forested category, there actually over 30 types of cover, which has been summarized within the table to simplify it. Thus forested land actually consists of approximately 40% of the total cover, where cropland and pasture is about 17%, sagebrush communities near 27%. The remaining 84% consists of various grasses, shrubs, riparian/wetland species, and non-vegetative cover, such as urban lands.

When looking just at the cover types just on private land, about 50% of private land is in cropland and pasture, 21% in various forest types, and 17% in various sagebrush types. State lands consist of 40% of various forested types, 39% in sagebrush type communities, and nearly 4% in cropland and pasture. Of the entire cropland and pasture, 92% is on private lands, 4% on BLM, 1% on state lands and 1% on Bureau of Indian Affairs. Forested lands are found to be 77%5 in Forest Service land, 16% on private lands, 5% on State lands, and 2% on BLM.

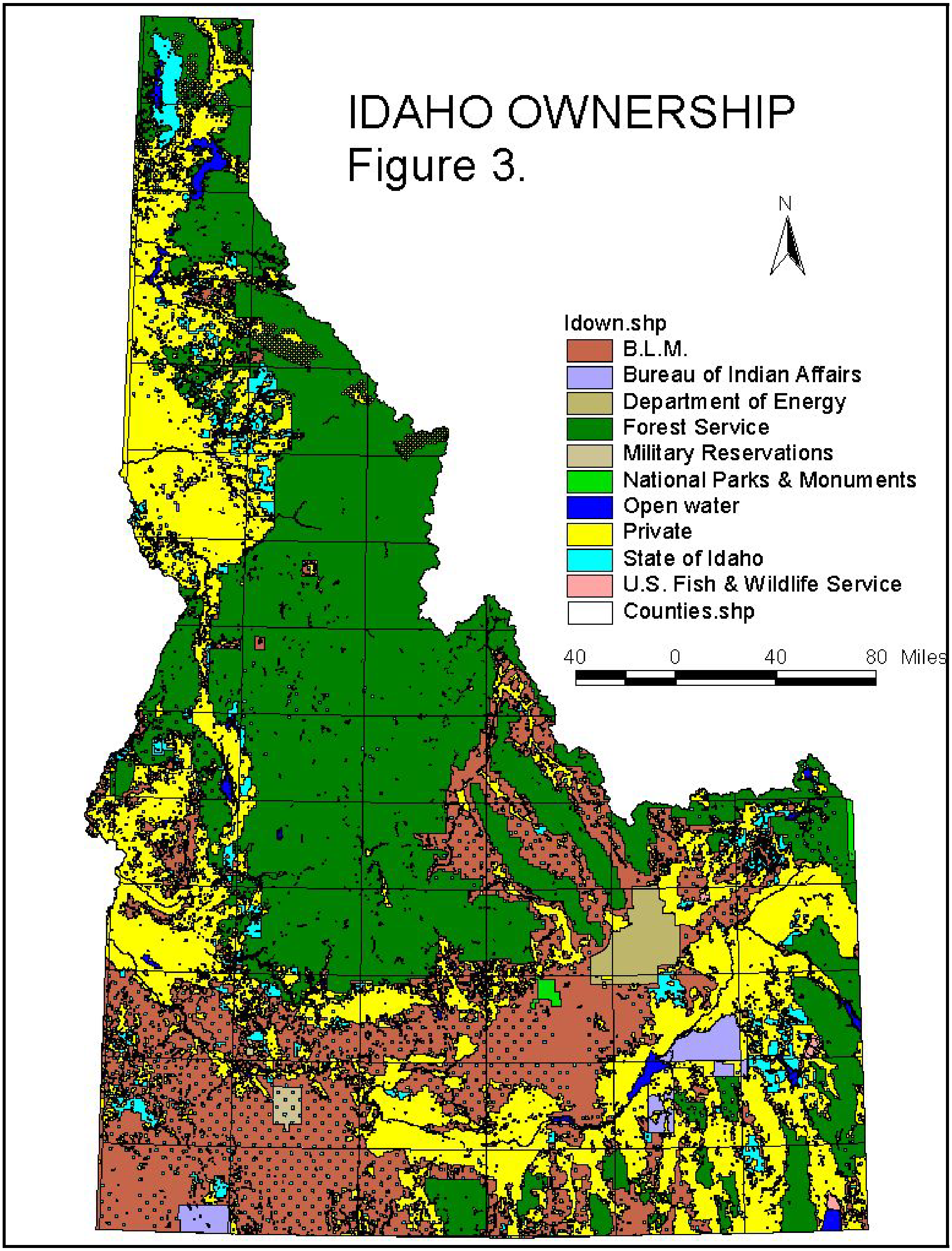
The percent land owner/type of cover type is shown in Appendix 1, Table 1. The bolded numbers are those greater than 10% for the sake of comparison. Where , for example 92% of Agricultural lands primarily exist on private lands and 78% perennial bunchgrass seedings are found on BLM. In contrast, Table 2 in Appendix 1 shows the percent of cover type within each land owner/type category, where private lands consist mostly of agricultural crop, pasture, Montane forests, and shrub steppe and grassland communities for example.

Once there is a basic understanding of Idaho's land resources, the analysis of potential carbon sequestration and reductions of greenhouse gases related to agricultural and forestry activities may be initiated. There are some additional steps and information that is needed, however, to effectively describe the potential for the implementation of activities. Land management, cropping histories, livestock population data, and other physical and social aspects need to evaluated in relationship to the effectiveness of various activities on carbon sequestration and greenhouse gas reductions.

3.2.4 Land Management

Like many states in the west, Idaho has a very significant amount of federally owned land. Private landowners and local state and tribal governments have the responsibility for conservation on 36 percent of the state. Nonfederal land is predominantly rural and supports a variety of land-based industries. Proper management of these lands is critical to the overall health of the State's natural resources.

Farmers and ranchers focused primarily on slowing erosion on our most susceptible soils in the 1980's and early 1990's. Those efforts have paid off by controlling erosion that not only sustains the long-term productivity of the land, but also affects the amount of soil, pesticides, fertilizer, and other substances that move into the Nation's waters. Sheet and rill erosion on cropland decreased about 35% between 1982 and 1997. Wind erosion on cropland decreased about 18%. NRCS-NRI reports indicate there was a reduction in the total sheet/rill and wind erosion on Idaho's agricultural lands, from an estimated 50.4 million tons per year in 1982 to 36.2 million tons per year in 1997. This is a decrease of 14.2 tons per year.


IDAHO OWNERSHIP
Figure 3.
N
Idown.shp
B.L.M.
Bureau of Indian Affairs
Department of Energy
Forest Service
Military Reservations
National Parks & Monuments
Open water
Private
State of Idaho
U.S. Fish & Wildlife Service
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Rangeland management, including riparian areas, have been heavily used by livestock producers over the last 150 years or more, with varying degrees of long-lasting impacts. Rangeland areas have been severely altered because of weed infestations or complete changes in vegetative communities (perennial grasses to annuals). The livestock industry has evolved from producing millions of sheep to cattle, the majority of the livestock now, mostly due to market demands and culture. A substantial amount of work has been done to improve grazing management, but much more is needed to improve the health of a majority of the existing rangelands. In some areas of the state, grazing practices have actually altered habitats, actually increasing water surface areas with stock ponds and increasing available wildlife food sources within pastures and riparian areas, and such.

Table 4. Cover Type by Land Owner/Type

Cover Type Group	B.L.M.	Bureau of Indian Affairs	Department of Energy	Forest Service	Military Reservations	National Parks & Monuments	Open water	Private	State of Idaho	U.S. Fish & Wildlife Service	Grand Total
Agricultural crop and pastureland	391173	114268	6015	38749	2027	309	35720	8197413	94519	11000	8891193
Alpine	620			207293			601	316			208829
Annual grasslands	1090662		3874	1634	40991		2612	456316	99460	1373	1696922
Foothills and Plains Woodlands	455921		10279	123983		17110	1980	117438	56823	947	784480
Montane Forests	273359	31144		10166286	15032	1120	12522	2732717	769067	311	14001558
Montane Forest-Steppe Transitions	486662	43479		3132790	3795		3822	830258	240406	384	4741595
Montane Shrubfields	241253	1177		964630			6038	335678	120410		1669185
Perennial bunchgrass seedings	955014		7613	5324	53346	3799	406	128742	58888	6797	1219930
Recent timber harvest areas	1428			310562	770	5	188	152804	54816		520574
Riparian and Wetland Types	18222	16688		41045	0	975	412830	177588	14083	46114	727545
Shrub Steppe and Grasslands	8301401	344224	538867	859893	16528	37940	24759	2942384	988546	4938	14059480
Subalpine Forests	30540			2717139		35872	3095	66650	19349		2872645
Subalpine Parklands	8254			1794495			4239	23169	73815		1903973
Urban and Industrial	2341			408	2771		3287	155076	315		164198
Grand Total	12256850	550980	566648	20364231	135260	97129	512098	16316548	2590498	71865	53462106

Source of data: idown.shp and veg.shp statewide gis coverage. Intersection of data was completed in ArcView 2.0 to create table. See http://www.idwr.state.id.us/ftp/gisdata/shapefiles/statewid/ for gis shape files and metadata information

Private, tribal, and state forest lands are operated similarly to farm and ranch owned lands, but with different natural resources. Forestry activities are governed by the Forest Practices Act and its associated practices, varying practices activities occur within the state's forests lands, ranging from logging to recreation to recreation, with vast natural resources contained within. Much of the activities that occur on private lands are unknown, where state and federal regulations tend to focus on state and public lands, requiring a substantial amount of inventories.

Among the urban areas of the state, there exist controversial issues among citizens within the rural-urban interface. Rural land uses are becoming surrounded by urban land uses, and conflicts arise from simply because of conflicting uses and their off-site impacts. Within these areas, smaller ranchettes exist in greater proportion, combining rural lifestyles with urban benefits, such as shopping and recreational activities close by.

3.2.5 Cropping History

Agricultural crops have been grown in Idaho since before 1900. Many crop varieties are found throughout the state, but most varieties exist under irrigation, primarily in southwestern and south central Idaho, within the Snake River Plain. The most common crops, those covering the majority of the cropland in the state, are listed in Table 6. Overall, there has been a reduction in crops planted since 1980, though some varieties have increased, such as corn for grain and silage, alfalfa hay, oats, potatoes, and sugarbeets. The year 2000 amount of winter wheat varieties is virtually ½ of that planted in 1980. Some increase in corn and alfalfa hay plantings have increased due to an increase in the size of local dairies and feedlots, causing county acreages to increase substantially, such as those in the Magic Valley.

Table 5. 2000 - 2001 Idaho Agriculture Statistics. See http://www.nass.usda.gov

Field Crop Summary: Harvested Acres, Yield, Production and Value, Idaho,2000-01

Crop	2000					2001				
	Harvested	Yield Per Acre	Unit	Production Total	Production Value	Harvested	Yield Per Acre	Unit	Production Total	Production Value
	Acres			*1,000*	*1,000 Dollars*	*Acres*			*1,000*	*1,000 Dollars*
Barley	730,000	76.0	Bu.	55,480	143,693	670,000	75.0	Bu.	50,250	138,188
Corn for Grain	57,000	160.0	Bu.	9,120	23,986	45,000	150.0	Bu.	6,750	17,213
Corn for Silage	135,000	25.0	Ton	3,375	NA	125,000	25.0	Ton	3,125	NA
Dry Beans, Commercial	88,000	19.5	Cwt	1,716	29,687	73,000	19.5	Cwt	1,424	27,056
Hay, Alfalfa	1,130,000	4.2	Ton	4,746	450,870	1,120,000	3.9	Ton	4,368	524,160
Hay, All	1,390,000	3.8	Ton	5,292	491,547	1,420,000	3.5	Ton	4,938	573,465
Hops	3,321	1,484.0	Lb.	4,930	8,775	3,469	1,329.0	Lb.	4,609	7,421
Mint										
Peppermint	15,000	95.0	Lb.	1,425	14,678	14,000	92.0	Lb.	1,288	13,524
Spearmint	1,000	130.0	Lb.	130	1,040	900	105.0	Lb.	95	798
Oats	20,000	70.0	Bu.	1,400	1,750	20,000	68.0	Bu.	1,360	2,108
Potatoes, All	413,000	369.0	Cwt	152,320	609,280	368,000	348.0	Cwt	127,980	691,092
10 S.W. Counties	28,000	490.0	Cwt	13,720	NA	26,000	450.0	Cwt	11,700	NA
Other Counties	385,000	360.0	Cwt	138,600	NA	342,000	340.0	Cwt	116,280	NA
Sugarbeets	191,000	29.3	Ton	5,596	212,088	179,000	25.9	Ton	4,636	NA
Wheat, All	1,300,000	83.4	Bu.	108,450	281,124	1,200,000	71.0	Bu.	85,150	279,144
Wheat, Spring	570,000	75.0	Bu.	42,750	118,845	490,000	68.0	Bu.	33,320	113,288
Wheat, Winter	730,000	90.0	Bu.	65,700	162,279	710,000	73.0	Bu.	51,830	165,856

NA-Not available

Crop varieties often require different management, especially specialty crops, such as seed crops. Small seeded crops, such as sugarbeets, are not easily cultivated with high levels of residue left over from the previous crop. Thus, tillage operations on many crops that require cultivation are fairly intensive, eliminating residues to ensure cultivation techniques are successful, and do not disturb the seeds and small plants. Surface irrigation has also hindered farmers in regards to tillage, where reconditioning sloped field surfaces and corrugates for uniform water delivery to the crops. Some progress has been made though fewer tillage passes under irrigation, primarily under sprinkler systems, as under dry cropland conditions. In Northern Idaho, direct seed, often more commonly known as no-till, is becoming widely adopted on the few of the crops grown in that region of the state.

Understanding the management that typically coincides with crop variety will help estimate the potential for carbon sequestration practices, primarily related to tillage. The potential for the conversion of cropland to a long-term forest stands that store carbon may also be based on current cropland profits. If crop markets are expected to continue or increase profits in the future, the conversion to a long-term forest stand may not be as economically viable within a carbon market. Conversion from one crop to another for the sake of carbon sequestration may not in itself be viable either, while carbon flux among vegetation types may not differ substantially. If the conversion of an annual crop requiring tillage to a perennial crop that does not require any tillage for maintenance happens, the carbon flux will most likely be reduced because of much less tillage, which tillage causes excess carbon dioxide losses on croplands.

3.2.6 Livestock

Estimating the potential methane and other greenhouse gases from livestock may be helpful when establishing state-wide policies on carbon sequestration activities. Where carbon is main focus of this report and current analysis, methane losses, as well as nitrous oxides and other gases may be as important Idaho to address in order to establish a state-wide net reduction in greenhouse gases. Sequestration activities may indeed offset a large quantity of other sources gases, but where Idaho's fossil fuel related emissions are low, agricultural related greenhouse gases may be considered as high a priority for reduction to outside interests and the federal government under potential future greenhouse gas regulations. The state of Idaho should assess all sources and establish documentation on those sources, prior to establishing priority actions, which may be needed to justify those chosen actions to outside interests in order for the agricultural and forest owners in Idaho to benefit through markets and trading activities.

Table 6. 2002 Idaho Agriculture Statistics. See http://www.nass.usda.gov

Cattle and Calves: Inventory, by Classes and Weight, Idaho, January 1, 1993-02

Year	All Cattle and Calves	All Cows & Heifers That Have Calved			Heifers 500 Pounds and Over				Steers 500 Lbs. & Over	Bulls 500 Lbs. & Over	Calves Under 500 Lbs.
		Total	Beef Cows	Milk Cows	Total	Beef Cow Replace-ments	Milk Cow Replace-ments	Other			
						1,000 Head					
1993	1,680	690	505	185	375	95	100	180	360	40	215
1994	1,740	700	507	193	405	100	105	200	365	40	230
1995	1,820	730	510	220	420	100	115	205	390	40	240
1996	1,820	760	515	245	410	95	110	205	385	40	225
1997	1,820	780	512	268	415	95	120	200	365	40	220
1998	1,860	800	520	280	440	95	135	210	360	40	220
1999	1,900	800	498	302	440	95	135	210	365	40	255
2000	1,950	820	488	332	465	100	160	205	365	40	260
2001	1,960	840	486	354	460	100	165	195	380	40	240
2002	1,990	870	493	377	460	85	175	200	360	40	260

From 1964 to 1997, the number of hogs, pigs, and sheep have declined, but calves, beef cattle, and milk cattle have increased. The 2002 Idaho Agriculture Statistics bulletin shows 2001 populations of dairy cows to be about 377,000 head. The number of livestock farms, however, have dramatically declined, suggesting a much larger number of livestock per farm, which is the case for beef and dairy operations. For instance, based on the able below, in 1964, the average number of beef cattle per farm was about 41 head. In 1997, the average number of beef cattle per farm was 66, an increase of about 61% number of cattle per farm. This increase in farm populations can have dramatic effects on production efficiency, environmental impacts, and social acceptance. New odor and nutrient management regulations have resulted because of social pressure and natural resource concerns. Greenhouse gas emissions from large feedlot and dairy operations, which may have liquid waste treatment ponds or those with composting facilities are subject, are likely to emit larger amounts than what possibly occurred under smaller operations with less manure waste and ruminant emissions per farm.

4 CARBON SEQUESTRATION PRACTICES AND EMISSION RELATED ACTIVITIES

Upon describing Idaho's natural resources, land use and management characteristics, the potential land-based practices that may provide future carbon sequestration and greenhouse gas reductions need to be explored. This section describes numerous practices and related activities that Idaho's landowners and business communities may adopt which can sequester carbon and reduce greenhouse gas emissions at various locations throughout the state. This report primarily focuses on private and state lands. Public land activity could benefit the state from similar activities.

4.1 CARBON SEQUESTRATION IN IDAHO

While scientists believe that rising levels of carbon dioxide and other greenhouse gases are contributing to global warming, the extent has been difficult to determine. While limiting fossil fuel consumption is one method of reducing emissions of carbon to the atmosphere, another is to increase the sequestration of carbon in 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 and forest land owners can help address greenhouse gas concerns by implementing practices that cause the land to act as a greater sink for carbon and that decrease agriculture and forest related emissions of greenhouse gases. Biofuels production can substitute fossil fuel use in the transportation sector and reduce greenhouse emissions greatly, while reducing our reliance on petroleum. Many of the activities that increase the organic content of soils, in trees, or reduce related greenhouse gas emissions can also increase agricultural productivity as well as improve soil, air and water quality.

Idaho's private landowners could profit from carbon sequestration if certain types of carbon trading or other financial incentives are put into place. There are, however, many 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. Little federal government action has resulted in the development of strong carbon markets in this country, however, the U.S. government has not done anything to prohibit American citizens and companies from participating in carbon sequestration activities. Some environmental interests, however, are against allowing industries to offset their emissions through carbon sequestration activities.

Though with the uncertainties associated with climate change and sequestration opportunities, the potential for Idahoans to profit could conceivably be enhanced if the state takes actions to ensure it can act quickly should significant carbon markets develop. If a carbon storage market does not develop but additional efforts in put into the implementation of various conservation practices, the benefits of increased conservation and improved land management related to carbon sequestration may still provide a long-term economic benefit to the state.

The advantage of carbon sequestration to Idahoans is, though it may contribute to curbing global warming and the perceived related impacts from such warming, economic benefits can be achieved. This report does not elaborate on the perceived effects of climate change and how the state may reduce the impacts, but focuses on the potential benefit that the state as a whole and its landowners can receive by participating in carbon markets. The most important first step is estimate the quantity of carbon that *might* be sequestered through agricultural and forestry practices and other related activities. The second step is to define the methodology in which to actually verify carbon sequestration and other related greenhouse gas reductions. Upon developing that methodology, which will not be entirely accomplished here, a process to assist the state and its landowners in participating in carbon markets would follow. This report and its evaluation of numerous practices will set the stage for a further and more comprehensive exploration of specific elements possibly desired in carbon sequestration markets.

The potential international and national law changes regarding emissions, possibly in response to international and national interests, would have the most relevance for Idaho agriculture and forestry if there become national carbon emission limits (restrictions) and related actions allowing for carbon sequestration to offset some of those emissions. The level of the emission offset by carbon sequestration would likely be determined by restrictions and the market value of a metric ton of carbon.

When evaluating the potential agricultural and forest related practices that can sequester carbon or reduce emission losses, the practical limits of sequestration needs to be addressed. Some practices will store carbon over a significant amount of time and achieve the physical upper limit of carbon storage. However, these practices may need to be in place for many years and operated in such a manner to achieve optimum carbon storage. At some point, the management needed to add still more carbon to land that already has high carbon levels may become cost prohibitive. If no program or incentives are in place to ensure continual application and maintenance of these practices are continued, the carbon previously stored could be re-released, which may not suit well within a carbon market, likely driven by regulations.

A large amount of carbon has been lost to the atmosphere due to the development to agricultural production. Tillage practices have caused minerals to oxidized at much greater rates than that of those undisturbed soils, but there are practices that can sequester carbon back into the soil, possibly back to the original amount. These carbon sequestering practices will generally have substantial ancillary benefits to the economy and natural resources. 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. Some of the agricultural and forestry practices and related activities that can increase carbon sequestration and/or reduce related greenhouse gas emissions are listed below:

- Residue management (direct seed, no-till),
- Nutrient management,
- Windbreaks,
- Short rotation woody crops,
- Riparian forest buffers,
- Prescribed grazing,
- Range and pasture planting.
- Methane reductions from livestock and waste storage ponds,
- Biogas recovery,
- Biofuels (ethanol & biodiesel),
- Afforestation and reforestation (forest, pasture, croplands).

The overall potential to sequester carbon and reduce related greenhouse gas emissions from some of the agricultural and forestry practices may be significant. For example, the potential benefits from combined total cropland and grazing land related emission reduction and sequestration practices could be over 400 million metric tons C (MMT C) of carbon per year. However, there is not total agreement on sequestration potential from various practices, especially on such topics as grazing land. In addition the amount of new or additional carbon sequestered may begin to decline as a soil reaches its capacity. Also, 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 sequestration is ultimately utilized to achieve global emission reductions

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. It is likely that only those additional quantities of carbon stored would qualify as carbon credits (offsets). Thus in this report, the actual amount of stored carbon in soils and biomass is not the main focus, but the addition through practices and activities.

4.1.1 Ancillary Benefits of Carbon Sequestration Practices

There are a number of ancillary benefits, along with some potential negative impacts, associated with many of the carbon related practices. 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, 1997a). 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 residue management, 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. Most all of these practices to be discussed in this report are or can provide numerous natural resource and economic benefit to the state.

4.1.2 Carbon Sequestration Practice Evaluation Criteria

To determine what practices are feasible in storing carbon, either in the soil or in above-ground biomass, or reducing a greenhouse gas emission, there needs to be consistent and comprehensive evaluation. Practice effectiveness, acceptability, cost, implementation capability, operation and maintenance capability, monitoring and verification capability, and ancillary benefits, are such criteria to evaluate a practice individually and deem whether or not it is feasible. When these following are used comprehensively to evaluate the overall potential of their use in the state, it results in a better understanding of what practices might most beneficial to the state. Appendix 5 shows a numeric rating system (a table) that the Advisory Committee used to initially evaluate each practice and activity discussed below. Those practices or activities that rated highest, utilizing each of the criteria below (with and without cost), will most likely will be those chosen by landowners and other carbon market participants to offset greenhouse gas emissions.

4.1.2.1 EFFECTIVENESS

How much carbon sequestration can occur or emissions offset by the individual practice, and its duration of its effectiveness is important. The certainty of results from a type of practice or actions and how well the public and government retains the practice as viable is important. The effectiveness of policies during economic fluctuations and growth, and technological change, are also variables that need considered while evaluating effectiveness. This evaluation criteria just looks at the individual practice in one location, not on a state-wide scale. Upon discussing its individual effectiveness, a state-wide estimate of sequestration (or emission reduction) presented (see Appendix 10). A summary of the state-wide benefit from the adoption of these practices are presented later in the report in Chapter 8.

4.1.2.2 ACCEPTABILITY

To what degree farmers, ranchers, and forestry land owners accept and adopt a practice is very important in forecasting the potential level of sequestration in the State. Under non-regulatory programs, such as those administered by the Idaho Soil Conservation Commission or within a carbon market, the cultural and social acceptance of a practice will determine its success in being implemented. Regulatory programs, mandating specific practices to be implemented, may or may not increase acceptability upon enactment of mandate. However, over a few years, the practices often become more acceptable and common, if not detrimental to a business, Economics play a large role in practice acceptance, along with numerous other factors, which are not easily analyzed to predict acceptance levels. Acceptability will be estimated primarily by looking at the historical application of practices and based on experience and expertise of those assisting with this report.

4.1.2.3 COST

For every dollar spent and time involved in setting up and implementing actions, there should be some benefit. Costs are, whether for installation, operation, or maintenance, very important to the landowner or operator. If installation costs are high, the investment must be replaced with adequate return to justify the practice, and to allow for its longevity. Alternatives may also be evaluated with a simple cost-to-benefit analysis, to determine if costs can be absorbed or possibly reclaimed later. Administration costs are also important, as with an agency or private organization responsible for a practice's implementation, operation and monitoring.

There may also exist transaction costs incurred while connecting the supplier of carbon "credits' to buyers. Aggregation of credits from multiple sources will increase transaction costs. Transaction need to be consideration in the evaluation or creation of local or state-wide carbon markets. If transaction costs are too great, minimal trading or selling of carbon credits will likely occur. Verification costs may be considered a part of transaction costs, along with administration costs. Legal costs may also enter in and need to be evaluated, but not necessarily on a practice-by-practice basis.

4.1.2.4 IMPLEMENTATION CAPABILITY

This evaluation criteria looks at the practicality and capability of installing the practice, as well as other conditions, such as legal constraints, permits, and landuse zoning. An example of a legal constraint may be with dairies and feedlots, where animal wastes are to be handled in a limited manner and may not necessarily coincide with methane reduction practices. Waste treatment lagoons are acceptable, but they produce methane and odor problems. If an operator wished to land apply manure for aerobic treatment, then nutrient management criteria may be exceeded. Also, waste incorporation into soils does not work well with a direct seed or no-till operation, where excessive soil disturbance occurs with tillage.

4.1.2.5 OPERATION AND MAINTENANCE CAPABILITY

Practices need to be operated properly and maintained in order to be effective over its expected life-span. Costly operation and maintenance on certain practices may not be acceptable or practical in achieving a high level of carbon sequestration, which should be evaluated prior to installation if possibly. Operation of a practice may need to be adjusted to maintain its highest or most feasible level of sequestration. Most practices should not require additional operation or maintenance effort beyond what they already require today, however, for longevity of carbon storage, there may be no allowance for departure from the practice due to the nature of carbon cycling, especially in soils.

4.1.2.6 MONITORING AND VERIFICATION CAPABILITY

Some activities implemented under new programs may or may not be actually measured to deem a success. Idaho should be careful not to eliminate practices or activities that are difficult to actually measure, but allow for alternative monitoring techniques, that still may show benefit from implementation. Verification is for the purpose of ensuring that a practice is actually increasing stored carbon by a minimal amount or reducing a given amount of emissions. Monitoring may require record keeping, and audits, where verification will likely require on-site measurement techniques. The capability of either monitoring and verification should be evaluated prior to installation.

4.1.2.7 ANCILLARY BENEFITS

Some actions initiated due to new greenhouse gas related programs may have positive and negative impacts locally and off-site. For example, tree planting programs that sequester carbon, may also reduce soil erosion and improve water quality, but if changes the landuse status, effect property values and taxation. In some cases, ancillary benefits may justify installation of practices without additional funding from carbon markets.

4.2 AGRICULTURAL CROPLAND ACTIVITIES

USDA estimates from 1998 indicate a U.S. cropland soil sequestration potential of 154 million metric tons of carbon (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 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).

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. Irrigation water management has significant carbon sequestration potential, in the irrigated portion of the Snake River plain for example. The extent to which fuel consumption required by irrigation has likely offset the carbon storage benefits of irrigated land needs however.

Idaho's calcareous soils, found mostly along the southern Idaho Snake River plain within a semi-arid climate, likely have increased soil organic content because of irrigation, fertilizer, and residue inputs. Farmlands within higher precipitation areas of the state have lowered soil organic content, with little or no irrigation development. Future carbon sequestration is likely to occur differently among these different areas within the state. Climatic conditions and other soil characteristics may enhance or limit the amount of carbon sequestered. The types of management practices will effect carbon sequestration rates. Some soils may be near or at soil capacity and changes in management may not increase soil carbon levels.

Afforestation of non-forested areas may provide a substantial amount of carbon sequestration due to increased woody biomass (wood). Soil carbon levels may also be increased under newly forested areas, where woody biomass increases and tillage practices are eliminated. A combination of practices on a farm might be most feasible to maintain conventional production and provide the greatest amount of carbon sequestration.

Potential biofuel sources that are currently produced in Idaho are corn, wheat, barley, and canola. Agricultural products can be utilized to reduce transportation related fossil fuel emissions through the use of biofuels. With predicted increases in U.S. and world energy demand, biofuels provide one method of meeting that demand without significantly increasing atmospheric carbon levels. 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 (USDOE, 1999). Biofuels will be discussed more in-depth within its own section later.

Photosynthesis removes carbon dioxide (CO_2) from the atmosphere and stores the carbon in plant materials and soils. U.S. cropland soils currently sequester 20 MMT/yr (of carbon per year), and have an estimated biophysical potential to sequester 60-150 MMT/yr more; grazing lands could sequester up to another 50 MMT. To put this in context, 60-200 MMT/yr is about 12–40 percent of the reduction that would be needed to return expected 2010 U.S. greenhouse gas emissions to their 1990 level. Carbon sequestration can be accomplished through many alternative practices.

4.2.1 Residue Management (No-till, strip-till, an direct seed)

4.2.1.1 DESCRIPTION

This practice is the management of the amount, orientation, and distribution of crop and other plant residues on the soil surface, while growing crops in narrow slots, tilled or residue free strips in soil previously untilled by full width inversion implements. The definition adopted by the Pacific Northwest Direct Seed Association is "a method of planting and fertilizing done with no prior tillage to prepare the soil. Includes systems that plant and fertilize into undisturbed soil, as one pass, and those that fertilize first and then plant, as two passes". See the NRCS conservation practices web site for more details regarding this and other practices (http://www.id.nrcs.usda.gov/Engdwnld/construction_specs.html).

Residue management, a term representing multiple types of tillage techniques such as no-till, direct seeding, reservoir tillage, and also known as conservation tillage, applies to environmentally friendly planting methods that help soils retain nutrients after completion of the planting process. Tillage systems that keep the majority of the crop residue after planting are considered to be no-till or direct seed. In this discussion, direct seed and no-till will be the primary focus, which are only those types of tillage that may sequester carbon.

4.2.1.2 EFFECTIVENESS

This practice is very effective in reducing sheet and rill erosion, wind erosion, and irrigation-induced erosion. Water infiltration is increased, organic matter increased, and possibly increase agronomic yields. Estimates on organic matter, soil carbon increase, may range from 0.12 metric tons of carbon (MT C) to 0.24 MT C, (Lal et al. 1998) The PNDSA has adopted 0.15 MT for northern Idaho conditions and direct seed practices. Effectiveness will vary depending on soils, climate, residue management, starting soil organic matter, pH, and other factors.

Soils have natural carbon-carrying capacities, and it may be difficult or impossible to increase their carbon content beyond these limits. Most soil carbon gains from residue tillage are achieved within approximately 20 years, but the carbon stored can be released later if farmers revert to conventional tillage practices. Reversion to conventional practices will result in most of the carbon being released back into the atmosphere within a few years. However, temporary storage of carbon may offer significant benefits by reducing the rate of increase of atmospheric CO_2 until more permanent solutions are found.

Intensive soil tillage is recognized as a significant factor causing soil organic matter oxidation (CO_2 emission) in cultivated soils. Intensive tillage, particularly with soil inversion (plowing) enhances decomposition by exposing organic matter protected within soil aggregates and by increasing soil temperature. Reduced tillage, and particularly no-till practices, have been shown to promote higher levels of organic matter in many systems, where productivity and organic matter inputs are not adversely affected. An analysis of 28 paired comparisons from no-till versus full tillage treatments in 19 long-term experiments (duration of the experiments ranged from 5 to 20 years) in Canada, Europe and the United States showed mean increases of soil organic matter under no-till of 0-30 % C, with an average of about 10 % (Paustian *et al*., 1997).

The Pacific Northwest Direct Seed Association and ENTERGY agreement uses a conservative carbon sequestration rate of 0.15 MT C per year under a direct seed system, which applies to northern Idaho, including eastern Washington state. A Iowa carbon budget for 640 acre farm, under a conservation tillage corn/soybean rotation was estimated to sequester 0.16 MT C/ac/yr (Hurley et al. 2000). Other various sources, such as from Bruce et al. 1999, and Lal et al, 1998 estimate sequestration rates at 0.16 and 0.20 for no-till respectively. These rates seem to be closely representative and likely applicable to northern Idaho, possibly eastern Idaho, where precipitation rates are higher than southern parts of the state. Where precipitation is low and soils have high pH, and irrigation is necessary to grow numerous crops, the sequestration rates are likely lower. The rate used by PNDSA also includes diesel fuel savings as compared to hours typically used under conventional tillage. The 0.5 MT CO_2e (converted from C to CO2 by 3.67) rate is a fair estimate for Idaho, but excluding the estimated savings of diesel fuel use, which has been estimated at a rate of 0.004 MT CO_2e. Some differences will occur, though under different soils, such as in Southern Idaho, where this soil carbon rate may be less, due to pre-agricultural differences in annual precipitation, irrigation, SOM, pH, and other factors.

Assuming that Idaho currently has about 4.5 million acres in active cropland, if 36% of those acres were converted to direct seed or no-till, then 0.8 MMT CO_2e could be sequestered. There are nearly 270,000 acres currently in some form of residue management (CTIC, 2002 – http://www.ctic.purdue.edu) which is sequestering 135,000 MT CO_2e. The percent of acres converted to no-till or direct seed is increasing, mostly in Northern Idaho. An additional 0.1 MMT CO_2e would be reduced in CO_2 and N_2O emissions relative to the traditional cropland management. If a carbon market came into existence, or some other program, and with it a substantial amount of funding to pay for new equipment and some for of crop yield insurance, then direct seed and no-till acres may increase much more. A whole-farm analysis would need to be done to better estimate actual carbon credits available for purchase.

4.2.1.3 ACCEPTABILITY

Residue management's acceptability by farmers varies from region to region in the nation. In Idaho, there are pockets of farmers widely accepting direct seed and no-till, completely changing their operation from conventional within a few years. The majority of the state's farmer's, however, have not accepted residue management widely, especially where multiple crops are grown and within higher elevations. Surface irrigation practices and commercial cash crops have also been a deterrent in the acceptance of this practice. Where multiple crops are grown, with small seeds and cultivation is important for weed control, given a rigorous irrigation schedule along with that, tillage practices that leave an amount of residue on the field's surface that can disturb small seeds or can clog irrigation furrows are not accepted. Tillage practices have, however, been modified for some crops and by some progressive farmers and have been successful. Cultural or tillage traditions, is likely the primary barrier for a wide-spread acceptance of this practice in Idaho.

While already widely practiced throughout the nation residue management, is also an important strategy for reducing on-farm energy use, labor reductions, reduced erosion, and smaller nutrient loss from soils. Almost any dry land crop can be grown under a residue management system (no-till, ridge-till, or mulch till). Under irrigation, primarily surface irrigation, residue tillage may more complex but is achievable. Crop residues must be maintained on the soil surface throughout all parts of the year to conserve soil and allow for maximum moisture entry and storage in crops. Spring warming of Eastern Idaho soil temperatures, primarily those in higher elevations, are considered hindered by high residues left on the soil surface, thus this practices has not been readily adopted in this area. In contrast, Northern Idaho farmers have more readily adopted additional residue management practices, primarily direct seed.

4.2.1.4 COST

The initial investment of residue management may be costly where a complete adoption of no-till or direct seed occurs, where new equipment is purchased. Where the same tillage equipment covers large amount of acres, every year, the cost should be relatively low. In regards to increasing soil carbon with this practice, the amount of acres to be treated, whether or not equipment is already available, and the ability for soils to further store carbon are the major factors in determining a cost. There should be relatively low annual costs to the farmer, once no-till or direct seed practice has been adopted, compared to a conventional tillage operation. Less fuel usage, less time, and hopefully less herbicide use over a long period of time should occur.

4.2.1.5 IMPLEMENTATION CAPABILITY

The initial investment of residue management may be costly where a complete adoption of no-till or direct seed occurs, where new equipment is purchased. Some modification of existing conventional drills and planters may be done for a few crops and has been done. Where new equipment has been purchased, large acres are usually acreage farms are involved. Many of the northern Idaho farm fields are much larger than southern Idaho fields. The large-scale farm, in which to work in a residue management operation, requires much less field adjustments between fields, where there are fewer but larger fields. Covering multiple acres without having to change equipment or seed simplifies the practices. Where no cultivation practices or irrigation is involved, this too simplifies adoption of this practice.

4.2.1.6 OPERATION AND MAINTENANCE CAPABILITY

Once implemented, operation is similar from one year to the next, except for the changes dictated by crop type and its nutrient, pesticide, and irrigation water management associated with it. Maintaining this practice over along period of time will be necessary to ensure soil carbon levels are maintained and increasing, up to the soil capacity. If at any time soils are inverted, such as with a plow, most soil carbon built up by the previous years no-till or direct seed operations will likely be lost within a very short period of time. Therefore, maintenance and constant attention to the practice will have to occur for soil carbon levels to be maintained and increased. Maintaining this practice should become easier after of use.

4.2.1.7 MONITORING AND VERIFICATION CAPABILITY

Along with field inspections to ensure that the practice was implemented correctly, soil testing or equivalent procedures will be needed to verify soil carbon levels are being maintained or increasing. Prior to the adoption of the practice or entrance into an agreement, there will likely need to be soil testing to establish a baseline soil carbon level. Carbon levels in soils, most likely those in or around 1990, (Kyoto baseline year), would likely have to be surpassed for there to be a carbon ‘credit’ to sell. If carbon levels are not found to be increasing a field, based on actual field measurements or adopted scientifically-based modeling, then it would be difficult to justify a sale of carbon credits. Any monitoring requirements of this practice would likely need to be outlined within a contract between the buyer and seller of carbon. Annual post-planting field inspections and some periodic carbon storage verification may likely be needed.

4.2.1.8 ANCILLARY BENEFITS

It is estimated that no-till systems can minimize erosion by up to nearly 95%, and reduce pesticide and water runoff by 70%. Farmers can benefit greatly from no-till planting because it can reduce their commercial fertilizer purchases and applications and lowers fuel usage. Surface water quality of adjacent streams and lakes are also going to benefit from such a practice.

4.2.2 Cover Crops

4.2.2.1 DESCRIPTION

Cover crops are usually planted with grasses, legumes, forbs, and other herbaceous plants, after the harvest of another short-season crop, for the purpose of maintaining soil moisture, reduce erosion, and add nutrients to the soil. Specific types of cover crops, while under a no-till or direct seed tillage operation, can and some carbon to its soils, up to the soil carrying capacity. Rotations will dictate when and how many years a cover crop can be planted within the farm rotation. Cover crops are generally tilled into soils the following spring, however, again, this practice would require no tillage to occur to increase soil carbon.

4.2.2.2 EFFECTIVENESS

Where no-till and direct seed can sequester about 0.9 MT CO_2e, a cover crop added to a rotation, can possibly sequester 0.3 to 0.5 MT CO_2e within the year that it is in place. The above-ground residues may not add any significant amount of carbon to soils if conventional tillage is continued. Even with the conversion to no-till or direct seed, the amount of carbon added to soils will be limited to soil capacities. Organic matter may only increase by up to 1% in most areas of the state with no-till and cover crop practices. If it assumed that the acres of cover crops are incorporated into the rotation is the same as those converted to no-till and direct seed, then nearly 36% of the total 4.5 million cropland acres would then produce around 0.2 MMT CO_2e, assuming that cover crops are only used 30% of the time within a crop rotation. This amount of sequestration is about 22% of that sequestered under a no-till operation. A whole-farm analysis would need to be done to better estimate actual carbon credits available for purchase.

4.2.2.3 ACCEPTABILITY

Most crop rotations have been adopted by cultural and family historical precedence. Cover crops, would also be adopted similarly. Often, crop prices may drive what crops are grown a specific year but does not generally cause a major shift of overall farm crop varieties. Cover crops may not likely have any return, and may increase some management time. Weed control, hopefully, would be easier with cover crops, but may not initially. The potential of shifting to more cover crops, such rye grass or winter peas, is low for Idaho, principally with the need for a change in tillage practices. Changes in tillage practices that follow a shift in crop varieties, crop prices, and historical barriers would weigh in heavily on a farmer's decision to change to a new rotation with cover crops. Fields that are rented out to other farmers having already made a shift to less intensive crop rotations may have the highest level of acceptability, such as when a farmer is near or at retirement but does not choose to sell the property. Other industries, such as in the cash crop or seed crops, may still provide large incentives for farmers to stay in an intensive rotation, without cover crops possibly interfering with annual crops and tillage needs.

4.2.2.4 COST

The costs of switching rotations, including some cover crops, should be relatively low, but would need to incorporate new tillage practices for carbon sequestration purposes. Additional cost of planting a cover crop would need to be absorbed initially, where benefits are not likely to be felt. Long-term commitment may see some return with less pesticide and disease control costs. Fuel use may also increase with cover crop planting.

4.2.2.5 IMPLEMENTATION CAPABILITY

For a farmer to add a cover crop, in essence, a new crop rotation, it should not interfere with any existing farm subsidy programs. Local cultural traditions usually play a role in the adoption of cover crops, but to what extent, that is not known. Cover crop use in dryland areas may limited if soil water is not available, similar to irrigated areas if there exists no additional water for establishment. Growing seasons lengths would also limit success.

4.2.2.6 OPERATION AND MAINTENANCE CAPABILITY

Specific crop rotations that are not much different from what a farmer is already practicing would not be difficult to maintain, but cover crops would add some complexity. If tillage practices must change with a change because of changes in rotation and added cover crops, then operation and maintenance capability efforts may need adjusted and increased to ensure desired benefits such as a minimum level of soil carbon and some return on investment. Planting and harvest periods would need additional planning to ensure that the cover crop was installed and successfully established for winter soil protection.

4.2.2.7 MONITORING AND VERIFICATION CAPABILITY

Verification of a specific cover crop may require contractual language to ensure the rotation is carried out and is verified as such. Field inspections and planting records may both be needed to truly monitor application. Field site soil sampling may also be needed to verify that soil carbon levels are truly increasing due to the practice, but would be difficult to weight out tillage effects. Continual and intensive soil testing, however, would generally not be acceptable as implementation costs would rise substantially as compared to traditional soil testing procedures.

4.2.2.8 ANCILLARY BENEFITS

Less soil erosion will occur over winter months with cover crops. Field maintenance, due to rill and gully erosion would be less. Increased soil nutrients or the uptake of carry-over nutrients may benefit the farmer and off-site natural resources. Local water surface and ground water quality may benefit with less soil erosion, and lower soil nutrient levels due to improved utilization and less fertilization requirements. Fewer pesticides may be used if cover crops limit weed infestations.

4.2.3 Grassland Cover

4.2.3.1 DESCRIPTION

Permanent grassland cover, similar to what occurs under the USDA-Conservation Reserve Program (CRP), maintains soil moisture, reduce erosion, and add nutrients to the soil. Specific types of grasses are prescribed that will be successful for at least 10 years. No cultivation is allowed on fields under the CRP, but some weed maintenance is necessary, which may include mowing and spraying. Soil carbon will increase under a vegetative cover, where soil disturbance is occurring.

4.2.3.2 EFFECTIVENESS

Where no-till and direct seed can sequester and cover crops may increase soil carbon about 0.45 million MT CO2e per year, so could grassland cover. Eliminating commercial cropping from a field, planting a perennial plant or mixture of plants, and maintained for long periods of time (at least 10 years) will increase soil carbon, but only up to its soil capacity. Organic matter may only increase, at most 1% in the state with no-till and cover crop practices, so to with this practice. If it assumed that the number of grassland acres are similar to the existing CRP acres (near 700 thousand), then those acres could sequester up 0.34 MMT CO_2e/y, but only up to so many years. The number of acres potentially available for this practice may only be 20% of the total 4.5 million acres of cropland. Upon reaching soil capacity C, maintaining that soil carbon level would need to occur for successful long-term emission offset. A whole-farm analysis would need to be done to better estimate actual carbon credits available for purchase.

4.2.3.3 ACCEPTABILITY

This practice would be much more acceptable if payments would cover property taxes, and supply typical net returns from commercial crop production. Generally, CRP has been limited to dryland farming rates, which are much lower compared to irrigated cropland rental rates. If payments were increased 3 to 4 times for irrigated areas, then this practice may be more acceptable throughout the southern part of the state. Otherwise, this practice may likely only be as successful at the existing CRP payment level. Rural-urban areas may have a higher likelihood of acceptance, where wildlife habitat and aesthetics may be more important than crop production.

4.2.3.4 COST

The cost of planting grass seed is relatively low, compared to some other crops, however, there is no net return on investment where it is not likely harvested. Maintenance costs are relatively low if germination and the first year's growth is not stunted by drought, disease, or weeds. Continued care will need to be taken in some areas however, because of fire hazard, insect, and weed problems, which could increase costs. In some cropland areas, where water availability is limited, planting costs will likely be higher because of replanting, where irrigation may not be available or is not adequately provided.

4.2.3.5 IMPLEMENTATION CAPABILITY

For a landowner to give up a commercial cropping operation on a field or farm, it may be a difficult decision to make. However, this is a very simple practice to implement. Local crop markets should not be impacted with this practice if acres are kept below 25% of most crop market production. Water availability is the key to this practice being implemented successfully.

4.2.3.6 OPERATION AND MAINTENANCE CAPABILITY

As mentioned before, successful germination and a first year's growth will determine operation and maintenance of this practice. Weed, insect, and fire prevention and control will be necessary, regardless of location. Adjacent to public lands or lands with poor maintenance, fire hazard and insect problems are likely to be more of a concern. In irrigated agricultural areas, periodic irrigation will still be needed unless shallow ground waters are adequate for grassland growth. Optimum growth may require similar irrigation usage on grasslands as with existing hay land.

4.2.3.7 MONITORING AND VERIFICATION CAPABILITY

Verifying that grassland cover is successful and adequate is relatively easy. Quantifying a carbon levels is also simple, if adequate soil samples are taken. If may be difficult to establish an exact level of carbon increase, however, if baseline data has not been generated similarly to what is required under a carbon market contract. In most cases, though, verification through soil sampling can establish baseline conditions for the first year of a contract.

4.2.3.8 ANCILLARY BENEFITS

Increased wildlife habitat, decreased soil erosion, and increased soil tilth will improve under a grassland practice. Water quality in surface and ground water bodies will also benefit from less soil movement and nutrient loss. Weed control in some areas may benefit from permanent perennial vegetation, holding back weed invasions. Some grasses, if more desirable to insects than surrounding crops, may be impacted more but would reduce the damage to those adjacent higher value crops. Some negative impacts could be known if too many acres were converted to grassland, rather than cropland where fertilizer sales and other agricultural relate products are no longer needed.

4.2.4 Grassed Waterways

4.2.4.1 DESCRIPTION

A grassed waterway is designed to be a natural or constructed channel that is shaped or graded to necessary dimensions for transferring overland flow, safely, to a field's outlet. Waterways are seeded with various grasses, but sometimes depends on soil slopes and upland runoff conditions. This practice can increase soil carbon within the waterway area, while reducing tillage and fertilization emission losses. Typical widths of these channels are 15 feet or greater, based on expected runoff flows. These are typically installed in dryland cropland areas.

4.2.4.2 EFFECTIVENESS

While these waterways are in place, it can sequester carbon in soils and reduced emissions if fertilization is not occurring within the waterway itself. If they are periodically removed, then only reduced emissions may occur, where tillage will likely release most all of the previously stored soil carbon. Soil capacity may limit the amount of stored soil carbon. If it assumed that up to 20% of cropland acres were available to install grassed waterways, then those acres actually in grass (in waterways) could sequester up to 4,142 MT CO_2e/y. These waterways are only assumed to take up 1% of a cropland acre. A whole-farm analysis would need to be done to better estimate actual carbon credits available for purchase.

4.2.4.3 ACCEPTABILITY

Grassed waterways are more acceptable and practical on dryland farms, where they don't interfere with irrigation system management. Even with no-till or direct seed in practice, this practice may be practical to install because of a greater gully or swale protection. There are, however, initially considered an obstruction to farming, but upon installation, tillage and spraying is quickly modified and benefits become greatly appreciated.

4.2.4.4 COST

The cost of planting grass seed is relatively low, compared to commercial crops, however, there is no net return on investment, except where erosion maintenance costs are reduced. Replacement of grassed waterways will occur periodically, therefore maintenance costs. If germination is not successful, then re-planting will raise installation costs. Weed control may be necessary, but may not increase costs compared to typical cropland weed control. Some grassed waterways may additional grading, drainage tile, and proper outlet structures, which will increase installation and maintenance costs.

4.2.4.5 IMPLEMENTATION CAPABILITY

This practice's design is relatively simple, but with some outlet considerations that may limit their use. Generally, these are placed in depression areas that already contain erosive swales or gullies, which are damaging down-grade uses, such as roadways or other cropland fields. These waterways are generally easy to install in swales, but not as easy in severe gullies, which require multiple structures. Waterway and pipeline outlets need protection from high flows. Most dryland farms are capable of waterway installation and maintenance, but vegetative species may be limited by climatic factors, such as winter temperatures and soil water availability.

4.2.4.6 OPERATION AND MAINTENANCE CAPABILITY

As mentioned before, successful germination and lifespan of vegetation will determine how extensive maintenance will be. Care will need to be taken during any tillage or spraying operations, so that they are not damaged or reduced in area and effectiveness, which typically happens with tillage over many years. Protection from weed and insect damage is needed to ensure proper functioning during runoff events. Replacement of waterway vegetation is expected, depending on maintenance and climatic variables.

4.2.4.7 MONITORING AND VERIFICATION CAPABILITY

Verifying that a waterway is successful and functioning adequately is relatively easy. Quantifying a carbon levels may be also be simple, if adequate soil samples are taken and site inspections verify maintenance. It may be difficult to establish an exact level of carbon increase, however, if baseline data has not been generated similarly to what is required under a carbon market contract. In most cases, though, verification through soil sampling can establish baseline conditions for the first year of a contract. Those acres no longer being tilled would result in reduced nitrogen losses if fertilization is not longer occurring within the waterway.

4.2.4.8 ANCILLARY BENEFITS

With permanent, perennial vegetative cover within gullies and depression areas, most of the erosion from dryland crop fields is reduced, benefiting downgrade offsite areas, such as streams and roads. Some wildlife habitat may be improved as well. Water quality in surface and ground water bodies will also benefit from less soil movement and nutrient loss.

4.2.5 <u>Nutrient Management</u>

4.2.5.1 DESCRIPTION

The primary definition of nutrient management is the managing the amount, source, placement, form, and timing of the application of nutrients and soil amendments. See the NRCS standards web site http://www.id.nrcs.usda.gov/Engdwnld/construction_specs.html for further information on this practice.

Nitrous oxide (N_2O) from agriculture soils can constitute a large amount of agricultural greenhouse gas emissions. Agricultural lands contribute to N_2O emissions through the breakdown of nitrogen fertilizers, manure decomposition in soils, and releases from legumes. Emissions can be reduced by increasing efficiency of fertilizer use, including more precise fertilizer placement and timing, with immediate incorporation of fertilizers into soils.

Fertilizers, whether industrially synthesized or organic (like animal manure and leguminous plant residue), add nitrogen to soils. Any nitrogen not fully utilized by agricultural crops grown in these soils undergoes natural chemical and biological transformations that can produce nitrous oxide (N_2O), a greenhouse gas.

Scientific knowledge regarding the precise nature and extent of nitrous oxide production and emissions from soils is limited. Significant uncertainties exist regarding the agricultural practices, soil properties, climatic conditions, and biogenic processes that determine how much nitrogen various crops absorb, how much remains in soils after fertilizer application, and in what ways that remaining nitrogen evolves into nitrous oxide emissions.

At many sites, more fertilizer is applied than can be effectively used by crops. Further, poor fertilization timing or placement often leads to additional nitrogen loss or unavailability to the plant. One major reason for the application of excess nitrogen in the fields is the lack of simple field testing for nitrogen. Also, many farmers believe that some "excess" may be necessary to ensure peak production. This is because precise crop needs are not always known, and weather and climatic conditions that affect crop growth and nitrogen requirements are unpredictable.

Several fertilization management approaches and some other specific fertilizer technologies offer opportunities for enhancing nitrogen-use efficiency. Several may be integrated into alternative agricultural systems that incorporate lower fertilizer usage and also achieve energy savings by reducing the need for plowing and other energy intensive practices. Management approaches include:

- Improve fertilizer application rate,
- Improve fertilizer application timing,
- Improve fertilizer placement,
- Utilize split applications,
- Utilize GPS technology,
- Regular soil testing,
- Use fertilizer compounds with lower nitrogen content,
- Implement residue management,
- Use fertilizers with nitrification inhibitors,
- Use fertilizers with reduced water solubility coatings,
- Reduce use of fertilizers containing anhydrous ammonia,
- Incorporate nitrogen-fixing crops.

The costs associated with all of these alternatives vary needs further examination by the farmer, prior to selecting the most beneficial methods, which may be dependent on the operation.

4.2.5.2 EFFECTIVENESS

Currently, Idaho has about 4.5 million acres of cultivated cropland, 8.5% of the state's total land. Under current state regulations, all cropland acres with manure applied from dairies are mandated to implement nutrient management plans, applying manure according to agronomic rates (crop needs), not to exceed specific levels of nutrients within the soils, and considers water quality concerns. It is expected that eventually all croplands will be required to implement nutrient management. Currently, where federal and state funding is provided to land owners, nutrient management plans are required as well. Further analysis and research is needed to better estimate what each alternative may do in regards to reducing nitrogen losses as a gas.

While improved nutrient management provides multiple benefits, there is much uncertainty as to the amount of nitrogen loss that may be reduced from nutrient management, one estimate of from Lal et al, 1999, and other sources ranges from 0.05 to 0.8 MT CO_2e. For Idaho, an average amount of 0.3 MT CO_2e will be used to estimate a statewide potential.

Assuming that eventually all cultivated cropland acres will be under a nutrient management plan in the future, and assuming that even recent nutrient management plans have not caused any reasonable reductions in nitrogen loss, one may conclude that with 4.5 million acres, 1.4 MMT CO_2e could be achieved. A whole-farm analysis would need to be done to better estimate actual carbon credits available for purchase.

4.2.5.3 ACCEPTABILITY

Of the alternatives described above, fertilization rate, soil testing, and coated fertilizers may be the most widely adopted. Given good soil testing data, rates are more likely to be reduced when a good analysis is done by a certified lab and fertilizer company, if the company recommends lesser rates. Annual soil testing, if it will ultimately improve production and possibly show some net savings, may be adopted readily. However, depending on the crop type, annual soil testing may not be necessary if little or no fertilizer is to be used, such as with pasture or hayland. Coated fertilizers, if effective, are adopted if they do not cost much more than conventional types.

One aspect of nutrient management is that under a conservation plan, developed with state or federal agency assistance, includes this practice. Cost-share programs also require this practice to be implemented and carried out throughout the life of the contract. This practice will likely be applied to all cropland acres within the state through existing future state regulations.

4.2.5.4 COST

The time and inputs used to gain a certain amount of reduction in nitrogen may or may not prove a substantial net gain. Over time, given increased knowledge and experience on a particular farm, long-term costs may be lowered and less nitrogen loss occurring. A long-term farm analysis would be needed to estimate fully the costs of implementing this practice.

4.2.5.5 IMPLEMENTATION CAPABILITY

Some of the alternatives listed, such as soil testing, fertilizer types, and cover crops may not be readily acceptable or even available. Manufacturers must be providing these types of fertilizers to local companies to sell, and then farmers must be willing to pay more for some types. Planting cover crops may require more intensive management on the farmer’s part, fitting in the planting within their normal late summer and fall work. There is usually no immediate return on the cover crop investment, but long-term in reduced pest problems, erosion losses, and other benefits. Some equipment is needed for better placement of fertilizers, which may or may be available to the farmer initially. A change in fertilization equipment may needed to achieve this practice.

4.2.5.6 OPERATION AND MAINTENANCE CAPABILITY

Upon adopting this practice and various alternatives, Operation and Maintenance Capability will likely be slightly more intensive. More soil testing to review, more records to keep, more or different equipment to maintain and understand, and a better understanding of fertilizer types will be important. A few years will be needed for a farmer to perfect the alternatives, while not likely seeing immediate results in soil fertility and net savings.

4.2.5.7 MONITORING AND VERIFICATION CAPABILITY

Intensive soil testing, record keeping and review, and other possible contractual requirements will be necessary to ensure that the nutrient management alternatives are being carried out properly. Monitoring costs can be excessive if allowed, making this practice not as a viable practice compared to others. Because there are really no visual aspects of this practice to check, except application method and timing, it will be difficult to verify that nutrient management indeed reduced nitrogen oxide losses.

4.2.5.8 ANCILLARY BENEFITS

Efficient fertilizer management may reduce nutrient runoff and leaching into surface and ground waters. Less fertilizer costs should occur, but may be offset by more soil testing, more expensive fertilizers, and time spent in record keeping. Measuring the physical benefits from an improvement in nutrient management is very difficult to measure, even at a research facility, therefore, actual benefits and costs are simply derived from simple expectations.

4.2.6 Windbreaks and Shelterbelts

4.2.6.1 DESCRIPTION

This practice is typically a linear planting of single or multiple rows of trees and or shrubs used to reduce wind velocities to reduce wind soil erosion, protect crop plants from wind related damage, manage snow deposition, shelter livestock and for recreational activities, and other uses. See the national NRCS web site for more information (http://www.ftw.nrcs.usda.gov/nhcp_2.html).

4.2.6.2 EFFECTIVENESS

These tree and shrub plantings are very effective in reducing wind velocity, but also provide long-term above and below ground carbon storage. Tillage practices are often used as an inexpensive method of weed control which may limit the amount of soil carbon storage. Longevity in windbreaks depend on maintenance, disease, extreme climatic conditions, and water availability. Irrigation waters are likely needed in semi-arid portions of the state for establishment and maintenance, which can effect the amount of carbon sequestration. Species types will also depend on climatic suitability and will effect the amount of sequestration. 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 need of replanting or rehabilitation.

In Idaho, if there were 22 thousand acres planted, and that for every 50 acres of land, there may be about 2 acres of land planted a windbreak (50 acres = 1476 ft^2), which is 50+ feet wide (= 4% of 50). If 15% all cropland fields maintained windbreaks or similar trees and shrubs, it may sequester nearly 0.3 MMT CO_2/ac/y. A whole-farm analysis would need to be done to better estimate actual carbon credits available for purchase.

4.2.6.3 ACCEPTABILITY

Many land owners in windy areas of the state are adopting windbreaks for wind erosion control and aesthetics. Dairies and feedlots also are utilizing these windbreaks for odor control and aesthetics. Along highly productive cropland fields, these windbreaks are not as acceptable, where wind erosion is not such a problem or can be solved with specific tillage alternatives, where there would be a loss of productive acreage.

4.2.6.4 COST

The cost of installation is expensive, especially in multi-row windbreaks. In semi-arid are of the state, irrigation is necessary for establishment and maintenance of the vegetative species. The carbon sequestered from most any type of woody species may be adequate to offset installation and maintenance costs if such a market exists. Soil stored within the above-ground biomass, roots, and soils within the windbreak area when not disturbed with tillage, may be a viable for credit amount to encourage additional practice installation throughout the state.

4.2.6.5 IMPLEMENTATION CAPABILITY

Semi-arid areas of the state would require irrigation of trees and shrubs for establishment and maintenance of windbreak. The water amount, its application costs, whether pumped from ground or surface water, or applied through gravity systems, and the time required for application may be considered additional time and money spent on little or no monetary return to a landowner that previous may have been seeing some return on investment on that productive portion of cropland. Some dryland areas may support this practice, but again, will depend on water availability.

4.2.6.6 OPERATION AND MAINTENANCE CAPABILITY

Upon establishment, minimal effort and time should be needed for maintenance, except when irrigation water is needed. Depending on the irrigation system, the time involved may still be minimal. Disease and weed control is very important and periodic inspections of windbreak and surrounding area should take place annually.

4.2.6.7 MONITORING AND VERIFICATION CAPABILITY

Determining if a windbreak is healthy and growing adequately should be relatively easy. Measuring annual carbon sequestration may not be feasible, where costs may be inhibitive. Periodic data collection, such as every 5 years, may be effective in understanding the rates of sequestration. A good understanding of the species and its capability of carbon storage may allow for modeling, which may be suitable for a carbon market. Annual inspections of windbreak health and maintenance should be completed, regardless of program.

4.2.6.8 ANCILLARY BENEFITS

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). Wildlife habitat is also enhanced with this practice.

4.2.7 Short Rotation Woody Crops

4.2.7.1 DESCRIPTION

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.

4.2.7.2 EFFECTIVENESS

Poplar plantations have many environmentally desirable applications, including use as buffer strips to decrease erosion and nitrate in runoff from highly erodible fields, for treatment and removal of toxic materials from landfills and other soil contaminations, and as an excellent sink of atmospheric CO_2. The rapid growth of these crops results in high rates of nutrient uptake and large amounts of carbon storage over rotation lengths as short as 5-15 years. Hybrid poplars could store carbon in woody biomass up to a 50-year period until primary production is offset by respiration and decay. As a long-term strategy, trees could be used as heating fuel for livestock buildings, home heating or corn drying, reducing propane or LPG consumption. Poplar trees would provide a similar carbon sequestration rate, but as a monoculture, they would be better managed as a renewable energy crop. A poplar tree buffer strip at Amana, established in 1988 by The University of Iowa, has produced 7.5 tons of dry matter per year after the third season.

If approximately 1 to 2 percent of all cropland converted to short rotation woody crops, for whatever purpose, there could be 0.56 MMT CO_2/y sequestered. A whole-farm analysis would need to be done to better estimate actual carbon credits available for purchase.

4.2.7.3 ACCEPTABILITY

As similar to conservation buffers and windbreaks, there would be replacement of cropland with long-term woody crops. However, this crop would take larger tracts of land, likely entire fields, for effective management and adequate net returns on the investment.

4.2.7.4 COST

While it seems there a substantial sequestration of carbon in woody biomass from poplar trees, switching to a long-term crop means eliminating the annual income from an annual crop. Therefore, farmers would need to adjust to larger payments, but fewer of them. Initial investments may not justify adopting this crop where the operation has been funded through annual harvest of crops and market prices. It is most likely that if such a market exists for a long-term crop, though a short period of growth for woody species, landowners would be more open to substituting annual crops with short-rotation woody species if the guarantee of payment is there. If irrigation water is continued to be used, the costs may not be recaptured until harvest, some years later.

4.2.7.5 IMPLEMENTATION CAPABILITY

There must be a market for these short-rotation woody crops. Local markets and infrastructure must be available and viable to process the biomass produced on small or large tracts of land, from multiple landowners. Harvest and transportation mechanisms must be in place so that the market for these crops is sustainable. Landowners will need the finances to establish this crop, while not likely receiving any return for at least 10 years until harvest. Adjustments in the typical crop management will need to take place, which include fertilization, pest control, and watering if in semi-arid parts of the state. Long-term contracts may not be as acceptable, or may, with landowners where if a crop failure occurs, replacement will be expensive.

4.2.7.6 OPERATION AND MAINTENANCE CAPABILITY

The trees can re-sprout (coppice) if allowed so there may be no need for replanting unless required by market demands. Replanting may be necessary to maintain some level of genetic purity. Harvesting equipment would need to be available, along with narrower light tillage equipment if other non-tillage, herbicide based weed control is difficult or restricted with woody crops. Adequate fertilizer and water needs will need to be met to ensure a minimum level of growth and sequestration. Some pruning may be needed if for a specific production.

4.2.7.7 MONITORING AND VERIFICATION CAPABILITY

Annual inspections of growth and health will likely take place if there is a market contract in place. Land owner and operator management will likely be more intensive to ensure a good return on investment, which with record keeping, may provide a greater amount of certainty of verification.

4.2.7.8 ANCILLARY BENEFITS

Planting trees within agricultural lands will benefit water quality, soil, groundwater, and wildlife habitat, while sequestering carbon dioxide in woody biomass. Poplar plantations have many environmentally desirable applications, including use as buffer strips to decrease erosion and nitrate in runoff from highly erodible fields, for treatment and removal of toxic materials from landfills and other soil contaminations, and as an excellent sink of atmospheric CO_2. Gasified poplar biomass could also be used as heating fuel for livestock buildings, home heating or corn drying (reduces propane or LPG consumption).

4.2.8 Crop Residue Alternative Uses

4.2.8.1 DESCRIPTION

Where there is open burning associated with agricultural practices, a number of greenhouse gases (GHGs) are emitted from combustion. All burning of biomass produces substantial CO_2 emissions, however, the CO_2 released is not considered to be net emission. The biomass burned is generally replaced by regrowth over the subsequent year. An equivalent amount of carbon is removed from the atmosphere during this regrowth, to offset the total carbon released from combustion. Therefore the long term net emissions of CO_2 may be considered zero. Agricultural burning releases other gases in addition to CO_2 which are by-products of incomplete combustion: methane, carbon monoxide, nitrous oxide, and oxides of nitrogen, among others. These non-CO_2 trace gas emissions from biomass burning are net transfers from the biosphere to the atmosphere. The majority of cropland related burning in Idaho comes from bluegrass and wheat stubble.

The potential usefulness of agricultural waste or residue could include composting, alternative (biomass) fuels, livestock feed supplements, substitution for paper or wood products, or building materials. Such applications require the mechanical removal of residues from the field. While compliance with some commodity support programs may prohibit this removal, if no conflicts or restrictions exist the crop residues can be used and marketed in a variety of ways.

Composting involves gathering agricultural wastes and setting them aside to decompose. Residue collection methods with this application include raking, residue flail-chopping, and vacuuming into sacks with soil and nitrogen sources such as chicken manure, and crew-cutting. After the waste has decomposed, the decayed material can either be marketed or returned to the soil as fertilizer. Composting can be relatively time-consuming compared to burning. The level of effort necessary for a productive program depends on several factors, including decomposition rates and weather and moisture conditions. Also, the process of large-scale composting is not fully understood or refined. The Agricultural Research Service (ARS) in Corvallis, Oregon, is researching the effectiveness of low-input composting and ideal composting procedures.

Agricultural crop wastes such as grass straw can be collected and sold in a supplemental feed market. The straw must be gathered, baled, stored, and compressed so that it can be shipped on order. This practice is currently one of Oregon's primary alternatives to burning. Approximately 150,000 - 250,00 tons of straw are shipped to Japan each year (Britton, 1992). Untreated straw makes for poor quality livestock feed because of low protein and high fiber content. With appropriate treatment (*e.g.*, ammoniation), the digestibility and palatability of straw can be increased substantially, making straw a potential component of maintenance diets for ruminant livestock.

Residues can also be gathered for fiber or building materials. The University of Illinois has been studying the fiber quality and chemical composition of corn stalks and corncobs grown in Illinois and the potential of agricultural waste fibers in producing composite construction materials. Studies on fiber properties showed that corn stems (core and outer layer in general) are a promising substitute for traditional fiber sources (Chow, et. al., 1997). Weyerhauser, a paper and lumber company, is investigating the possibility of using agricultural residues as filler in particle boards.

4.2.8.2 EFFECTIVENESS

Most alternatives that eliminates burning should provide some greenhouse emission reductions (CH_4, CO, N_2O, NOx). However, the selected alternatives, such as harvesting those crop residues that would have been burnt, may have additional equipment usage associated with it that may increase nitrous oxide emissions from the farm. Any additional equipment usage that wouldn't have normally occurred under the current burning operation, may in fact offset a portion of the emissions no longer being released through burning. Net emissions need to be calculated to determine if this practice is a viable alternative.

To calculate what amount of emissions may be reduced, depends on the amount currently lost due to burning, with its use considered after. Factors used in determining emissions are:

- Amount of crops produced with residues that are commonly burned;
- Ratio of residue to crop product;
- Fraction of residue burned;
- Dry matter content of residue;
- Fraction oxidized in burning; and
- Carbon content of the residue.

Idaho has approximately 1.2 million acres of wheat (Ag statistics 2001 data), 670,000 acres of barley, and about 35,000 acres of bluegrass. If 150,000 acres of wheat, barley, and bluegrass are burned annually (12.5% of those crops), and all burning was eliminated, total net emission reductions could be nearly 0.5 MMT CO_2e/y. This estimate is simply looking at annual net emissions derived from burning. It does not factor in long-term benefit or what change in cropland residue management may occur following a no-burn situation. A whole-farm analysis would be needed to estimate actual net reductions in emissions, where alternatives would likely increase fossil fuel use for residue collection, transportation, and production. Depending on its ultimate use, net reduction in emissions will vary. The equation used to estimate the potential can be found in Appendix 7.

4.2.8.3 ACCEPTABILITY

It is much less expensive to burn excess residues than to operate equipment to collect and transport residues for other uses. If residue were incorporated into soils, additional tillage would be needed, which may not be acceptable. Where technology has not completely satisfied operators with effective alternatives to burning, it is likely that burning will continue to be the most economical and successful alternative for production, especially for bluegrass. Air quality regulations will likely cause farmers to further evaluate alternatives to burning rather than a climate change program or carbon market, unless, of course, incentives are large enough.

4.2.8.4 COST

With the amount of national emissions being contributed to agricultural burning is very low, the global benefits to reducing burning may also be low. The costs involved with adopting a practice that no longer involves residue burning will likely be higher and the net benefit to the farmer from adopting this practice is not yet well known. There may likely be some production loss in the case of bluegrass production, but the market demand may be offset by increasing acres of this crop. Regardless of the alternative, initial costs to the producer will increase.

4.2.8.5 IMPLEMENTATION CAPABILITY

Switching to a no-burning alternative may not be easily implemented, especially if the residues are collected for alternative uses. Marketing these residues in Idaho or anywhere within the United States may be more difficult than in foreign markets due to the erratic and competitive nature of U.S. markets. Combustion for heat generation may be the most appropriate means of replacing fuel oil with residues, because much less investment is necessary compared to replacing fuel oil in power generation. Also, the total maximum efficiency of the power produced by means of a turbine or steam engine is approximately 15 percent, even though the combustion of biomass can be accomplished with high efficiency (Strehler and Stützle, 1987). The disadvantages of gasifiers include a high particulate and tar content of the gas. Furthermore, current gasifier designs do not accept all types of crop residues. Finally, after biomass burns, a silicate remains, creating a sludge problem that inhibits acceptance of residues as an alternative fuel.

When considering residues as alternative sources for paper and fiber products, major retooling in the wood fiber industry may be needed because wood chips do not require storage from rainy weather, whereas residues would need protection from the climate during storage. Despite this, however, grass straw is becoming a more economically attractive alternative to using hardwoods. The reason for this is the projected shortage of hardwoods in the near future and the fact that straw fibers from grass seeds are very similar in structure to hardwoods.

4.2.8.6 OPERATION AND MAINTENANCE CAPABILITY

Tillage and residue collection activities will change how the farmer operates. If there is no source demanding the residues, then significant changes in tillage practices will occur to deal with the residue.. As with any new operation and facilities, there will be substantial oversight to ensure that it is functioning properly and meeting its objectives. There will increased costs to the operator that will need to be offset by the sale of its product, possibly coming in the form of incentives from government or other carbon market participants.

4.2.8.7 MONITORING AND VERIFICATION CAPABILITY

Depending on the selected alternative here, continual monitoring to ensure operation and maintenance is occurring properly is foremost. Verification of actual emissions reductions may be estimated by the elimination or reduced level of residue burning. A quantity of emissions reduced on a per acre bases may be used primarily in conjunction with monitoring to calculate an actual emission reduction, sellable through a carbon market. Specific requirements for monitoring are likely to ensure that estimated emission reductions are occurring. Verification will likely not occur frequently due to costs and its research-like process. Satellite or aerial photography may be a feasible method of tracking its implementation. Monitoring the use of the residue will be addressed in the bioenergy section.

4.2.8.8 ANCILLARY BENEFITS

Fewer air quality concerns and complaints, actual emission reductions through less burning, higher facility and equipment operation costs and time input, reduced potential soil erosion on burnt land, and other benefits and costs may occur. Further research and analysis is needed for each alternative to better understand costs and benefits. If residues are used for co-fired energy or long-term products, then additional benefit may be known. Health issues would also be resolved with this practice.

4.2.9 Alternative Burning Techniques

4.2.9.1 DESCRIPTION

A number of alternatives that still involve burning might reduce emissions. This can be accomplished, for example, either by creating a hotter, more controlled burn that combusts crop residues more thoroughly, or by reducing the frequency of burning in conjunction with mechanical crop removal techniques. Technologies and methodologies to achieve these objectives include mobile field sanitizers, propane flaming, bale/stack burning, reduced burning and crewcut-vacuum sweeping. Further research is needed to truly identify those alternatives that are certain to reduce emissions generated from burning. Eliminating or reducing burning might reduce daily greenhouse gas emissions but the long-term benefit is not yet fully apparent. Other alternatives are being studies and may provide better alternatives than these below.

Mobile Field Sanitizer. This is a machine designed to burn agricultural residues in place. It serves as a method of both straw removal and field sanitation.

Propane Flaming. Propane flamers consist of a propane tank and a series of nozzles. The propane is released, ignited, and directed at ground level. Because straw residue must be removed first for this method to be effective, this technique is typically used with other disposal methods such as bale/stack burning.

Bale/Stack Burning. Bale/stack burning, the collection of crop residues into bales or stacks to facilitate controlled burning, is a companion practice to propane flaming (which requires straw removal). Some growers have turned to bale/stack burning to dispose of unmarketable crop residues.

Reduced Burning. This involves alternating open field burning with various methods of mechanical removal techniques. Reduced burning would involve burning every second or third year instead of annually.

Crewcut-vacuum sweeping. University of Idaho researchers have conducting production research under a system that does not include burning of post-harvest residues, but mechanical residue removal systems. Seed yields in bluegrass seed production ranged from 400 to 1000 lbs/ac under this mechanical system, which results in similar yields under burning systems. This is a promising alternative to burning which would reduce emissions.

4.2.9.2 EFFECTIVENESS

There are uncertainties regarding net impact on greenhouse gas emissions from each of these alternatives, as well as crop residue burning. While field tests have shown that sanitizers can reduce carbon monoxide and hydrocarbon emissions, their applicability appears limited. While propane flaming are thought to bring about a slight reduction in emissions when used together, they are much more time consuming than open field burning. If most of the straw residue is removed prior to flaming, this technique should not result in major seed yield losses. Bale/stack burning may result in slight reductions in emissions, but is more time consuming than open field burning.

These alternatives to burning would yield similar reductions in emissions as would the non-burning alternative uses of residues, except, these residues may or may not be removed physically from field, which then could be used for further biomass power generation or other uses. If reduced burning to every 2nd or 3rd year, then emission reductions would be reduced respectively. Eliminating burning, such as discussed within the alternative residue uses above, might provide the greatest emission reductions, but depends on its use. These alternatives may reduce daily greenhouse emissions, but it is not clear on long-term benefits.

4.2.9.3 ACCEPTABILITY

Developing or purchasing field sanitizers and propane flamers, as well as stockpiling excess residues, have high costs that may not be feasible. The uncertainties of these methods on their effects of crop production (as with bluegrass seed) and actual net emission reductions may keep the acceptance level low. Adoption of any practice by a farmer or even other carbon market participants looking to offset their emissions will be limited to the available data regarding their impacts. To the farmer, little or no loss in production and greater net returns are to be confidently expected prior adoption. The buyer of carbon credits must be certain that the practices are going be effective, delivering what has been promised through research and confidence in the seller. The expectation of these practices being widely adopted is low due to the uncertainties and high costs.

4.2.9.4 COST

Technical and economic evaluations of field sanitizers have found problems with high operating costs, durability, maneuverability, energy use, and operating speed. Based on these studies, many states have discontinued research and development of mobile field sanitizers, although there has been some success with their private development.

Where high value crops exist, propane flaming may be found economical to develop and maintain the sanitizer. However, typically, the high costs associated with development frequently prevent other farmers from pursuing this option.

4.2.9.5 IMPLEMENTATION CAPABILITY

There are a number of uncertainties that limit the applicability of some alternative burning techniques. For example, mobile field sanitizers have not been fully developed and have proven successful only in isolated cases. The technical problems associated with field sanitizers mentioned above need to be addressed before widespread acceptance of this option can be expected. Similarly, improvements in techniques like propane flaming may be required to make it an attractive alternative. For example, studies have shown that because of the temperature and duration of propane flaming, many of the weed seeds are not destroyed, ultimately resulting in increased weed infestation (U.S. EPA, 1992b). Moreover, the fossil energy inputs required for these techniques emit greenhouse gases, so the net effect on emissions is not clear. These problems will need to be addressed in order to facilitate acceptance of these alternatives.

4.2.9.6 OPERATION AND MAINTENANCE CAPABILITY

With additional equipment there comes additional operation time and maintenance, thus greater costs. There would also be a greater emphasis on operation and its procedures to ensure successful crop production, while not burning with the same technique used for decades. There will be a great of amount of self education required by each farmer adopting these practices, before and during operation.

4.2.9.7 MONITORING AND VERIFICATION CAPABILITY

Record keeping on operation times and location, which would coincide with the crop rotation, will provide most of the information necessary to ensure emission reductions are to occur. Field verification periodically upon operation completion may occur to ensure compliance while under a contract. Remote sensing may also provide for monitoring. Actual verification of emission reductions may be very limited due to costs and its research oriented procedures.

4.2.9.8 ANCILLARY BENEFITS

Less burning will provide for cleaner air during periods that burning typically occurred. Fewer citizen complaints and lawsuits should occur as well. Costs of operation will likely rise which could be offset within a carbon market. Better ground cover with alternative perennial crops, primarily during the winter months, can reduce soil erosion, thus improving the quality of local water bodies.

4.3 RIPARIAN/WETLAND AREA ACTIVITIES

4.3.1 Riparian Forest Buffers

4.3.1.1 DESCRIPTION

These buffers are largely areas consisting predominantly of trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies, usually associated with croplands and pastureland. Rangelands, forest lands or other those lands not as effected by farming practices, would most likely be addressed by riparian conservation/restoration practices, discussed later. Where windbreaks are designed to reduce wind velocities and odor, these buffers are likely more diverse in species types and planting arrangements. These buffers are meant to help improve stream-side riparian conditions, filter upland runoff to water bodies, and provide in-stream benefits, such as cooler temperatures and riparian area habitat diversity. These buffers would not be planted within the water body itself, as would the channel vegetation practice.

4.3.1.2 EFFECTIVENESS

Where woody vegetative species are planted and maintained for long periods of time, carbon storage is certainly to increase. Diversity in buffer strip vegetation is beneficial for natural succession and health. Above-ground biomass and root carbon storage will depend on vegetative species types. Further research is needed to better quantify the effectiveness or these buffers, primarily their effect on soil carbon.

However, with some preliminary estimates on forested, above-ground biomass, some estimate of sequestration may be made. There are approximately 70,000 miles of perennial streams in Idaho, associated with private and state lands. Some of these streams are actually artificial drainages which may have been naturally intermittent or perennial, but altered in shape and flow. These are usually found within private irrigated areas (derived from GIS shapefile query with idown.shp and hydro100.shp, found at http://www.idwr.state.id.us/ftp/gisdata/shapefiles/statewid/).

If riparian buffers consist of about 6 acres per mile of length, and 1 to 2% of available croplands installed buffers, then this amount of newly forested land would sequester about 49,000 MT CO_2/y. A whole-farm analysis would need to be done to better estimate actual carbon credits available for purchase.

4.3.1.3 ACCEPTABILITY

Where riparian areas are continually grazed or used for other purposes, buffer strips are not as likely to be adopted without assurance that the existing use may continue. Buffer strips, installed through cost-share programs, usually require some or complete protection during establishment, possibly throughout its lifespan. Woody species may reduce the amount of herbaceous grass-like riparian species once shading has increased, which may not be considered a benefit for livestock grazing. Other benefits of riparian health that can come from buffers may be realized through increased wildlife and fisheries populations, though not easily accounted for. Where irrigation waters and diversions are a part of the water corridor, drainage districts, irrigation companies, and private landowners may have some maintenance rights and continual activities that may not be suitable for buffer installation. Within forested areas, the Forest Practices Act requires some buffering along riparian areas, therefore, acceptance here may not be a factor.

4.3.1.4 COST

Installation costs are relatively high, depending on species types, density, and availability. If adequate surface and ground water is available, then establishment and maintenance should require less input and replacement may be less. Fencing may be required where grazing has been occurring, which may increase installation and maintenance costs. The amount of carbon sequestration may offset these costs if the market exists.

4.3.1.5 IMPLEMENTATION CAPABILITY

Climatic conditions, drought tolerance, perennial flows, grazing and other uses, installation and maintenance costs and other factors would likely be considered barriers to implementation of riparian buffers. Any potential loss of existing use would likely be considered a negative aspect to a landowner. Establishment costs may be prohibitive where a quantity of vegetative species water availability is limited. Fencing exclosures, if required, would likely not be acceptable to most ranchers, as there an additional maintenance burden and may be considered a permanent loss of riparian use.

4.3.1.6 OPERATION AND MAINTENANCE CAPABILITY

Upon establishment of vegetative species and appurtenances, such as fencing, operation is likely rather simple, but maintenance will ongoing, especially within areas with highly reoccurring fire hazard. Fire prevention, such as thinning and annual grass and weed control may need to take place. Fencing, if a required component, would be maintained to ensure no or limited access by livestock. Where grazing is allowed or some other use, restrictions are likely to be in place, requiring the landowner further inspections and a higher level of management to ensure vegetative species health. Soils would need to be protected for minimal erosion and compaction as well.

4.3.1.7 MONITORING AND VERIFICATION CAPABILITY

Annual inspections would likely be necessary to ensure vegetative species health. Water body and flood area stability would need to be evaluated to determine if flood waters would cause excessive erosion or harm to vegetation. Some periodic soil and vegetation carbon analysis may be necessary to ensure sequestration is taking place at a given rate or expected quantity, specified within a contract. Fencing and grazing management records may need to be inspected to ensure maintenance is taking place as prescribed within a contract between parties.

4.3.1.8 ANCILLARY BENEFITS

Tree growth is accelerated in riparian zones due to favorable moisture and nutrient conditions. When buffer 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 upland activities. Wildlife habitat is greater enhanced, for multiple species, depending on vegetative species and management.

4.3.2 Riparian conservation/restoration

4.3.2.1 DESCRIPTION

This practice includes management that enhances, preserves or restores stream-side vegetation. Typically, this practice is implemented to improve stream bank protection and increase flood zone areas. This helps prevent erosion and siltation of the streams, and maintains habitat for fish and wildlife. Since the effort promotes vegetative growth, it provides an opportunity for carbon sequestration.

4.3.2.2 EFFECTIVENESS

Riparian areas benefit greatly from increased woody vegetation, if in the proper setting. Some riparian areas are not suitable for long-term production of woody species due to anaerobic conditions caused by flat valley bottoms, sinuous stream channels, and low gradients, such as with natural wetlands. Where found appropriate for long-term growth and natural regeneration, riparian areas could provide additional carbon sequestration.

Similar to riparian buffers, some preliminary estimates on forested land carbon sequestration may be made. The difference between buffers and this practice is that riparian areas may continue to be grazed. With prescribed grazing practices, riparian vegetation may be kept at a particular threshold, such as a 50/50 combination of grass (forage) and trees (mainly riparian shrubs). With there being approximately 70,000 miles or less of private and state land perennial streams in Idaho then an estimate of carbon sequestered within riparian areas can be made. If the average width of the entire riparian area (both sides of stream) is nearly 70 feet, then a riparian conservation system per mile may consist of 9 acres. If up to 35% those private and state riparian lands a riparian conservation project, then there could be up to about 0.3 MT CO_2/y. If public lands were included, this amount would increase substantially. A whole-project area analysis would need to be done to better estimate actual carbon credits available for purchase.

4.3.2.3 ACCEPTABILITY

Many streams in Idaho are on public land or are not easily reached. Unless initiated by the landowner, a large amount of riparian plantings for additional carbon storage will not likely occur. Riparian areas utilized by livestock are not as likely to be planted to achieve increased woody species. Where riparian areas are used for recreation, then areas may be more susceptible for actual plantings, where the public are more aware of the existing conditions. Non-planting riparian improvements may likely occur more frequently in areas not easily reached.

Some riparian areas within irrigated portions of the state have been altered for irrigation drainage purposes and are within a drainage district or canal company jurisdiction, which enables channel cleaning.

These areas are not likely going to be planted with woody species or allow for intensive riparian conservation due to existing maintenance procedures.

4.3.2.4 COST

The benefits in increasing or changing from one herbaceous, grass-like vegetative species to a woody species would increase carbon storage, primarily in biomass. Ancillary benefits, if used in cost analysis, would hopefully return high. Costs of planting, additional fencing components, livestock watering facilities, and other measures to ensure long-term growth and protection would initially be high. Thus low acceptability by landowners. However, if long-term analysis is used, looking into future benefits, such as aesthetics, increased wildlife, reduced pressures from outside interests in protection of riparian areas, should outweigh initial costs, especially if cost-share programs or incentive payments are provided to assist in the implementation of this practice. Maintenance and operation costs would need to be expected to effectively assess cost in the long-term.

4.3.2.5 IMPLEMENTATION CAPABILITY

With natural perennial stream areas, riparian improvements are more likely achievable. Water availability is absolutely necessary, over long periods of time, for carbon sequestration and storage to continue. If beaver activity subsides due to trapping or other natural reasons, beaver dams are going to eventually fail, lowering the adjacent water table, then no longer available to young woody species necessary for natural regeneration. The woody species would eventually be replaced with non-hydrophytic upland species, while the active floodplain much more narrow, reducing the quantity of woody species.

Cost-share programs, easements, continuous payment programs (such as continuous signup CRP) are needed to encourage landowners to improve riparian areas. Some landowners, however, do improve riparian areas with woody species for various reasons, such as aesthetics and wildlife. Given a purpose and the funding, landowners may adopt this practice is maintenance requirements is low. In areas with natural regeneration capability, there may be easier implementation.

4.3.2.6 OPERATION AND MAINTENANCE CAPABILITY

If water availability is fairly constant, riparian woody vegetation can be maintained. Where livestock use is eliminated, there will generally be a natural succession to mature woody species, unless soil conditions are super-saturated. Maintenance of riparian areas may be dictated by a contractual agreement, consisting of a specified level of carbon flux or ultimate storage. Fire management tools, livestock grazing, and other practices may be utilized to ensure a minimum rate of carbon flux, but care will need to be taken so that excessive utilization of vegetation does not occur.

4.3.2.7 MONITORING AND VERIFICATION CAPABILITY

Periodic inspections of riparian areas will be needed to ensure good management is occurring and that woody species are vigorous and regenerating. Annual grass species, weeds, insects, and disease will need to be looked for to prevent excessive damage or loss to the desired species. Floodplain management will also need to occur through proper streambank protection and conservation of vegetative species. Records would likely need to be kept on livestock and other uses to ensure long-term maintenance is occurring.

Actual verification of carbon sequestration may be difficult, even if monitoring is completed. Measuring tree growth within non-shaded, highly wet, riparian areas may be difficult compared to a forest setting where shrub-like species will generally dominate, making it difficult to estimate the quantity of biomass.

4.3.2.8 ANCILLARY BENEFITS

Enhanced wildlife habitat, aquatic habitat, bio-diversity, streambank stability, aesthetics and other benefits are realized through riparian improvements. Social pressure on land users and mangers may also be realized with ongoing and progressive riparian improvements and maintenance. Within state lands, there could be additional areas for recreation, possibly on private lands if authorized by the landowner.

4.3.3 Constructed or Restored Wetlands

4.3.3.1 DESCRIPTION

These wetlands, whether artificially developed or restored back to its natural state, can provide hydrophytic vegetation that can sequester carbon. Constructed wetlands are primarily built for water quality treatment. A restored wetland is simply within an area once a natural wetland, having been drained for other purposes, converted back to its pre-developed state.

4.3.3.2 EFFECTIVENESS

The effectiveness of a wetland in sequestering carbon in the vegetation and hydric soils, will be variable, depending on species, soils, climatic area, and management. With constructed wetlands, they may not always be operated year-round, where maintenance may be required to keep its capacity and vegetation within a specific age class. There are likely more water fluctuations in constructed than with a natural wetland because of their purpose, where storm and irrigation wastewater runoff is generally treated. Further research will be needed to determine general carbon sequestration effectiveness.

Ogden 2001 examined the potential effectiveness of waste treatment constructed wetlands and though the carbon cycle is extremely complex and rates of net carbon retention or sequestration are difficult to measure, he submitted a formula to estimate rates for wetlands in south eastern US. states. For a 9-10 acre wetland, treating about 1 million gallons a day (MGD) of effluent, would sequester about 0.35 MT/acre/yr. Ogden does discuss the uncertainties and further research needed to better estimate rates. Nitrogen availability and metabolic activity are such variables.

If Idaho were to install and maintain 7,500 acres of wetlands in the state, then 2,625 MT CO2/y could be sequestered. A whole-project analysis would need to be done to better estimate actual carbon credits available for purchase.

4.3.3.3 ACCEPTABILITY

The type of wetland and the area it may be developed in may be a factor in its acceptability. In irrigated areas of the state, irrigation districts and canal companies are becoming more acceptable of the constructed wetlands to treat waste water runoff, prior to it entering water bodies. This acceptance is largely due to the potential of future regulation under the Clean Water Act, which impacts water quality improvements in both point and nonpoint source activities. Natural wetlands that were drained for other purposes, such as cropland or urban development, may not be converted back to its pre-development state very easily, especially those under urban development. If very little structural work is needed to convert it a wetland once again, then there may likely be a higher acceptance level, if the current land use profits are offset. Wildlife and other benefits may be enough to convince some landowners to revert the land back into its pre-development state. With the recent outbreak of the West Nile Virus, landowners wishing to install these wetlands may face community resistance.

4.3.3.4 COST

These constructed wetlands are generally very expensive to install, generally in the millions of dollars for large systems. If few structural modifications are needed to build or convert land into a wetland, then the cost should be much lower. Without knowing site-specific information and having a design in hand, construction, operation, and maintenance costs are unknown.

4.3.3.5 IMPLEMENTATION CAPABILITY

There may not be many constraints to building or restoring a wetland in soils and climates that are already suitable. Building a new wetland where soils are not suitable to hold water, such as in sandy soils, there would be a great cost to line the bottom of the holding ponds. Adjacent lands, possibly not owned by the same owner, may be impacted by raised water tables because of a new wetland. Engineers usually determine water tables and a wetland's impact on surrounding areas, so there may be enough information to keep the wetland from being built. If a new wetland has been built, and neighboring lands are becoming wet, there will likely be complaints and legal action to ratify the situation.

4.3.3.6 OPERATION AND MAINTENANCE CAPABILITY

With any new practice, there comes additional operation and maintenance. Constructed wetlands are certainly a practice that requires annual maintenance, and a good understanding of its operation to perform as designed. Natural wetlands should not require much maintenance, accept repairs due to storm or flood events. If a certain climax vegetative community is to be maintained, then maintenance may be increased where vegetative species are replaced to re-start the natural succession of species. Excessive soils and vegetative growth may need removed periodically to ensure that the wetland is functioning according to its design.

4.3.3.7 MONITORING AND VERIFICATION CAPABILITY

Constructed wetlands inflows and outflows are measurable because the are usually designed for such activity. Measuring for sequestration may nearly impossibly except with intensive research methods, which would likely be cost-prohibitive. Verifying that sequestration actually occurred for a period of time may only be feasibly based on typical rates of carbon flux per species. A wetland could easily be inspected annually to ensure that operation and maintenance is occurring.

4.3.3.8 ANCILLARY BENEFITS

Waterfowl, wildlife, water quality, and other natural resource improvements can be achieved with wetlands. Increased waterfowl may be hunted near and around the wetlands, which may increase the landowner's profit margin, and provide funds for operation and maintenance. Where constructed wetlands are installed, operators that treat upland land user's waste waters may, if legally capable, charge annual maintenance fees to offset costs of operating the wetland. The property in which the wetland is built may have tax incentives or property tax adjustments which may increase or decrease property values.

4.4 GRAZING LAND ACTIVITIES

4.4.1 Prescribed Grazing

4.4.1.1 DESCRIPTION

This is a practice of a controlled harvest of vegetation with grazing or browsing animals, managed with the intent to achieve a specified objective, such as weight gain for beef cattle and weight and health maintenance of dairy cattle. In regards to carbon sequestration, improvements of vegetative stands or seeking additional diversity of species may be the objective, which may increase below-ground carbon storage (soils, roots). See the Idaho NRCS web site for additional information on this practice: http://www.id.nrcs.usda.gov/Engdwnld/construction_specs.html.

4.4.1.2 EFFECTIVENESS

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). 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. Given current research, some caution seems in order when considering carbon sequestration potential on grazing land.

Schuman et al. 1999 showed that well managed grazing of mixed grasses on rangelands may increase carbon storage by 0.13 tons, compared to non-grazed exclosures. This evidence needs explored further to better estimate carbon sequestration and ancillary benefits.

Idaho has about 4.9 million acres of rangeland and pastureland, in which prescribed grazing could be implemented. If 50% to 75% of those private and state lands were in poor condition, and this practice was implemented, then up to 0.67 MMT CO_2/y could be sequestered after conditions became good. A whole-ranch analysis would need to be done to better estimate actual carbon credits available for purchase.

4.4.1.3 ACCEPTABILITY

Where improved grazing management is seen as a benefit to a livestock operation, primarily in weight gain and health, this practice may be well accepted. This practice is prescribed, however, on rate and physiological conditions of plant growth, which will set vegetative use in amounts and timing. Depending on available soil water and climatic conditions, this practice may be difficult to meet when livestock numbers are not adjusted for lesser vegetative quantities. Continuous monitoring or livestock use, fencing, and other component practices, such as watering facilities, may likely al be necessary to fully achieve this practice's objectives. Installation costs of fencing and watering facilities to achieve a prescribed grazing objective may be high, possibly cost prohibitive, unless phased in over several years. Additional herding time is necessary regardless of additional structural measures, which will raise management costs. Maintenance costs will also rise with additional structural components. Livestock production gains and other natural resource benefits may be adequate in some operations however that may provide a higher level of acceptance, though not easily seen in the short-term.

4.4.1.4 COST

The initial start-up costs, installation of component practices to effectively meet a prescribed grazing plan may or may not be offset by the level of carbon sequestration gained through a carbon market. Further analysis is needed on pasture and rangeland grazing systems to determine carbon storage rates to better describe a cost.

4.4.1.5 IMPLEMENTATION CAPABILITY

Installation costs of component practices, additional herding management, fire prevention measures, and the likelihood of having to reduce livestock numbers and duration of grazing on pastures are likely to be barriers to a rancher in adopting this practice. There is still much uncertainty with how much carbon sequestration can occur on range and pasture lands under specific vegetative species, regardless of grazing practices. Monitoring this practice will likely rely mostly on records and some field investigations, which are not always reflective of overall health of vegetation and grazing management. The success of existing grasses may also limit the success of this practice. Native and introduced grasses will likely differ in carbon sequestration, operation and maintenance.

4.4.1.6 OPERATION AND MAINTENANCE CAPABILITY

Prescribed grazing is an intensive grazing management system for a rancher. Additional hands may be needed for herding, and fencing, if not already in place. Maintenance costs are higher because of additional structural components, such as fencing and watering facilities. Grazing timing is very dependant on water availability and climatic condition sin regards to vegetative growth and dormancy. Disease control and preventive fire measures need considered to maintain healthy stands of vegetation to meet contractual provisions likely to be enforced through any carbon market.

4.4.1.7 MONITORING AND VERIFICATION CAPABILITY

Keeping to a prescribed grazing plan may be difficult as well as its monitoring. Verification is likely to be even more difficult. Record keeping would likely be the primary means of monitoring with some field site inspections on vegetative health and characteristics. For carbon sequestration, soil testing would likely be needed to establish baseline conditions and then future levels. Further research and discussion needs to be accomplished to best estimate carbon sequestration potential on rangeland and pastureland species, soils, and grazing techniques, which would then assist in the development of a monitoring plan.

4.4.1.8 ANCILLARY BENEFITS

Any improvements on upland and riparian sites, regarding vegetation and soil stability, will benefit multiple natural resources. Less soil erosion, improved water quality, improved wildlife habitat, improved riparian habitat for multiple wildlife and aquatic species, greater livestock weight gain, and other benefits are sure to be achieved, though not immediately recognized. If livestock numbers are reduced or managed in such a manner that improves rangeland conditions, public pressures would likely decrease on ranchers, especially on public lands.

4.4.2 Range and Pasture Planting

4.4.2.1 DESCRIPTION

This planting practice is to establish native or acceptable introduced vegetative species on range and pastureland, such as grasses, forbs, legumes, and trees. In regards to carbon sequestration, improvements of vegetative stands or seeking additional diversity of species may be the objective, which may increase below-ground carbon storage. Above-ground carbon sequestration may be short-term and needs further analysis. See the Idaho NRCS web site for additional information on this practice:

http://www.id.nrcs.usda.gov/Engdwnld/construction_specs.html. Refer to Range Planting, Pasture and Hay Planting, and Upland Wildlife Habitat Management standards.

4.4.2.2 EFFECTIVENESS

The replacement of poor condition pasture or rangeland grasses and weeds to native or site-appropriate species, such as crested wheat, basin wild rye, and sage brush in sage-steppe regions or high quality grass forages on irrigated or dryland pastures, some amount of sequestration is sure to occur. The amount of course, depends on previous conditions, water availability, and species planted.

If Idaho replaced poor condition pasture and rangeland acres with the most appropriate and likely successful vegetative species, which may include some woody species, sequestration rates may be somewhat higher than under a prescribed grazing practice. If 2-5% of pasture and rangelands were re-planted and maintained, then there might be about 0.07 MMT CO_2/y sequestered. A 20-25% application would yield 0.5 MMT CO_2/y. Further research is needed to really predict what replanting rangelands to native or improved introduced vegetative species would do regarding carbon sequestration. A whole-project analysis would need to be done to better estimate actual carbon credits available for purchase.

4.4.2.3 ACCEPTABILITY

Improving existing range and pasture stands, through replanting or over-seeding, is likely always acceptable, because of the direct benefit to livestock and wildlife. Depending on available soil water and climatic conditions, the specie to be planted will vary. Livestock use, fencing, and other component practices, such as watering facilities, may likely be necessary for the establishment of new stands, unless grazing is completely deferred a couple of years. Installation costs of fencing and watering facilities to achieve a prescribed grazing objective may be high, possibly cost prohibitive, unless phased in over several years. Maintenance costs will also rise with additional structural components. Livestock production gains and other natural resource benefits may be adequate in some operations however that may provide a higher level of acceptance, though not easily seen in the short-term. Wildlife habitat should also be improved and species populations may or may not respond quickly depending on planted species and other conditions.

4.4.2.4 COST

The initial planting costs, along with any additional installation of component practices to effectively protect the new plantings the first year or two, may be offset by the level of carbon sequestration gained through a carbon market, but only likely through a long-term period. Further analysis is needed on suitable pasture and rangeland vegetation species to determine carbon storage rates to better describe a cost.

4.4.2.5 IMPLEMENTATION CAPABILITY

Planting costs, additional prescribed grazing requirements, fire prevention measures, and other non-typical operation factors are likely to be barriers to a rancher in adopting this practice. There is still much uncertainty in regards to how and what level of carbon sequestration can occur on range and pasture lands under specific vegetative species, regardless of grazing practices. Monitoring this practice will likely rely mostly on records and some field investigations, which are not always reflective of overall health of vegetation and grazing management. Conversion of grazing land to a permanent cover without grazing, if considered an alternative here, may be not be acceptable by the rancher due to the reduced number of acres.

4.4.2.6 OPERATION AND MAINTENANCE CAPABILITY

Maintaining a new stand of vegetative species in drought conditions may be difficult. Available soil moisture is critical to when planting and for long-term maintenance. If the soil moisture is not adequate at planting, seed germination may be limited and require replanting, adding costs. During low water years, drought conditions may lower desired plant vigor, and allow for annual grasses and weeds to encroach the stand, requiring additional weed control. Fire damage is likely to more severe occur on stands with excessive weeds and annual grasses. Prescribed grazing will be more critical to maintain vigorous stands of perennial grasses and forbs.

4.4.2.7 MONITORING AND VERIFICATION CAPABILITY

Maintaining a vigorous stand of perennial vegetation may require attention beyond typical maintenance that occurs on range and pasture lands in Idaho. Record keeping and some field investigations will likely be the primary means of verification of the practice. For carbon sequestration, soil testing would be used for establishing baseline conditions and future levels, though not likely need taken every year. Further research and discussion needs to be accomplished to best estimate carbon sequestration potential on rangeland and pastureland species and soils, which would then assist in the development of a monitoring plan.

4.4.2.8 ANCILLARY BENEFITS

Any improvements on range and pasture lands, regarding vegetation and soil stability, will benefit multiple natural resources. Less soil erosion, improved water quality, improved wildlife habitat, improved riparian habitat for multiple wildlife and aquatic species, greater livestock weight gain, and other benefits are sure to be achieved, though not immediately recognized.

4.5 LIVESTOCK RELATED ACTIVITIES

4.5.1 Reducing Methane (CH4) Emissions from Ruminant Livestock

4.5.1.1 DESCRIPTION

Most of the U.S. CH_4 emissions are due to livestock, both from the digestion process and from manure. Digestive processes of cattle account for 96 percent of these emissions. Further reduction of these emissions through more efficient feed rations is somewhat limited given the large feed efficiency gains over the last 20 years. However, digestive process CH_4 emissions can be further reduced through improvements in grazing-plant quality.

The breakdown of carbohydrates in the digestive track of herbivores (including insects and humans) results in the production of methane. The volume of methane produced from this process (enteric fermentation) is largest in those animals that possess a rumen, or forestomach, such as cattle, sheep, and goats. The forestomach allows these animals to digest large quantities of cellulose found in plant material. This digestion is accomplished by microorganisms in the rumen, some of which are methanogenic bacteria. These bacteria produce methane while removing hydrogen from the rumen.

In general, methane production by livestock represents an inefficiency because the feed energy converted to methane is not used by the animal for maintenance, growth, production, or reproduction. While efforts to improve efficiency by reducing methane formation in the rumen directly have been of limited success, it is recognized that improvements in overall production efficiency will reduce methane emissions per unit of product produced. A wide variety of techniques and management practices are currently implemented to various degrees among livestock producers which improve production efficiency and reduce methane emissions per unit of product produced. Improving livestock production efficiency so that less methane is emitted per unit of product is among the most promising and cost effective techniques for reducing livestock emissions. Specific strategies for reducing methane emissions per unit product have been identified and evaluated for each sector of the beef and dairy cattle industry. Throughout the industry, proper veterinary care, sanitation, ventilation (for enclosed animals), nutrition, and animal comfort provide the basics for improving livestock production efficiency. Within this context, a variety of techniques can help improve animal productivity and reduce methane emissions per unit of product.

Improved herd management, particularly improved nutrition and increasing the percent of cows producing calves, can reduce CH_4 emissions per unit of beef produced. It is estimated that widespread adoption of these measures could reduce CH_4 emissions from beef cattle by 20 percent.

For the dairy industry, significant improvements in milk production per cow are anticipated in the dairy industry as the result of continued improvements in management and genetics. Additionally, production-enhancing technologies, such as bovine somatotropin (bST), are being deployed that accelerate the rate of productivity improvement. By increasing milk production per cow, methane emissions per unit of milk produced declines. To increase milk production per cow, the industry is currently using a growth hormone known as bovine somatotropin (bST). By maximizing production per cow, overall emissions should decline with increased use. However, the use of bST is somewhat controversial because of health and safety concerns for both cows and humans.

Improving productivity within the cow-calf sector of the beef industry requires additional education and training. The importance and value of better nutritional management and supplementation must be communicated. Energy, protein, and mineral supplementation programs tailored for specific regions and conditions need to be developed to improve the implementation of these techniques. The special needs of small producers must also be identified and addressed. Cow-calf productivity can potentially play a significant role reducing emissions. Increasing the rate at which cows reproduce would reduce the number of breeding cows needed. In terms of methane emissions, this is important because the breeding herd required to sustain the beef industry is significantly larger than that in the dairy industry.

Ionophore feed additives provide yet another strategy for reducing emissions. These antibiotics are mixed into feed to improve the efficiency of digestion and use. Ultimately, less feed per cow translates into less methane per cow. A final strategy consists of using anabolic steroid implants. These implants increase the rate of weight gain in cattle, thereby decreasing the number of cows and the quantity of methane emissions per unit of beef product.

In addition to these near term strategies, several long-term options may prove viable depending on the success of ongoing research. These strategies include: 1) the transfer of desirable genetic traits among species (transgenic manipulation); 2) the production of healthy twins from cattle (twinning); and 3) the bioengineering of rumen microbes that can utilize feed more efficiently. Competitive pressures to increase efficiency will encourage the dairy and beef industries to adopt some or all of the short-term process changes described. Since 1950, however, the number of dairy cattle in the United States has declined by over 50 percent, proving the dramatic impact that production efficiency has had on the cattle industry. However, these numbers have increased in Idaho.

4.5.1.2 EFFECTIVENESS

According to industry estimates, methane emissions could be reduced by up to two percent per year if the above practices are employed. If the above discussed methods were used on 50% of Idaho's dairy, beef, sheep, hog, and pig populations, the estimated amount of methane reduced may be about 1.5 MMT CO_2e. The IPCC 1996 Tier one calculations were used to estimate Idaho's statewide potential, found in Appendix 7.

Rangeland livestock may or may not be much of a source of methane, in either case, it would more difficult to track and be effective in reducing methane, while they are not contained and primarily grass fed. However, some ranchers do utilize protein supplements that may increase productivity, thus less methane. If changes were made in diets of any ruminant livestock, and production was to be maintained for net profits, then any reduction in methane would likely be a result of reduced product, which then would be replaced by additional numbers of livestock, therefore, no net reduction in methane. A whole-ranch analysis would need to be done to better estimate actual carbon credits available for purchase.

4.5.1.3 ACCEPTABILITY

Competitive pressures to increase efficiency may encourage the dairy and beef industries to adopt some or all of the short-term processes, such as nutritional supplements. Long-term processes, such as the breeding techniques, will likely not be a priority for adoption at this time, with current markets.

4.5.1.4 COST

Costs for each alternative vary and long-term benefits may not easily determined. Long-term analysis of most of these alternatives may be the only method for estimating a cost. It is likely that the short-term practices, such as livestock supplements, may be least expensive with some return on investment, but may not warrant a substantial greenhouse gas market attention for individual operators. If numerous livestock operations pool resources, then the supply of credits (offsets) may be large enough to encourage buyers of these credits. Acceptability might increase if there shows a return on investment or with increased incentives through a carbon market.

4.5.1.5 IMPLEMENTATION CAPABILITY

Uncertainty in most of these practices will likely deter implementation. Willingness of a potential carbon buyer may be less with these practices because of uncertainties in the research and the long-term benefit to emission reductions. There will exist start-up costs and management changes necessary that may not fit in well with an existing operation.

4.5.1.6 OPERATION AND MAINTENANCE CAPABILITY

Continual operation of these practices where there lacks good science and understanding of their effect on livestock production and methane reductions may hinder a consistent operation of these practices. When an operator is convinced that a practice will succeed in reaching a set objective, such as a return ion investment, the continual operation and maintenance of a practice will likely occur for longer periods of time. While these practice are mostly management type practices, maintenance is not such an issue, such as with structural practices.

4.5.1.7 MONITORING AND VERIFICATION CAPABILITY

Record keeping is likely the key to verifying that the practice is being implemented according to contract provisions. Verifying that actual methane emission from individual livestock is virtually impossible, except under research conditions. Modeling, utilizing specific management inputs and scientifically-based data, may provide adequate estimates of the practice's effectiveness, which may or may not be adequate for a carbon market. Uncertainties may outweigh the potential benefit from implementing these types of practices where verification is nearly impossible.

4.5.1.8 ANCILLARY BENEFITS

If these practices do increase livestock production, then, hopefully, net income should increase per unit livestock, if markets acknowledges the improvement and pays more for the product. Greater attention to production may have unknown livestock health benefits, but also negative impacts on health or product demand, where supplements are concerned.

4.6 BIOENERGY DEVELOPMENT

Fossil fuel combustion is the major source of U.S. greenhouse gas emissions. The agricultural sector can help reduce reliance on fossil fuels in several ways. Agriculture residues and other products can be an energy source can help reduce reliance on fossil fuels. Plant materials can be used either to generate electricity or to produce transportation fuels (biofuels). Unlike the release of CO_2 from fossil fuel combustion, CO_2 released during combustion of plant materials and animal wastes is counterbalanced by the CO_2 that plants remove from the atmosphere during photo-synthesis. However, the overall net greenhouse gas benefits of biofuels are variable due to greenhouse gas emissions from the farming, transportation, and conversion methods currently used in the U.S. Where large amounts of animal wastes are available in a concentrated location, as in large confined animal feeding operations (CAFOs), CH_4 can be captured and used to generate electricity. The most significant constraints to utilization of animal wastes for power generation are: initial costs, the rates offered by utilities to small and medium-scale independent power producers; lack of access to capital; lack of appropriate farm-scale technologies; lack of standardized connection requirements; and lack of “net metering” requirements.

4.6.1 Biogas Recovery

4.6.1.1 DESCRIPTION

Biogas technology is a manure management tool that promotes the recovery and use of biogas as energy by adapting manure management practices to collect biogas. The biogas can be used as a fuel source to generate electricity for on-farm use or for sale to the electrical grid, or for heating or cooling needs. The biologically stabilized by-products of anaerobic digestion can be used in a number of ways, depending on local needs and resources. Successful byproduct applications include use as a crop fertilizer, animal feed, bedding, and as aquaculture supplements.

When livestock manure is handled under anaerobic conditions (in an oxygen free environment), microbial fermentation of the waste produces methane. Liquid and slurry waste management systems are especially conducive to anaerobic fermentation and to methane production. Because confined livestock operations such as dairy and hog farms rely on liquid and/or slurry systems to manage a large portion of their manure, they account for a majority of all animal manure methane emissions in the U.S., as well as Idaho. Emissions depend on farm characteristics (including number and type of animals, manure management practices, and animal diet) and climatic conditions (including temperature and relative humidity).

In order to comply with these federal and state regulations, many confined livestock operations (*i.e.*, non-grazing operations) are utilizing anaerobic lagoons or storage ponds to contain runoff and to manage their manure. These systems are simple, cost-effective, and relatively safe. However, because anaerobic systems produce more methane than aerobic systems, their increased use could significantly increase methane emissions from livestock operations. Most of the methane generated from these anaerobic systems could recover the methane and use it for energy instead of being vented to the atmosphere. A technique called anaerobic digestion (also known as anaerobic fermentation) can be used to maximize methane generation from livestock waste within a controlled, oxygen-free environment. The gas produced is called biogas (generally about 60-70% methane and 30-40% carbon dioxide) and can be used as a substitute for natural gas or combusted for electricity generation.

Feasible and cost-effective technologies exist to recover methane produced from the liquid manure management systems used at dairy and swine operations. Methane can be captured, for example, by placing a cover over an anaerobic lagoon. A collection device is placed under the cover and methane is removed by a vacuum. Alternatively, methane can be recovered from mixed tank or plug flow digesters that produce methane. These and other technologies can be used on individual farms or at centrally located facilities. Thus far, however, anaerobic digesters have only proven cost-effective in the U.S. for large livestock operations.

Some cost analysis of these systems has been done which provides some costs and benefit expectation with digester systems. Assuming facility livestock populations ranging from 250 to 1,000 head, installation costs range from about \$50 to \$260 thousand (USEPA 1993). Operation costs range from about \$1,000 to \$8,500. Annual benefits however, range from \$6,200 to \$42,000, with payback ranging from 6 to 21 years.

A primary drawback to methane collection from lagoons is the apparent lack of cost effectiveness when confined to a single farm. An important aspect of the cost is the corrosiveness of some of the gases produced, in particular hydrogen sulfide (H_2S). Mitigation measures that reduce this gas also have costs involved. For example, the necessary use of absorbents such as iron oxide adds labor and transportation costs to the cost of disposal. Once the methane has been collected, it may be flared, burned for heat, or burned or sold for electricity. Flaring produces no financial benefit but does reduce the global warming potential. Burning for heat may be beneficial, especially for farms at higher elevations, but since most farms do not require the amount of heat that can be generated, much of the heat would be wasted (USEPA 1993).

A typical biogas system consists of a system of manure collection, anaerobic digester, effluent storage, gas handling, and gas use. The manure can be handled by numerous methods. Raw manure consists of 8 to 25 percent solids, depending upon animal type. It can be diluted by various process waters or thickened by air drying or by adding bedding materials. Liquid Manure has less than 3 percent solids. This manure is typically “flushed” from where it is deposited, often using fresh or recycled water. Slurry manure consists of 3 to 10 percent solids. Slurry manure is usually collected by a mechanical “scraper” system. Semi-solid manure consists of 10 to 20 percent solids. This manure is typically scraped. Solid manure consists of greater than 20 percent solids and is handled as a solid by a scoop loader.

The digester is the component of the manure management system that optimizes naturally occurring anaerobic bacteria to decompose and treat the manure while producing biogas. Digesters are covered with an air-tight impermeable cover to trap the biogas for on-farm energy use. The choice of which digester to use is driven by the existing (or planned) manure handling system at the facility. The digester must be designed to operate as part of the facility’s operations. One of three basic options will generally be suitable for most conditions:

- Covered Lagoon - Covered lagoons are used to treat and produce biogas from liquid manure with less than 2 percent solids. Generally, large lagoon volumes are required, preferably with depths greater than 12 feet. The typical volume of the required lagoon can be roughly estimated by multiplying the daily manure flush volume by 40 to 60 days. Covered lagoons for energy recovery are compatible with flush manure systems in warm climates. Covered lagoons may be used in cold climates for seasonal biogas recovery and odor control (gas flaring). Typically, multiple modules cover the lagoon surface and can be fabricated from various materials.

- Complete Mix Digester - Complete mix digesters are engineered tanks, above or below ground, that treat slurry manure with a solids concentration in the range of 3 to 10 percent. These structures require less land than lagoons and are heated. Complete mix digesters are compatible with combinations of scraped and flushed manure.

- Plug Flow Digester - Plug flow digesters are engineered, heated, rectangular tanks that treat scraped dairy manure with a range of 11 to 13 percent total solids. Swine manure cannot be treated with a plug flow digester due to its lack of fiber.

A gas handling system removes biogas from the digester and transports it to the end-use, such as an engine or boiler. Gas handling includes: piping; gas pump or blower; gas meter; pressure regulator; and condensate drain(s). Biogas produced in the digester is trapped under an air-tight cover placed over the digester. The biogas is removed by pulling a slight vacuum on the collection pipe (e.g., by connecting a gas pump/blower to the end of the pipe) which draws the collected gas from under the cover. A gas meter is used to monitor the gas flow rate. Sometimes a gas scrubber is needed to clean or "scrub" the biogas of corrosive compounds contained in the biogas (e.g., hydrogen sulfide). Since the gas storage space is limited (i.e., the volume under the cover), a pressure regulator is used to release excess gas pressure from the cover. Warm biogas cools as it travels through the piping and water vapor in the gas condenses. A condensate drain(s) removes the condensate produced.

Recovered biogas can be utilized in a variety of ways. The recovered gas is 60-80 percent methane, with a heating value of approximately 600-800 Btu/ft3. Gas of this quality can be used to generate electricity; it may be used as fuel for a boiler, space heater, or refrigeration equipment; or it may be directly combusted as a cooking and lighting fuel. Most equipment that uses natural gas, propane, or butane as fuel can be fueled by biogas.

Electricity can be generated for on-farm use or for sale to the local electric power grid. The most common technology for generating electricity is an internal combustion engine with a generator. The predicted gas flow rate and the operating plan are used to size the electricity generation equipment. Engine-generator sets are available in many sizes. Some brands have a long history of reliable operation when fueled by biogas. Electricity generated in this manner can replace energy purchased from the local utility, or can be sold directly to the local electricity supply system. In addition, waste heat from these engines can provide heating or hot water for farm use.

While waste-to-energy plants at individual farms are generally not cost-effective unless the farms are of moderate to large size, combining the waste from a group of neighboring farms may be significantly more economical. For example, this could involve construction of one or more small plants within high density dairy facility areas. The process may be centered on anaerobic digestion, wherein the waste is converted into biogas, granular fertilizer, compost, and irrigation water. The biogas fuels a generator, which satisfies most of the facility's energy requirements. The fertilizer and compost produced are sold to plant nurseries, golf courses and landscapers, and the irrigation water is kept for moisture needs or donated to local farmers via a plastic pipeline. Wastewater to be used for irrigation water may need to be permitted by regulatory agencies.

A centralized plant for livestock biomethanation would have both positive and negative aspects. Benefits may include cost reduction per cubic meter of digester volume, smoother input, since variations in feed from one farm are partially mitigated by feed from other farms, and the opportunity to site the plant for maximum use of available animal waste. Disadvantages would include added costs for transport to the plant, increased complexity of administration, and possible additional odors around the plant.

4.6.1.2 EFFECTIVENESS

Depending on the number of large dairy and swine operations in a state, utilization of livestock methane can significantly reduce methane emissions. These systems can reduce emissions at individual farms by up to 80 percent (U.S. EPA, 1993b). Furthermore, developing methane recovery and utilization projects will have an immediate impact on reducing emissions since these systems can be installed within one year.

In Idaho, there exists approximately 810 dairy facilities (ISDA, 2002), where nearly 700 of those facilities contain less than 1000 head of cows, with a total of about 190,000 head. These facilities, individually, are not as likely capable of producing an adequate amount of methane for digestion through anaerobic conditions, to produce adequate bioenergy for substantial marketing, except through cooperatives and centralized facilities. Transportation of filtered waste liquids would need to occur, but within a feasible distance. Initial investigations indicate that up to a maximum of 20 centralized facilities may be physically installed in the state, primarily in the highest density areas. Those individual facilities, nearly 100, may be able to produce bioenergy from capturing and processing methane. All of these dairy facilities, however, would need to re-tool their existing storage systems to be able to capture methane. Most existing storage ponds are less than 10 feet deep and cover large areas of land, thus not effective as digesters themselves. Storage ponds are currently not the most effective for complete anaerobic fermentation of wastes, but are not effective as aerobic systems either.

If these small dairies were to divert wastes to centralized bioenergy facilities, then bioenergy may be feasible. Centralized facilities, however, would need to be placed in locations that liquids could easily be piped or transported by truck, within the shortest distances. The profits from facilities would need to more than cover the construction and operation costs for such an endeavor to be feasible. A total maximum number of bioenergy facilities, either placed at individual dairy facilities or at a centralized site (without dairy production), then up to 120 bioenergy facilities could be built. Until a further, highly comprehensive analysis is done regarding centralized facilities, the estimate here is very gross. Total metric tons of methane that could possibly reduced from bioenergy facilities on the larger dairy facilities is about 0.73 MMT CO_2e. The amount of nitrous oxide would be about 29,000 MT CO2e/y. The assumptions in the calculation are found in Appendix 7.

4.6.1.3 ACCEPTABILITY

The installation costs for such a system to capture methane to flare, pipe, or burn for alternative power generation is high, along with operation and maintenance costs, which may hinder the adoption of this practice on dairy facilities. Current potential for cost-share and outside funding, such as through a carbon market, may help with installation costs, and may help increase the potential for adoption. Widespread adoption within the state is unlikely unless installation and maintenance costs lower, alternative power generation demand increases, and outside funding sources become more available. Regardless of the funding sources, installation costs will need supplemented and operation costs may need supplemented if the operation cannot reclaim the cost through less power usage. State regulatory agencies will need to evaluate how these systems will work with existing requirements for odor and nutrient and waste management. If government subsidies, tax credits, or other initiatives could be used to make implementation of such measures more economical for operators, emissions reduction potentials could increase considerably.

Government initiatives for increasing the capture rate for methane emissions from animal manure could include both incentives and regulations. Possible incentives include tax rebates, low-interest loans and training workshops. Regulations could mirror those of several other states that currently require farms to more stringently manage their animal wastes (USEPA 1993a). Care must be taken to ensure that such anaerobic digesters work properly. When not working optimally, they can increase methane emissions from animal waste. It should be noted that policies regarding methane recovery systems may be compatible with policies encouraging the use of manure instead of commercial fertilizer. Methane recovery systems could be employed during the storage period before application to fields.

Recent trends in manure management, such as using anaerobic lagoons to meet requirements of the Clean Water Act, have prompted interest in developing and installing on-farm methane recovery systems. Many of the operational problems initially experienced with methane recovery systems in the early 1970s have been overcome during the past two decades through advances in the methane recovery industry. EPA's AgStar program focuses on providing support to farms considering implementing methane recovery systems. As of late 1997 there were 40 farm operations participating as AgStar partners.

Implementation of recovery systems usually focuses on large dairy or hog farms (for example, farms with over 500 milking cows or over 1,500 hogs) that use liquid or slurry manure management systems which are especially conducive to methane production. The current trend in livestock production is away from the small family farm (less than 200 cows) with limited manure storage capabilities toward large production farms (over 500 cows) that use manure storage systems as a matter of routine. This trend may mean that an increasing number of farms will find it economic to capture methane. Additionally, methane recovery and use may be more economical for farms located in a relatively warm climate.

According to the Idaho Department of Water Resources, the Energy Division, they launched a five-year effort to educate the dairy and livestock industry on anaerobic digestion processes and to help them incorporate digester technologies into their operations. A long-range goal was to install at least 5 digester systems on Idaho dairies in the Magic Valley area near Twin Falls, Idaho, by 2005. If regulations require odor completely controlled, then acceptability will not likely be such a factor.

4.6.1.4 COST

The potential for available methane to be sold to pipelines for distribution through the existing natural gas pipeline network has some limitations. When gas is produced from livestock manure, it is typically composed of about 40 to 50 percent carbon dioxide and trace quantities of other gases such as hydrogen sulfide (H_2S), which need to be removed before the gas can be injected into a pipeline. The cost of upgrading the gas to pipeline quality makes this option uneconomical at the current time. Methane must be processed before it can be used in most equipment. The amount of processing necessary depends on the specifications of the equipment and the characteristics of the gas. Small farmers' profit margins and numbers of animals, however, are not sufficient to afford new, energy efficient technology or the necessary CH_4 recovery technology.

4.6.1.5 IMPLEMENTATION CAPABILITY

Again, installation and operation costs will likely deter implementation of these methane recovery systems. Regulatory requirements must be met as and coincide with the system. Physical layout of existing operations may not fit well wit the systems without some additional component practices, which would increase costs, and effect, potential additional impacts.

In the U.S., there have been many reasons implementation prior to the early 1980s has not been successful (USEPA, 1993a). Reasons for biogas failure before were:

1. Operators did not have the skills or the time required to keep a marginal system operating.
2. Producers selected digester systems that were not compatible with their manure handling methods or layout of their farms.
3. Some designer/builders sold “cookie cutter” designs to farms. For example, of the 30 plug flow digesters built, 19 were built by one designer and 90 percent failed.
4. The designer/builders installed the wrong type of equipment, such as incorrectly sized engine-generators, gas transmission equipment, and electrical relays.
5. The systems became too expensive to maintain and repair because of poor system design.
6. Farmers did not receive adequate training and technical support for their systems.
7. There were no financial returns of the system or returns diminished over time.
8. Farms went out of business due to non-digester factors.

4.6.1.6 OPERATION AND MAINTENANCE CAPABILITY

Operation and maintenance is likely very involved, especially to a new user. There would be constant inspections of components, additional care in ensuring anaerobic conditions are suitable for electrical generators, heat generators, chillers, and other equipment. Operation will likely need to ensure that odors and other potential nuisance problems are monitored to stay in compliance with existing regulations. Fencing and other protective structures may need to be in place and maintained to ensure trespass is limited and employee safety.

4.6.1.7 MONITORING AND VERIFICATION CAPABILITY

Monitoring is going to be needed within a carbon market to ensure that the system is operating and being maintained properly, as well as annual verification of methane reductions (use). If the system is designed and functioning properly, then the calculated usage and reductions of methane emissions should be occur ongoing.

4.6.1.8 ANCILLARY BENEFITS

Where properly designed methane recovery systems are installed, odor requirements may be met when methane is flared off or utilized for power, heat, or chiller equipment. Less off-site power usage may be appreciated with these systems if adequate methane is produced. If a carbon market exists, where a emission source is in need of offsets, the facility may be a viable choice as compared to other carbon sequestration practices that are not as easily monitored and verified as increasing carbon storage or reducing other gases. Also the potential for ground and surface water contamination is reduced by the conversion of organic nitrogen to ammonium compounds through digestion.

Other benefits include: recovering biogas and producing on-farm energy, livestock producers can reduce monthly energy purchases from electric and gas suppliers; in the process of anaerobic digestion, the organic nitrogen in the manure is largely converted to ammonium, the primary constituent of commercial fertilizer, which is readily available and utilized by plants; digester effluent is a more uniform and predictable product than untreated manure. The higher ammonium content allows better crop utilization and the physical properties allow easier land application. Properly applied, digester effluent reduces the likelihood of surface or groundwater pollution; and heated digesters reduce pathogen populations dramatically in a few days. Lagoon digesters isolate pathogens and allow pathogen kill and die-off prior to entering storage for land application.

Biogas recovery can improve profitability while improving environmental quality. Maximizing farm resources in such a manner may prove essential to remain competitive and environmentally sustainable in today's livestock industry. In addition, more widespread use of biogas technology will create jobs related to the design, operation, and manufacture of energy recovery systems and lead to the advancement of U.S. agri-business.

4.6.2 Biofuels Production

4.6.2.1 DESCRIPTION

There is considerable interest in producing large quantities of alternative liquid fuel products from biomass, such as corn, wheat, barley and canola. Not only is this interest driven by the desires for greater energy security, but also by changes in federal policy promulgated under the Clean Air Act Amendments of 1990 and the National Energy Policy Act of 1992 (EPACT) which focus attention on the environmental impacts of transportation fuels. These legislative acts are stimulating the search for cleaner-burning alternatives to gasoline and diesel fuels. One alternative to gasoline is biomass-derived ethanol, which can be used in pure form or blended with gasoline to increase oxygenation and thereby reduce the amounts of certain pollutants. One alternative to conventional diesel fuel is biodiesel, which can be used in unmodified diesel engines. Biodiesel is produced from some animal fats or vegetable oils and canola after undergoing a relatively simple process called transesterfication. All Regional Biomass Energy Program (RBEP) regions have been involved in the area of alternative liquid fuels from biomass and continue to fund significant projects in this field.

Several short-rotation woody crops have been identified as "model" energy crop species based on their rapid biomass yield potential. These species include silver maple, sweetgum, sycamore, black locust, eucalyptus species or hybrids, and poplar species or hybrids. The highest yielding crop appropriate for a given region may depending on soil and other characteristics within a geographical region (Sampson and Hair, 1992). The National Academy of Sciences Mitigation Panel classify methanol and ethanol from wood biomass fuel as alternative fuel that eliminate greenhouse gas emissions (NAS, 1991). In corn processing, ethanol is produced from the starch-based carbohydrate fraction of the corn kernel. But the corn fiber represents about 13% of the ethanol that could be produced from the kernel (U.S. DOE, 1998). The U.S. Department of Energy's National Renewable Energy Laboratory (NREL) seeks ways to economically increase the yield of ethanol from biomass such as corn fiber. Corn stover, crop residues, and/or other corn fiber could also be utilized in ethanol production.

4.6.2.2 EFFECTIVENESS

Burning ethanol in blends with gasoline (commonly 10% by volume) has a slight advantage over gasoline and diesel fuel from a greenhouse gas emissions standpoint. These emission factors in units of tons CO2 per million BTU (tons CO_2 /MMBTU) are given from the U.S. EPA (1995) State Workbook as: ethanol, 0.0760; gasoline, 0.0777 and diesel, 0.0799. But the big potential advantage of burning ethanol in lieu of gasoline is in the energy and CO_2 emissions that are saved by using renewable fuels. The energy in ethanol comes from photosynthesis and the sequestration of CO_2 from the atmosphere. Some energy is utilized and CO_2 emitted in the production of the ethanol, but, on a net basis, it saves energy and emissions.

Corn ethanol production creates 24 percent more energy than it uses, according to a study performed by the U.S. Department of Agriculture ("Estimating the Net Energy Value of Corn-Ethanol," USDA) which results in a net reduction in greenhouse gas emissions. Furthermore, the study found ethanol could replace petroleum imports by a factor of 7 to 1 because it uses abundant domestic feedstocks such as natural gas and propane.

With a significant level of activity around the country directed toward the development of alternative liquid fuel products from biomass, it seems inevitable that transportation sector emissions will at some point be reduced from the use of bio-fuels. The timing of those greenhouse gas emissions reductions as well as the specific fuels and technologies that will penetrate the market place are not clear at this time.

Renewable ethanol burns "cleaner" than gasoline and diesel (less CO2, CO, and hydrocarbons emitted). The controversy lies in estimates of the amount of nonrenewable fossil fuels that must be combusted to produce a gallon of clean burning ethanol. Most recent articles estimate energy requirements to be in the range of 50 to 100% of the energy equivalent in ethanol. Obviously, if 100% of the energy contained in ethanol is required to produce it using nonrenewable fossil fuels, then there is no greenhouse benefit. However, if only 75% of the energy in a gallon of ethanol is required to produce it, then a large benefit accrues in diminished CO_2 emissions because a renewable corn crop has been utilized, which sequestered CO_2 from the atmosphere during the growing season.

Various sources for biofuels and bioenergy include corn, sugar, and other products; biodiesel from soybeans and other products; electric power generation from animal wastes or generation grasses and trees grown in shelterbelts or on marginal & abandoned cropland. Biomass resources, including wood and agricultural wastes, timber, and grain crops accounted for about 3.3 percent of U.S. energy consumption in 1990. Because plants that produce these resources sequester carbon while growing, using biomass as a renewable energy source to displace fossil fuels helps mitigate carbon dioxide buildup in the atmosphere.

Utilizing biofuels to create carbon credits has the potential of increasing the benefit per acre of agricultural land beyond that of improving the land management practices. An example analysis of the total cropland acres needed to produce nearly 95 million gallons of ethanol is summarized in Table 7. For example, if up to 25% of the total acres of barley, wheat (variety ignored), and grain corn were used for ethanol production, if would result in 86.2 million gallons of ethanol. As seen in Table 1. corn has the highest emission offset per acre due the crops higher yield (150 bu/acre in 2001). Corn results in about 2.6 MT CO_2e per acre, whereas barley and wheat yield only 1.3 and 1.2 respectively. The total CO_2e offset would be about 0.57 MMT. The total acres (25% of total) used here is nearly 480 thousand. If the state wished to increase ethanol production to 100 million gallons per year, but maintain the same number of acres, then more acres of corn would need to be grown, with less barley and/or wheat.

Table 7. Estmated Ethanol Production with Existing Crop Base

Crops	2001 acres	2001 yield - bushels	ethanol acres	gallons ethanol	CO2e @ 13.2lb/gal or .0066 MT	metric ton CO2e/acre	% acres of total acres
corn, grain	45000	150	11250	4471875	29514	2.62	2%
Barley	670000	75	167500	26381250	174116	1.04	35%
Wheat	1200000	71	300000	55380000	365508	1.22	63%
Totals	1915000		478750	86233125	569139	1.19	100%

Table 8 shows the adjusted acreage of the crops to produce just over 100 million gallons. Corn acreage would need increased to about 16% of the total acreage of the 3 crop total. The new amount of CO_2e offset would then be about 0.67 MMT. A statewide project analysis would need to be done to better estimate actual carbon credits available for purchase. A discussion on ethanol and biodiesel potential in the state is presented in Appendix 3.

Biodiesel production was evaluated by looking only at canola production. One MT of oil seed produces approximately 110 gallons of biodiesel. One gallon of biodiesel, is used in place of diesel fuel, reduced CO_2 emissions by 17.7 lbs, or 0.008 MT. If 50% of the 2001 acres (22,500, 0.72 MT/acre production) of canola were used to produce biodiesel, then approximately 9,000 MT CO_2e could be offset per year. A whole-farm/project analysis is needed to determine the net CO_2e offset.

Table 8. Cropland Acres Needed to Produce 100 million gallons of Ethanol

	% of total	new total crop acres	25% of acres	gallons ethanol	CO2e @ 13.2lb/gal or .0066 MT	metric ton CO2e/acre
corn, grain	16%	306400	76600	30448500	200960	2.62
Barley	28%	539300	134825	21234938	140151	1.04
Wheat	56%	1069300	267325	49348195	325698	1.22
Totals	100%	1915000	478750	101031633	666809	1.39

4.6.2.3 ACCEPTABILITY

There are many issues that may impact biofuels supply and demand. Many issues surrounding the use of ethanol from corn, such as the use of methyl-tertiary-butyl ether (MTBE) rather than ethyl-tertiary-butyl ether (ETBE) in reformulated gasoline, price subsidies required for ethanol and ETBE from corn, disputed air quality benefits of smog and ozone formation, ethanol trade barriers with Brazil, strategic reliance on foreign oil, balance of payments, the cost of maintaining a military presence in the Middle East to protect oil supplies, energy self-sufficiency, and soil erosion as a result of a renewable crop such as corn. Currently, only tax incentives exists to the sales of ethanol, not production. If this was applied to production of ethanol, the supply may increase if other barriers were removed and demand was high.

4.6.2.4 COST

While the market price for a barrel of oil is about $20, the U.S. General Accounting Office estimates its true cost is really about $126 per barrel. When calculating the real cost of gasoline, ethanol becomes even more attractive. The cost of building a biofuels facilities is no doubt expensive. However, the demands for ethanol, for example, would return substantial profits if the market exists, in fact, likely within a few years. Costs, then are soon recovered if demand is high.

4.6.2.5 IMPLEMENTATION CAPABILITY

The biggest problem facing increased reliance on ethanol from corn at the present time is when the price of corn reaches levels, such as more than $3 per bushel, and the politics of maintaining federal and state subsidies to make it cost competitive. There is a potential for ethanol to increase as a result of the 1990 Clean Air Act Amendments as ethanol is used in areas trying to meet mandated ambient air quality standards for ozone.

Environmental or toxicity characteristics may be associated with the new fuel. Institutional resistance to alternative fuels could be significant: converting to any of the alternative fuels at this point does not offer additional, tangible, and recognized benefits to vehicle operators. Without the certainty of a customer base, few suppliers would venture into the alternative fuels arena. Alternative fuels policies may, therefore, need to address both supplier and customer concerns to ensure program success. Currently, the refueling infrastructure exists in the state to support ethanol production and use, except for parent company restrictions on its mixing.

4.6.2.6 OPERATION AND MAINTENANCE CAPABILITY

With any new facility, there will be a great amount of operation and maintenance measures taking place. The level of maintenance may increase with the age of the operation, where equipment repair or replacement will occur more frequently. Maintaining a feasible operation will require some level of marketing, ensuring adequate biomass is available and being shipped to the facility for processing.

4.6.2.7 MONITORING AND VERIFICATION CAPABILITY

Based on the facilities operation records, if under a carbon market contract, the actual production and use of biofuels may be verified. Some record of the actual addition of biofuels to petroleum fuels and its sale at each of the service station may be used to verify actual us of the biofuels.

4.6.2.8 ANCILLARY BENEFITS

The use of biofuels may provide an unlimited industrial market for agricultural products beyond the limited traditional feed and food markets, and thereby stimulate rural investment and employment opportunities. The environmental benefits of reduced air emissions and the biodegradability of biodiesel would provide additional benefits for communities and metropolitan areas with air quality problems. Further, the nation would enjoy increased energy security from the reduction in imported oil. MTBE could be replaced by ethanol.

4.6.3 Cropland and Forest Biomass Energy Source

4.6.3.1 DESCRIPTION

Agricultural residues can be used as an alternative (biomass) fuel source for cooking, space heating, drying of agricultural products, and the production of power by steam engines or motors. Specific applications include burning the residues in furnaces to generate heat for drying units or for space heating at home. Combustion for heat generation may be the most appropriate means of replacing fuel oil with residues, because much less investment is necessary compared to replacing fuel oil in power generation. Also, the total maximum efficiency of the power produced by means of a turbine or steam engine is approximately 15 percent, even though the combustion of biomass can be accomplished with high efficiency.

Wood wastes and agricultural crop residues are often considered to be the most cost-effective biomass resources since they result from other productive economic activities and are readily available. Wastes and residues are currently used extensively for energy production in some sectors such as the paper industry. In addition to replacing fossil fuels that produce greenhouse gas emissions, increasing the use of these resources may help alleviate other problems such as costs and methane production associated with waste disposal and landfills. Wood and crop residues can be gasified, liquified (into ethanol), burned directly for use in on-site power generation, or burned to heat commercial buildings and homes.

Short rotation woody crops can be burned to heat buildings or to fire conventional power plants in a process similar to coal combustion. For example, in 1990 New York state generated around 3 megawatts of electricity using wood power and in 1991 Vermont generated approximately 1.7 percent of its electricity from biomass at a woodchip burning plant. Wood can also be transformed into liquid fuels such as ethanol through enzymatic processes, although these processes are expensive to use at the current time. Several short-rotation woody crops have been identified as "model" energy crop species based on their rapid biomass yield potential. These crops include silver maple, sweetgum, sycamore, black locust, eucalyptus species or hybrids, and poplar species or hybrids. The highest yielding crop appropriate for a given region may be among these model crops or may be different, depending on soil and other characteristics within a geographical region (Sampson and Hair, 1992).

Biomass has supplied approximately 9 percent of the total energy used in Idaho in recent years and there potentially is enough biomass waste (forest and logging residue, municipal solid waste, agricultural residues, animal waste, agricultural processing residue) to supply all the energy Idaho uses (http://www.idwr.state.id.us/energy/alternative_fuels/bio.htm).

Some facilities in Idaho have used biomass for many purposes. A new wood pellet mill feedstock dryer at the Jensen Lumber mill in southeast Idaho, a biogas cleaning system at the Nampa Wastewater Treatment Plant and a small backpressure turbine at the Ceda-Pine Veneer mill in Samuels are some examples. The University of Idaho has installed wood-fired boiler for campus heating and cooling.

Increased use of biomass can reduce the use of fossil fuels. Highly efficient and clean systems of residential, industrial and commercial scale wood energy technology exist and have found increasing use throughout the country. When biomass is grown sustainably and used to displace fossil fuels, or crop residues utilized, net carbon emissions are avoided since the CO_2 released in converting biomass to energy is sequestered within the regrowing biomass through photosynthesis. There is no such advantage with fossil fuel energy since the coal, oil and natural gas only make a net carbon increase to the greenhouse gas equation.

Through silviculture practices, such as related to forest land fire prevention or alternative use of crop residues, there is significant available amount for additional bioenergy facilities. There are virtually unlimited end uses for wood and some end use markets are, or potentially could be, extremely large. Some of the major end uses for wood waste include fuel and wood pellets. Wood waste may be processed and used as fuel in residential, institutional, municipal, commercial, industrial, or utility boilers or furnaces for the production of thermal and/or electrical energy. Wood may be used as the only fuel or it may be cofired with other fuels, such as coal and oil. Combustion equipment may be specifically designed to burn wood, or may be retrofitted equipment originally designed to burn other fuels.

4.6.3.2 EFFECTIVENESS

The efficient utilization of excess forest wood (waste) and crop residues in Idaho as an alternative energy source could have a positive affect on the state's greenhouse gas emissions, a well as the local economy. Advantages of processing wood from forested land, through timber harvesting practices or fire (disease, etc.) prevention measures, include reduced greenhouse emissions and smoke, reduced risk of severe fires, and reduced fossil fuel use. Domestic generated wood wastes may also utilized for bioenergy instead of dumped in landfills. The use of wood and crop residue as fuel has some air emission benefits compared to fossil fuels. Due to the low sulfur content of wood, significantly less sulfur dioxide, reduced sulfur compounds, and sulfuric acid are emitted than during fossil fuel combustion. Carbon emissions may also be reduced compared to fossil fuel combustion. Wood and crop waste may be cofired with coal in utility and industrial boilers, resulting in significant acid gas emission reductions. Air pollution control regulators and permit engineers are familiar with the combustion characteristics and emissions of clean, untreated wood. Research, demonstration, and operating experience indicates that several types of treated wood waste may be burned with minor or no negative impact on air and ash emissions.

If Idaho wheat, barley, and bluegrass residues were utilized in the production of bioenergy, a substantial amount of CO_2e emissions could be reduced. The Chariton Valley Biomass Project in Iowa showed that by utilizing switchgrass, about 0.52 MT CO2e/y emissions could be reduced, replacing a percentage of coal in a power plant. Grass and coal would be cofired, where 12.5 tons per hour would be used along with the coal. Where Idaho's wheat, barley, and bluegrass production and remaining residue is less, by about ½ of switchgrass, an gross amount of CO_2 emissions could be reduced in cofiring plants. This estimate is not dependent on existing or potential energy or similar plants, but on the capability and available amount of residues.

If crop residues were used on co-fired plant, where similar amounts were used in place of fossil fuels, such as coal, there could be could reduction in CO_2 by about 1.3 MMT where over ½ of those residues previously burned were used instead. The use of wood wastes in cofirng plants would produce a greater amount of CO_2 reductions on a per tonnage basis, where the density of wood is much greater than straw or grass residue. The heating capability of coal is higher than wood, possibly 1 to 3 times as high. Depending on the coal type, or other fossil fuels used, 1 to 3 times more biomass residue may need to be used for equivalent power or heat generation. where coal most available to Idaho (bituminous), produces about 20 or more million Btu's per ton, where wood generates about 17.2 million Btu's per ton. The comparison of wood to coal for heat generation shows that though wood is slightly less, the value wood as an alternative to coal is substantial. Emissions are substantially offset as well, where additional emissions of compounds are eliminated or reduced.

The amount of wood on forest floor is about 1 MT C/acre in a poorly stocked or non-stocked forest (see Appendix 2). If only 50% of forest floor wood litter is collectable for bioenergy use (0.5 MT C/ac or 1.8 MT CO_2e) and 0.52 MT CO_2 is offset per MT of biomass (wood), then 0.95 MT CO_2/acre of offset may result. If a total of 10% of those poorly stocked forest lands (about 350,000) were to provide wood for fossil fuel replacement, then about 0.3 MMT CO_2e could be offset. The amount of carbon previously sequestered in the wood however, if not captured during its burning, would need to be discounted in estimating a net offset. A whole-project analysis would need to be done to better estimate actual CO_2e offsets.

4.6.3.3 ACCEPTABILITY

Market and institutional barriers prevent industry and small business from choosing wood energy over fossil fuels. The lack of a fully active technology transfer program also hinders the appeal of biomass as an energy source. The market potential for wood waste used as fuel here in Idaho is not realized, therefore, a market for wood-generated energy is unlikely to be developed within the near future. Currently Idaho Power has only 3 coal fired power generation plants for the state. If coal was used more widely in the state, this alternative use of residues would likely be more important to the state.

4.6.3.4 COST

The total costs of biomass fuel development will vary depending on crop productivity and biomass handling and transportation costs. The benefits from utilizing renewable biomass is simply greater than using fossil fuels, though not always easily measured. Costs of using either source, however is. From the planting to harvest to its use, biomass costs may be calculated based on its actual production and utilization. Fossil fuel production and its use costs may also be calculated. These differences in costs need to be compared to for an operation to evaluate its operation effectiveness and its long-term operation. Benefits from using biomass instead of fossil fuels, in regards to carbon sequestration and emission reductions, would need to be measured or calculated with effective models to determine an actual cost. Some estimates , though, seem to indicate that there is a high cost, especially if regulatory policies com into effect on industries, where fines may be imposed if it does not meet emission objectives. If forest products were to be used for bioenergy, collection, onsite preparation, and transportation preparation would be expensive

4.6.3.5 IMPLEMENTATION CAPABILITY

Again, there must be a market or cost-effective purpose of collecting, separating, and processing wood wastes for one to adopt such a practice. If costs are offset by the benefits of reducing landfill wastes, reduced reliance of petroleum-based fuels, and other needs, then this practice may more readily be adopted. The infrastructure is really not in existence, therefore would need to be built first. There very steep conditions within forested areas, which would make forest wastes difficult to collect and transport to nearby roads. There is little demand for co-fired electrical demand in the state, therefore, reduces implementation.

4.6.3.6 OPERATION AND MAINTENANCE CAPABILITY

The challenge for biomass in the future is to ensure a sustainable harvest, possibly from plantations, to develop efficient and non-polluting systems for fuel conversion and use, and to lower production costs so these fuels can compete with traditional sources. A variety of factors affect wood waste processing facilities. This is particularly true because processing facilities require successful operation of two distinct components. One component involves obtaining sufficient supplies of wood waste. The second component involves securing a reliable demand, and suitable price, for products recovered from the wood. In some locations, there is an adequate supply of wood needing “disposal,” but there are insufficient end use markets. In other locations, the reverse is true. Major factors affecting wood waste processors include: existing solid waste and recycling programs, policies, and regulations; the availability of wood waste for processing; the extent of end use markets; and specifications for end products. These factors affect a processor’s selection of equipment, determination of the appropriate capacity of a facility, and facility location.

4.6.3.7 MONITORING AND VERIFICATION CAPABILITY

The primary monitoring tool may be the at the user end. If a supply of biomass is used by an industry for heating, processing, or energy production, and the source is known, then the quantity used may establish the carbon credit or emission reduction through calculations. Record keeping and periodic audits would need to occur, at least annually, to ensure that emission reductions are indeed happening, where fossil fuels have been replaced with biomass.

4.6.3.8 ANCILLARY BENEFITS

Landfill owners themselves can also benefit from separating wood. A number of landfill operators have invested in wood processing equipment or allow another party to process it. The landfill stockpiles wood that is delivered by haulers and then processes the waste. The purpose is either to reduce its volume or to sell for reuse. Some landfills may charge a lower tipping fee for wood separated from other waste before it is delivered to the landfill. Forests cleared of excessive deadfall, then used for other purposes can benefit from fire prevention or excessive devastation. Cleaner air would occur if crop residues were not burned on fields and was used instead for bioenergy production.

4.7 FORESTED, TIMBER LANDS

Professional management of forestland can result in multiple natural resource improvements, as well as maximum stocking and productivity of forestland acreage in our state. Increased productivity can maximize the carbon sequestration benefits. Silvicultural (forest management) practices to increase tree growth, adjust species composition and insure optimum stocking will yield beneficial carbon sequestration on existing forestland resources of our state.

Wood utilization technology is also being developed nation-wide by the forest industry and the federal government to meet the demand for wood products with low value, previously underutilized timber. Doing so may mean that less wood residue is left on the forest floor or discarded at the mill to decay. The carbon benefits derived from improved wood utilization depend upon the degree to which such utilization allows for reduced harvests of virgin timber.

Trees and other vegetation remove, or sequester, carbon dioxide from the atmosphere as they grow, storing it as carbon in trunks, limbs, roots, and soil. Through this process, forests provide an important terrestrial "sink" for CO_2. Furthermore, wood products are relatively long-lived structures that store carbon, which makes up about half the dry weight of wood, rather than allowing it to be released back to the atmosphere. Forest-related land use changes can affect the carbon sequestration in a number of ways.

Many practices can improve forest productivity and health, which are discussed below. Some other silviculture and forest-related practices are further discussed which include pest management, fire management, afforestation and reforestation, rural/urban residential tree planting, riparian conservation/restoration and forest biomass energy source.

4.7.1 Improve Forest Productivity and Health

4.7.1.1 DESCRIPTION

By increasing the productivity of forest species, demand for forest products could be met with fewer trees extracted, less carbon released to the atmosphere, and potentially more carbon sequestered. Management approaches that can be used to improve timber stand productivity and carbon sequestration include: Stand composition control, stand density control, protection and salvage (includes disease control), controlling rotation length, regeneration harvesting, edaphic (site) modification, fire management and forest insect and disease control. See Appendix 2 for additional information regarding forest practices.

4.7.1.2 EFFECTIVENESS

As mentioned before, substantial gains in carbon sequestration are possible through increased forest health and prevention of losses. Vigorously growing trees sequester carbon more rapidly than poorly growing ones. Stored carbon can be high in uneven-aged stands as there is a continuing stand of trees at all times. Carbon flux will depend on how intensively this harvest method is practiced. Sequestration is enhanced through the frequent extraction of forest products.

Tree species differ in carbon sequestration ability, by growth rate and density, so quantifying the amount of stored carbon with high level of certainty is difficult without site-specific data. Quantification can be, however, based on some givens, such as soil types and tree species, where previous data has been collected on similar sites. Trees with more dense wood contain more carbon per unit volume. Examples are Douglas-fir with a specific gravity of 0.473, ponderosa pine with 0.416, spruce/fir with 0.349 and western larch at the highest with 0.508 (Birdsey, in Sampson et al. 1992). Changing the species mix can affect the amount of carbon sequestered, either positively or negatively.

Silviculture practices themselves may not be measured directly, as one would in a specific tree, but may be considered an indirect positive effect on carbon storage. It may be that these practices can be viewed as some form of insurance or amount to offset an carbon market’s uncertainties with specific practice implementation.

Some estimates have been made on how much sequestration and emissions reductions might occur with silviculture practices implemented, like these discussed here. If Idaho adopted these silviculture practices on 50% of its state and private forest lands, a significant amount of CO_2e could be sequestered. Very few field studies seem to be available to estimate accurately benefits in carbon sequestration and emissions reduction. A whole forest-wide project analysis would need to be done to better estimate actual carbon credits available for purchase.

4.7.1.3 ACCEPTABILITY

While public forest may be intensively managed, most private non-industrially owned forest is not. Various studies identify a number of reasons why nonindustrial timberland owners may not manage their forests for higher productivity. First, many landowners are not aware of what can be done to improve forest growth. Second, among those who are aware of the opportunities, many may be unwilling to undertake projects with a long payback period or relatively modest rates of return. Third, many lack the up-front capital needed to invest in a crop that, although profitable, may not generate income for 10 to 15 years. Additionally, landowners may resist investing in improving their forested land because of the low financial liquidity of young stands and an inability to use future forest values as collateral. Last, some landowners use their timberland for other purposes, such as recreation, which do not require high productivity.

Often, funding is limited for land owners who are desirous of participating in programs to prevent or control insects or diseases that kill or damage trees. Increasing the opportunities for monetary returns associated with increasing forest health will help stimulate forest owners be able and willing to participate in these activities. Finding new uses, of timber products, such small diameter logs that result from thinning is an example, where there is a demand, may help improve acceptability. Sale of carbon credits by forest owners may have potential for providing increased returns from forested acres, stimulating increased participation in all programs.

4.7.1.4 COST

The benefits of silviculture practices may be great towards carbon sequestration if regeneration, fast growth, and fire suppression occurs. The benefits are not easily quantified here but should be further evaluated and researched. Individual forest acreages and practices would need evaluated individually to assess a long-term carbon sequestration amount. Some modeling may be adequate to encourage the adoption of specific practices and sale of carbon credits with some level of certainty at this date. There is a higher level of certainty for above-ground biomass generation of carbon as compared to below-ground biomass and soils. Though initial costs may be greater, the cost of adopting pest management may be offset through forest health improvements, with the sale of good quality timber.

4.7.1.5 IMPLEMENTATION CAPABILITY

These silviculture practices can be implemented, and successful, if the landowner or forest manager is committed to a long-term plan. If the landowner can absorb initial costs, periodic natural setbacks, such as fire and disease, then ultimately this and similar practices can be implemented successfully, over a long period, meeting the landowner’s objectives. If there is sustainable production occurring along with these practices, then implementation is likely to continue where a net profit is seen. Flexibility must be a part any long-term forest conservation and productivity plan.

4.7.1.6 OPERATION AND MAINTENANCE CAPABILITY

Timber management is generally not based on short-term decision making, but long-term objectives. Keeping to a management program that has little or no return on investment may be difficult maintain. However, if there is already an established forest that is steadily producing a product, where gradually, benefits are seen with improved management, the operation may be provided some encouragement seeing results in its products. While under a contractual agreement, continual implementation will be necessary, and hopefully, within that agreement, there are stipulations and understandings on what is needed to ensure proper operation and management. Again, as mentioned before, natural setbacks, market variability, and other factors will occur, therefore, the landowner needs to be flexible within its operation and maintenance plan.

4.7.1.7 MONITORING AND VERIFICATION CAPABILITY

Conceptually, improved timber stands and growth will increase carbon sequestration and effect positively other natural resources. Evaluating silviculture and its effectiveness may be difficult, if one was to attempt to measure it directly, such as in reduced decomposition or below-ground biomass production and soil carbon. Research activities have been ongoing looking into carbon cycling under various scenarios, but on a limited scale. costs and time input are high research projects, where physical data collection is time consuming. Actual data collection, under a carbon market, used to verify and quantify carbon stored, and would not likely be feasible. Research data collected on specific sites may be used to estimate what occurs on other similar sites. Modeling may be the most effective and feasible method for a carbon market. Uncertainties with modeling would be acknowledged in a market, reflected in prices and contractual provisions. Ensuring silviculture practices are being utilized correctly, over a long period of time, may simply be based on records and periodic inspection by a qualified forester.

4.7.1.8 ANCILLARY BENEFITS

Multiple natural resource benefits should occur with good management practices within a forest. When good silviculture practices are implemented, disease and fire damage is limited, thereby, reducing the sometimes devastating impacts to water bodies and wildlife habitat. Enhanced timber production is an objective within silviculture practices, where hopefully, a greater benefit to a landowner if implemented properly.

4.7.2 Afforestation and Reforestation

4.7.2.1 DESCRIPTION

Afforestation is the process of converting non-forest lands into forest stands. Afforestation of marginal cropland, pasture and riparian areas increases forestland acreage on open land not being productively utilized could provide substantial greenhouse gas benefits by planting trees on these properties. Tree species, particularly productive in sequestering carbon and/or fixing soil nitrogen, could be selected to obtain maximum greenhouse gas advantages per acre. Reforestation is simply replanting an area recently harvested for timber products or where trees have been damaged by fire or disease.

One example is where center pivot irrigation systems, commonly installed on large tracts of land, (80 to 160 acres), attempt to irrigate about 6 acres in each corner of the tract. The efficiency of such irrigation is usually low, and crop production limited. Many center pivot owners do not adequately irrigate these corners because of their inefficiencies, often letting some or all of the corners set idle. These irregular shaped corners also make maneuvering equipment difficult, however in areas where precipitation is adequate for crop production, farmers may still resort to dry land cropping. There are many acres of center pivot corners that could be planted to trees and shrubs to provide wildlife habitat and crop protection, while storing carbon, if adequate water was made available during establishment.

The following afforestation activities were evaluated:

- Poorly stocked forest land
- Non-stocked forest land
- Marginal cropland land

- Marginal pasture land
- Center pivot corners

4.7.2.2 EFFECTIVENESS

New forest plantings will cause an immediate increase in carbon sequestration on these sites. Reduced tillage within these areas will also reduced soil carbon losses in soils having been depleted by conventional tillage. Abandoned pasture and croplands are able to sequester C through the natural re-growth process. However, converting this land to managed forests allows for more C to be sequestered at a faster rate because youthful trees, generally through the first 10 to 20 years, maximize their uptake of CO_2.

Afforestation, new forest lands, seems to have the largest potential for carbon sequestration. Not only does creation of new forest inventory imply a large new carbon sink, increased forest products have long-term carbon storage properties. Lands converted from a use to forest land, may likely be those low-productive agricultural lands, or those being encroached upon by development, no longer viewed as prime farmland where production activities are susceptible urban pressures.

It is difficult, practically impossible to predict how many acres would be converted to new forest lands, there is data on the rate per acre of relative carbon fixation that could be generated. These conversions measure soil and biomass carbon, but calculate only net carbon gain between uses. Many variables and different combinations of these variables make it very difficult, if not impossible, to accurately predict a maximum level of carbon that could be sequestered in Idaho forests. However, if some assumptions are were made, a predicted level of carbon sequestration can be estimated through afforestation on specific land uses.

Afforestation might be financially feasible on only 20% of the biologically suitable acreage. Poorly stocked forest land may be under-stocked by 75%. Marginal pasture land is more available than good condition pasturelands. Marginal cropland has little or no carbon in the top one foot due to repeated tillage and may more likely be available for afforestation. If about 500,000 acres of these lands were converted to trees, there might be up to 3.7 MMT CO2e/yr sequestered. Further analysis would need to be done on site-specific areas to estimate a net carbon sequestration.

4.7.2.3 ACCEPTABILITY

Within the agricultural sector, giving up cropland is not readily acceptable, even if production is low. Aesthetics and wildlife benefits play a large role in causing landowners to plant some lands into trees, shrubs and grass. In southern Idaho, irrigation is needed to establish plantings, and longevity. Irrigation costs may need to be offset if large acres are planted. Small acreages may be easily incorporated into the much larger irrigation costs of farming. In orchard areas, increased wildlife habitat may increase fruit tree damage by wildlife, such as rodents and deer. Planting costs may be high, which may hinder the acceptability as well, with loss of some annual return from crop production. If the newly planted acreage can be considered alternative to cropland, property taxes may change, hopefully less while no annual profit is expected. Reforestation is required under Forest Practices Act regulations, within harvested forests, therefore, would likely be implemented regardless of how acceptable.

4.7.2.4 COST

The benefits of newly planted forests and timbered areas can be substantial in regards to carbon sequestration and reduced greenhouse gas emission reductions, primarily on intensively used lands. This practice will provide emissions offsets primarily in carbon storage. Above- and below- ground biomass will create the most stored carbon. Some soil carbon increases may be expected, but only in those soils where because of previous land use, organic matter has been reduced. If carbon markets become active in Idaho, the benefits should be great enough to offset planting and maintenance costs. Additional benefits in aesthetics and wildlife habitat could also be considered in a cost analysis for a landowner. If trees are grown for a specific product, then those expected returns would be realized upon the sale of the product, while estimated prior to the sale.

4.7.2.5 IMPLEMENTATION CAPABILITY

Once a landowner decides to convert a field to trees, implementation is easily achievable. The most difficult period is in making that decision. Planting trees or shrubs can be expensive if large acreages are involved. It may be best, however, to create a rotation and multiple age classes and species by planting only so many acres every year. This diversity in age classes may be wise to maintain so that damage from disease and other impacts may be less on the entire area planted. Cost-share programs and other funding sources may help in the implementation of such a practice.

Alternatives to completely setting aside acreages just for tree production may be considered. For example, trees may be incorporated into grazing areas, such as pastures, if woody utilization is controlled. Alfalfa hay could be planted within tree rows and utilized for livestock feed, though such a species competes with tree production and management would need adjusted to optimize carbon storage in the trees.

4.7.2.6 OPERATION AND MAINTENANCE CAPABILITY

Upon installation of new forest setting, disease control, irrigation, fertilization, and other operational and maintenance management needs to occur to ensure good health and long-term growth. Depending on the landowner's commitment and long-term objectives for the tree stand, the operation and maintenance will vary. If there is an expected return on the trees, then maintenance is likely going to be more important and likely carries out. If these plantings are on small acreages and to be permanent, then maintenance will likely occur as readily, because of there being no return on investment. If the landowner is in agreement and under a contractual arrangement with a carbon credit purchaser, then maintenance will simply have to occur in order receive payments or other incentives.

4.7.2.7 MONITORING AND VERIFICATION CAPABILITY

Periodic inspections will likely be all that is needed to verify that trees are growing adequately and being maintained. This practice is so visible that a higher degree of certainty exists. Where all parties can see results. Carbon sequestration could be physically measured through biomass production and core samples, but may be costly. Soil samples may be a part of the verification as well, but would require additional time and costs.

4.7.2.8 ANCILLARY BENEFITS

Increase wildlife habitat, aesthetics, reduced farm operation inputs (e.g. fuel use), and other benefits may be enjoyed with such a practice. These plantings may provide additional benefits, such as reduced odor and visual problems along side dairies, feedlots, and industries. Water quality may also benefit from greater vegetation diversity within the catchment provide by additional forested lands.

5 MEASURING AND MODELING NET CARBON SEQUESTRATION

5.1 MEASURING CARBON SEQUESTRATION LEVELS

Two significant issues pertaining to the measurement and modeling of carbon sequestration are: 1) How can net carbon sequestration and/or greenhouse gas emissions best be measured at an individual site, 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 sites must be measured in order to calculate the potential gains and losses from different land use activities. Second, measurements may 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. The year of 1990, which seems to be the accepted baseline year for which countries are to reduce greenhouse gas emissions, may be compared back to when measuring current or future sequestration. How stringent any future carbon sequestration markets are on utilizing a 1990 baseline year is not yet determined. For the purpose of this report, on-site and state-wide measurement and modeling will be the focus, where the third challenge is best dealt with on a national-scale.

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, above- and below-ground biomass 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 (CO_2e). 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. The uncertainties associated with county-wide and state-wide estimates will likely be much larger, therefore may not be as marketable as credits.

On a statewide basis, one of the first items required is a baseline of current soil carbon levels. 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 on-site measurements of soil carbon, biomass or carbon flux;
2. Indirect remote sensing techniques;
3. Default values for land/activity based practices.

Which method or methods are acceptable 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 carbon markets and international agreements. The overriding question is how accurate an accounting of sequestration is needed and how expensive it is to conduct.

5.1.1 Direct on-site Measurements

Direct on-site methods include field sampling and laboratory measurements of total carbon in the soil and biomass. Changes in carbon content resulting from changes in land management may then be expressed as the change in carbon amount on an area or volume basis (biomass would require volume calculations, vertical height included with acreage). 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). The accuracy and precision of the eddy covariance method is improving as more experience is gained and is being used at about 150 locations worldwide.

There is some uncertainty of 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 in combination with satellite imagery and computer modeling could result in a more comprehensive assessment. There is still debate 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. Long-term projects may be measured more accurately than short-term projects, due to the problems encountered with trying to measure changes in soil carbon within a few years, which soil carbon change is not linear.

Above-ground biomass may be easier to measure, where foresters have been measuring timber for years for wood production. These measurements, combined with biomass equations for a species of tree and shrub, can provide a fairly accurate estimate. Forestry and agroforestry measurements are discussed further below. Landowners themselves are capable of measuring tree dbh (diameter at breast height), where random trees can be sampled and with the species carbon default values, an average quantity of carbon stored can be estimated.

5.1.2 Indirect Remote Sensing Techniques

Even where field measurement programs 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. It is likely that a combination of field site visits may used as an audit means while utilizing a remote sensing program to estimate annual sequestration. Field operations may also provide records to assist in project implementation verification, used to compare with remotely sensed estimates. Remote sensing may not only be from high-altitude imagery, but from equipment ran across a field, sensing what carbon concentrations may be below the surface. Research is currently looking at soil conductivity and other factors to remotely estimate soil carbon levels, with accuracy.

5.1.3 Default Values for Activity Based Practices

Another approach to estimating carbon storage is the use of default values 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 monitoring that shows that a particular practice was used on the land in question. Land use monitoring can be readily measured by remote sensing techniques, eliminating the need for an army of field inspectors. Field plots may need to be set up, representing the average or a range of conditions of the entire project area, utilized as a reference to provide actual estimates, to increase the accuracy of large-scale project.

Biofuel use would simply be tracked by production and sales of ethanol and biodiesel. Where a number of gallons are produced and sold within the state, it can be assumed that a similar quantity of gasoline and diesel is not used, thus a reduction in emissions from the transportation sector. The amount of emissions related to the production of each gallon of ethanol and biodiesel would need subtracted from the estimated reduction of emissions from motor vehicles.

5.1.4 Measuring Forestry and Agroforestry Carbon

A distinct advantage of forest and agroforestry is the relative ease with which carbon accumulation can be measured and monitored. The baseline for agroforestry practices that involve tree planting could 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.

The need for the development of biomass equations for trees and shrubs grown in agroforestry practices is still needed, however. 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. Some researchers estimate that equations underestimate biomass within windbreaks and other similar practices where 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.

For a further information on forest-based project monitoring, see
http://www.winrock.org/REEP/Guidelines.html.

5.1.5 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. There is an ongoing assessment of Nebraska soil carbon being conducted 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.

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.

Another method that can provide valuable information to farmers the NRCS Soil Conditioning Index (SCI), which evaluates existing tillage and management practices, and gives an estimate increase or decrease of soil organic matter. The accuracy of the index is not adequate for carbon market use, but could be used to initiate carbon sequestration activities, providing farmers with an understanding of commitment to long-term soil conditioning.

Random soil sampling of fields will provide the most detailed and precise amount of carbon in soils. Soil survey information and soil reference sites may be most efficient, however, and provide adequate method of gross comparison of fields and regions. Looking at a 30 cm depth for example, its soil bulk density, and organic matter content, one can estimate a volume or weight of carbon on a per unit acre. One can assume that carbon is approximately 50% of the total organic matter content of soils, though it does vary with bulk density and other factors. For instance, a study in Amana, Iowa analyzed soil samples along a buffer strip and found that with a bulk density average of 38% of the organic matter, where organic matter averaged 3.5% within the top 33 cm. This study resulted in estimating soil carbon at 21.2 metric tons of organic matter per acre or 9.7 metric tons of carbon Of course, there other variables that may need to be looked at to improve these estimates.

5.1.6 Measuring Other Greenhouse gases

The basic approach used to measure other greenhouse gases 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 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 difficult.

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. But field measurements are not easily obtained either. Research activities afford scientists the ability to compare a control to an alternative tillage scenario, where plots are measured with expensive testing equipment, while requiring some level of technician support. Farmers, as well as those potential buyers of emission offsets, are not likely to invest actual measurements, for likely such a small return. Research plots may be set up to compare practices and conditions initially and some time in the future to be used as a reference case to better estimate typical carbon sequestration rates for other similar project areas. Specific case studies for whole-farm analysis would be very beneficial in estimate net carbon and emissions benefits. This analysis would basically use an annual balance sheet to determine if the operation as a whole actually increases carbon sequestration above its farm related emissions.

5.1.7 Carbon Sequestration Verification for Carbon Markets

For a landowner to actually produce a carbon credit, which will likely consider the actual carbon sequestered and the emissions associated with the land use activities, a process that determines their baseline carbon and greenhouse gas emissions level is needed. There exist some methods used to verify an amount of carbon sequestered or reduced greenhouse gas emissions and may be acceptable to carbon market participants. Further work is needed, however, to better predict and measure a 'whole-farm' net credit. All sequestered carbon and greenhouse emissions relative to the land use activity will need to be calculated to determine a true credit, which is then potentially available for purchase.

6 UNCERTAINTIES IN CARBON SEQUESTRATION

There are many uncertainties related to carbon sequestration, such as the driving issue, global warming. Actual temperature data is basically unavailable prior to the 1800's, which make it very difficult to determine if the recent increase in global temperatures is part of a long-term trend or not. Models have been used to estimate temperatures based on geological physical properties, but without actual temperature data, is primarily speculative. However, in this discussion, the focus will not be on climate change but carbon sequestration and carbon markets.

The majority of the uncertainties related to carbon sequestration is in quantification and its effect on offsetting greenhouse gas emissions. There are also uncertainties regarding practice acceptability, local impacts, economic benefit, and other non-scientific elements that need to be further addressed during any development of carbon sequestration activities and markets.

There are issues outside of the control of the state, such those driving forces that will make or break carbon markets. Regulations restricting emissions of greenhouse gases will certainly have the greatest impact on carbon markets. Without direct restrictions on sources, there will not likely be any incentive to offset emissions. If regulations arise, then what will their real effect be on sources? Will they be so restrictive requires sources to look elsewhere to offset what they cannot reduce on-site? Are there sources that cannot simply upgrade facilities to meet new restrictions? If these restrictions come to pass on sources, and greenhouse gas offsets are needed, then carbon markets are likely to become beneficial to landowners and Idaho. How much benefit the state could see is completely yet to be determined.

Based on the assumption that greenhouse gas emissions will be restricted, and that sources will not meet those requirements entirely at the source, carbon dioxide and other greenhouse gases could be offset by voluntary carbon sinks (or by non-regulated emission sources). What assurance will those being regulated need to ensure that a specific quantity of carbon dioxide or other gases are actually offset? What assurance will the carbon sink have from regulators that they won't become regulated once providing those offsets? Numerous carbon market (emissions trading) rules will need to be worked out prior to much participation. There is much uncertainty regarding the legality of emissions trading, which will have to be worked out among regulators, emission sources, and potential carbon offset participants.

The economics of carbon markets are uncertain. Will there be a wide margin of costs between emission source mitigation and carbon offset costs? The emission source will need offset costs to be lower than their own mitigation costs for it to be feasible. Additional funds may be needed, for items such as legal fees, transaction costs, trade tracking, and monitoring. If the margin of cost is relatively narrow between two potential participants, than it may not be feasible to participate in trades.

There also physical, cultural, social, and economic barriers and uncertainties that keep landowners from adopting some conservation practices, which could be used to generate carbon credits in the state. A study has recently been done by the USDA-NRCS Social Sciences Institute, regarding the barriers and strategies for adoption of conservation buffers, explored landowner's attitudes, behaviors, and uncertainties (see http://www.ssi.nrcs.usda.gov/ssi/B_Stories/2_Tech_Notes/T022_Buffers.pdf). Based on numerous interviews with producer groups, field specialists and other conservation partners, observations on the common barriers to adoption of conservation buffers were recorded for analysis. Some of the barriers and uncertainties keeping landowners from adopting these observation practices included:

- Lack of information on site-specific agronomic, economic, and environmental cost and benefits
- Costs of installing buffers seemed excessive,
- Practice not in line with farmer's personal goals and values, or fit in operation

- If buffers installed, land viewed as idle, no longer productive,
- Landowners unsure that equipment operators would keep buffers in place.

An Idaho demonstration project that basically develops a system of emissions trading, carbon market, would clear up many of these uncertainties and issues described above. The demonstration would involve numerous public interests, besides those potential carbon market participants, to ensure public approval. Many of the issues that a demonstration project would have to address are listed below:

- The effect of regulations on greenhouse gas sources
- Predicting and quantifying soil carbon, above- and below-ground biomass stored carbon
- Predicting and quantifying methane emissions from animal waste storage ponds and livestock enteric fermentation
- Predicting and quantifying nitrous oxide emissions from cropland activities,
- Calculating a whole-farm, field, or project's net carbon sequestration level, which discounts land use related greenhouse emissions
- The potential quantity of agricultural products that are available and could be made available for biofuels production
- The potential quantity of agricultural products that are available and could be made available for bioenergy production, such as in co-fired facilities
- The potential future electrical demand in the state, from coal-fired electrical facilities
- Legal ramifications of long-term contracts between buyers and agricultural and forest landowners
- Landowner costs and benefits while implementing practices and participating in carbon markets
- Statewide costs and benefits while implementing practices and participating in carbon markets

Most of those barriers and uncertainties listed above could be overcome through the employment of a carbon market demonstration project. If the state and carbon market participants understand the landowner's and emission source's positions as to why and how they perceive barriers and uncertainties, the development of a sound carbon market is more likely to occur. Within a demonstration project, a few comprehensive whole-farm and state-wide analysis could also be done simultaneously to help address these uncertainties.

7 CARBON SEQUESTRATION MARKETS

Carbon sequestration markets have the potential to increase the level of conservation practice implementation in Idaho, as well as increase ethanol, biodiesel, and bioenergy production. Marketing CO_2 may be similar to what is already occurring with emissions trading of sulfur and nitrous oxide in the Acid Rain Program. Electrical producers and other industries with relatively high greenhouse gas emissions are expecting that in the future, there will come regulations that 'cap' their carbon dioxide emissions, possibly some other greenhouse gases as well. There are some energy producers already experimenting with purchasing or leasing carbon 'credits' (emission offsets) from farm and forest land activities that increase stored carbon in soils and woody vegetation. Carbon markets in Idaho could provide funding and incentives through a non-regulatory process towards the implementation of practices that have also numerous ancillary benefits, such as increased net profits, lower local unemployment, water quality improvements, and endangered species conservation.

Carbon markets can be a cost-effective way to meet a state or national greenhouse emission goal. The key to keeping costs low is to allow all potential emission reductions or offset practices, particularly those that can achieve these reductions or offsets at low costs. Most evidence points to agriculture and forestry, generally speaking, as being a low-cost provider of carbon sequestration and greenhouse gas reductions (and offsets). The costs of sequestering soil carbon and reducing agricultural CH_4 and N_2O emissions are likely low relative to the costs of emission reductions from fossil fuel combustion.

Carbon markets would require more elaborate baseline information and measurement, monitoring, and verification processes because buyers of greenhouse gas reductions need to document, with confidence, those reductions taking place on agricultural and forested lands. Although there is substantial U.S. experience in point source emissions trading, such as in the acid rain program, there is very limited experience with trading programs that allow trades to take place between point sources and land-based offsets. However, Idaho has some experience in the development of water quality trading, which is likely to be very similar to carbon markets.

The Lower Boise River Pollution Trading Project, which the Soil Conservation Commission played an instrumental part in developing, provides an avenue for a municipality to offset a portion of their waste water phosphorus loads entering the river system. The municipality can fund agricultural conservation practices elsewhere in the river's catchment, but only by showing that an reduction on the farm is equal to their contribution on-site. Once point sources, these municipalities, are required to meet a new Total Maximum Daily Load (TMDL) mandate, reductions of phosphorus discharges are to begin and trading can occur if necessary. Statewide rules have been generated by the DEQ for water quality pollution trading anywhere in the state. This water quality trading project has set up an excellent process to connect buyers and sellers of phosphorus credits, procedures to estimate and document equal portions of phosphorus within a trade, minimal contract requirements, and trade tracking mechanisms. A carbon market that includes emission sources, agriculture and forest landowners, could be developed very similar to the acid rain cap-and-trade program and the water quality trading program previously described.

There seem to be three important elements missing or yet to occur that would kick-start a carbon market in the U.S. and Idaho. 1) Regulatory CO_2 emission reductions on sources, such as electrical producers, 2) Public acceptance of carbon markets, allowing emission sources to be offsets, and 3) Carbon market and trading rules. Upon regulatory action, likely first by the U.S. Congress and EPA, carbon market development is sure to progress at a much faster pace. Until CO_2 emissions are regulated, then there is little need or demand to offset greenhouse emissions.

7.1 CARBON MARKET AND EMISSION TRADING ACTIVITIES

A number of companies, anticipating the establishment of domestic and international greenhouse gas emissions trading systems, are investing in a variety of emissions trading activities. A recent Pew Center report, "The Emerging International Greenhouse gas Market," estimated that approximately 65 greenhouse gas trades for quantities above 1,000 metric tons of CO_2-equivalent have occurred worldwide since 1996. However, this figure probably underestimates the level of trading because not all trades are made public. Although the United States has withdrawn from the Kyoto Protocol, U.S.-based multinational companies whose overseas operations will be subject to emissions limits in countries that will be party to the Protocol are likely to participate in Kyoto's trading mechanisms.

Some of the carbon market and emission trading activities follow
(see EPA http://yosemite.epa.gov/oar/globalwarming.nsf/content/index.html for additional information):

- The Chicago Climate Exchange is based in Chicago and involves seven Midwestern states (Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, and Wisconsin). The Midwest was chosen as the pilot location because of its 20 percent share of national greenhouse gas emissions and its mix of manufacturing, transport, energy, agriculture, and forestry sectors. Currently, 25 companies are participating, including Agriliance, Alliant Energy, Calpine, Cinergy, DuPont, Ford, GROWMARK, International Paper, NiSource, PG&E National Energy Group, STMicroelectronics, Suncor Energy, Temple -Inland, Wisconsin Energy, and ZAPCO. The project hopes to expand to the rest of the United States and parts of Canada and Mexico by 2003 and internationally by 2004. In this emissions trading program, participating companies are issued tradable emission allowances. Emitting companies commit to a phased reduction schedule of 5 percent below 1999 levels by 2005. To achieve this goal, the companies can use a variety of options. One option is to cut their emissions; another is to buy allowances from companies that have achieved surplus reductions. A third option is to buy credits from agricultural carbon sequestration projects or other offset projects such as sustainable power generation.

- BP launched the world's first global emissions trading system in January 2000. All 150 business units of the company participate in trading. In its first year of operation, 2.7 million metric tons of CO_2 equivalent were exchanged at an average price of $7.60 per metric ton. The system is now in its third year and includes the former Arco and Vastar assets.

- Cinergy Corp. is working with other industries and organizations to pilot emissions trading systems, and through its subsidiary company United States Energy Bio-gas has completed the trading of carbon equivalent offsets with a Canadian company. Cinergy is in partners in the Rio Bravo Carbon Sequestration Project to protect 65,000 acres of endangered rainforest in Belize. The project combines land acquisition and a sustainable forestry program and is expected to sequester approximately 2.4 million metric tons of carbon over 40 years.

- DuPont is working with others to pilot emissions trading systems and has completed small trades in Canada and the United Kingdom.

- Entergy and Elsam, the largest Danish electricity supplier, executed the first-ever international trade in CO_2 allowances under the Danish climate change program. Under the transaction, Entergy purchased 10,000 Danish allowances from Elsam and will remove the allowances from the market, eliminating 10,000 metric tons of CO2 emissions.

- Ontario Power Generation (OPG) and PG&E's subsidiary U.S. Gen New England (US Gen) successfully completed a greenhouse gas emissions trade in April 2000. US Gen sold OPG 1 million metric tons of CO_2 equivalent emissions reductions generated by capturing and destroying methane that would otherwise be emitted from the Johnston Landfill in Rhode Island from 1998-2000. OPG has committed to have all of its emissions reduction purchases, such as this one, verified by the Ontario, Canada Pilot Emissions Trading Project (PERT) and report them to Canada's Climate Change Voluntary Challenge and Registry (VCR) Inc., where they are transferred and retired.

- TransAlta has led the development of options, forwards, and other innovative contracts for greenhouse gas emissions reductions and efficient markets. TransAlta develops and trades for approximately 4 million tons of CO_2-equivalent per year in offset projects, with 80 million tons currently under contract. Offset projects incorporate gas recovery, energy efficiency, ruminant methane, landfill and coal mine gas to electricity, forestry, and soil sequestration, among others. In a recent upgrade of its United States operations, the company reduced its CO_2 emissions by an amount equal to the annual emissions of 27,800 cars, and sold the resulting credits to a United States integrated oil company. TransAlta is contributing to the development of liquid markets in greenhouse gas emissions reductions by engaging in selling fractions of its portfolio. To date, sales transactions in excess of 1 million metric tons have been consummated.

- American Electric Power and BP are part of a collaborative greenhouse gas mitigation pilot project with the Government of Bolivia, The Nature Conservancy, and the Bolivian Friends of Nature Foundation. The Noel Kempff Mercado Climate Action Project will protect nearly 4 million acres of threatened forest and offset 5 – 7 million tons of carbon over the next 30 years. AEP is also a partner in the Guaraqueçaba Climate Action Project, which seeks to restore and protect nearly 20,000 acres of partially degraded and/or deforested land in the tropical Atlantic rainforest of Brazil. The Project is expected to offset approximately 1 million metric tons of carbon over the next 40 years.

- Baxter has "adopted" a 150,000-acre rain forest in Costa Rica to help protect biodiversity and promote carbon sequestration. With the support of the Costa Rican government, Baxter performs infrastructure improvements in the rain forest and plans to fund the building of a related education center.

- Wisconsin Energy Corporation participates in a project that involves fuel-switching (coal to natural gas), cogeneration, and efficiency improvements to a power plant in the city of Decin, Czech Republic.

- 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.

- 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).

- 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).

- The Chicago-based firm of Environmental Financial Products, LLC is 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. (see http://www.pert.org/pert.html)."

- 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. A consortium of power companies in Canada has been actively searching for carbon offsets that they might apply against their baseline emissions (see http://www.gert.org/background/#greenhouse).

- Carbon banks are also emerging. The International Carbon Bank and Exchange (see http://www.carbonexchange.com) "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.

- The New Jersey Department of Environmental Protection (NJDEP), in collaboration with the Center for Clean Air Policy (CCAP), had received a grant from the USEPA to design a carbon emissions trading, or "banking" system for carbon emissions reductions credits that could operate on a national or international scale. Efforts to develop the design of such a greenhouse gas trading bank focused on the following key elements: 1) methods of recording and certifying credits generated, 2) methods of recording and certifying credits used, 3) methods of recording and tracking credits banked, 4) establishing baselines for credit generation, 5) encouragement of innovative technologies that generate energy with lower greenhouse gas emissions, 6) ensuring public availability information, 7) ensuring accuracy of all records and transactions, 8) procedures to enforce compliance, and 9) government oversight of operations and quality assurance auditing.

Based on the world-wide carbon market activity, there suggests that there will be greater activity when the Kyoto or something similar officially begins and the U.S. begins to regulate greenhouse gas emission sources. Until then, carbon market development in Idaho will be limited, except through incentives provided by companies to voluntarily initiate further exploration and development of carbon market activity in the state.

7.2 CARBON MARKET PROCESS

There are some possible strategies that Idaho might initiate carbon sequestration activities and specific greenhouse gas reductions. The extent to which Idaho chooses to rely on non-regulatory measures to achieve offset or reduction objectives, including free market transactions, as opposed to regulations, is largely a matter of public policy. While some voluntary action would occur without some new regulations or policies, more interest would be generated by regulations and need. There is an advantage to voluntary action where acceptance may be greater and a higher potential for greater economic efficiency in achieving environmental goals.

At least in the United States, it is likely that a greenhouse gas abatement program would incorporate carbon market mechanisms in conjunction with government setting bounds and helping the market operate in equitable and just ways. It appears that no legal impediments prevent the development of markets for carbon sequestration benefits, where there have been numerous early attempts to acquire carbon sequestration offsets (see above examples). At a minimum there are some structures necessary for a carbon 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, such as through aggregators. The pool could be privately operated through an aggregator, organized locally, or, with an appropriate grant of authority, organized through such entities as a Soil Conservation District. Finally, there needs to be some way for future participants of discovering what is a fair market price for a carbon offset representing carbon in storage. Markets price negotiation must be allowed among participants.

The most recent carbon market transaction in Idaho, possibly one of the first in the U.S., is the PNDSA and Entergy agreement. Looking to this market transaction will assist the state and future participants understand some of the processes it takes to create a market. At this point in time, it is difficult to predict the fair market value of such carbon sequestration and offsets. Until the regulatory programs are enacted, the economic value of potential carbon offsets will not be truly be known. Values are a function of company emission reduction costs, carbon measurement techniques (verification), the amount of carbon sequestered (established from a baseline), and cost associated with contract develop among participants.

Carbon markets are likely going to effected by international agreements, rules, and interest. The value of carbon offsets will depend on the cost of achieving the same carbon reduction benefits at any location on the globe. There will likely be at least two kinds of offsets that could be considered in market trading: 1) carbon offsets in flow (COIF) and 2) carbon offsets in stock (COIS). The COIF 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. While in COIF, it is likely that carbon baselines will be established to keep a perverse incentive to reduce the stock in place from happening, which then could actually increase the amount of COIF available for purchase in a market. In other words, preventing the removal of a practice previously installed through a carbon market, then re-applied at a later date, to once again receive a carbon incentive payment. Carbon market tracking will have to occur as well to ensure fair market play. The COIS might offer a greater certainty of credits to an interest in need of carbon offsets for a period of time.

Carbon trade might commence and be tracked using certificates, with each certificate representing an amount 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, hold onto the carbon and keep it out of the atmosphere.

Focusing on the stock in place (COIS) 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, there needs to be an incentive to maintain it at full capacity. These variables will need to be worked out prior the state wholly engaging in carbon markets.

7.3 CARBON SEQUESTRATION SUPPORTING PROGRAMS

By focusing on the agriculture, forestry, and biofuels sectors, policy-makers can integrate several carbon sequestration and greenhouse gas reduction measures into a single, comprehensive program. The greatest opportunities for reducing greenhouse gas emissions in the agriculture, forestry and biofuels sectors may involve not only direct actions to address each of these sources but also innovative approaches that combine policies so that emission reductions from one source support reductions from others. The carbon market may look favorably to practices that provide duel offsets. For example, methane can realistically be captured from animal waste storage ponds and then be used as an energy source. This decreases direct methane emissions and reduces the need for energy from traditional fossil fuel sources. Another example is eliminating bluegrass burning and utilizing the residue in co-fired energy plants. Reduced nitrogen fertilizer (synthetically produced) can reduce field N_2O emissions as well reduce the amount of fertilizer produced, which lower production related emissions. There needs to be mechanisms and potentially programs that capitalize and encourage dual or multi-benefit emission reduction practices.

Public recognition or other rewards for landowners who increase carbon sequestration and reduce related emissions from more than one source simultaneously may also enhance farmer interest in these activities. Support for demonstration projects or whole-farm case studies in multiple-source emission reductions can also generate farmer interest. A common message about the potential benefits of carbon sequestration and emission reductions from state agricultural agencies, environmental agencies, extension agents, and even in trade journals and other publications can consistently reinforce the fact that landowners can simultaneously sequester carbon, reduce emissions, and enhance net productivity.

7.3.1 Example Comprehensive Programs

There exist numerous state and federal programs and projects that Idaho can look to for example while exploring program development
(see EPA http://yosemite.epa.gov/oar/globalwarming.nsf/content/index.html for additional information):

- Cool Communities is a voluntary program sponsored by DOE. The function of Cool Communities is to encourage the strategic planting of trees to provide shade and windbreaks to residential and commercial buildings, thereby, improving energy efficiency and reducing the urban heat island effect. These trees also serve as a carbon sink, contributing to the overall carbon reservoir both above and below ground. (Cool Communities is Action #11 of the CCAP)

- Iowa's Department of Natural Resources provides support, funding, and information to promote switchgrass as a biomass energy crop with the potential for large-scale production across Iowa. In a demonstration project, 35 MW of power will be generated by co-firing coal and switchgrass, displacing coal use and reducing approximately 114,000 tons of CO_2 emissions per year.

- Maryland provides income tax credits for the production and sale of electric power from biomass combustion, including energy crops and poultry litter.

- Wisconsin assists one of its largest dairy farms with manure-to-energy technology that eliminates 26,250 tons of CO_2-equivalent emissions through methane capture and replacement of coal-fueled electric generation.

- The Oregon Forest Resource Trust provides up to 100 percent of reforestation costs to help landowners establish and maintain healthy forests on under-producing forest lands. Landowners forego ownership of any carbon-offset credits to the Trust, but share net revenues from any profitable timber harvest. Net emissions reductions of 1.16 million metric tons of CO_2 are estimated over the life of the program.

- The Vermont Methane Pilot Project promotes the use of methane recovery technology on dairy farms. This method of dealing with livestock waste reduces emissions of a potent greenhouse gas to the atmosphere and displaces fossil fuel energy. In addition, through Vermont's net metering law, farmers that produce up to 125 kilowatt (kW) can sell their excess energy to the grid, providing supplementary income. Methane recovery from dairy manure alone could provide Vermont with 28,000 kW of renewable energy.

- Wyoming recently established an advisory committee to implement a carbon sequestration and carbon credit-marketing program.

- Georgia's No-Tillage Assistance Program leases "no-till" equipment to farmers, providing them with the quickest and most cost-effective method of replanting, and reducing thousands of gallons of fuel use.

7.3.2 Existing Agricultural, Forestry and Biofuels Programs

At present, there are a large number of agricultural conservation programs. Responsibility for implementing these programs is divided between the Natural Resources Conservation Service (NRCS) and the Farm Services Agency (FSA), both agencies of the U.S. Department of Agriculture (USDA). The large number of programs and the numerous eligibility requirements are sometimes barriers to farmer participation. Some major conservation programs are starting to encourage soil carbon storage, CH_4 reductions, N_2O reductions, CO_2 reductions, and water quality benefits. These programs include CRP: Conservation Reserve Program; CREP: Conservation Reserve Enhancement Program; WHIP: Wildlife Habitat Incentive Program; FPP: Farmland Protection Program; EQIP: Environmental Quality Incentive Program. Participation in environmental programs such as the CRP, WRP, and EQIP has been voluntary. These programs provide payments to farmers for adopting conservation practices.

Idaho has its own agricultural programs, such as those administered by the SCC. The Water Quality Program for Agriculture (WQPA), the Resource Conservation and Rangeland Development Program (RCRDP), and the State Revolving Loan Program (SRF) (DEQ administered) are such examples. These are also conservation oriented, increasing conservation on cropland, rangelands, pasturelands, and some timber lands, enhancing and improving multiple natural resources. These might also consider promoting carbon sequestration practices and linking with industries to secure funding for dual or comprehensive practices that sequester carbon and result in emissions reductions elsewhere.

Tree and timber expansion programs in general may include reforestation (replanting former forests) and afforestation (converting other land uses to trees). Either way, the net amount of carbon dioxide that is sequestered annually by new tree growth varies with the quality of the land, the age of the tree and its species, climate, and other factors. There are programs currently in use to convert idle cropland and pasture into managed forests have shown good results in maintaining a majority of the forest acreage planted, such as the Conservation Reserve Program (CRP) and a program formally known as the Forest Incentives program (FIP), cropland and pasture can be converted to managed forests. The programs involve private landowners, who receive financial and technical assistance, being bound by contract to maintain tree plantings for at least ten years. Millions of acres of trees have been planted since these programs were initiated. The FIP has been quite successful in keeping forested areas from converting back to non-forest uses. Over 90% of the acres planted since 1975 are still in the original plantings. Carbon sequestration benefits from such forested areas, however, may not yet be realized, depending on a future long-term maintenance.

Idaho currently offers a tax deduction for the use of biodiesel and ethanol. Fuel mixtures containing either fuel are eligible. Idaho does not offer a production-based tax incentive program, which may increase its state-wide use (see http://www.fleets.doe.gov). The U.S. Internal Revenue Service offers a tax deduction for the purchase of a new original equipment manufacturer (OEM) qualified clean fuel vehicle, or for the conversion of a vehicle to use a clean-burning fuel. The actual deduction depends on the vehicle type(see also http://www.fleets.doe.gov).

Most of these programs could enhance carbon sequestration in Idaho. On the flip side, carbon markets could help each of these programs in meeting their objectives. Funding from either carbon markets or programs could leverage additional funds for the other. Most of these federal or state programs require matching funds from other sources. The state could seek avenues to legitimately supplement its own programs with funds generated through carbon markets. Multiple objectives could be reached through a comprehensive and cooperative partnerships among state government, private landowners, and companies.

7.3.3 Demonstration Projects

A demonstration project or projects would be a relatively low-cost way to demonstrate the feasibility of encouraging a large proportion of farmers to adopt carbon sequestration and emission reduction practices. Demonstration projects placed in at least 3 areas of the state and on various farm and forestry situations would provide critical information on how landowners could participate in carbon markets. Other facets would also be made known to enable the state to better understand a carbon market's benefit. Demonstration projects could also serve to test methods for measurement, monitoring, and verification. There exist some actual activities occurring within the state, such as with the PNDSA, that may be utilized to further understand the complexity of carbon markets. There is a need to better understand the economic benefit to a landowner, and to the state, while participating in carbon markets. These demonstration projects may provide the best avenue to accomplish that.

Biofuels production (ethanol and biodiesel) could have a substantial benefit to local economies and state revenue. A demonstration project, a comprehensive economic analysis, that evaluates actual ethanol and biodiesel production in the state, while including a projected increase of production and use, would likely show that it enhances local and state economies. Any state incentives programs that encourage increased production and use of biofuels should be considered carefully during economic crises, especially during the early stages of biofuels production. When state budgets need to be cut because of low revenue during recession periods, programs are generally cut. A comprehensive economic analysis could show that any cut to state incentive payments of biofuels, might actually reduce state-wide revenue more than what is gained by cutting the incentives. After a time, where biofuels is at or near peak production and use within the state, the incentives payments may no longer be needed.

8 POTENTIAL CARBON SEQUESTRATION IN IDAHO

There exists a number of existing practices and activities that could widely be adopted within the state, with the capability to increase carbon sequestration or reduce agricultural related emissions. Costs are typically the greatest barrier to their adoption. If costs are offset by supplemental income, such as through state, federal, or carbon market funds, then adoption would increase. Long-term operation and maintenance costs, however, may need to also be offset through productivity or sales of a product. If increased productivity of sales of products are not sufficient, then funding from outside sources would need to be available to continue the practice or activity. Carbon market funds could very well be used to supplement operation and maintenance costs.

Within carbon markets, there will be monitoring and verification of carbon sequestered. These requirements will increase costs, which will have to be addressed within the market. The actual amount of carbon sequestered or emission reduced may drive the level of funding, thus the more effective the practice, the high the value. Practices with low effectiveness, but high costs, are not likely to survive in a carbon market. The demand for highly effective practices with low to moderate installation, operation, and maintenance costs will be high. Monitoring and verification costs will also need to be low to moderate, or the practice may not fair well in a market. If practices provide a quick return on investment and are self-sustaining, paying for its own operation, maintenance, monitoring, and verification costs, then market viability may not be so important, where the practice may likely be adopted regardless of carbon market influences.

Based on preliminary evaluation of some practices and activities, the Committee has predicted that a carbon market is highly viable within the state. If the state and its landowners can prepare itself by creating a process to establish carbon credits, likely through existing agricultural and forestry programs, then marketing carbon credits should follow similar agricultural product marketing techniques. If, for instance, the Department of Commerce and private brokers, such as for grain, begin to include carbon credits with the product, the state can become well known for producing carbon credits. With an established process in place, from the encouragement of landowners to adopt practices, through the verification and marketing of carbon credits, outside funding sources will likely be attracted to the state, especially if the state is part of the marketing and tracking of carbon credits.

Before the state should begin establishing a carbon market of its own, or begin to market carbon credits, the process used to create carbon credits must be developed. One critical step towards developing a process is to steer additional research towards creating feasible verification techniques. Economic studies relative to adoption through verification also need to occur.

Those practices with the greatest potential to sequester carbon and/or reduce agricultural emissions seem to afforestation, nutrient management, no-till (direct seed), ethanol production, and methane reductions from ruminant animals and animal waste storage ponds. These were determined through a rigorous evaluation of the Advisory Committee and numerous other agricultural, forestry, and biofuels experts. A rating system was used to determine a practice’s potential for adoption, operation, maintenance, costs, and other criteria. Each of the practice’s predicted effectiveness was then evaluated against its predicted state-wide adoption. This provided the Committee with a good understanding of each practice and how it may effect a carbon market. The practice ratings are found in Appendix 3, and each practice’s potential state-wide effectiveness in Appendix 4.

Before wholly adopting this initial evaluation and prediction of a state-wide potential carbon sequestration, the Committee has recommended further analysis, economic and research related activities on many practices, many related. This initial step, however, has provided valuable insight on the needs of the state regarding carbon sequestration knowledge, economic benefits, and verification procedures. In determining the potential statewide benefit of carbon sequestration and markets, some assumptions have to made.

The first assumption made is the available land area or product is suitable for practices, such acres of wheat, barley, and corn for ethanol production or croplands likely suitable for afforestation, which changes its use. Another assumption is the maximum land area that a specific practice would be adopted on or would produce for alternative uses, different than current uses. Costs are considered but it was assumed that if costs were not overcome by any means, the practice would not be adopted, regardless of other criteria, therefore temporarily set-aside for the sake of predicting its adoption within a carbon market. Another assumption is that no more than any one crop market would not tolerate more than 25% of it being lost to other uses, such with ethanol production, where initial estimates are based on no more than 25% of the small grain market would be used. Nor would it likely be that practices such as afforestation, replace more than 20% of existing pastureland and cropland with trees. Similar thought went into each practice to ensure a reasonable carbon sequestration and emission reduction estimates. For the purpose of estimating a state-wide potential, only some selected practices with the greatest CO2e level were selected, instead of simply summing all available practices for each land use category below. It cannot be assumed that all practices can be applied to the same field or forest tract, but a one or a few. The practices found in Table 9. below represent those that could be applied within the state without effecting local crop markets and the best practices or activities.

Table 9. Potential Statewide Carbon Sequestration

Practice/Activity	**CO_2e Million Metric Tons/y**
Cropland related	6.9
Forest land related	2.6
Livestock related	2.1
Grazing land related	1.5
Ethanol & biodiesel production	1.1
Riparian & wetland area related	0.4
Total Potential CO2e, selected practices	**14.6**

If there were about 14.6 million metric tons of CO2e offsets (credits) produced in the state, and these offsets were purchased at $10 per metric ton, then the state could see $146 million dollars come into the state. Oregon passed a law in 1997 that requires new utilities to emit less than 17% of the most efficient plant available. New energy facilities can meet this requirement at the plant or pay a per-ton CO2 offset of $0.57 to the Climate Trust which then purchases offsets, provided through various agricultural and forest practices. Using the Oregon rate per-ton CO_2 offset rate of $0.57, Idaho could see a benefit of $8 million. Regardless of the per-ton price of CO_2 offset, there could be significant amount of funds come into the state through a carbon market. Because of practice related installation, operation, maintenance, and monitoring costs, the owner of the practice may only see 25 to 50% of these amounts. However, if most of those practice related needs were supplied from within the state, the state economy would appreciate most of those funds.

9 ADVISORY COMMITTEE RECOMMENDATIONS

Idaho should consider a number of options that might potentially: 1) position the state to take advantage of carbon markets, 2) increase knowledge of carbon sequestration and greenhouse gas emissions, 3) increase understanding of Idaho greenhouse gas and carbon sequestration related practices and activities, 4) improve management of existing stored carbon, 5) expand the storage of carbon, or 6) increase the use of agricultural and forestry products to produce substitute energy, such as ethanol and biodiesel and on-farm alternative power generation. There are many non-agricultural related activities that could result in emission reductions, which could benefit the state, however, they are beyond scope of report, legislative intent.

Maintain the carbon sequestration advisory committee to monitor ongoing developments, facilitate economic analysis, facilitate research activities, and provide information to landowners

Recent international action on climate change and carbon sequestration has been very significant in the past few years. The potential market implications of international action are developing. A standing carbon sequestration advisory committee could respond quickly to international or national legal changes and changing market conditions. Activities that a standing committee may initiate or continue include:

- Provide guidance to the state on continuing carbon sequestration market development,
- Facilitate statewide and regional research activities,
- Improve the state's visibility to enhance the benefits to landowners through national carbon markets,
- Secure private and federal funds to support advisory committee, economic analysis, additional research activities, carbon market development, landowner education, and implementation of carbon sequestration practices and biofuels production.
- Where appropriate, enter into partnerships or agreements with other states or organizations, to further enhance benefits to Idaho.

Initiate a carbon market pilot project

A pilot project, involving Idaho interests and potential carbon market participants, would address numerous uncertainties and issues within carbon markets and emissions trading. Within a pilot project there would be specific activities carried out to prepare the state for potential markets and develop a system to encourage and facilitate emission trading agreements. A pilot project would encourage future participation in carbon markets and enhance the state's potential in drawing outside funding into the state.

Improve landowner's understanding of climate change and carbon sequestration

Idaho's landowners do not fully appreciate their potential for sequestering carbon and benefiting from a carbon market. Actions should be explored to increase their understanding of their potential:

- State and local federal natural resource agencies could include into their existing programs, strategies to improve landowner's understanding of climate change and carbon sequestration
- Universities and governmental research agencies could include in their existing research activities, relative carbon sequestration information
- Organize and host one or more state-wide forums devoted to carbon sequestration.

Enhance carbon sequestration research relevant to Idaho

These actions could conceivably include research on a variety of topics, including potential methods of monitoring, measuring, and verifying of sequestration and reduced agricultural or forestry related emissions. Cooperative efforts with researchers in other states and Canada should be enhanced. Local, state, federal , and private funding sources should all be explored to assist in the coordination and research priorities. Where cooperative partnerships already exist between private landowners and state agencies, there is the potential to expand research activities.

Some specific areas of research are listed below:

- The effects of no-till or direct seed tillage practices within high-elevation areas and irrigated areas
- Verification of carbon sequestration and emissions reductions within forest and cropland areas, consistent with international methods
- Remote sensing techniques, correlated with field measurements
- The effect of land use change on carbon sequestration, such as the conversion of native rangeland to irrigated agriculture, then to urbanization
- The effect of nutrient management on nitrous oxide reductions
- Methane recovery system effectiveness and aerobic treatment, such as with digesters and composting, respectively
- The effects of dietary adjustments on methane emissions from ruminant animals
- Feasible alternatives to crop residue burning, the effects on greenhouse gas emissions
- The effect of multiple practices on carbon sequestration, such as the combination of no-till, nutrient management and irrigation

Complete carbon sequestration and greenhouse gas baseline analyses to prepare for future carbon sequestration markets

For the purposes of this report, some initial baseline estimates have been used to determine statewide benefits of carbon sequestration. Further analyses is needed to improve statewide estimates, such as:

- Develop a state-wide greenhouse gas inventory – primary gases include carbon dioxide, methane, and nitrous oxide
- Document currently active carbon sequestration practices in the state
- Determine baseline soil carbon conditions in the state
- Calculate current carbon flux within forest and croplands
- Develop and maintain a comprehensive database, with GIS capability

Further study the potential economic benefits to Idaho landowners and the state through carbon markets

To understand the economic benefits of a carbon market, some actions should be taken:

- Initiate at least three case studies to evaluate the ‘whole-farm’ cost and benefit of implementing practices within a carbon market (northern, southern, and eastern Idaho)
- Initiate at least one case study to evaluate the forest related ‘whole-farm’ cost and benefit of implementing practices within a carbon market
- Further evaluate the potential economic impacts of additional ethanol and biodiesel production within the state, considering the local impacts surrounding a facilities

Explore requiring carbon participants to be registered with the state

Through a registration process, with the development of a registry, some additional legal protection could be provided to landowners and the public against potential questionable carbon brokers and aggregators. This registration can help encourage credible marketing activity and help bring additional funds to agriculture and forestry. There exists a federal registry within the Energy Policy Act (EPACT) of 1992 that contains a program called "section 1605(b) reporting" that could be utilized in the development of a state registry.

Explore avenues to increase carbon sequestration in the state

To promote increased carbon sequestration activities in the state of Idaho, and a mechanism to connect landowners to potential buyers of carbon credits. Potential avenues are listed below:

- Enable or enhance existing state agricultural and forestry programs to include and promote carbon related practices,
- Include state lands in the carbon sequestration activity related programs, where endowment lands may potentially receive greater economic benefit through carbon sequestration activities
- Encourage public lands to be included in potential carbon sequestration markets
- Explore the potential of continuing existing practices implemented through other programs, such as Conservation Reserve Program, with carbon sequestration market funds
- Explore increasing necessary technical assistance to landowners with carbon sequestration market funds
- Explore designating a state agency to track carbon market activities
- Explore the potential of a state agency to act as an aggregator, where appropriate, to increase the marketability of a landowner's sequestration activity

Explore the potential for improving the production and use of biofuels in the state and their economic benefit

The state should explore preparing an economic study to evaluate the benefit to the state through biofuels production, while utilizing Idaho resources. A comprehensive program includes economic analysis will be important for future biofuels activities.

A comprehensive program should consider:

- The percent of biofuel blended in the parent fuel,
- Promote ethanol in the manufacturing of biodiesel,
- Changing the present incentive to a producer's credit,
- Future technologies,
- The removal of gasoline franchise restrictions on fuel additives
- State government automobile fleet use of ethanol and biodiesel
- The use of forest wastes in biofuels, conversion of cellulose into liquid fuel
- The effect of state-wide use of E10 and B20 on air quality

10 GLOSSARY

Aerosol: Particulate material, other than water or ice, in the atmosphere. Aerosols are important in the atmosphere as nuclei for the condensation of water droplets and ice crystals, as participants in various chemical cycles, and as absorbers and scatterers of solar radiation, thereby influencing the radiation budget of the earth-atmosphere system, which in turn influences the climate on the surface of the Earth.

Afforestation: The process of establishing a forest on land not previously forested.

Anaerobic Fermentation: Fermentation that occurs under conditions where oxygen is not present. For example, methane emissions from landfills result from anaerobic fermentation of the land filled waste.

Anthropogenic: Of, relating to, or resulting from the influence of human beings on nature.

Atmosphere: The envelope of air surrounding the Earth and bound to it by the Earth's gravitational attraction.

Biomass: The total dry organic matter or stored energy content of living organisms that is present at a specific time in a defined unit (ecosystem, crop, etc.) of the Earth's surface.

Biosphere: The portion of Earth and its atmosphere that can support life.

Carbon Sink: A pool (reservoir) that absorbs or takes up released carbon from another part of the carbon cycle. For example, if the net exchange between the biosphere and the atmosphere is toward the atmosphere, the biosphere is the source, and the atmosphere is the sink.

Carbon Dioxide (CO_2): Carbon dioxide is an abundant greenhouse gas, accounting for about 66 percent of the total contribution in 1990 of all greenhouse gases to radiative forcing. Atmospheric concentrations have risen 25% since the beginning of the Industrial Revolution. Anthropogenic source of carbon dioxide emissions include combustion of solid, liquid, and gases fuels, (e.g., coal, oil, and natural gas, respectively), deforestation, and non-energy production processes such as cement-production.

Carbon Monoxide (CO): Carbon monoxide is an odorless, invisible gas created when carbon containing fuels are burned incompletely. Participating in various chemical reactions in the atmosphere, CO contributes to smog formation, acid rain, and the buildup of methane (CH_4). CO elevates concentrations of CH_4 and tropospheric ozone (O_3) by chemical reactions with the atmospheric constituents (i.e., the hydroxyl radical) that would otherwise assist in destroying CH_4 and O_3.

Chlorofluorocarbons (CFCs): A family of inert non-toxic and easily liquified chemicals used in refrigeration, air conditioning, packaging, and insulation or as solvents or aerosol propellants. Because they are not destroyed in the lower atmosphere, they drift into the upper atmosphere where their chlorine components destroy ozone.

Climate Change: The long-term fluctuations in temperature, precipitation, wind, and all other aspects of the Earth's climate.

Deforestation: The removal of forest stands by cutting and burning to provide land for agricultural purposes, residential or industrial building sites, roads, etc. or by harvesting trees for building materials or fuel.

Enteric Fermentation: Fermentation that occurs in the intestines. For example, methane emissions produced as part of the normal digestive processes of ruminant animals is referred to as "enteric fermentation."

Flux: Rate of substance flowing into the atmosphere (e.g. lbs/ft_2/second).

Global Warming Potential (GWP): Gases can exert a radiative forcing both directly and indirectly: direct forcing occurs when the gas itself is a greenhouse gas; indirect forcing occurs when chemical transformation of the original gas produces a gas or gases which themselves are greenhouse gases. The concept of the Global Warming Potential has been developed for policymakers as a measure of the possible warming effect on the surface-troposphere system arising from the emissions of each gas relative to CO_2.

Greenhouse Effect: A popular term used to describe the roles of water vapor, carbon dioxide, and other trace gases in keeping the Earth's surface warmer than it would be otherwise.

Greenhouse gases: Those gases, such as water vapor, carbon dioxide, tropospheric ozone, nitrous oxide, and methane that are transparent to solar radiation but opaque to infrared or longwave radiation. Their action is similar to that of glass in a greenhouse.

Hydrofluorocarbons (HFCs): HFCs are substitutes for CFCs and HCFCs which are being phased-out under the *Montreal Protocol on Substances that Deplete the Ozone Layer*. HFCs may have an ozone depletion potential (ODP) of zero, however, they are very powerful greenhouse gases. For example, HFC-23 and HFC-134a have a GWPs of 10,000 and 1,200 respectively.

Methane (CH_4): Following carbon dioxide, methane is the most important greenhouse gas in terms of global contribution to radiative forcing (18 percent). Anthropogenic sources of methane include wetland rice cultivation, enteric fermentation by domestic livestock, anaerobic fermentation of organic wastes, coal mining, biomass burning, and the production, transportation, and distribution of natural gas.

Nitrous Oxide (N_2O): Nitrous oxide is responsible for about 5 percent of the total contribution in 1990 of all greenhouse gases to radiative forcing. Nitrous oxide is produced from a wide variety of biological and anthropogenic sources. Activities as diverse as the applications of nitrogen fertilizers and the consumption of fuel emit N_2O.

Nitrogen Oxides (NO_x): One form of odd-nitrogen, denoted as NO_x is defined as the sum of two species, NO and NO_2. NO_x is created in lighting, in natural fires, in fossil-fuel combustion, and in the stratosphere from N_2O. It plays an important role in the global warming process due to its G-3 contribution to the formation of ozone (O_3).

Ozone (O_3): A molecule made up of three atoms of oxygen. In the stratosphere, it occurs naturally and it provides a protective layer shielding the Earth from ultraviolet radiation and subsequent harmful health effects on humans and the environment. In the troposphere, it is a chemical oxidant and major component of photochemical smog.

Perfluorinated Carbons (PFCs): PFCs are powerful greenhouse gases that are emitted during the reduction of alumina in the primary smelting process. Eventually, PFCs are to be used as substitutes for CFCs and HCFCs. PFCs have a GWP of 5,400.

Radiative Forcing: The measure used to determine the extent to which the atmosphere is trapping heat due to emissions of greenhouse gases.

Radiatively Active Gases: Gases that absorb incoming solar radiation or outgoing infrared radiation, thus affecting the vertical temperature profile of the atmosphere. Most frequently cited as being radiatively active gases are water vapor, carbon dioxide, nitrous oxide, chlorofluorocarbons, and ozone.

Reforestation: The re-planting of a forest or timber stand, having been previously harvested or lost due to natural or man-made causes, such as fire.

Stratosphere: Region of the upper atmosphere extending from the tropopause (about 5 to 9 miles altitude) to about 30 miles.

Trace Gas: A minor constituent of the atmosphere. The most important trace gases contributing to the greenhouse effect include water vapor, carbon dioxide, ozone, methane, ammonia, nitric acid, nitrous oxide, and sulfur dioxide.

Troposphere: The inner layer of the atmosphere below about 15 km, within which there is normally a steady decrease of temperature with increasing altitude. Nearly all clouds form and weather conditions manifest themselves within this region, and its thermal structure is caused primarily by the heating of the Earth's surface by solar radiation, followed by heat transfer by turbulent mixing and convection.

Volatile Organic Compounds (VOCs): Volatile organic compounds along with nitrogen oxides are participants in atmospheric chemical and physical processes that result in the formation of ozone and other photochemical oxidants. The largest sources of reactive VOC emissions are transportation sources and industrial processes. Miscellaneous sources, primarily forest wildfires and non-industrial consumption of organic solvents, also contribute significantly to total VOC emissions.

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13 APPENDICES

13.1 APPENDIX 1 - LAND COVER PERCENTAGES

Tables to summarize land ownership by cover types, Table 1 and Table2.

Table 1. Percent Land Owner/Type per Cover Type

Cover Type Group	B.L.M.	Bureau of Indian Affairs	Department of Energy	Forest Service	Military Reservations	National Parks & Monuments	Open water	Private	State of Idaho	U.S. Fish & Wildlife Service	Grand Total
Agricultural crop and pastureland	4.4%	1.3%	0.1%	0.4%	0.0%	0.0%	0.4%	**92.2%**	1.1%	0.1%	100%
Alpine	0.3%	0.0%	0.0%	**99.3%**	0.0%	0.0%	0.3%	0.2%	0.0%	0.0%	100%
Annual grasslands	**64.3%**	0.0%	0.2%	0.1%	2.4%	0.0%	0.2%	**26.9%**	5.9%	0.1%	100%
Foothills and Plains Woodlands	**58.1%**	0.0%	1.3%	**15.8%**	0.0%	2.2%	0.3%	**15.0%**	7.2%	0.1%	100%
Montane Forests	2.0%	0.2%	0.0%	**72.6%**	0.1%	0.0%	0.1%	**19.5%**	5.5%	0.0%	100%
Montane Forest-Steppe Transitions	**10.3%**	0.9%	0.0%	**66.1%**	0.1%	0.0%	0.1%	**17.5%**	5.1%	0.0%	100%
Montane Shrub fields	**14.5%**	0.1%	0.0%	**57.8%**	0.0%	0.0%	0.4%	**20.1%**	7.2%	0.0%	100%
Perennial bunchgrass seedings	**78.3%**	0.0%	0.6%	0.4%	4.4%	0.3%	0.0%	**10.6%**	4.8%	0.6%	100%
Recent timber harvest areas	0.3%	0.0%	0.0%	**59.7%**	0.1%	0.0%	0.0%	**29.4%**	**10.5%**	0.0%	100%
Riparian and Wetland Types	2.5%	2.3%	0.0%	5.6%	0.0%	0.1%	**56.7%**	**24.4%**	1.9%	6.3%	100%
Shrub Steppe and Grasslands	**59.0%**	2.4%	3.8%	6.1%	0.1%	0.3%	0.2%	**20.9%**	7.0%	0.0%	100%
Sub alpine Forests	1.1%	0.0%	0.0%	**94.6%**	0.0%	1.2%	0.1%	2.3%	0.7%	0.0%	100%
Sub alpine Parklands	0.4%	0.0%	0.0%	**94.3%**	0.0%	0.0%	0.2%	1.2%	3.9%	0.0%	100%
Urban and Industrial	1.4%	0.0%	0.0%	0.2%	1.7%	0.0%	2.0%	**94.4%**	0.2%	0.0%	100%

Source of data: idown.shp and veg.shp statewide gis coverage. Intersection of data was completed in Arcview 2.0 to create table. See http://www.idwr.state.id.us/ftp/gisdata/shapefiles/statewid/for gis shape files and metadata information. Bolded numbers are greater than 10%.

Table 2. Percent Cover Type by Land Owner/Type

Cover Type Group	B.L.M.	Bureau of Indian Affairs	Department of Energy	Forest Service	Military Reservations	National Parks & Monuments	Open water	Private	State of Idaho	U.S. Fish & Wildlife Service	All Lands
Agricultural crop and pastureland	3.2%	**20.7%**	1.1%	0.2%	1.5%	0.3%	7.0%	**50.2%**	3.6%	**15.3%**	16.6%
Alpine	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0%
Annual grasslands	8.9%	0.0%	0.7%	0.0%	**30.3%**	0.0%	0.5%	2.8%	3.8%	1.9%	3%
Foothills and Plains Woodlands	3.7%	0.0%	1.8%	0.6%	0.0%	**17.6%**	0.4%	0.7%	2.2%	1.3%	1%
Montane Forests	2.2%	5.7%	0.0%	**49.9%**	**11.1%**	1.2%	2.4%	**16.7%**	**29.7%**	0.4%	26%
Montane Forest-Steppe Transitions	4.0%	7.9%	0.0%	**15.4%**	2.8%	0.0%	0.7%	5.1%	9.3%	0.5%	9%
Montane Shrub fields	2.0%	0.2%	0.0%	4.7%	0.0%	0.0%	1.2%	2.1%	4.6%	0.0%	3%
Perennial bunchgrass seedings	7.8%	0.0%	1.3%	0.0%	**39.4%**	3.9%	0.1%	0.8%	2.3%	9.5%	2%
Recent timber harvest areas	0.0%	0.0%	0.0%	1.5%	0.6%	0.0%	0.0%	0.9%	2.1%	0.0%	1%
Riparian and Wetland Types	0.1%	3.0%	0.0%	0.2%	0.0%	1.0%	**80.6%**	1.1%	0.5%	**64.2%**	1%
Shrub Steppe and Grasslands	**67.7%**	**62.5%**	**95.1%**	4.2%	**12.2%**	**39.1%**	4.8%	**18.0%**	**38.2%**	6.9%	26%
Sub alpine Forests	0.2%	0.0%	0.0%	**13.3%**	0.0%	**36.9%**	0.6%	0.4%	0.7%	0.0%	5%
Sub alpine Parklands	0.1%	0.0%	0.0%	8.8%	0.0%	0.0%	0.8%	0.1%	2.8%	0.0%	4%
Urban and Industrial	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.6%	1.0%	0.0%	0.0%	0%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Source of data: idown.shp and veg.shp statewide gis coverage. Intersection of data was completed in Arcview 2.0 to create table. See http://www.idwr.state.id.us/ftp/gisdata/shapefiles/statewid/ for gis shape files and metadata information. Bolded numbers are greater than 10%.

13.2 APPENDIX 2 - CARBON SEQUESTRATION OPPORTUNITIES IN IDAHO FORESTS

Carbon Sequestration Opportunities in Idaho Forests

By:

Brian Kummet, Nez Perce Tribal Forestry
Ladd Livingston, Idaho Department of Lands
Charley McKetta, Forest Econ Inc.

Idaho Carbon Sequestration Advisory Committee
Forestry Subcommittee
Draft Interim Report 12/19/2002

Carbon Sequestration Opportunities in Idaho Forests
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Brian Kummet, Nez Perce Tribal Forestry
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EXECUTIVE SUMMARY

Idaho forests already probably sequester more carbon than any other sector, and have potential to continually augment that sequestration. These forests are controlled by owners with very different objectives that cause some of their forests to act as net sinks and others as net sources of atmospheric carbon. The largest ownerships are controlled by the federal government whose current policies appear to conflict with active carbon conservation. However, the state has no regulatory power and minimal political influence over federal forests.

This report focuses on Idaho's state, tribal and private forests. They control less forest area (about 21%), but their active timber management may already be complementary with carbon conservation. Their potential to enhance sequestration by changing silvicultural practices is very large relative to other rural land uses.

Afforestation alone could sequester over an additional 120 million metric tons of CO_2. Other practices could substantially add to this total. We perceive that profit-oriented forest owners would respond positively to incentives and facilitation of carbon credit sales, but that regulatory intervention could be counter-productive.

The forestry subcommittee recommends that the state of Idaho continue to explore the opportunities afforded by developing carbon credit markets and adopt a facilitation posture toward the state, tribal and private production and sale of carbon credits.

A CONTEXT OF WOOD AND CARBON

Wood use for fuel, fiber and shelter framed the development of mankind. Wood use is described in its earliest literature. Perlin (1991) tracks western references to 2100 BC and concludes; "Wood, indeed, was our ancestor's chief resource."

Wood is a biologically fixed hydrocarbon and molecular carbon (C_2) is the dominant component of its substance. As society begins to overtly manage carbon, managing wood and forests that fix it is a necessary corollary. Our subcommittee focused narrowly on carbon within forest resource management. Readers should recognize that total carbon management goes more to changing the overriding relationship of humans to the wider set of fuels and materials that sustain our species. They should not miss the bigger role of wood by looking with us too closely at trees.

> "Wood is the most renewable and sustainable of the major building materials. Comparing the environmental effects of common building materials, wood has the least impact on total energy use, green house gases, air and water pollution, and solid waste. For every billion board feet of wood we use instead of other building materials like steel and concrete, we save 720 million tons of carbon dioxide emissions from entering our atmosphere."
>
> From "Forests, A Legacy to Our Children" 2002

FORESTRY SUBCOMMITTEE CHARGE

The forestry subcommittee sees its purpose as collecting background information about C_2 sequestration in Idaho forest management. Knowledge about forests' C_2 content and sequestration response to management, is an essential basis to the formulation of any policy that might influence foresters and forest owners to consider C_2 flux as a part of their forest land management objectives.

We believe that a summary of the forest carbon baseline data and a quantification of the C_2 aspects of management practices is a necessary starting point for policy recommendations. However, a manager's recognition of C_2 conservation as a relevant forest criterion and their adoption of any C_2 sensitive practices is an economic consideration. Economic choices must be made within the cost-benefit framework of other forestry objectives.

A FOCUS ON STATE, TRIBAL AND PRIVATE FORESTS

The State of Idaho has significant interests in the management by the National Forest System and the Bureau of Land Management. However, these agencies are controlled by congressional mandates, including the 1976 national forest management act, the 1969 national environmental policy act, and numerous later environmental acts including the 1973 Endangered Species Act. The precedence of federal legislation precludes any state control over federal forest carbon management. However, as interests of states, particularly in concert, may exert needed influences, we included some data on federal forests.

For state lands and private lands, the state has economic and regulatory interests in their functioning. We believe that this report should focus on the potential and socially appropriate exercise of those interests. Tribal forests are usually found on sovereign reservations, however, the state still has an interest in coordinating with those ownerships in the establishment of a mutually beneficial and cohesive carbon policy.

SNAPSHOT OF IDAHO FORESTS

On an ecological scale, forest lands across the country have been divided into land divisions or ecoregions, based on similarity of conditions. Idaho has 5 principle ecological provinces. Each of these has significantly different carbon budgets and potentials for enhancing carbon sequestration.

Bailey (1995) delimits ecoregions based on physiography, soils, potential vegetation and climate, classified in descending orders of scale, by domains, divisions, provinces, and sections. In Idaho there are five provincial-level ecoregions and each has significantly different carbon budgets and potentials for enhancing carbon sequestration.

Northern Rocky Mountain-Steppe Province:

The Northern Rockies are characterized by rugged mountains, separated by flat valley bottoms. Relief ranges from 3,000 to over 9,000 feet. Soils are less rocky than surrounding mountain provinces and have a volcanic influence providing for excellent soils that influence forest biomass. Precipitation is generally greater than the rest of the Rocky Mountains, averaging between 16-100 inches annually. Vegetation is unique due to precipitation and soil patterns resembling the Pacific Northwest. Common forest types are Douglas-fir, grand fir, and cedar-hemlock. The understory is characterized by a cover of ferns, forbs, and regenerating trees.

Palouse Dry Steppe Province:

This includes the Idaho portion of the Palouse region that extends into Eastern Washington. It has rolling hills and tablelands of moderate relief, ranging from below 1,000 to about 4,000 feet. Soils are loess-covered basalt. The area is in the rain shadow of the Cascade Range with average annual precipitation about 15 inches, most of which comes as winter rain or snow with sporadic spring and summer thunderstorms. Vegetation is primarily of grasses, forbs and small shrubs. Forested portions are small and mostly confined to moisture-holding aspects and draws. Forested areas include scattered stands of ponderosa pine and Douglas-fir with cottonwoods along riparian zones. Much of the Palouse has been converted to agricultural or urban uses.

Middle Rocky Mountain Steppe Province:

This central Idaho area is the Salmon River Mountains. Mostly granitic intrusions collectively make up the Idaho Batholith. Altitudes range from 3,000 to 9,000 ft. with the highest peak in the state at 12,000 ft. The batholith is deeply dissected; the granite is heavily weathered over large areas. Eastward is a basin-and-range area consisting of mountains, alluvial fans at their bases and floodplains along the streams. Ponderosa occupies lower elevations and drier aspects. Douglas-fir, grand fir, lodgepole pine and Engleman spruce are on the middle slopes. Subalpine firs are found on higher slopes.

Southern Rocky Mountain Province:

The Southern Rocky Mountain Province is confined to southeastern Idaho and the Yellowstone Plateau. The mountains are glaciated with elevations ranging from under 4,000 to 10,000 feet. Valleys are mostly developed farmlands or sagebrush steppe. Soils vary wildly from valley floors to high elevation sites. Climate is variable with warm, dry valleys where precipitation averages 15-25 inches. Mountain ranges are much cooler and precipitation is 40 inches or more. Much comes as snow. Because of great variation in elevation and aspect, soil types, direction of prevailing winds, rainfall and evaporation rates, mountain vegetation is a large-scale mosaic of conifers, hardwoods, and shrub/grasslands. The uppermost (alpine) zone is characterized by alpine tundra and absence of trees. Directly below, the subalpine zone is dominated by subalpine fir with Engelmann spruce with Douglas-fir at lower elevations. Lodgepole pine and aspen become dominant after fires. Grasses and sagebrush dominate at lower elevations with shrubs and mountain-mahogany.

Intermountain Semi-desert Province:

This province covers most of the southern third of the state, including the Snake River Plateau--extensive lava fields which have been folded or faulted into ridges. Numerous small mountain ranges average 7,000 to 9,000 feet. Lower valleys are between 2,000 and 4,000 feet. Soils are characterized by extensive alluvial deposits in stream floodplains streams and in fans at the foot of mountains. Annual precipitation is about 15 inches evenly distributed through the seasons, except for summer when little rain falls. Vegetation is primarily sagebrush, rabbitbrush, and bunch grasses. Riparian zones are lined with cottonwoods, willows and sedges. Forested areas are sparse in isolated mountain ranges of Douglas-fir, aspen and juniper. In the Owyhee Desert, there are large forests of western juniper, with occasional Douglas-fir.

For each province, forest inventory data can be converted to existing carbon content estimates. However, the potential for increased sequestration varies greatly by province. We must first establish a baseline to ask any meaningful questions about forest carbon flux in Idaho. That baseline should include both a static component, i.e. how much carbon is present, and a dynamic component, i.e. how the current pattern of forest dynamics (growth, removals, mortality) is affecting the carbon balance in the forestry sector. We need to be able to ask whether current forest management on different ownerships makes forests function as C_2 sinks or C_2 sources. Only then can we address how deliberate changes in forest stand management and forest fires management would change the current Idaho forest carbon balance.

IDAHO FOREST LAND AREA AND OWNERSHIP

Idaho forest acreage is owned and managed by a diversity of interests. Each has different objectives that might affect carbon flux and the potential for carbon sequestration. Of the 22.3 million total forest acres, 21.4 million are classified as timberlands, with the remaining 0.9 million classified as woodlands where juniper is the predominant species (Brown and Chojnacky 1996). Ownership acreages in table 1 are dominated by the federal government.

Table 1: Idaho Forest Land Acreage

OWNER	ACRES (MM)	% of TOTAL
National Forests	12.8	57.4
Reserves (Mainly Fed)	3.8	17.0
Forest Industry	1.2	5.4
Other Public	1.5	6.7
NIPF	2.0	9.0
Woodlands	0.9	4.0
Misc.	0.1	0.5
TOTAL	22.3	100

National Forests are lands owned by the federal government and managed by the USDA forest Service. The current management philosophy for National Forest Lands is “Ecosystem restoration” with limited opportunity for removal of products. (% change in sales/harvest cuts)

Reserved Forest lands are withdrawn from tree utilization. They include wilderness areas, study areas, national and state parks.

Forest Industry lands are owned by a company or individual and managed primarily for wood products.

Other Public lands include both federal and state ownerships such as the Bureau of Land Management, the Idaho Department of Lands, State and Federal Parks, State Fish and Game, county and other local government agencies.

NIPF: These are lands owned by non-industrial private owners generally with no more than 1000 acres. Management often includes objectives other than timber production.

Woodlands are lands where the plant community is typically composed of small, short-boled trees, with open canopy and intervening area occupied by grasses. They have less than 10 percent stocking of timber species.

IDAHO FORESTS’ EXISTING SEQUESTERED CARBON

The literature on forest carbon is growing rapidly. The scientific determination of the variables and methods used to determine the total tons of existing carbon is an on-going study. Refining them lies outside our scope of work. We reference known documents and reproduce numbers where appropriate. Rather than provide an exhaustive survey of all relevant literature, we identified references that speak to specific questions relevant to our charge. The most applicable references are of two types: basic quantification of the forest carbon flux, and how the forest carbon balance can be affected by forest managers modifying the behavior of forests.

Forest Carbon Components

Forest carbon can be broken down into 5 basic components: soil by location: tree bole or stem, crown, site (soil, duff, and litter) and understory vegetation. Each component contains carbon; how much depends on the individual site and many variables such as species, slope, aspect, habitat type, region or area, etc. Some researchers lump various portions of the above components together (e.g. soil, duff, and roots comprise the soil carbon), so it is important to know what is included for calculations.

Generally, 30% of the carbon on a given site is located in the stem or bole of the trees. About 10% is in the crown (limbs and leaves). The leaf component cycles rapidly and their carbon flux is almost constant (Marshall 2002). 10% is in the understory if present, and approximately 50 – 60% is in the soil, duff and litter (Harmon 1998). Soil carbon is directly related to organic matter content. Even though organic material may often be only 2% of soil bulk density, soil is heavy, making the carbon content significant (Marshall 2002).

We use coefficients from the literature to quantify Idaho forest's current carbon content. This approach is a gross quantification for a ballpark idea of the forest carbon system magnitude. Stem carbon is almost a constant proportion of wood volume. It can be estimated from knowing wood volume and specific gravity for individual tree species.

Knowing the distribution of carbon within the system, allows a quick method of calculating the remaining on-site carbon by applying an expansion multiplier to measured stem biomass. This biomass multiplier then gives a gross estimate of carbon for the other forest components.

Idaho Gross Forest Carbon Baseline

Estimating Carbon on Timberlands: An Idaho Case Study, (Heath and Joyce, 1997) used numbers compiled by Birdsey (1992) from inventory data. They estimated that 1.47 billion metric tons of carbon are stored in Idaho forests. Approximately 41 percent of the stored carbon is in trees, 43 percent is in soil, 15 percent is in the forest floor and approximately 1 percent is understory vegetation.

The Heath and Joyce computations provide an excellent starting point for determining the absolute and relative scales of forest carbon sequestration. Table 2 compares Idaho forest carbon to other averaged western states.

Table 2: Average Forest Carbon Storage in the Western U.S.
1000 Pounds of C_2/acre by forest component (Birdsey 1992)

	- - - - - - - - - 1000 pounds of carbon stored per acre in - - - - - - - - - -				
State	**Total**	**Trees**	**Soil**	**Duff/Litter**	**Understory**
9 Mountain States Average	124.5	47.1	61.3	15.0	1.1
3 Pacific States Average	167.6	67.7	76.7	19.7	3.4
22 Western States Averages	136.3	52.7	65.5	16.3	1.7
Idaho	**148.2**	**61.0**	**64.4**	**21.7**	**1.1**

To validate their computation, we multiplied the total Idaho forestland acreage (21,937,000 acres) by the per acre figure indicated in the table above (148.2 M pounds) and divide by 2.204 to convert to metric tons. We arrive at a figure very close to 1.47 billion metric tons of carbon.

Table 3 shows the estimated standing live woody biomass volume in Idaho forests by species (USDA-Forest Service FIA 2002). We converted above ground biomass data by species into gross estimates of live sequestered carbon. We multiplied each species unique specific gravity by a biomass factor of 2.25 and a carbon factor of 0.512 from another source to estimate fixed carbon weight by species.

Table 3: Calculating Existing Idaho Forest Carbon
Calculations by species

Tree Species	**1000 Cu. Ft.**	**1000 Metric tons**
Douglas fir	12,406,798	191,350
Ponderosa pine	2,734,030	37,085
Western white pine	436,775	5,127
Lodgepole pine	5,529,102	76,261
Whitebark pine	230,521	3,608

Limber pine	54,276	849
Western larch	1,476,368	24,455
Grand fir	5,749,109	80,608
Subalpine fir	3,727,191	43,751
Engelman spruce	2,487,765	30,825
Western hemlock	1,079,128	15,130
Mountain hemlock	573,679	6,734
Western redcedar	2,273,377	26,686
Total softwoods	**38,758,119**	**542,470**
Aspen	509,736	7,047
Cottonwood	292,513	4,044
Total hardwoods	**802,249**	**11,091**
All Species	**39,560,368**	**553,561**

Spreading total carbon weight over gross forest acreage implies that Idaho forests have on average 24.8 metric tones of per acre in tree stems. This estimate does not include root carbon or soil carbon which might expand estimates by as much as 40%. This is a much smaller estimate than implied by table 2 (61 metric tones/acre). Such low comparability suggests the variability of current gross carbon estimation methods. Sorting by tree species provides insights into natural sources of carbon variability due to a tremendous variability in forest stands. With further analysis, more accirate standing carbon estimates could be made by land site productivity, stand density and age classes.

IDAHO FORESTS C_2 FLUX COMPUTATIONS

Flux is the flow of forest carbon in continuous dynamic change. There is natural flux in the life of trees and in ecological cycles of succession. If managers are to influence flux and augment sequestration, they need to have a baseline measure of natural flux and knowledge of the manipulatable factors that influence it.

Forest Ownership Affects Carbon Flux

Forest ownership appears to have a large influence on background carbon sequestration as well as flux. Ownerships vary considerably by the types of forests they own and the objectives of ownership. For example, Inventory accumulation is the result of managerial policies affecting forest structure and removals, the biology of growth on the age classes and species represented and how the forest health affects the rate of mortality. Different owners would manipulate each of these factors differently.

Table 4 shows how existing wood volume inventory is distributed. Using the same conservative stem biomass factor used in building table 3, we assume that standing forest biomass is directly proportional to fixed carbon. This would actually vary by species and forest conditions that also vary by ownership. Our approximations are crude, but it is clear that Idaho's fixed forest carbon inventory is overwhelmingly controlled by the national forests (76.7%). The forests targeted by this report have relatively small standing carbon inventories, private/tribal forests (14.6%), and state forests (5.7%).

Table 4: Forest Inventory Wood and Carbon by Ownership
Source: USDA-Forest Service FIA data (2002)

Forest Ownership	Wood Volume MMCF	Carbon Wt MM MT	Distribution %
National Forests	30,641.4	428.7	76.66%
BLM/other public	1,110.2	15.5	2.78%
State of Idaho	2,279.4	31.9	5.70%
Private/tribal	5,940.3	83.1	14.86%
Total	**39,971.3**	**559.3**	**100.00%**

Current Background Forest Carbon Flux Rates

Changes in forest carbon (flux) are associated with forest area changes, stand treatments, wildfire, growth, removals (harvests), and non-fire mortality. Most of these changes are (or can be) influenced by ownership management policies. Forest area changes are ignored as land uses are relatively stable. We have not yet found estimates of Idaho wildfire carbon releases. Stand treatments are intentional changes in forest character that are covered in a later section.

We focus on growth, removals, and non-fire mortality as regular background processes for the baseline estimate. Table 5 shows the fixed carbon implications of only forest stem volume change rates as of 2000. For these stem carbon calculations, we hold soil, branch, and root biomass constant. Growth and mortality rates in cubic feet/year were derived from Resource Planning Act statistics. Harvest statistics in MBF/year are from USDA-Forest Service Region 1 reports. We standardized volume estimates and converted to fixed carbon weights.

Table 5: Forest Carbon Flux by Ownership
Million metric tones (MM MT) per year

Forest Ownership	Growth	Mortality	Harvest	(G+H)-M
National Forests	5.2	5.1	0.4	0.5
BLM/other public	0.3	0.1	0.0	0.2
State of Idaho	0.7	0.2	0.6	1.1
Private/tribal	2.6	0.6	2.0	4.0
Totals	**8.9**	**6.0**	**3.0**	**5.9**

Idaho's forest carbon inventories are experiencing significant background growth (+1.6%/year). Inventory accumulation is offset by mortality (- 1.1%/year) and harvests (-0.5%/year). Normally, managed forests attempt to capture mortality in well-timed harvests, but Idaho has almost twice as much mortality as harvest.

The calculated (G+H)-M is a rough estimate of net carbon accumulation at current rates. Growth stores carbon in tree boles; harvest stores carbon in products; and mortality releases carbon as dead trees decay. Our use of total harvest as a storage indicator overstates that form of sequestration as some harvest volume is waste, and some wood product also decays, releasing carbon. Still, Idaho forests appear to be increasing carbon sequestration as an ordinary part of timber management.

Table 5 also demonstrates that carbon flux varies wildly by ownership. Most of the forest carbon sink function is on actively managed private and tribal forests even though they control a much smaller portion of Idaho forests. The fact that state, tribal and private forests have relatively less accumulated inventory and more carbon sink function is counterintuitive. More intensive timber management attempts to capture the most possible site productivity as rapidly harvestable product. Growth (carbon fixation) is optimized, rotation cycles are short, mortality is avoided or captured, and the forest carbon is repeatedly stored in wood products rather than as standing inventory.

The national forests had most of the forest area (57%) but these lands hold even more of the volume (77%). There is relatively little annual harvest on these older, denser stands. As a result growth is low. Mortality is high and has been increasing rapidly over the last three decades (O'Laughlin et al 1993). Although they have enormous volumes of stored carbon, this ownership probably functions as a net carbon source from the estimated mortality, decay and the uncalculated large fires.

INFLUENCING FOREST CARBON SEQUESTRATION

Forest carbon flux is extremely malleable. Historical carbon stores that have been established as an artifact of prior carbon insensitive management can be augmented or liquidated. From a given carbon stock, future flux can be similarly redirected. As carbon sequestration appears to be correlated with overall intensive timber management, increased timber and carbon management may have financial as well as environmental complementarity.

Silvicultural practices are management activities that change the nature of the forest stand or ecosystems. These practices are already exercised to varying extents for a variety of reasons. They may enhance wood product value and profits, change watershed quality, and provide wildlife habitat. Many traditional practices already have a direct effect on the degree of carbon sequestration. These individual practice effects may be positive or negative. This section identifies common practices in Idaho forest management and reviews their current flux effect. We note trade-offs with carbon sequestration objectives and make rudimentary quantifications of their potential influence.

Defining Units of Forest Carbon Production

To influence management, first the carbon product must be quantified. The term carbon credit has had many different meanings and has been known by many different terms. Now that carbon sequestration is becoming an accepted objective, one general definition is emerging. Most agree that a "carbon credit" is used to represent an amount of organic carbon sequestered in wood or soil. It is equivalent to the removal of one metric ton (2,204.6 pounds) of carbon dioxide (CO2) from the atmosphere. Most people define a carbon credit as one metric ton of CO_2 equivalents instead of a ton of C_2 alone.

The transfer of solid carbon compounds into gaseous CO_2 means that for each unit of carbon converted into gas, 3.67 units of CO_2 are produced (NCOC 2002). This conversion uses the molecular weight of carbon (C=12) and oxygen (O=16). Therefore, when one unit of carbon combines with 2 units of oxygen (12 + 16 + 16 = 44/12 = 3.67), the result is 3.67 units of CO_2 for each unit of C_2.

Standards for Calculating Carbon Yields

As there are currently no uniform standard guidelines for carbon sequestration projects, there is not one standard method of calculating carbon yields from forests. However, most carbon authorities agree on the following basic steps that have emerged as the basis in calculating carbon yields or credits:

1. Establish baseline conditions – How much carbon is there now?
2. Establish a project case scenario – How much carbon will be there at the completion of a project?
3. Calculate net carbon changes – How much additional carbon did your project actually produce?

4. Address special considerations of carbon sequestration projects:
   - **Additionality** – A project must reduce carbon emissions or increase a carbon sink as a direct result of an intentional activity that would not have occurred otherwise.
   - **Leakage** – Will the emission reductions in this project cause emissions elsewhere that partially or totally offset the emission reductions of the project?
   - **Permanence** – How long will the project build and maintain a carbon pool? Is it likely that the project will continue to sequester carbon after the initial contract has expired?
   - **Risk** – What are the potential risks that the project will not be implemented or will be lost to other factors such as disaster, abandonment, politics, etc.
   - **Duration** – How long is the commitment period of the project? When does the contract expire?
   - **Transparency and Accuracy** – How clear and accurate is the plan, so as to provide a clean audit trail for subsequent verification?
   - **Monitoring and Verification** – How will the project be monitored to sample carbon pools as they are sequestered and compare this to the original plan or contract?

Silviculture and Carbon Management

Silvicultural practices are management activities that change the nature of a forest stand or forest ecosystems. Foresters employ these practices for a variety of reasons. They may enhance wood product value, change watershed quality, or provide wildlife habitat. Many traditional practices already have a direct effect on carbon sequestration. These effects may be positive or negative. This section identifies common practices in Idaho forest management and reviews their current flux effect. We note trade-offs with carbon sequestration objectives and make a rudimentary quantification of their potential influence. Typical contemporary silvicultural practices include the following.

- **Stand Composition Control**

  This is regulating a stand's species composition to the species or mix of species most suited to a location either biologically, or economically. It is accomplished with species cutting targets and regulating species regenerated, either in natural seeding or by planting. Tree species differ in carbon sequestration ability; by growth rate and density. Those with more dense wood contain more carbon per unit volume. Examples are Douglas-fir with a specific gravity of 0.473, ponderosa pine with 0.416, spruce/fir with 0.349 and western larch at the highest with 0.508 (Birdsey, in Sampson et al. 1992). Changing the species mix can affect the amount of carbon sequestered, either positively or negatively.
- **Stand Density Control**

  Thinning regulates the number of trees and their size class distribution in a forest stand. Tree/stand density can significantly impact forest carbon. Vigorously growing trees sequester carbon more rapidly than poorly growing ones. They are generally more healthy and resistant to attack by insects and diseases and will remain alive, sequestering carbon for longer periods. Conversely, trees in dense stands grow slower and are subject to attack by insects and diseases, thus reducing the carbon sequestration ability and longevity. Sparsely occupied stands will be less productive economically and in carbon fixation. Example methods include:

  Commercial thinning_— cutting salable trees to control forest density. This causes a short-term release of carbon in slash burning and the decay of tops, branches and folliage, however, log sales provide long-term sequestration through the utilization of forest products.

  Precommercial thinning_— cutting solely to improve the stand growth, health or structure. Cut trees are generally too small to sell, thus there will be a short term carbon releases as cut trees decay. This will be offset by the increased growth of the trees left on the site. As merchantable log sizes are becoming smaller, more thinning is becoming commercial

Interplanting – establishing young trees among existing forest growth by natural seeding or by planting. When there are fewer trees or plants than can be supported by the physiography of the site, interplanting provides obvious new carbon sequestration.

- **Protection and Salvage**
  Severe tree mortality is caused by insects, pathogens, fire and wind. Dead trees eventually release of carbon through decomposition or directly by burning. Accumulations of dead fuels increase the risks of fire to nearby living trees. Losses of all types are greater in unmanaged stands where tree high density contributes to competition, low tree vigor, growth loss, and increased impact of the previously mentioned factors. Substantial gains in carbon sequestration are possible through increased forest health and prevention of losses. This can be achieved through management that optimizes (usually reduce) stand density and removes suppressed, poorly growing trees. Salvage of dead and dying trees contributes to productivity and sequestration of carbon by increasing site occupancy and the utilization of wood products. Direct control of damaging agents such as bark beetles, dwarf mistletoe, or fire prevents tree killing providing a significant increase in fiber production and carbon sequestration. More detail on the role of forest insects and diseases and efforts to prevent or control damage resulting from them is presented in Appendix B.
- **Controlling Rotation Length**
  Rotation length, how old trees are before harvest, is the most common and influential silvicultural decision. Rates of stand carbon sequestration are influenced by tree size, age and vigor. Younger trees grow faster and are more efficient at sequestering carbon. Growth slows with age and older trees are more subject to decay, attack by insects, and diseases with a net carbon loss. Optimal rotation age varies. Maximizing mean annual increment leads to long rotations and large stand carbon accumulations, but very slow product storage. Highest financial returns leads to lower average growth rates and less stand accumulation, but more rapid cycling to products. An optimal carbon flux rotation is probably between these cycles and could be uniquely determined for each site. Then joint revenue and carbon flux could be optimized depending on landowner incentives for carbon fixation.
- **Regeneration Harvesting**
  When harvesting is a management objective, it is necessary to replace trees that have been removed. This is "regeneration," a task accomplished by artificial or natural reproduction. Planned silvicultural treatments to remove old trees while creating an environment favorable for establishing new trees are referred to as regeneration harvests. Sequestered carbon is moved from the forest to products. Slash left after the cutting is often burned with an immediate release of carbon into the atmosphere. Carbon sequestration in new trees starts as soon as the new crop of trees is established. Regeneration harvests have many variants:

  Even-aged -- creating a stand composed of a single age class or even-aged strata. Tree ages in the same area are usually within ±20 percent of the rotation age. Examples of even-aged regeneration harvests include:

  Clearcuts--entire stands are removed in one cutting with regeneration. Often used to stimulate reproduction of shade intolerant trees, clearcuts ecologically mimic catastrophic events such as wildfire. Regeneration is often artificial.

  Seed-tree cuts -- the majority of the mature trees are cut in one entry except for a small number of seed trees left singly or in small groups to provide seed for a new generation.

  Shelterwood cuts -- mature timber is removed in a series of successive entries over the rotation. This produces three or fewer layers of generations being essentially of the same age.

  Uneven-aged -- planned sequences of continual harvest entries designed to maintain and regenerate a stand with three or more intermingled age classes. The principal example is the **selection method** where harvests cut widely spaced individual trees or small groups of trees at relatively short intervals repeated indefinitely. Used particularly for shade tolerant species, reproduction is usually by natural seeding from the remaining stand. Stored carbon can be high in uneven-aged stands as there is a continuing stand of trees at all times. Carbon flux will depend on how intensively this harvest method is practiced. Sequestration is enhanced through the frequent extraction of forest products.

- **Pruning** – removes side branches and multiple leaders from standing trees, usually to improve timber quality, or to improve aesthetics or health. It can marginally reduce growth rates. As cut branches are left on the forest floor to rot, this practice contributes, albeit at a small scale, to the release of carbon.
- **Riparian zone conservation/restoration –** preserves or restores stream-side vegetation. This helps prevent erosion and siltation of the streams, and maintains habitat for fish and wildlife. Since the effort promotes growth of vegetation, it provides an opportunity for carbon sequestration.
- **Edaphic (site) modification –** enhancing seedling survival and rapid tree growth. Typically these treatments also increase carbon sequestration. These practices include fertilization, irrigation, and control of competing vegetation. Fertilization and control of competing vegetation are common forest practices used when the economic return is positive. Irrigation can only be used on a small scale usually in plantations. This is often done where fast-growing trees are planted for specific purposes such as to provide fiber for pulp mills.
- **Fire management –** as fires result in immediate release of carbon, their use in forest management may be looked upon as suspect in value relative to carbon sequestration. This is especially the case with wild fires that burn many acres, releasing tons of carbon as they burn. The general philosophy for dealing with **wildfires** is to let them burn if they are in wilderness areas and are not threatening other resources. Those fires burning in commercial forest or that do threaten other resources are suppress as quickly as possible. Burning also helps recycle all nutrients tied up in the wood to make it available to the next generation. However, fire used as a management tool needs to be looked at more closely.

  Broadcast burning—widespread low intensity fire to prepare sites for planting. It would be a major contributor to atmospheric carbon, yet many sites need this type of treatment to start new stands.

  Underburning --reduces competing vegetation allowing surviving trees to grow more vigorously. There is initial litter and duff carbon release, but long-run increases in carbon that is sequestered in the boles of the trees where it will remain until it is harvested or it dies of natural causes.
- **Regenerating Unstocked Areas**

  Logging, clearing of land for agriculture as well as fires and other catastrophic events have created many large, open areas that often can only be reforested by planting. Cutting practices may also result in temporary reductions of the number of trees growing on a site that are best remedied by planting. **Restocking** efforts will cause an immediate increase in carbon sequestration on these sites. **Afforestation** is the process of converting non-forest lands such as crop agriculture or pastures into forest stands. Such land use conversions of pasture land or lands with similar cover types often provide the greatest potential increases in carbon sequestration.

INFLUENCING IDAHO SILVICULTURAL DECISIONS

Getting Idaho forest owners to modify silviculture to increase sensitivity for carbon issues would vary significantly by type of owner. National forest and other federal forested agencies respond primarily to national political and regulatory influences. We address only the potential modification of forest management on state, tribal and private forests. Our ownerships all have significant financial objectives even though each group has different sets of non-financial management criteria as well. In most of them a change in operating or regulatory costs, or in revenues has very predictable effects on the choice of silvicultural activities. As we consider influencing forest carbon decisions, the mechanism will have predictable qualitative effects on growth rates, rotation ages, intensity of management (amount of silvicultural practices), propensity to hold inventory, and incentives to change land area allocated to forests.

Forest carbon policy intervention can appear to landowners as costs (typically from taxes or regulatory compliance) or benefits (such as tax breaks, carbon credit sales, or subsidies). For example, the value of a carbon credit has been hypothesized from $2 to $18. If forest owners could produce and sell enough of these, there might be substantive chances in their behavior.

If we condense the set of possible influences into: 1) an increase in management costs and 2) an increase in forest revenues, we can extrapolate from Hyde's (1980) predictive analytics of such changes. The behaviors are caused by complex interactions of financial indicators with the interest rate and biological growth, but the basic responses when these are held constant are summarized in table 6. We qualify a general carbon sequestration response (- or +) set from the practice descriptions above. Individual cases can differ from the general response.

Table 6: Forestry Responses to Higher Costs or Revenues

Effect	**+Δ Costs**	**Δ C_2 flux**	**+Δ Revenues**	**Δ C_2 flux**
Rotation Age	Longer	_	Shorter	+
Growth Rate	Lower	_	Lower	_
Practices	Fewer	_	More	+
Inventory	Lower	_	Lower	_
Forest Acres	Fewer	_	More	+
Forest Fires	More	_	Fewer	+

The growth rate response to increased costs is particularly counter-intuitive. There is a longer rotation due to decreased investment. Longer rotations usually have higher average growth rates for the same investment, but the investment effect is empirically larger than the rotation effect on growth. Also, less product is cycled less frequently. The qualitative indicators suggest that interventions increasing costs without reward should actually lower forest carbon flux. Incentives generally increase it although not all factors are affected the same direction.

CALCULATING CARBON POTENTIALS IN AFFORESTATION

Afforestation is the largest potential contributor to increases in carbon sequestration. Not only does creation of new forest inventory imply a large new carbon sink, increased forest products have long-term carbon storage properties. Land use conversion usually depends on the economic differences between agricultural or pastoral use and timber investment potential. Conversion of high productivity agricultural lands is unlikely, however, the land use allocation margin between low quality ag and forest is a function of relative crop yields, relative crop values, transportation costs and the interest rate (Barlowe 1978). Carbon sequestration incentives would accelerate the process.

While we can't predict how many acres would be converted without knowing financial variables, we do have data on the rate per acre of relative carbon fixation that could be generated. These conversions measure soil and biomass carbon, but calculate only net carbon gain between uses. Many variables and different combinations of these variables make it very difficult, if not impossible, to accurately predict a maximum level of carbon that could be sequestered in Idaho forests.

The intent of our report is to simply demonstrate how some of the generally accepted silvicultural practices in forestry could impact carbon storage and flux in Idaho forests. For example, planting trees into unforested areas is probably the highest response practice. Using published acreage figures for poorly stocked and non-stocked forest ground (Brown & Chojnacky, 1991) and acreage suitable for conversion to trees from pasture and marginal agricultural land (Sampson and Hair, 1996), we can estimate how much impact this one practice might have in Idaho's carbon storage.

Table 7: Idaho Lands Suitable for Tree Planting

Land Class	Acres
Poorly Stocked Forest Land	3,493,040
Non - Stocked Forest Land	1,097,831
Pasture land to Forest Land	273,100
Marginal Agric. Land to Forest Land	600,900
Total all land classes	**5,464,871**

We make broad assumptions such as: 1) realistically, afforestation might be financially feasible on only 20% of biologically suitable acreage; 2) poorly stocked forest land is understocked by 75%; 3) pasture land has no forest cover; and 4) agricultural land has no carbon in the top one foot due to repeated tillage. Using Birdsey's forest component figures from table 3 above, and expanding table 7, we find that afforestation could potentially fix about 34.734 Million Metric tons of additional carbon (table 8).

Table 8: Carbon Potential of Afforesting 20% of Suitable Idaho Lands

Land Class	20% of Acreage	Pounds of Carbon/acre	Carbon Metric Tons
Poorly Stocked Forest Land	698,608	55,413	17,564,397
Tree Component		45,721	14,492,233
Soil		6,442	2,041,844
Forest Floor		2,174	688,940
Understory		1,077	341,380
Non – Stocked Forest Land	219,566	70,653	7,038,591
Tree Component		60,961	6,073,038
Soil		6,442	641,733
Forest Floor		2,174	216,528
Understory		1,077	107,293
Pasture land to Forest Land	54,620	82,768	2,051,180
Tree Component		60,961	1,510,749
Soil		16,104	399,099
Forest Floor		5,434	134,660
Understory		269	6,673
Marginal Agric. Land to Forest Land	120,180	148,190	8,080,524
Tree Component		60,961	3,324,089
Soil		64,417	3,512,539
Forest Floor		21,735	1,185,169
Understory		1,077	58,727
TOTALS	**1,092,974**		**34,734,692**

This is metric tons of C_2, not CO_2. If we multiply our figure by 3.67 to convert to carbon credits, we sequester 127.5 million metric tons of CO_2. Even at only $2/carbon credit, we are looking at a reasonably significant forest by-product. Although the numbers of new carbon credits would probably never be as dramatic as our assumed afforestation alone, there are more carbon credits that could be calculated for all of the other silvicultural practices that are discussed in this document.

CARBON SEQUESTRATION EXAMPLE CASES

There is not a carbon registry for Idaho, so accurately quantifying active carbon projects is difficult. Thus far, interest in carbon sequestration projects peaked in year 2000 or 2001. Forest carbon projects are limited to a few small tribal and non-industrial early adopters. Although carbon information meetings were attended by state and federal agencies as well as private industry, members of this committee are not aware of any current projects being implemented or set up by these agencies or companies. The following examples are representative of Idaho forest carbon projects so far.

The Nez Perce Tribe

The Nez Perce Reservation is in North Central Idaho. They became interested in carbon sequestration in 1995 as a possible funding source to replant failed plantations. In August, 1997 tribal forestry began working with the Upper Columbia RC&D on potential Carbon Contracts. The tribe also became a working member of the Pacific N.W. Carbon Sequestration Coalition (6/99) and the Montana Carbon Offset Coalition (10/99). The latter became the National Carbon Offset Coalition (NCOC) in 2002.

The Nez Perce Tribe has developed five carbon sequestration projects or contracts. Four have been reforestation projects and one is an afforestation project. Afforestation has drawn the most interest, converting four hundred (400) acres of marginal agricultural ground into a forest. Together, a conservative sequestration estimate is 336 thousand metric tons of CO_2 on 1,033 acres. Another 1,000 + acre afforestation project is being developed. The tribe has not yet actually sold a carbon contract, but they are confident that it is just a matter of time.

Upper Columbia RC&D

Although the Upper Columbia RC&D is located in Spokane, Washington, forester Tim King is regarded as a carbon sequestration leader throughout the Pacific Northwest. He aided and facilitated other RC&D's in Idaho in developing carbon projects. They developed many individual small landowner projects in North Idaho. Two private forests totaling one hundred acres were part of a carbon sale to Pacific Corp. in 1993 & 1994. In 1995, 1996, and 1997 another eight private land owners (~ 1,000 acres) in North Idaho benefited from another sale, this time with the Tenaska Corporation. With both of these carbon sales many other private landowners in other states and two Native American tribes also benefited. However, because of internal financial and political reasons, the Upper Columbia RC&D is no longer facilitating carbon sequestration contracts. As a result, several of the latest private forest projects developed registered carbon credits that remain unsold.

National (Montana) Carbon Offset Coalition - NCOC

The National Carbon Offset Coalition (NCOC) is comprised of eight Montana non-profit organizations. NCOC provides an opportunity for landowners, public, and private corporations, tribal, local and state governments to participate in a market-based carbon conservation program to help offset greenhouse gases impacts. It is designed to assist planning carbon sequestration projects and documents potential carbon credits in a format that follows international standards and protocols, while meeting the needs of potential buyers. (NCOC 2002)

Although this NCOC is not located in Idaho, it has facilitated two projects with the Nez Perce Tribe in Idaho. They have also facilitated one carbon contract sale for the Confederated Tribes of the Salish and Kootenai in Northwest Montana. NCOC remains very active in seeking and promoting viable carbon projects nationwide. They work directly with Montana state government as well as various federal agencies such as the Department of Energy (DOE) and the Environmental Protection Agency (EPA) on carbon sequestration policy.

POTENTIAL ROLE OF STATE GOVERNMENT

The scientific study of organic carbon fixation is well-developed, but the application of that science to the practical management and manipulation of atmospheric carbon is relatively new. Many global warming experts have attributed warming to human releases of C_2 particularly the use of fossil fuels. The concern is widespread enough to cause international policy formation on the rate of fossil fuel C_2 emissions. The Kyoto protocol was an international treaty defining the acceptable emissions levels.

Intentional mitigation of atmospheric C_2 levels, while technically feasible, has been controversial and there is neither international treaty nor national governmental policy on its exercise. As the U.S. Congress has not ratified the Kyoto accord, there is no coherent American national mandate to reduce or use mitigation to reverse C_2 emissions. There are regulatory constraints calling for new industrial carbon emissions mitigation that have stimulated interest in carbon offset contracts. The fact that agricultural and forestry sectors may have very large potential in such mitigation has led to a few institutional experiments in fostering or encouraging mitigation practices.

The active sequestration process is new and takes many forms. Most of the active sequestration projects are experimental private transactions between C_2 emitters and carbon credit brokers. These brokers supply a unit definition to quantify the rate and total amount of fixed carbon. They organize and small coalitions of agricultural and forest owners to change their vegetative rate of carbon fixation producing these credits. These credits are accumulated into contract packages that are sold to carbon emitters who need to mitigate C_2 emissions. The arrangement is usually a private contract that specifies the agreed sequestration parameters. These include:

1. Defining carbon credits—1 metric ton equivalent of atmospheric CO_2
2. Methods of measuring the rate and total production of carbon credits
3. Specifications for distinguishing mitigation credits from existing C_2 inventory and fixation from existing management from new sequestration
4. Spatial identification of the sequestration project
5. Timespan of credit production and degree of long-run sequestration in vegetative inventory or final product
6. Agreement on the production and transaction value of credits
7. A system of reassigning rights to those credits
8. Acceptable patterns of compensation
9. Provisions for contract change
10. Assignment of credit loss risk
11. Provisions for monitoring credit production
12. A protocol for certifying the quantity and quality of credits, and
13. Provisions for adjusting contract specifications

Early carbon credits transactions have been competitive market negotiations with little participation of government other than specific national case requirements for mitigation such as in new power plant licensing. The role of state and local governments in carbon sequestration varies from market facilitation to regulation and no standard pattern has evolved.

Sequestration activities could potentially be organized in either centralized government or decentralized market processes. Government involvement in the production of a marketable commodity is usually justified by the failure of private markets to correctly provide public goods, usually from ignoring the non-financial social costs or social benefits of economic activities (such as carbon and global warming). Government intervention can take many forms;

1. **Moral suasion** includes public organization of information and social pressures to suggest socially preferable changes in private carbon emitter and sequestration behavior. For example, a public education program on the social costs of increased atmospheric carbon or an enlightenment on C_2 conservation practices in forests.
2. **Regulation** is the formal involuntary legal process of specifying allowable behavior for emission and sequestration. Emissions caps on new energy facilities or new car fuel requirements are existing emissions regulations. On the sequestration side, there could eventually be penalties for not maintaining a minimum vegetative cover crop on open lands.
3. **Taxes and subsidies** are involuntary negative and voluntary positive financial incentives to adjust carbon related production and consumption behavior. Government sets socially optimal targets and charges or pays individuals that choose to deviate from them.
4. **Direct production** is the nationalization or other form of centralizing ownership and decision authority in carbon sensitive sectors. The national forests could perform direct government sequestration. Public transit replacement of private automobiles could reduce emissions.

These are widely extreme categories of government involvement potential. The most appropriate carbon transaction system may be between the extremes of lassiz faire market non-interference and soviet style autocracy. The social goal is to achieve a new standard of environmental quality efficiently—the most gain for the lowest cost.

Osborne and Gaebler (1992) argue that neither organizational extreme is an efficient provider of goods with public overtones. Private markets malfunction and so do governments. In designing systems they suggest vesting each group with the responsibility to achieve the parts where they have the highest relative efficiency.

Government is good at providing information, setting standards and institutional settings, politically identifying public values, and enforcing contracts. The private sector is good at optimizing investment levels, efficiently allocating resources, effectively executing projects and production, and the transaction and distribution of goods. The actual carbon sequestration process could occur on both private and public forests. We presume that a joint government/private sector structure would make any Idaho carbon sequestration efforts more effective. To that end, we list the potentially **positive** functions of state government in regulating, organizing or managing a combined state/private carbon sequestration process.

Function 1: Provide carbon sequestration standards.

a. The state could codify the current working definition of a carbon credit.
b. It could standardize the production estimation process and provide technical expertise on converting Idaho sequestration practices into long-run estimates of fixed carbon.
c. It could provide carbon credit grading to identify credit quality and distinguish from existing carbon sinks.

Function 2: Facilitate carbon credit information

a. Establish a spatial data base to estimate locate the existing Idaho carbon sinks, their carbon content and state of flux.
b. Begin an extension effort to publicize carbon sequestration opportunities, describe the importance of conserving existing carbon and educating potential carbon sequesters
c. Prepare regular analyses of carbon sequestration polices, existing markets and sales potential to identify carbon credit current values and the potential timing for future investment
d. Identify and fund potential technical research projects on: forest soil and biomass carbon, carbon BMP's, role of agricultural burning & forest fire in carbon flux and credit production

e. Identify and fund potential project investment research establishing cost effectiveness guides for possible sequestration BMP's

Function 3: Facilitate carbon credit transactions to lower their costs

a. Act as a clearing house for participating carbon sequestration to organize participants and advertise mitigation credit availability
b. Use the central data base to spatially locate potential carbon sequestration projects and maintain a spatial data base on the changing status of existing and potential credit production
c. Develop a suggested contract format for carbon credit transactions
d. Use the central data base and GIS mapping to assist landowners in defining the location and parameters of new projects

Function 4: Provide an institutional and regulatory setting

a. Establish a new office of carbon management in the Idaho Dept of Agriculture
b. Study existing ag and forest regulations to identify the need for new statutes and the revisions of existing regulations where their enforcement might conflict with carbon
c. Explore the creation of carbon credit insurance similar to crop insurance to reduce sequestration production and contract risks
d. Study the effect of existing agricultural and forest tax systems with respect to their effects on existing carbon sink conservation. Evaluate tax incentive mechanisms for proactive sequestration.

Function 5: Enforce carbon credit contracts and standards

a. Develop a centralized program of carbon project inspection and production certification
b. Set non-compliance sanctions and penalties relevant to breech of carbon credit contract, non-compliance or fraud

Function 6: Manage public lands carbon sequestration activities

a. Establish carbon credit sales as a legitimate product of state land management
b. Recommend how current state land practices could be adapted to increase salable carbon credits
c. Coordinate state & private activities with federal lands agencies to optimize the Idaho potential for credit sales

RECOMMENDATIONS OF THE FORESTRY SUBCOMMITTEE

The forest subcommittee generally supports the interest of the Idaho legislative and executive branches in facilitating the development of carbon sequestration opportunities for Idaho's state, tribal and private forests. However, we expect that some regulatory approaches could actually increase costs to carbon sequesters and actually reduce Idaho's capacity to capitalize on this new, and environmentally beneficial, forest product. From the list of possible roles above, our specific recommendations for immediate consideration include:

1. Expand this committee's exploratory research into a more detailed evaluation of what other states have accomplished and use their mistakes and successes as a guideline to develop Idaho forest carbon policy.
2. Charge a state agency (such as Idaho Dept of Agriculture) to provide standards & guidelines for defining, measuring, estimating and monitoring carbon production that are compatible with national and international systems.
3. Fund the calibration of an existing baseline model to quantify the baseline levels of forest carbon sequestration.
4. Contract research to actually measure the carbon response of Idaho forest types to various silvicultural practices and create carbon projection protocols that could easily be followed by foresters.

5. The state should provide or fund adequate extension training to Idaho foresters and forest owners to enhance awareness on carbon sequestration opportunities, methods, and marketing potential (i.e. how to sequester carbon).
6. The state should maintain an updated and easily accessible list of carbon credit opportunities (perhaps a web site) and provide marketing information and assistance to citizens interested in selling carbon credits.
7. Develop guidelines and training for setting up carbon projects and calculating the carbon credits on specific sites. These should be very similar to other states and countries, realizing that items may change as the carbon sequestration programs and the science surrounding them evolve.
8. The state should provide a legal standard contract format and process for carbon credit sales.
9. Pass the necessary enabling legislation to authorize the Idaho Department of Lands to design carbon projects and implement carbon credit sales to enhance the state educational endowment fund when credits become a viable and tradable commodity.
10. Provide one (1) entity or agency to register all carbon projects and credits within the state and group these projects by type (e.g. reforestation, afforestation, no-till agriculture, etc.). Project registry should be sensitive to special consideration projects such as: tribal jurisdictional issues, industry with ownership in more than one state etc.

We believe that this is just a starting point for facilitating this new market. The process should be reevaluated at regular intervals and adjusted to meet new considerations as they develop. However, we expect that our recommended approach establishes a design philosophy for the state and private cooperation to develop Idaho's forests to their highest sustainable financial and environmental potential.

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FORESTRY SUBCOMMITTEE BIOS

Brian Kummet, Nez Perce Tribal Forestry
P.O. Box 365, Lapwai, ID, 83540, (208) 843-7328, briank@nezperce.org

Brian began his career in 1984 as a BLM timber cruiser in Missoula, Mt. The summers of 1985 & 1986 were spent in Dillon, Mt. on a BLM Engine Crew in fire suppression. After graduating in 1986 from the University of Wisconsin at Stevens Point with a B.S. degree in Forest Management, Brian worked as a project forester for the Menominee Tribe in Northeastern Wisconsin from 1986 to 1989. In 1989, Brian was promoted to a timber sale administration forester. He relocated to Idaho in the fall of 1991 to accept the position of reforestation & timber stand improvement (TSI) forester for the Nez Perce Tribe in North Central Idaho. Since reorganizing the program in 1999, Brian is currently the fee lands forester for the Nez Perce.

R. Ladd Livingston, Idaho Department of Lands
3780 Industrial Ave. S, Coeur d'Alene, ID, (208) 666-8624, llivingston@idl.state.id.us

Dr. Livingston is supervisor of the Forest Insect and Disease Section, assigned to the Staff Headquarters in Coeur d'Alene. He provides technical assistance to state and private forest managers across Idaho. Ladd has a Bachelor of Science Degree in zoology and botany from Brigham Young University, and a Ph.D. in entomology and plant pathology from Washington State University. He has 30 years of experience in the state forest insect and disease management program, including practices of prevention, detection, evaluation, and suppression. He also is responsible for gypsy moth detection and control in Idaho and is the state coordinator for the National Forest Health Monitoring program. He has participated on numerous national and international working groups including a North American test of Criteria and Indicators of Forest Sustainability sponsored by the Center for International Forest Research, serving on the Management Team of the USFS Forest Inventory and Analysis / Forest Health Monitoring programs, and is the state representative to National Working Groups for Bark Beetles and Western Defoliators.

Charley McKetta, Forest Econ Inc.
1150 Alturas, Suite 102, Moscow, ID, 83843, (208) 301-4634, forestecon@moscow.com

Dr. McKetta is a consulting forest economist, CEO of Forest Econ Inc, and University of Idaho professor emeritus. His degrees are in forest management, applied physics and forest economics from U. Michigan and U. Washington, with ecological training at the Organizacion de Estudios Tropicales in Costa Rica. He has 30 years of experience in strategic forest planning, timber investment analysis, forest taxation, non-timber valuation and optimization, and analyzing forest sector markets and impacts. He has participated in forest sector development policy with AID, World Bank & 2 international development banks in 4 Latin and 3 south Asian countries. There was former employment as a logger, commercial pilot, and as US Forest Service fire researcher and district recreation officer. He is active in the Society of American Foresters, and the Idaho Forest Owners Association. He manages his own Tree Farm Association certified and stewardship certified 400-acre private forest near Troy, Idaho.

Appendix A

Appendix Table 1: Average per-acre storage of carbon in 11 Western States
by state and forest component, 1987 (from Birdsey 1992).

	- - - - - - - - - Pounds of carbon stored per acre in - - - - - - - - -				
State	Total	Trees	Soil	Forest Floor	Understory
Arizona	106,218	44,658	49,227	11,256	1,077
Coloado	124,993	44,405	62,536	16,975	1,077
Idaho	**148,190**	**60,961**	**64,417**	**21,735**	**1,077**
Montana	185,386	67,902	95,732	20,657	1,077
Nevada	83,098	42,658	32,608	6,755	1,077
New Mexico	90,610	30,643	45,790	13,100	1,077
Utah	107,585	38,459	58,225	9,824	1,077
Wyoming	150,012	47,034	81,892	20,009	1,077
Average, Mountain States	124,512	47,090	61,303	15,039	1,077
California	127,372	55,672	53,224	15,042	3,434
Oregon	172,749	64,469	82,976	21,870	3,434
Washington	202,655	83,073	93,911	22,237	3,434
Average Pacific States	167,592	67,738	76,704	19,716	3,434
Average, 22 Western States	136,261	52,721	65,503	16,315	1,720

Appendix B
Detailed Carbon Influences from Forest Insect and Disease Control

Forest insects and diseases attack all parts of a tree including the foliage, branches, twigs, bark and inner bark, wood, cones/seeds and roots. The main ecological role of many of these is nutrient recycling. They are counted as agents of change. This is due to the consumption / utilization of needles and wood and the killing of many trees that can cause distinct changes to forest composition and structure. The feeding activity of the insects and the decay of dead trees by microorganisms contribute to the return of nutrients to the soil with the eventual return of carbon to the atmosphere as carbon dioxide or methane. Because of the threat from these agents to timber, recreation and watershed values, the State of Idaho, Department of Lands has a forest pest management and abatement program which has been established by State code. Forest management practices and control projects aimed at minimizing the impacts of forest insect and disease pests help enhance carbon storage potential by the promotion and maintenance of healthy, fast growing trees and forests and the reduce emission form biomass decay.

The principle aim of the forest insect and disease management program of the Idaho Department of Lands is to prevent problems before they happen. This is accomplished by providing information and training to all forest owners on how to develop and maintain healthy forests, which will in-turn be resistant to attacks by the various insects and diseases. Surveys of damage are conducted annually to detect new outbreaks providing the opportunity to salvage killed or damaged trees. The utilization of these dead or threatened trees contributes to the storage of carbon as wood products are incorporated into utilization projects. When outbreaks occur with damage that exceeds economic or esthetic levels, control projects may be implemented to reduce the impacts on trees and forest stands. Each agent requires its own unique methods of prevention techniques, survey methods and controls. This information is provided to forest owners with field visits and classroom training.

Prevention centers on those silvicultural activities that will produce healthy, vigorously growing forests. An example is the thinning of overstalked stands, both of young, noncommercial trees, and of commercial sized trees. The increased spacing reduces competition resulting in healthier trees that grow more vigorously. Not only are they are resistant to attack by the insects and diseases, but they store carbon faster than the trees of a stagnated, poorly growing forest. Other activities that help prevent damage are the promotion of a stand composition of fast-growing, shade intolerant trees such as pines and western larch. These species are, in general, less susceptible to root diseases which are common in many parts of Idaho and which accounts for very high numbers of killed trees. Another prevention activity is the prompt removal of trees heavily stress or downed by catastrophic events such as fire, winter ice storms, heavy snow or wind. The damaged or downed trees become a breeding site for tree-killing beetles that build up high populations then emerge to kill more trees in the area. They also provide food for wood decaying microbes. The prompt removal of these downed trees both prevents the beetle activity and removes the wood from the decay process, thus contributing in two ways to the reduction of carbon release into the atmosphere. The disposal of slash from logging or natural causes is another practice that can contribute to this phenomenon as there are certain insects that can build high populations in larger pieces of slash and, again, emerge to attack unharvested trees. The down side to this is that slash treatment is often accomplished by burning, a practice that causes an immediate release of carbon into the atmosphere. Some of this can be mitigated through the utilization of smaller sized stems, converting them into products, with commensurate carbon storage.

When outbreaks of pest insects or diseases occur, control activities may need to be implemented. These may include the removal on insect or disease infested trees (sanitation/salvage), or control applied directly to the pest. Examples include the application of pesticides or the development of genetic resistance in the trees themselves. An example of genetic resistance is the development of disease resistant western white pine. This species is very susceptible to an exotic disease, blister rust, which was introduced into the northwest in the early 1900's. A long-term breeding program has lead to the development of resistant trees and the propagation of seeds for reforestation. Outbreaks of defoliating insects, such as the Douglas-fir tussock moth, have been controlled through the aerial application of various pesticides. Bark beetles have been controlled by removal of infested trees or by manipulation of populations with behavior-modifying chemicals that mimic natural compounds produced by the beetles themselves. Sometimes, pests can be controlled biologically through the introduction of parasites or predators that are capable of maintaining populations at low levels, or by the introduction of diseases that are very specific to one or only a very few hosts.

Often, land owners are desirous of participating in programs to prevent or control insects or diseases that kill or damage trees, but are limited in their ability to do so by lack of funds. Increasing the opportunities for monetary returns associated with increasing forest health will help stimulate forest owners be able and willing to participate in these activities. Finding new uses, and the demand, for small diameter logs that result from thinning is an example. Government sponsored cost share programs would also help this cause. There are several programs currently available from the federal government; however, they are also limited by funding. Sales of carbon credits by forest owners also have potential for providing increased returns from forested acres, stimulating increased participation in all programs.

These subject areas, increasing forest health for resistance to insects and diseases, controlling pests, and increasing funding for landowner participation have the potential to make significant contributions to carbon sequestration.

13.3 APPENDIX 3 - BIOFUELS CONTRIBUTION TO CARBON SEQUESTRATION

BIOFUELS CONTRIBUTION TO CARBON SEQUESTRATION

Introduction

Idaho has a large agricultural and forestry economic base and a potential to sequester carbon. In addition to promoting agricultural and forestry management practices to increase the sequestration of carbon there are opportunities to offset carbon emissions from fossil fuels by utilizing biofuels.

The State has a history in producing fuel grade ethanol and biodiesel research. Today there are two small fuel grade ethanol plants owned by the J.R. Simplot Company producing fuel grade ethanol from potato peel and chips. These plants having been producing ethanol since the mid-80's. There are other entities considering building several large modern ethanol plants in the near future.

The University of Idaho Department of Biological and Agricultural Engineering has been investigating the feasibility of utilizing plant-derived oils as fuels in compression ignition engines. Demonstration projects have ranged from using raw unrefined oil as fuel to ASTM grade biodiesel powering an 18-wheeler with a 50:50 blend of biodiesel and No. 2 diesel for 200,000 miles.

Analysis

<u>Ethanol</u>

Presently the blending of ethanol with gasoline occurs less than 1 per cent of the time in Idaho. It should be noted that there is a marketing incentive to use ethanol in gasoline. It is an exemption of the excise tax for the use of 10% ethanol blends or E-10. There are no incentives for other biofuels.

The fuel usage for Idaho in 2001 is given in Table 1. If the State were to blend 10 per cent ethanol in the gasoline pool, there would an offset of approximately 400,000 tons of carbon dioxide due to the reduction in burning fossil fuels. This calculation takes into consideration that for every gallon of ethanol produced by fermentation there are 6.3 lb of CO_2 produced. It was also assumed that a gallon of gasoline produces approximately 19.5 lb of carbon dioxide when consumed in an internal combustion engine.

Table 1. Idaho 2001 Fuel Usage*

Fuel	Gallons (000,000)
Gasoline	603
Diesel	222
Dyed diesel	124

* Idaho Tax Commission

<u>Biodiesel</u>

Biodiesel is the result of chemically modifying plant or animal oils by replacing the glycerin molecule in the triglyerides with an alcohol. The alcohols of choice are either methanol or ethanol. It was assumed that since diesel contains 12.5 percent more energy per pound than gasoline that diesel would produce approximately 24 pounds of carbon dioxide per gallon.

It can be seen in Table 1 that Idaho uses approximately 346 million gallons of on-road and off-road diesel fuels.

For this analysis it will be assumed that there would be a 20 per blend of biodiesel in the diesel pool. The alcohol used in the manufacturing influences the benefit of blending biodiesel. If it were assumed that ethanol was the alcohol of choice, then quantity of carbon dioxide offset would be approximately 784 thousand tons. In contrast if methanol were the alcohol of choice, then the offset would be approximately 730 thousand tons of carbon dioxide.

A summary of the benefits for using certain biofuels for offsetting carbon dioxide produced from burning fossil fuels is given in Table 2.

Table 2. Carbon Dioxide Offsets for selected Renewable Fuels

Fuel	CO2 Offset (000 tons)
Ethanol (E-10)	400
Diesel (B-20)	730 if methanol were used
	784 if ethanol were used
Total	1,100 to 1,200

Discussion

Utilizing biofuels to create carbon credits has the potential of increasing the benefit per acre of agricultural land beyond that of improving the land management practices. For example if it were assume that E-10 were utilized in the state gasoline pool it would require approximately 60 million gallons of ethanol. If it were assumed that the grain used to produce the ethanol had a yield of 130 bushels per acre and that the yield per bushel to produce ethanol was 2.65 gal, it would require about 175,000 acres of land to produce the grain to produce the ethanol. If the offset for ethanol (Table 2) were distributed over those acres, the offset benefit per acre would be about 2.27 tons of CO2 per acre.

The benefit per acre will vary with the yield per acre for the grain and by the yield per bushel for producing the ethanol.

A similar analysis for biodiesel shows that the offset for carbon dioxide per acre is 1.13 ton/acre. This is based on the following assumptions: 10 ton of oil seed per acre and 10 gal of oil per ton. Due to the diverse agriculture within the State, the benefits of offsetting carbon dioxide will vary with crop yield.

The use of biofuels to offset carbon dioxide from fossil fuels is an effective means to reduce the production of greenhouse gases. The use of biofuels has many times the benefit described elsewhere for improving land management practices to sequester carbon.

For the State to promote the sequestering of carbon, it should consider a comprehensive biofuels program as an effective means to accomplish this.

Presently there is an ethanol incentive, which is an exemption of the excise tax on gasoline. This program should be expanded to cover other bio-based fuels such as biodiesel. Also, it should be changed to be a producer incentive, to promote the production of biofuels within Idaho.

Such a program should be comprehensive to cover future developments in this field so that the legislature is not approached with requests for programs promoting new technologies as they are developed.

Such a comprehensive program should address the percentage of biofuels utilized in the parent fuel blend. For example, Brazil has a national program to promote the use of its agricultural production in biofuels. Brazil promotes the use of sugar in the production of fuel grade ethanol. On the consumption side the blend ratios vary from the mid-teens to 22 percent ethanol.

The Energy Policy Act of 1992 (EPACT) requires that private, state, and federal fleet operators purchase vehicles that can run on alternative fuels. One those options is to purchase vehicles that can run on E-85 or 85 percent ethanol and 15 percent gasoline. The automobile manufactures are producing certain vehicle models that are E-85 compatible for sale to the public. How should that fuel be considered?

The percentage of biodiesel in diesel fuel blends can vary from zero to 100 percent.

For examples of new technologies, there is a small company in northern Idaho that is developing the fuels and associated technologies to run engines on ethanol fuels that are approximately 70 percent ethanol and 30 percent water. Such fuel and fuel systems greatly reduce harmful emissions and offset greenhouse gases. Also, there is great interest and effort being expended to convert cellulose into ethanol. Such technology could be a tool to assist with the management of Idaho forests by providing an outlet for salvage trees and thinnings.

As part of a comprehensive biofuels program, the legislature should review the franchise agreements between major oil companies and the local retailer, which discourage or prohibit the use of biofuels. Presently some agreements prevent the use of fuel additives not approved by the supplier even though those companies use ethanol blends in many areas of the country that have oxygenated fuel requirements. Are those agreements in the best public interest if they are a hindrance to developing public policy to promote carbon sequestration?

In addition to blending biodiesel with diesel fuels, ethanol can be blended with diesel fuels in the 5 to 15 percent range with the use of an emulsifier.

It can be seen that there are many opportunities to utilize biofuels in Idaho. Such use would improve air quality and offset greenhouse gases from fossil fuels.

To address the economic benefit of promoting means to sequestering carbon dioxide and reduce greenhouse gases, the legislature should request the appropriate economic study be conducted.

Recommendations

Develop a comprehensive biofuels incentive program for Idaho that considers:

- All bio- or renewable fuels.
- The percent of biofuel blended in the parent fuel.
- Promote ethanol in the manufacturing of biodiesel.
- Changing the present incentive to a producer’s credit.
- Future technologies.
- Question fuel distribution agreements, which inhibit or discourage the use of biofuels.
- Commission a study to address the economic benefit to Idaho of sequestering carbon.

13.4 APPENDIX 4 – PNDSA SOIL CARBON SEQUESTRATION SYNOPSIS

A Synopsis of the PNDSA Soil Carbon Sequestration Lease Contract

History in the Making

On April 15, 2002 a contract was signed between the Pacific Northwest Direct Seed Association [PNDSA], a producer based organization, and Entergy, an energy producing company based in New Orleans Louisiana serving costumers in Louisiana, Texas and Arkansas. The contract is for a ten [10] year lease of CO2 credits generated through the practice of direct seeding crop land in the Pacific Northwest [PNW]. An annual trade of 3,000 tons CO2 is contracted between PNDSA and Entergy for the next ten years for a total of 30,000 tons CO2. PNDSA was paid $75,000 to aggregate a base of growers for this sequestration project. PNDSA then contracted with 77 grower members representing 6,470 production acres to meet its obligation with Entergy. The grower is being paid to direct seed a designated acreage for the next ten years, which will sequester 55/100ths [.55] tons of CO2 per acre per year. The acreage will be monitored and verified as direct seeded by local NRCS Conservation Districts, which have contracted growers participating. The contract meets the Kyoto protocols involving additionality, duration, permanence and leakage.

The PNDSA was started in January 2000 by a group of producers and university researchers from the three-state region known as the PNW (Oregon, Idaho and Washington). The PNDSA is a grower driven organization whose mission is to facilitate the development and adoption of direct seed cropping systems through research coordination, funding and information exchange. The board of directors is made up of four directors from each state. The three state land grant universities are represented on the board of directors as ex-officio members. Within the framework of our mission we developed a working relationship with Environmental Defense Fund [now called Environmental Defense]. That relationship resulted in a one-page offer sheet being solicited from PNDSA to lease CO2 credits to emitters. Environmental Defense [ED] took the one page offer and circulated it among a consortium of energy companies that had made a commitment to ED to reduce their emissions. Entergy submitted a counter offer to PNDSA and the negotiations began. The negotiations focused on creating a contract that would be verifiable under the Kyoto protocol if and when it became ratified. Those articles are now stated as Article 3.3 and 3.4 and include *additionality, permanence, duration* and *leakage*. *Additionality* means that credits generated must be additional to any changes in carbon that would have occurred under a “business as usual” scenario. *Permanence* refers to the length of time carbon is sequestered and maintained in a sink such as agricultural soil. *Duration* refers to the length of the contract. *Leakage* concerns the issue of project activities causing economic agents to take actions that would increase Green House Gas [GHG] emissions elsewhere. These negotiation issues were resolved with input from ED and other resources.

After considerable research and interaction with other global partners also studying this issue, the PNDSA elected to pursue leasing versus selling of carbon credits. The lease allows temporary control of the management of the land by the energy company. The sale of a C-credit would allow control in perpetuity, and the sale raises a number of legal issues concerning obligations, measurement and performance that are not clearly understood by either potential sellers or buyers. The lease allows the grower to retain ownership of the C-credits at the end of the contract. The lease in the opinion of PNDSA is a win-win for the environment and the contract parties. The emitter is forced to reduce emissions, create an internal sequestration system or renegotiate to continue leasing sequestration systems from the contracted growers. The ultimate goal of PNDSA in this contract is to stimulate research to develop a whole-farm accounting of carbon and carbon equivalent changes occurring as a result of direct seed cropping systems. Our vision is to have a yield of carbon equivalents for each farm based on the many environmental and management decisions that the farmer employs. That farmer could then market C-credits they earn or sequester.

After completing and signing an agreement with Entergy, the PNDSA developed an agreement with its grower members to meet the obligations stated within the Entergy contract. That agreement contained the definition of direct seed that would be used to verify sequestration per our agreement. The contract also included other necessary requirements and penalties to protect PNDSA. The PNDSA has the ability to solicit additional acres if existing producer contracts go into default. We restricted our growers to a maximum of 100 acres to spread the risk of default and to protect the producers from committing too many acres too early in the development of the carbon sink market. It is widely accepted that the price paid per ton of CO_2 sequestered will be impacted upward with any regulated emission controls. Grower contracts were completed in November 2002 and money was transferred to the producers. PNDSA is presently developing a verification agreement with local Conservation Districts who have grower contracts within their districts (The average number of producers per district is four).

This project highlights the ability of the private sector to manage an environmental change without federal mandates. The United States is involved in political debate, industry discussion and market formation to deal with GHG reductions. The PNDSA is very proud to be an early innovator in the implementation of a leasing strategy to aggregate agricultural producers in the development of a market for C-credits. Our relationship with Entergy and Environmental Defense is unprecedented in the U.S. agriculture. We commend each of those entities for their willingness and commitment to assist us in developing an agriculture production system that benefits society, the environment and producers. Environmental marketing of direct seed benefits can play a major role in economic sustainability of American Agriculture.

13.5 APPENDIX 5 – PRACTICE/ACTIVITY RATINGS

PRACTICE/ACTIVITY RATINGS TABLE

Table 1. Practice/Activity Ratings										
Carbon-GHG Practice	Accept-ability	Effectiv-eness	Cost	Implemen-tation	Operation & Maintenance	Monitoring	Verification	Ancillary Benefits	SUM OF RATINGS	SUM W/O COST
Windbreaks and shelterbelts	-1	2	-2	2	2	3	2	3	11	13
Reforestation	2	1	-2	2	1	2	2	2	10	12
Grassland cover	0	2	0	1	2	1	0	2	8	8
Short rotation woody crops	-2	3	-2	1	1	2	2	1	6	8
Riparian forest buffers	-2	2	-2	1	1	2	1	3	6	8
Riparian conservation/restoration	-2	2	-2	1	1	2	1	3	6	8
Residue management (no-till, direct seed)	1	1	0	1	1	2	-1	2	7	7
Afforestation, marginal pasture	0	3	-1	0	1	1	1	1	6	7
Alley cropping	-2	1	-1	1	0	3	2	2	6	7
Fire management	1	1	-2	1	1	2	-2	2	4	6
Afforestation, marginal cropland	-1	3	-1	0	1	1	1	1	5	6
Biofuels production	1	2	-3	1	-1	2	1	0	3	6
Grass waterways	1	2	0	1	1	1	-1	0	5	5
Range and pasture planting	1	0	-1	3	1	2	-2	0	4	5
Afforestation, pivot corners	-1	3	0	0	1	1	1	0	5	5
Cropland biomass energy source	-1	2	-2	0	-1	2	1	1	2	4
Afforestation, poorly stocked forest	1	2	-2	-1	-1	0	0	2	1	3
Afforestation, non-stocked forest	1	2	-2	-1	-1	0	0	2	1	3
Regeneration harvesting	0	0	-2	1	1	1	-2	1	0	2
Pest management	0	0	-2	1	1	0	-2	2	0	2
Forestland biomass energy source	-2	2	-3	-2	0	1	1	2	-1	2
Cover crops	-1	1	0	1	-1	1	-1	1	1	1
Crop residue burning - alternative uses	-1	2	-1	-1	-1	0	0	2	0	1
Stand density control	-1	0	-2	1	1	1	-2	1	-1	1
Salvage	-1	0	-2	1	1	1	-2	1	-1	1
Stand composition control	-2	0	-2	1	1	1	-2	1	-2	0
Wetland construction/enhancement	-1	1	-3	-2	-1	2	-1	2	-3	0
Reduced methane emissions from ruminant livestock	0	1	0	1	1	-1	-2	0	0	0
Biogas recovery - digesters	-2	1	-3	-1	-1	1	1	1	-3	0
Controlling rotation length	-2	0	-1	1	1	0	-2	1	-2	-1
Nutrient management	-1	0	2	0	0	1	-2	0	0	-2
Crop residue burning - alternative burning techniques	-2	1	-2	-2	-2	1	0	1	-5	-3
Prescribed grazing	-2	0	-2	0	-1	0	-2	1	-6	-4
Edaphic (site) modification	-2	0	-2	0	0	-1	-2	1	-6	-4
Rate -3 (negative) to 3. Where -3 is considered poor, low, high cost, etc., where 3 is excellent, high, or low cost. For example, a -2 rating would be very low chance of a practice being accepted, whereas a 2, might be considered a good chance, and so on. Another example: effectiveness is high (rating = 2) or implementation is difficult (-2).										

13.6 APPENDIX 6 – PRACTICE/ACTIVITY EFFECTIVENESS

PRACTICE/ACTIVITY EFFECTIVENESS – Subject to change with further analysis.

Table 1. Practice/activity Effectiveness, State-wide

Practice	Total available acres, or number	Minimum % Applied	Maximum % Applied	Range of Effectiveness ($MTCO_2e$/ac or #/y)	Selected value (MTco2e/ac or #/y)	Minimum CO_2e MT/y	Maximum CO_2e MT/y
Nutrient management (N_2O reductions)	4541300	30%	100%	0.05 - 0.8	0.30	408717	1362390
Cropland biomass energy source (wheat, barley, bluegrass)	1905000	5%	50%	0.52	0.52	130915	1309152
Afforestation, marginal cropland (13% of cropland)	600900	2%	15%	247/20y	12.30	147821	1108661
Biofuels production, ethanol (wheat, barley, corn acres)	1915000	5%	35%	1.2-2.6	1.63	156073	1092508
Residue management (no-till, direct seed) (60% of all crop)	2724780	10%	60%	0.2 - 0.7	0.50	136239	817434
Short rotation woody crops (50% of irrigated)	1400000	1%	5%	8.3-11.6	8.00	112000	560000
Crop residue burning alternative uses or techniques (burned ac)	150000	40%	100%	reduced by 100%	3.31	198722	496804
Grassland cover (similar to CRP) (20% cropland)	900000	15%	100%	0.4 - 0.7	0.50	67500	450000
Windbreaks, shelterbelts (4%/acre) 40% of cropland)	1816520	1%	40%	2.2-24.8	10.00	7266	290643
Cover crop (used 30% of time in rotation) (60% of cropland)	2724780	20%	60%	0.3-0.51	0.40	65395	196184
Nutrient management, N production CO_2	4541300	10%	100%	0.039	0.04	18165	181652
Afforestation, pivot corners (400 ea, 12.5%/acre)	640000	0.5%	30%	2.7-5.3	3.50	1400	84000
No-till, direct seed - N_2O field emissions (60% of cropland)	2724780	10%	60%	0.05	0.05	13624	81743
No-till, direct seed - CO_2 fuel emissions (60% of cropland)	2724780	10%	60%	0.01 - 0.02	0.01	2725	16349
Biofuels production, biodiesel (canola acres)	22500	5%	50%	0.6 – 1.1	0.80	900	9000
Grassed waterways (1%/acre) (non-irrigated cropland)	1725694	5%	50%	0.48	0.48	414	4142
Prescribed grazing, rangeland (private, state)	3580233	25%	75%	0.2 - 0.5	0.20	179012	537035
Range planting (private, state)	3580233	2%	20%	0.2, 1.1-1.8	0.50	35802	358023
Afforestation, marginal pasture land (20% of total pasture)	273100	2%	15%	138/20y	6.90	37688	282659
Pasture planting (private, state)	1365500	5%	25%	0.2, 1.1-1.8	0.50	34138	170688
Prescribed grazing, pastureland (private, state)	1365500	10%	50%	0.2 - 0.5	0.20	27310	136550
Afforestation, poorly stocked forest land (private, state)	3493040	2%	10%	92/20y	4.60	321360	1606798
Afforestation, non-stocked forest land (private, state)	1097831	2%	10%	118/20y	5.90	129544	647720
Forest biomass energy source (forest floor litter)	3493040	1%	10%	1.80	1.80	36535	365355
Riparian conservation/restoration (acres) (private land,6 ac/mile	163308	1%	35%	118/20y	5.90	9635	337231
Riparian forest buffers (nonforested land, 6 ac/mile)	142155	1%	5%	3.2-6.4	6.90	4904	49043
Riparian conservation/restoration (acres) (state land,6 ac/mile	14280	1%	35%	118/20y	5.90	843	29488
Wetland construction and enhancement (1000 @ 10 ac. ea)	10000	5%	75%	0.2 - 0.5	0.35	175	2625
Biogas recovery, (CH_4), digesters, (# cows)	377000	20%	50%	reduced by 80%	3.91	294974	737434
Reduced CH_4 emissions from dairy livestock (# cows)	377000	20%	50%	reduced 3-20%	0.10	163882	409705
Reduced CH_4 emissions from dairy replacements, 12-23 mo.	175000	20%	50%	reduced 3-20%	0.10	154674	386685
Reduced CH_4 emissions from bulls	40000	20%	50%	reduced 4-30%	0.15	80968	202419
Reduced CH_4 emissions from steers	360000	20%	50%	reduced 4-30%	0.15	44982	112455
Reduced CH_4 emissions from beef livestock	493000	20%	50%	reduced 4-30%	0.15	22152	55380
Reduced CH_4 emissions from beef replacements, 12-23 mo.	85000	20%	50%	reduced 4-30%	0.15	39359	98398
Reduced CH_4 emissions from sheep	260000	20%	50%	reduced 4-30%	0.15	14280	35700
Reduced CH_4 emissions from goats	4600	20%	50%	reduced 4-30%	0.15	7426	18564
Reduced CH_4 emissions from swine	240000	20%	50%	reduced 4-30%	0.15	82	205
Biogas recovery, (N_2O), digesters, (# cows)	377000	20%	50%	reduced by 80%	0.06	4715	11787

13.7 APPENDIX 7 – EQUATIONS, CALCULATIONS

EQUATIONS – CALCULATIONS

The following equations and process are used to estimate carbon sequestration or reduced emissions from the application of specific practices or the implementation of activities:

N_2O emissions from cropland fields, soil, nutrient (nitrogen) management:

While improved nutrient management provides multiple benefits, there is much uncertainty as to the amount of nitrogen loss that may be reduced from nutrient management, one estimate of from Lal et al, 1999, ranges from **0.22 to 0.74 MT CO_2e**. For Idaho, 0.3 MT CO_2e will be used to estimate a statewide potential. See IPCC and EPA methodology to estimate soil emissions, then would apply practice for reduction estimate.

If we want to first estimate N emissions, then a series of equations provided by IPCC 1996 could be used, however, the only variables that will significantly reduce total N_2O loss is EF_2 (emission factor), crop acres, and manure applied (N content and quantity). EF_2 is effected by tillage, cultivation, thus no-till should reduce N losses substantially, if EF_2 variable is determined for no-till.

Cropland N_20 emissions from soils		
N2Odirect =	[(Fsn + Faw + Fbn + Fcr) x EF1] + Fos x EF2	
N2Odirect =	35164033	kg N/yr
EF1	0.0125	kg N2O-N/kg N input
EF2	5	kg N2O-N ha/yr
Fos	1710432	total crop ha
Faw	96009600	= total Fawd + Fawb
Fawd	21489000	= Nex x (1-(Fracfuel + Fracgraz + Fracgasm)) kg N/yr - dairy
Fawb	74520600	= Nex x (1-(Fracfuel + Fracgraz + Fracgasm)) kg N/yr - beef
Nex	100	kg N/yr total dairy manure/yr
Nex	70	kg N/yr total beef manure/yr
Dairy pop.	377000	number of dairy cows in 2001
Beef pop.	1613000	number of cattle, minus dairy, in 2001
Fracfuel	0	kg N/yr
Fracgraz	0.23	kg N/ kg N excreted- dairy
Fracgraz	0.14	kg N/ kg N excreted- beef
Fracgasm	0.2	kg NH3-N + Nox-N/kg of excreted
Fbn	4402305.9	= 2 x Cropbf x Fracncrbf kg N/yr
Fracncrbf	0.03	kg N/kg dry biomass
Fcr	325377980	= 2 x [Cropo x Fracncro + Cropbf x Fracncrbf)] x (1-Fracr) x (1-Fracburn) kg N/yr
Cropo	21764231571	kg dry biomass non-fixing crops
Fracncro	0.015	kg N/kg of dry biomass
Cropbf	73371765	kg dry biomass/yr, legume seed yield + soybeans (alfalfa seed, beans only here)
Fracr	0.45	kg N/kg crop-N, residue removed from field
Fracburn	0.1	kg N/kg crop-N, fraction of residue burned field
Fsn	61.2	= Nfert x (1-Fracgasf) kg N/yr
Fracgasf	0.1	= kg NH3-N + Nox-N/kg of N input
Nfert	68	kg N/yr (150 lbs/ac average)

Reduced CO_2 diesel emissions by reducing N fertilizer production, through less N used,
See Iowa fertilizer and tillage reduction case study:

12 million acres 145 reduced to 127 lbs N/acre. 18 lbs N /ac or 216 million lbs saved, (97,977 MT), 13% reduction in N applied. 3.6 gallons diesel reduced (1 gallon diesel used /5 lbs N produced). 24 lbs C/gallon diesel used (24 lbs CO_2 or 0.011 MT CO_2). Thus **0.039 MT CO_2/ac/yr** reduced.

145 – 127 lbs/ac = 18 lbs/ac/yr saved
(18 lbs/ac/yr) / (5 lbs N/gallon) = 3.6 gallons/ac/yr
(3.6 gallons x 24 lbs CO_2) / 2204.6 lbs/metric ton = **0.039 MT CO_2/acre/yr**

This emission offset was included in the nutrient (nitrogen) management state-wide estimate (0.3 MT CO_2).

Reduced CO_2 diesel emissions through less tillage, as with no-till and direct seed,
See Iowa fertilizer and tillage reduction case study:

12 million acres used residue management (conservation tillage, no-till), 127,000 to 257,000 MT CO_2e, where 1-2 gallons diesel saved per acre, 24 lbs CO_2/gallon diesel used, thus **0.01 to 0.02 MT CO_2/ac/yr.**

(1 gallon x 24 lbs CO_2) / 2204.6 lb/metric ton = **0.01 MT CO_2/ac/yr**
(2 gallon x 24 lbs CO_2) / 2204.6 lb/metric ton = **0.02 MT CO_2/ac/yr**

Anaerobic, dairy lagoon methane (CH_4), emissions - See EPA-Annex L

Total metric tons of methane that could possibly reduced from bioenergy facilities on the larger dairy facilities or from centralized facilities, supplied by smaller dairies, is about 0.74 MMT CO_2e. The assumptions in the calculation are as follows:

The total number of cows on facilities with > 1000 head (population) = 377,000
Average total volatile solids (VS)* (kg/head/y) = 3325 (Idaho rate)
Maximum methane generation potential (B_o)* = 0.24 CH_4/kg.
Weighted methane conversion factor (MCF) = 0.4408
Conversion factor of m^3 CH_4 to kg CH_4 (kg CH_4/m^3 CH_4) = 0.662

The global warming potential (GWP) for CH_4 is 21 (50yrs)

Calculation derived from USEPA 2002 and IPCC 1996.

Methane equation: Methane = (population x VS/y x B_o x MCF x 0.662)/1000*21 GWP CH_4/CO_2e:

(377,000 x 3325 x 0.24 x 0.4408 x 0.662)/1000 kg/MT x 21 CH_4/CO_2e = 1.8 MMT CO_2e. If digesters are only 80% effective and only 50% of large dairies install digesters, then the result is about 0.74 MMT CO_2e.

Anaerobic, dairy lagoon nitrous oxide (N_2O) emissions See EPA-Annex L

The use of digesters would also capture N_2O, which is similar conditions apply with dairy facilities. The equation to calculation total N_2O emissions for state dairy livestock is:

The total number of cows on facilities with > 1000 head (population) = 377,000
Total Kjeldahl nitrogen excreted annually per head/day (N_{ex})= 0.44 kg (161 kg/365 day year)
Weighted nitrous oxide emission factor ($EF_{animal, state}$) = 0.001 kg N_20-N/kg N

Conversion factor of N_2O-N to N_2O = 44/28 = 1.57
The GWP conversion of N_2O is 310 (50 yrs).

Calculation from USEPA 2002 and IPCC 1996:

Nitrous oxide equation: N_2O = (population x N_{ex} x $EF_{animal, state}$ x1.57)/1000*310

(377,000 x 0.44 * 365 x 0.001 x 1.57)/1000 x 310 GWP N2O/CO2e = 29,468 MT CO_2

If 50% of the dairy cow population N_2O emissions were captured by digester systems, with 80% efficiency, then approximately 11,787 MT CO_2e may result.

Biofuels fossil fuel emission offset – See Biofuels subcommittee report.

Ethanol:

Table utilizes 2001 NASS for Idaho.

Table 1. Estimated Ethanol Production with Existing Crop Base

Crops	2001 acres	2001 yield - bushels	ethanol acres	gallons ethanol	CO2e @ 13.2lb/gal or .0066 MT	metric ton CO2e/acre	% acres of total acres
corn, grain	45000	150	11250	4471875	29514	2.62	2%
barley	670000	75	167500	26381250	174116	1.04	35%
wheat	1200000	71	300000	55380000	365508	1.22	63%
totals	1915000		478750	86233125	569139	Ave. 1.63	100%

Gallons ethanol produced from 1 bu of corn = 2.65
Gallons ethanol produced from 1 bu of wheat = 2.6
Gallons ethanol produced from 1 bu of barley = 2.1

Gasoline produces 19.5 lbs CO2, diesel 24 lbs, ethanol 6.3 lbs. Thus 13.2 lbs reduced when gasoline replaced with ethanol. To achieve a specific quantity of ethanol per year, adjust acres:

Table 1. Adjusted acreage to reach 1 million gallons of ethanol

	% of total	new total crop acres	25% of acres	gallons ethanol	CO2e @ 13.2lb/gal or .0066 MT	metric ton CO_2e/acre
corn, grain	16%	306400	76600	30448500	200960	2.62
barley	28%	539300	134825	21234938	140151	1.04
wheat	56%	1069300	267325	49348195	325698	1.22
totals	100%	1915000	478750	101031633	666809	Ave. 1.39

Biodiesel:

Canola acres in 2001 were 22,500, where yields were 0.72 MT of oil seed per acre. One MT of canola oil seed produces 110 gallons of diesel. If 50% of these total canola acres (11,250 acres) were used for biodiesel production, where 1 gallon of biodiesel provides a 17.7 lb CO_2 (or 0.008 MT) offset per gallon of diesel fuel, then approximately 9,000 MT of CO_2 offset is generated.

Crop residue burning alternatives – See IPCC Guidelines… 4.4

To calculate what amount of emissions may be reduced, depends on the amount currently lost due to burning. Factors used in determining emissions are:

Amount of crops produced with residues that are commonly burned,
Ratio of residue to crop product,
Fraction of residue burned,
Dry matter content of residue,
Fraction oxidized in burning,
Carbon content of the residue.

The equation used: Total carbon released = sum of:
annual production of crop (metric tons)
X ratio of residue to crop product (fraction)
X average dry matter fraction of residue (MT dry matter/MT biomass)
X fraction actually burned (amount residue burned of total residue)
X fraction oxidized
X carbon fraction (MT carbon/MT dry matter)

The ratio of residue to crop product will be replaced with the average amount of residue per yield, in bushels, for Idaho crops. For instance, an average of 90 and 70 pounds of residue remains per bushel of wheat and barley respectively.

Once the carbon released from field burning of agricultural residues has been estimated, the emissions of CH_4, CO, N_2O, and NO_x can be calculated based on emission ratios:

CH_4	0.005; Range 0.003 - 0.007	N_2O	0.007; Range 0.005 - 0.009
CO	0.06; Range 0.04 - 0.08	NO_x	0.121; Range 0.094 - 0.148

The calculation for trace gas emissions from burning is summarized as follows:

CH_4 Emissions = Carbon Released x (emission ratio) x 16/12
CO Emissions = Carbon Released x (emission ratio) x 28/12
N_2O Emissions = Carbon Released x (N/C ratio) x (emission ratio) x 44/28
NO_x Emissions = Carbon Released x (N/C ratio) x (emission ratio) x 46/14

Enteric fermentation, methane emissions – See IPCC Guidelines… 4.2

According to industry estimates, methane emissions could be reduced by up to two percent per year if the above practices are employed. If the above-discussed methods were used on all of Idaho's dairy and beef cattle populations, then the maximum amount of methane reduced may be 1.3 MMT CO_2e (50,386 dairy + 2,169 beef). The IPCC 1996 Tier one calculation follows:

[Emission factor (kg/head/yr) x population (head) / (1000 kg/MT)] x 2.75 (CH_4/CO_2) = total methane emissions for state.

The IPCC 1996 guidelines provide that for dairy cows in temperate climates, such as Idaho, 54 kg/head/yr emission factor, and 2 kg/head/yr for non-dairy (beef) cattle. If the above methods resulted in a 20% reduction of emissions, then 0.5 MMT CO_2e (25,193 dairy + 1,085 beef) may be reduced. If 20% of sheep, goats, and swine populations were involved in methane reductions, about 22,000 MT CO_2e could be reduced.

For future estimates, that may be a part of a carbon sequestration, emissions reduction market or program, it is recommended that the Tier 2 calculation approach be used to estimate methane reductions due to practice methods. This calculation, which involves numerous equations, can be found in IPCC, 1996.

Cropland biomass to bioenergy – Refer to Chariton Valley Biomass Project

If Idaho wheat, barley, and bluegrass residues were utilized in the production of bioenergy, a substantial amount of CO_2e emissions could be reduced. The Chariton Valley Biomass Project in Iowa showed that by utilizing switchgrass, about 0.52 MT CO_2e/y emissions could be reduced, replacing a percentage of coal in a power plant. Grass and coal would be cofired, where 12.5 tons per hour would be used along with the coal. Where Idaho's wheat, barley, and bluegrass production and remaining residue is less, by about ½ of switchgrass, an gross amount of CO_2 emissions could be reduced in cofiring plants. This estimate is not dependent on existing or potential energy or similar plants, but on the capability and available amount of residues.

As discussed above regarding reducing crop residue burning, 16.2 million MT CO_2e/y could be reduced. If these residues, replacing similar amounts of fossil fuels, such as coal, could reduce CO_2 by about 0.13 to 1.3 million MT (5% to 50% use of available residue – see Table 1). The use of wood wastes in cofirng plants would produce a greater amount of CO_2 reductions on a per tonnage basis, where the density of wood is much greater than straw or grass residue. The heating capability of coal is higher than wood, possibly 1 to 3 times as high. Depending on the coal type, or other fossil fuels used, 1 to 3 times more biomass residue may need to be used for equivalent power or heat generation. Where coal most available to Idaho (bituminous), produces about 20 or more million Btu's per ton, where wood generates about 17.2 million Btu's per ton. The comparison of wood to coal for heat generation shows that though wood is slightly less, the value wood as an alternative to coal is substantial. Emissions are substantially offset as well, where additional emissions of compounds are eliminated or reduced.

Table 1. Crop Residue for Bioenergy, assume 0.52 MT CO2/MT biomass fossil fuel emissions offset

Crop	2001 Acres	2001 Yield bu/a	Residue kg/bu	Usable Biomass MT	CO2e MT 5% acres	CO2e MT 50% acres
Wheat	1200000	71	40	3408000	88608	886080
Barley	670000	75	32	1608000	41808	418080
Bluegrass	35000	181-454 kg/ac	320 kg/ac	11200	291	2912
Totals	6495870		50% useable	10054203	273977	2739768

Forest floor biomass to bioenergy – Refer to Appendix 2

The amount of wood on forest floor is about 1 MT C/acre in a poorly stocked or non-stocked forest (see Appendix 2). If only 50% of forest floor wood litter is collectable for bioenergy use (0.5 MT C/ac or 1.8 MT CO_2e) and 0.52 MT CO_2 is offset per MT of biomass (wood), then MT CO_2/acre of offset may result. If a total of 10% of those poorly stocked forest lands (about 350,000) were to provide wood for fossil fuel replacement, then about 0.3 MMT CO_2e could be offset.

Note: If the wood used to burn in place of fossil fuels, such as coal, and the CO_2 is not captured at the plant, sequestered elsewhere, the previous amount of CO_2 sequestered within the wood may have to be discounted to determine the actual net CO_2 offset.

Windbreaks, shelterbelts

Assume that windbreaks/shelterbelts are at least 50 ft wide. For a 50acre square field, side length is 1475 feet.

$\frac{1475 \text{ x } 50 \text{ ft}}{43560 \text{ ft}^2/\text{acre}}$ = 1.7 acres, use 2 acres per 50 acre field, or 4% of field planted to trees, shrubs (2 / 50)

Grassed waterway

Assume that a waterway is at least 15 feet wide, use 20 ft. For a 50 acre field, side length is 1475, use this for estimated length of waterway within field. Similar to windbreak/shelterbelts:

$\frac{1475 \text{ x } 20 \text{ ft}}{43560 \text{ ft}^2/\text{acre}}$ = 0.7 acres, use 1 acres per 50 acre field, or 2% of field planted to grass (1 / 50)

The assumption is made that only non-irrigated cropland acres are available for grassed waterways. If only 50% of these acres incorporated grassed waterways, then 4,142 MT CO_2e is offset.

Grassland cover

If there are 4.5 million acres of cropland, but only 900,000 are really available for conversion to grassland, and then only 25% of those acres are converted to grasslands (225,000), then about 0.4 MMT CO_2e could be offset. 0.5 MT CO_2e/ac is used here to estimate total potential offsets.

Riparian forest buffer, non-forested areas

Assume that a buffer is at least 100 feet on one side of stream, planted within floodplain and possibly on adjacent uplands. Assume, then that for only one side of stream, per mile of stream, there are 12 acres per mile. Assume that only 75% of the stream is capable of supporting forest buffers, therefore 9 acres per mile.

$\frac{5280 \text{ ft/mile x } 100 \text{ ft x } 0.75}{43560 \text{ ft}^2/\text{acre}}$ = 9 acres per mile stream, one side.

Assume that are 3.2 million acres of private/tribal forested acres and 1.3 million acres of state forest land which are under Forest Practices Act rules. These lands are assumed to have or will have adequate riparian protection, possibly not eligible for carbon market funds, so they will not be considered in this estimate at this time. Using a rough estimate that 16.7 million acres of private and tribal land, then only 19% of private and tribal lands are in forest. Assume then only 19% of streams are forested, therefore under forest practices act, and will not be considered for additional sequestration with riparian forest buffers at this time. Utilizing the state Hydro100 GIS shape file provided through the state ftp GIS website, that there are about 31,590 miles of stream on non-forested lands and 7,410 miles within forested lands. Assume that only ½ of those miles are perennial and/or have potential for riparian buffers and adequate available water. Many drains, canals, and other water bodies show up within the Hydro100 layer, not labeled, and are not considered natural streams, therefore will not be considered here for riparian forest buffers.

Private, state, tribal non-forested stream miles = 31,590 miles x 50% x 9 acres/stream mile = 142,155 acres

If on average, riparian forest buffers offset 6.9 MT CO_2e/acre, then if 5% of the available acres for buffers were installed, 4,903 MT CO_2e offset could result.

Riparian conservation/restoration

Assume that the average width of a typical intermittent or perennial stream in Idaho is about 70 feet. Conservation/restoration would include both sides of stream, across the floodplain, wetland area. This would estimate that there are 8.5 acres per mile of stream, a gross estimate.

$\frac{5280 \text{ ft/mile} \times 70 \text{ ft}}{43560 \text{ ft}^2\text{/acre}}$ = 8.5 acres per mile stream, across entire floodplain, wetland area. 75% capability of woody species. Use 6 acres per mile.

Utilizing the data generated from intersecting a GIS vegetation (land cover) and land ownership layer through ArcView 2.0, there are 177,588 acres of state and private land riparian/wetland. About 14,280 acres are on state lands, 163,308 on private. Assume that only 50% of those miles are perennial and/or have potential for restoration and adequate available water. Many stream, drains, canals show up within the Hydro100 layer, and are not considered natural streams, therefore will not be considered here for riparian conservation.

Private land riparian areas could offset 0.3 MMT CO_2e, state land nearly 25,000 MMT, utilizing 5.9 MT/acre offset.

Pivot corners

Assume 20 acres per 160 acre pivot (5 acres/corner), or 12.5 % of pivot acres available for plantings. If 640,000 acres is assumed and are available for afforestation (total corner acres), but only 30% are actually afforested, then 84,000 MT CO_2e offset results, based on 5.9 MT CO_2e/acre.

Constructed wetlands

Assume 10 acres per wetland. 10,000 potential acres total for wetlands development. If 75% are developed, then 2,625 MT CO_2e offset results, where 0.35 MT CO2e/acre is used.

13.8 APPENDIX 8 – REFERENCE DATA

REFERENCE DATA – Subject to addition.

practice	attribute	amount	units	mtco2	mtco2/ac/y	area	source	Site
biofuel, grass	biomass	0.16	mtc/ac/y	0.587	0.587	ia	carbon budget for 640 acre farm in iowa	
biofuel, grass	biomass	0.400	mtc/ha/y	1.468	0.594	ia	Iowa farm budget	lal 98
conservation till, from plow	soil carbon	0.16	mtc/ac/y	0.587	0.587	ia	carbon budget for 640 acre farm in iowa	
conservation till, from plow	soil carbon	9.5	Mg c/ha/30y	34.865	0.471	id	entry, et al, 2002	soil sci soc am j 66:1957-1964 (2002)
conservation tillage, from sage	soil carbon	8.0	Mg c/ha/30y	29.360	0.396	id	entry, et al, 2002	soil sci soc am j 66:1957-1964 (2002)
cover crops	soil carbon	0.2	mtc/ha/y	0.734	0.297	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
cover crops	soil carbon	0.23-0.34	mtc/ha/y	0.84-1.25	0.34-0.51	usa	donigian et al, 95	www.nrdc.org/globalwarming/psoil.asp?pf=-1
CRP	biomass	0.3-0.7	mtc/ha/y	1.10-2.57	0.44-1.04	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
direct seed	soil carbon	.24-.40	mtc/ha/y	0.88-1.47	0.36-0.60	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
eliminate fallow	biomass	0.09	mtc/ac/y	0.330	0.330	wy	wyoming carbon sequestration report	
eliminate fallow	soil carbon	0.2	mtc/ha/y	0.734	0.297	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
erosion control	soil carbon	0.1-0.3	mtc/ha/y	0.37-1.10	0.15-0.44	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
existing soils carbon	soil carbon	20-61	mtc/ac	73.4-223.9		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forages added	soil carbon	0.2	mtc/ac/y	0.734	0.734	ia	carbon budget for 640 acre farm in iowa	
forested, afforestation	biomass	0.191	mtc/ac/y	0.700	0.700	nc	north carolina sensible ghg reduction strategies	http://www.geo.appstate.edu/bulletin/EPA_projects/NCaction/intro.html
forested, afforestation	biomass	0.204	mtc/ac/y	0.750	0.750	nj	new jersey greenhouse action plan	http://www.epa.gov/globalwarming/publications/actions/state/nj_actionplan.pdf
forested, aspen-birch	biomass	12.03	lb c/ft3	0.020		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, aspen-birch	biomass	14.45	lb c/ft3	0.024		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, aspen-birch	biomass	7.56	mtc/ac	27.745		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, crop to douglas/fir	biomass	6657	lb c/ac/80y	11.082	0.139	pc usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to oak-hickory	biomass	3247	lb c/ac/40y	5.405	0.135	se usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to ponerosa pine	biomass	2074	lb c/ac/100y	3.453	0.035	pc usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to spruce/fir	biomass	1979	lb c/ac/80y	3.294	0.041	nc usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to spruce/fir	biomass	2460	lb c/ac/80y	4.095	0.051	ne usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to white/red pine	biomass	2854	lb c/ac/65y	4.751	0.073	ne usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to white/red pine	biomass	4344	lb c/ac/80y	7.231	0.090	nc usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, elm-ash-cottonwood	biomass	12.03	lb c/ft3	0.020		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, elm-ash-cottonwood	biomass	14.45	lb c/ft3	0.024		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, elm-ash-cottonwood	biomass	5.46	mtc/ac	20.038		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, existing stands	biomass	63.2-65.0	mtc/ac	231.9-238.5		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, forest plantings	biomass	290	lb c/ac/y	0.483	0.483	in	living memorial tree planting program	http://yosemite.epa.gov/globalwarming/ghg.nsf
forested, from crop	biomass	0.750	mtc/ha/y	2.753	1.114	ne	quanitifying change in GHG emmisions...in neb.-01	neb-01
forested, from crop	biomass	2.64	mtc/ac/y	9.689	9.689	il	climate change action for illinois	http://dnr.state.il.us/orep/inrin/eq/iccp/toc.htm
forested, from crop	biomass	13.5	mtc/ac/y	49.545	49.545	ia	iowa GHG action plan	http://www.cgrer.uiowa.edu/research/reports/iggap
forested, from eroded lands	biomass	0.3-0.7	mtc/ha/y	1.10-2.57	0.44-1.04	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99

practice	attribute	amount	units	mtco2	mtco2/ac/y	area	source	Site
forested, from grazed forest	biomass	2.3	mtc/ac/y	8.441	8.441	il	climate change action for illinois	http://dnr.state.il.us/orep/inrin/eq/iccp/toc.htm
forested, from pasture	biomass	2.06	mtc/ac/y	7.560	7.560	il	climate change action for illinois	http://dnr.state.il.us/orep/inrin/eq/iccp/toc.htm
forested, loblolly-shortleafed pine	biomass	13.69	lb c/ft3	0.023		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, loblolly-shortleafed pine	biomass	16.47	lb c/ft3	0.027		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, loblolly-shortleafed pine	biomass	10.46	mtc/ac	38.388		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, maple-beech-birch	biomass	12.09	lb c/ft3	0.020		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, maple-beech-birch	biomass	17.99	lb c/ft3	0.030		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, maple-beech-birch	biomass	7.56	mtc/ac	27.745		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak hickory	biomass	13.52	lb c/ft3	0.023		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak hickory	biomass	19.64	lb c/ft3	0.033		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak hickory	biomass	5.46	mtc/ac	20.038		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak-pine	biomass	13.69	lb c/ft3	0.023		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak-pine	biomass	16.47	lb c/ft3	0.027		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak-pine	biomass	10.46	mtc/ac	38.388		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, others	biomass	16.00	lb c/ft3	0.027		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, others	biomass	16.00	lb c/ft3	0.027		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, others	biomass	5.46	mtc/ac	20.038		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, pine	biomass	3757	lb c/ac/30y	6.254	0.208	se usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, pivot corners	biomass	15-29	mtc/ac total	55.1-106.4		neb	quanitifying change in GHG emmisions...in neb.-01	neb-01
forested, plantation	biomass	5.6-7.8	mtc/ha/y	20.5-28.6	8.30-11.58	ia	from Iowa farm budget	colletti 99
forested, ponderosa pine	biomass	1.6	mtc/ac/y	5.872	5.872	id	nez perce tribe - kummett, 02	
forested, ponderosa pine	biomass	1.9	mtc/ac/y	6.973	6.973	id	nez perce tribe - kummett, 02	
forested, reserved forest	biomass	6.51	mtc/ac	23.892		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, riparian buffer	biomass	17.6-35.2	mtc/ac total	64.6-129.2	3.2-6.4	ne	quanitifying change in GHG emmisions...in neb.	neb-01
forested, enhancement	biomass	7.1	mtc total	26.057	0.651	ne	quanitifying change in GHG emmisions...in neb.	neb-01
forested, trees/shrubs	biomass	42.9	mtc total	157.443	3.936	ne	quanitifying change in GHG emmisions...in neb.	neb-01
forested, various types	biomass	0.63	mtc/ac	2.312		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, various types	biomass	22.2	mtc/ac	81.474		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, various types	soil carbon	40.12	mtc/ac	147.240		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, windbreak	biomass	3.24	mtc/ac/y	11.891	11.891	ia	carbon budget for 640 acre farm in iowa	
forested, windbreak/shelterbelt	biomass	67.5-135	mtc/ac total	248-495	12.4-24.8	ne	quanitifying change in GHG emmisions...in neb.	neb-01
forested, windbreak/shelterbelt	biomass	15-30	mtc/ac total	55.1-110.1	2.2-5.5	ne	quanitifying change in GHG emmisions...in neb.	neb-01
grass waterways/buffers	biomass	0.13	mtc/ac/y	0.477	0.477	wy	wyoming carbon sequestration report	
grass, from crop	soil carbon	0.3-0.5	mtc/ha/y	1.10-1.83	0.44-0.74	usa	ipcc/oecd	www.nrdc.org/globalwarming/psoil.asp?pf=-1
grazing, prescribed	biomass	0.01	mtc/ha/y	0.037	0.015	ne	quanitifying change in GHG emmisions...in neb.-01	neb-01
grazing, prescribed	biomass	0.1	mtc/ha/y	0.367	0.149	ne	quanitifying change in GHG emmisions...in neb.-01	neb-01
grazing, prescribed	biomass	0.25	mtc/ha/y	0.918	0.371	ne	quanitifying change in GHG emmisions...in neb.-01	neb-01

practice	attribute	amount	units	mtco2	mtco2/ac/y	area	source	Site
grazing, prescribed	biomass	0.13+	mtc/ac/y	0.477+	0.477+	wy	Schuman et al, 1999	wyoming carbon sequestration report
grazing, proper stock rates	biomass	0.13	mtc/ac/y	0.477	0.477	wy	Schuman et al, 1999	wyoming carbon sequestration report
irrigation (sub), on poor soils	soil carbon	0.1	mtc/ha/y	0.367	0.149	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
irrigation, added	soil carbon	0.1	mtc/ha/y	0.367	0.149	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
irrigation, mngt improved	soil carbon	0.02	mtc/ac/y	0.073	0.073	wy	wyoming carbon sequestration report	
mine lands restoration	biomass	1-3	mtc/ha/y	3.67-11.0	1.49-4.45	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
mulch till	soil carbon	0.5	mtc/ha/y	1.835	0.743	ia	from Iowa farm budget	lal, 98
nitrogen fert.-mtn meadows	emmissions	0.300	mtc/ha/y	1.101	0.446	neb	quanitifying change in GHG emmisions...in neb.-01	neb-01
no til & cover crop	soil carbon	0.09	mtc/ac/y	0.330	0.330	wy	wyoming carbon sequestration report	
no till	soil carbon	0.09	mtc/ac/y	0.330	0.330	wy	wyoming carbon sequestration report	
no-till	soil carbon	0.14	mtc/ha/y	0.514	0.208	mid-w	buyanovsky, wagner, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
no-till	soil carbon	0.14	mtc/ha/y	0.514	0.208	usa	grant et al, 97	www.nrdc.org/globalwarming/psoil.asp?pf=-1
no-till	soil carbon	0.5	mtc/ha/y	1.835	0.743	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
no-till N2O field emission	emmissions	0.050	mt co2/ac/y	0.050	0.050	ia	iowa integrated farm mngt demo proj.	http://extension.agron.iastate.edu/soils
no-till C diesel emission	emmissions	6.5-13	lbs c/ac/y	.01-.02	.01-.02	ia	iowa integrated farm mngt demo proj.	http://extension.agron.iastate.edu/soils
no-till	soil carbon	0.3-0.5	mtc/ha/y	1.10-1.83	0.44-0.74	ia	from Iowa farm budget	bruce, 99
no-till, residue mngt	soil carbon	0.15	mtc/ac/y	0.551	0.551	id-wa	PNDSA-ENTERGY agreement	
nutrient management	soil carbon	0.1	mtc/ha/y	0.367	0.149	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
nutrient management	soil carbon	.09-.22	mtc/ac/y	0.33-0.81	0.33-0.81	wy	wyoming carbon sequestration report	
nutrient management	emmissions	0.15-0.50	mtc/ha/y	0.55-1.83	0.22-0.74	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
nutrient management N2O	emmissions	0.050	mtc/ac/y	0.050	0.050	ia	reducing nitrogen fertilizer use	http://yosemite.epa.gov/globalwarming/ghg.nsf/CaseStudiesNew/Reducing+Nitrogen+Fertilizer+Use+(Iowa)/$file/IA_reduce.pdf
nutrient management CO2 diesel	emissions	0.039	mtco2/ac/y	0.039	0.039	ia	iowa integrated farm mngt demo proj.	http://extension.agron.iastate.edu/soils
pasture (irr.) from sage	soil carbon	3.56	Mg c/ha/30y	13.065	0.176	id	entry, et al, 2002	soil sci soc am j 66:1957-1964 (2002)
pasture, from crop	soil carbon	0.75-1.0	mtc/ha/y	2.75-3.67	1.11-1.48	usa	tyson et al, 90, haynes et al, 91	www.nrdc.org/globalwarming/psoil.asp?pf=-1
pasture, from plow	soil carbon	3.71	Mg c/ha/30y	13.616	0.184	id	entry, et al, 2002	soil sci soc am j 66:1957-1964 (2002)
permanent cover, from crop	biomass	0.13	mtc/ac/y	0.477	0.477	wy	wyoming carbon sequestration report	
residue mngt, type?	soil carbon	0.18	mtc/ha/y	0.661	0.267	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
ridge till	soil carbon	0.05	mtc/ac/y	0.184	0.184	wy	wyoming carbon sequestration report	
sage brush, from plow	soil carbon	0.15	Mg c/ha/30y	0.551	0.007	id	entry, et al, 2002	soil sci soc am j 66:1957-1964 (2002)
sawdust & nitrogen	soil carbon	0.35	mtc/ha/y	1.285	0.520	usa	paustian et al, 92	www.nrdc.org/globalwarming/psoil.asp?pf=-1
straw incorporated	soil carbon	0.33	mtc/ha/y	1.211	0.490	can	paustian et al, 96	www.nrdc.org/globalwarming/psoil.asp?pf=-1
summer fallow elimination	biomass	0.1-0.3	mtc/ha/y	0.37-1.10	0.15-0.44	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
switchgrass, from crop	biomass	0.3	mtc/ac/y	1.101	1.101	ia	iowa GHG action plan	http://www.cgrer.uiowa.edu/research/reports/iggap
wetland restoration	biomass	0.250	mtc/ha/y	0.918	0.371	ia?	from Iowa farm budget	lal 98
WRP	biomass	.15-.35	mtc/ha/y	0.55-1.28	0.22-0.52	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99