Terrestrial Carbon Sequestration: A Survey of Policies and Programs

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This white paper is one of three papers produced by the Minnesota Terrestrial Carbon Sequestration Project, a research and public forum on biophysical, economic, and policy aspects of terrestrial sequestration. The Project is sponsored by the University of Minnesota Water Resources Center and the Initiative for Renewable Energy and Environment, Xcel Energy Foundation, the Minnesota Department of Agriculture and the Natural Resources Conservation Service. Papers and information are available at the Project's Web site: http://wrc.umn.edu/outreach/carbon/.

Executive Summary

Efforts to reduce atmospheric buildup of greenhouse gases—whether orchestrated through international treaties or emerging "bottom up" from public and private entities—are increasing worldwide. In the past decade, overwhelming scientific evidence has confirmed that excess carbon dioxide and other greenhouse gases are warming the earth's atmosphere and setting in motion long-term (century to millennial) changes in weather patterns. Managing carbon is quickly becoming the key natural resource issue of the 21st century, demanding broad and sustained participation by governments, businesses, civic organizations, and individuals. A key to this participation is availability of options and opportunities that combine climate protection with other environmental, social, and economic goals.

Carbon management covers a broad group of activities to reduce carbon dioxide (CO_2) buildup in the atmosphere, including protection and enhancement of terrestrial carbon sinks. Vegetation absorbs CO_2 from the atmosphere, converts it to organic carbon, and stores it in above-ground and below-ground biomass and soils. Carbon sinks in the conterminous U.S. currently offset 12-14% of annual CO_2 emissions (USEPA 2006). An array of forestry, farming, and conservation practices well-known for their benefits to water and other natural resources could help protect and enhance the ability of ecosystems to store, or "sequester," carbon relatively quickly and at modest cost. Existing government programs, new carbon offset markets, and other initiatives are being proposed to significantly scale up sequestration activities and their contributions to climate protection.

Minnesota, with its vast natural resource base, can contribute to and benefit from these developments. Maintaining the health and productivity of the state's agricultural lands, coniferous and deciduous forests, wetlands, peatlands, and prairies will pose both challenges and opportunities in coming decades. This paper looks at how terrestrial carbon sequestration programs might factor into management of these ecosystems. It begins with an explanation of the critical role that terrestrial sinks play in the earth's carbon balance. It summarizes international climate policies, the emerging carbon market, and major scientific and policy issues pertaining to sequestration. It describes an array of state and federal programs that serve as both examples and resources for terrestrial sequestration activities here. The paper summarizes input from stakeholder discussions held in Minnesota in early 2006. Finally, it concludes with preliminary findings and recommendations for Minnesotans to consider regarding the state's carbon sinks. In summary the recommendations are:

- **Recommendation # 1**: Inventory Minnesota's terrestrial sinks to develop a better understanding of the state's carbon stocks and flows; to establish baselines and project future conditions; to assess risks and mitigation strategies; and to guide programs for public management and private investment.
- **Recommendation # 2:** Create a stakeholder council to provide advice and recommendations on terrestrial carbon sequestration initiatives and scenarios to benefit climate, environment, and society.
- **Recommendation # 3:** Assist Minnesota landowners to participate in carbon sequestration opportunities by evaluating and providing information on alternative

approaches to trading, registering, aggregating, investing, and banking CO_2 reduction credits.

- **Recommendation # 4:** Develop and implement research and demonstration projects on critical scientific, economic, management, and policy issues in a timely and efficient way. Involve educators from UMN Extension, federal, state and local agencies, and private and non-profit organizations in multi-faceted information and education programs.

Carbon Sinks and Terrestrial Carbon Sequestration

Fifty years ago, scientists at the National Oceanic and Atmospheric Administration (NOAA) observatory at Mauna Loa, Hawaii, first detected a rapid rise in carbon dioxide in the earth's atmosphere. The now-famous Mauna Loa Curve is a jagged upward-trending line tracking atmospheric CO_2 concentrations since that time. Besides documenting the rapid rise in CO_2, the curve records another phenomenon: the large role terrestrial ecosystems play in the global carbon cycle. Each jig-jag records the seasonal uptake and release of CO_2 by northern hemisphere forests as plants, through photosynthesis, capture and convert CO_2 into plant tissue or release it during decay (Keeling at al. 1996, Keeling et al. 2002, Sarmiento and Gruber 2002).

Carbon is one of the fundamental building blocks of life, flowing continuously through the biosphere, atmosphere, and oceans. In the past two hundred years, burning of fossil fuels and land conversions have greatly accelerated flows of carbon out of terrestrial systems. Atmospheric concentrations of CO_2 are 30% higher today than at the beginning of the industrial era. The Intergovernmental Panel on Climate Change (IPCC), a scientific panel organized by the World Meteorological Organization and the United Nations in the 1988 to advise policymakers, estimates that approximately one-third of global CO_2 emissions between 1850 and 1998 resulted from land-use change. During the 1990s, global fossil fuel combustion and cement production emitted ~ 6.3 billion tons of CO_2 to the atmosphere per year while land use change, predominately deforestation, emitted another ~ 1.6 billion tons (IPCC, 2000).

In the past two decades, terrestrial ecosystems have functioned as a small net sink (more CO_2 flowing in than out), but there is some indication that uptake of carbon could level off or decline in the future. Temperature and precipitation regulate biological processes, affecting not only conditions and functions of ecosystems, but their links and feedbacks with the climate system. A warmer and drier climate could weaken and degrade terrestrial sinks and lead to re-emission of biotic carbon. There is growing concern about the impact of warming on arctic and subarctic peatlands, which rank among the world's top carbon stores (Rouse, 1997). Re-emission of large amounts of CO_2 from peat that has been accumulating since the last ice age could significantly accelerate global warming. Major factors determining whether terrestrial sinks strengthen or weaken over the next century include effects or feedbacks of climate change (drier or wetter weather, longer growing seasons); changes in atmospheric chemistry (including CO_2 fertilization and nitrogen deposition); land uses and conversions (deforestation, urbanization); forest regrowth (a major effect in the eastern US); and success of fire suppression and pest control efforts (Hurtt et al. 2002, Myneni et al. 1997). Federal agencies have recently reported that a combination of these factors has resulted in substantial declines in net U.S. carbon sequestration between 1990 and 2004 (EIA 2005, USEPA 2006). Declining or reversing terrestrial sinks would require much larger reductions in emissions to stabilize atmospheric greenhouse gas levels.

There are three basic approaches for managing forest, agricultural, urban, and other land uses for carbon:

1. *Protect existing carbon stocks.* Avoid the loss of CO_2 from terrestrial sinks through reforestation; extending tree harvest cycles; modifying management practices; thinning and controlled burns to reduce wildfires; discouraging loss of natural vegetation in development; reducing soil disturbances; avoiding cultivation and drainage of organic soils; increasing use of cover crops; maintaining agricultural set-asides.
2. *Enhance and expand existing sinks*. Increase "carbon density" per acre through afforestation (tree-planting on lands not forested in 50 or more years) particularly on marginal cropland; planting both short-rotation and long-lived tree species; expanding buffers and greenbelts; increasing use of deep-rooted perennials in agricultural production; restoration of wetlands and prairies; rehabilitation of brownfields and other disturbed land with little organic content.
3. *Reduce emissions associated with land-uses*. Adopt "stop loss" activities such as reducing fossil fuel use in land management operations; encouraging urban forestry to reduce energy consumption for heating and cooling; encouraging land uses that reduce high fuel-consumption in transportation associated with urban sprawl. Increasing use of biomass crops that sequester carbon above and below ground, increase soil carbon, and offer renewable substitutes for carbon intensive fuels. Substitute bio-based products for more carbon-intensive products. Increase use of wood to produce long-lasting products that delay CO_2 from re-entering the atmosphere.

In addition to sequestering carbon, these practices can provide benefits to local and regional environmental and economic objectives. Agricultural soil management that increases carbon enhances soil fertility and moisture retention, reduces erosion, and contributes to regional water quality protection and floodwater retention. Re-establishing prairie and wetlands on land retirements, riparian buffers, and marginal land moderates flood pulses, reduces turbidity and nutrients in waterways, and increases wildlife habitat and biodiversity. Reforestation protects and stabilizes soils, regulates stream flows, and provides habitat niches for different wildlife communities. Afforestation increases timber supplies and biomass fuels. Sustainable forest management reduces fuel loads and protects against wildfires.

Many sequestration practices could also help reduce the state's vulnerability to the impacts of a warmer, stormier world. Atmospheric warming accelerates cycling of water between ocean, atmosphere, and land and increases the energy that drives storms. Although region-specific information about impacts of global warming is limited, mid-latitude continental interiors are expected to experience increased intensity of storms, floods, and soil erosion. In an apparent paradox, warmer temperatures increase evaporation, thus causing soil moisture deficit, reduction in lake and river levels, and increased risk of drought (IPCC 2001a, NAST 2000). Adaptation strategies include protection of floodplains and other highly-erodible areas; planting shelterbelts; residue management and cover crops; planting crops and trees that are adapted to warmer conditions and are more wind-firm; and expanding wildfire prevention. Designing programs to integrate climate mitigation (lessening CO_2 buildup) and adaptation (reducing its impacts) could help address costs and uncertainties of sequestration projects. Experience in other countries indicates that collaborative projects between private and public sectors may increase social and environmental benefits (Mendez 2006).

IPCC estimates that the global potential of biological mitigation is on the order of 100 billion tons of carbon (cumulative) by the year 2050, the equivalent of 10% to 20% of total fossil fuel emissions during that time (2001b). The scientific panel states that, while biological sequestration is not permanent, it is important as an early and mid-term strategy while other emission reduction options are being developed and implemented. As such, it can serve an important near-term role of helping slow the rate of warming, giving biological systems time to adapt, and reducing the severity of climate change impacts (*ibid.*).

In an influential paper on climate change strategies, Princeton researchers Pacala and Socolow (2004) included protection and enhancement of carbon sinks in a portfolio of existing technologies that could be ramped up over the next 50 years to help stabilize atmospheric CO_2 levels. Their analysis concludes that implementing reforestation and afforestation on hundreds of millions of acres worldwide could remove 15% to 20% of projected fossil fuel emissions. If tropical deforestation could be eliminated and conservation tillage adopted on all cropland, another 15% of emissions could be removed. The scale of such an effort—and the financial resources it would require—presents an enormous challenge, particularly in light of even larger efforts and investments needed to reduce fossil fuel emissions at their source.

Institutional Options for Managing Terrestrial Sinks

Traditional conservation programs for soil, water, forests, and wildlife provide the essential foundation for managing the nation's terrestrial sinks. The federal government manages millions of acres of public lands and provides billions of dollars annually for conservation of private lands. State and local governments have major responsibilities for managing public lands, regulating private lands, and promoting best management practices with technical assistance and financial incentives. Traditional conservation organizations educate the public, acquire and manage lands, assist landowners, and mobilize support for protecting or restoring natural resources, many containing carbon sinks. Funding for large scale conservation, however, has rarely been adequate and has never reached the scale contemplated above.

Recognition of the biosphere's climate mitigation effects—or, if ignored, its potential contributions to global warming—could usher in a new era of resource conservation. This section describes an evolving infrastructure of international, national, and state-level programs and policies that are accelerating sequestration activities and investment. It begins by describing United Nations climate treaties, including the Kyoto Protocol. Hundreds of governments and thousands of businesses participate in UN climate and emissions trading programs. Although the United States is not a party to the Kyoto process, a growing number of states are adopting similar approaches to combating climate change. Their programs and a wide array of other approaches affecting carbon sinks, particularly in the context of climate mitigation, are also described.

International Framework

There are two major pieces of international law applicable to global reduction of greenhouse gases: The United Nations Framework Convention on Climate Change ("Convention") and the Kyoto Protocol. The Convention—ratified by 189 countries, including the U.S.—is intended to coordinate international efforts combating climate change. It states in part:

> *The ultimate objective of this Convention and any related legal instruments… is the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.*

To achieve these goals, the Convention establishes a coordinated international research, education, and policy-making process, and a basic set of definitions, objectives, principles, and commitments to be used in subsequent implementation agreements (UNFCCC 1992). It also calls upon signatory nations to take a number of actions. Each nation is to establish an inventory of GHG sources and sinks and a national GHG registry to track emission reductions and removals. Nations are to adopt policies and programs to both reduce GHG emissions at their source and remove them from the atmosphere through terrestrial sequestration practices (collectively referred to as "land use, land use change, and forestry," or LULUCF). Article 4 commits nations to promote sustainable management and "to cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases including biomass, forests, and oceans as well as other terrestrial, coastal, and marine ecosystems." The Convention also calls for national plans for adaptation to impacts of climate change, noting specifically integrated plans for water resources, agriculture, drought, and floods.

The Kyoto Protocol (1997) is a single 5-year (2008–2012) "first step" in a long process aimed at implementing the goals and timeframes of the Convention. The essential framework of the Kyoto Protocol is:

- *Setting mandatory emission targets and timetables.* Emission reduction targets are set for six greenhouse gases. Ratifying nations must meet and maintain these targets during the first commitment period. Each developed nation is assigned a specific goal for reducing emissions by 2008; the average is ~ 5.2% below its 1990 emissions level.
- *Identifying actions to be used in complying with targets*. The Protocol requires industrialized nations to increase energy efficiency, renewable energy, methane reductions, and to remove GHG subsidies of all kind. It also requires "protection and enhancement of sinks and reservoirs of greenhouse gases; sustainable forest management practices; afforestation; reforestation; and sustainable forms of agriculture" including cropland management, grazing land management, and re-vegetation. However, for a variety of reasons discussed below, the Protocol limits land-based activities that can be used toward compliance with emission targets. Only "direct, human-induced land-use change and forestry activities, limited to afforestation and reforestation…since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet commitments…" (Article 3.3). Restricting sequestration activities during the first commitment period is, in part, a prudent decision to put early focus on practices that are relatively easily managed and understood, and which demonstrably expand forest sinks. The Protocol states that rules and guidelines for additional activities in agricultural soils and land-use change categories will be developed for the second and subsequent commitment periods (Article 3.4).
- *Allowing use of emissions trading to speed up and reduce costs of compliance*. To improve the cost-effectiveness and political viability of complying with emission targets,

the Protocol adopts a "cap-and-trade" approach to pollution abatement (successfully pioneered in the U.S. Clean Air Act of 1990 to address sulphur dioxide and acid rain). Under Kyoto, each nation is allocated a set of allowances equaling its emission targets. These allowances (entitling the holder to emit one metric ton of CO_2-equivalent greenhouse gases per year) are then distributed among the country's major GHG-emitting companies. The number of allowances allocated or issued to a company is its "cap"; this cap cannot be exceeded without penalty. In general, companies can manage their allowances in three ways. They can use them to cover internal emissions up to their cap; they can reserve or "bank" them to cover emissions in future years; or they can transfer them to other entities that need to offset excessive emissions.

In a key innovation, the Kyoto Protocol also allows countries to transfer or acquire credits generated by emission reduction or sink-enhancement activities conducted elsewhere. As with allowances, these project-based credits (certified emission reductions) can be counted toward the holder's emission reduction target. Kyoto uses "flexibility" or trading mechanisms for transferring carbon credits. Two of these mechanisms, Clean Development Mechanism (CDM) and Joint Implementation (JI), allow industrialized nations to invest in reduction or removal projects in other nations in exchange for certified emission reductions to apply against their targets. The third mechanism, Emissions Trading (ET), allows industrialized nations to trade emission allowances or certified emission reductions in order to cover all emissions at the end of the compliance period.

Several economic analyses estimate that use of market mechanisms would lower costs of complying with Kyoto's targets between 43 and 86% (Goulder and Nadreau 2002). The mechanisms essentially turn greenhouse gases into valuable commodities and create a global market for them. Unlike the earlier U.S. acid rain program, which operated among a relatively small number of American companies, the rapidly expanding greenhouse gas market is global in scope and cuts across many economic sectors. The World Bank reported that carbon trading more than doubled in volume and value in the first nine months of 2006, to over one billion metric tons CO_2 valued at $21.5 billion. While most of the trading was of emission allowances, the project-based offset market grew in value to $2.41 billion during the same period (Capoor and Ambrosi, 2006). A range of carbon market issues—volatility, liquidity, integrity, and enforceability of market transactions—can be expected to emerge in coming years. How they are handled will determine the level of public confidence and long-term viability of market approaches to managing pollution.

Projects currently certified to offset carbon emissions under Kyoto are dominated by methane capture from landfills and animal waste management systems and by renewable energy systems. A representative land-based project currently seeking offset certification is a reforestation of 4,000 hectares of degraded land in the middle and upper reaches of the Pearl River watershed in China. The project is part of a larger program to protect the region's water quality, soils, and biodiversity. Objectives include sequestration of ~25,800 metric tons of CO_2-equivalent per year; increasing forest connectivity; improved erosion control; and increased income for local communities. Two implementation strategies will be tested.

- Individual farmers will contract with a private forest company to provide lands and labor in exchange for payments for labor, planting activities, inputs, and insurance covering

natural and investment risks. The contract spells out revenue-sharing from forest products and carbon transactions.

- Alternatively, a farmer cooperative will invest and undertake projects (with assistance from forestry agencies) on lands owned by local villages. Income from forest products and carbon transactions would belong solely to the cooperatives.

Partners in the project are the BioCarbon Fund, one of a group of carbon offset funds at the World Bank; the People's Republic of China; Italy; and Spain. If the project wins CDM certification (considered highest-grade credits) it would be assured of generating top fees from countries needing to offset excess emissions (BioCarbon Fund).

Issues Affecting Terrestrial Carbon Sequestration in Kyoto Protocol

While the UN treaties recognize and explicitly call for protection and enhancement of terrestrial sinks, the eligibility of terrestrial sequestration options in emissions trading is very limited. Only afforestation and reforestation can be used to meet Kyoto's compliance targets. To some extent, this reflects political dynamics that existed in the mid-1990s when the Protocol was negotiated. There are, however, several major areas of scientific, technical, and policy uncertainty that need resolution as other sequestration activities are considered.

1. Scientific

Terrestrial carbon stocks exist in a wide range of environments and structural forms; these forms respond at different rates to current and past management and environmental factors. The rates and trends in carbon uptake are not well understood, nor are the impacts of climate changes and other factors. Three characteristics of carbon stocks are of particular interest. (1) *Non-permanence* and potential *reversal* of sequestered carbon either by natural causes and land use decisions. (2) *Saturation*, or the maximum carbon density of a site or region, and potential changes because of altered climate, nutrient inputs, species, or other conditions. (3) *Instability of carbon storage*. Changes in temperature and rainfall cause very large year-to-year variations in carbon uptake and release. Interactions among El Niño/Southern Oscillation cycles, climate warming, and increased CO_2 respiration are topics of growing interest, as is the impact of nitrogen fertilization and other air toxins on the stability of terrestrial stocks (IPCC 2003a).

2. Technical

Measurement, monitoring, and verification (MMV). The central requirement of an emissions offset program is a rigorously quantified and transparent system to verify that carbon sequestration projects are, in fact, increasing carbon stocks. At present, practicable methods for measuring, monitoring, and verifying changes in carbon stocks against background variations do not exist for a broad range of sequestration activities and circumstances. Systems capable of identifying carbon stock changes attributable to direct human-induced efforts rather than natural causes will likely take a decade to develop (*ibid.*). In the meantime, default tables and monitoring tools are being developed for agricultural soils and forests. Greenhouse gas registries and trading programs vary in their MMV requirements and, consequently, their acceptance of these tools.

Accounting for terrestrial sequestration is not only a matter of verifying carbon stock changes over time (IPCC 2003B, Schlamadinger and Marland 2000; Sampson 2004). In contrast to the

relatively straight-forward calculations of emission reductions resulting from efficiency or technological improvements, land-based activities must account for a complicated set of circumstances inside and outside a project's boundaries. Greenhouse gas registries vary in accounting requirements and no single, standardized protocol has been approved for general use. In addition to requiring verification that changes in carbon stocks result from "human-induced" or deliberate mitigation efforts and that they occurred after 1990, accounting protocols may require the following documentation:

- that they produce "additional" removals (or emission reductions) than would have occurred in the absence of the project, i.e., above a "business-as-usual" baseline;
- that "leakages" of GHG benefits caused by a shift of emission-producing activities to outside the project area are deducted to determine net removal;
- that "reversals" or re-emission of sequestered carbon because of fire, disease, or other causes are deducted; and
- that they contribute to biodiversity conservation and sustainable natural resource use.

3. Economic

Although terrestrial projects can provide a relatively inexpensive method of reducing atmospheric CO_2, they can also entail high transaction costs that reduce their competitive advantage. Typical transaction costs incurred by project sponsors include feasibility studies, negotiations, insurance, regulatory approval, and verification. Recent analyses of transaction costs found a range between $0.50 -$ 4.50 metric ton/C for forestry projects sequestering between 10,000,000 and 10,000 metric tons of carbon, respectively, with monitoring consuming a significant proportion of costs. Not surprisingly, economies of scale play a large role in transaction costs, which rise steeply for projects sequestering less than 100,000 MT/C (Andrasko 2006).

4. Policy

During Kyoto negotiations, serious policy disagreements arose about the appropriate role of land-based projects in offsetting source emissions. A major concern is that the low costs of sequestration projects will deflect attention from more-expensive replacement of fossil fuel combustion, the main driver of global warming. In this view, limits should be placed on the percentage of emissions that can be offset by terrestrial sequestration. Another policy concern is the potential for negative environmental and water resource impacts from poorly designed or sited afforestation projects.

Over time, as technical and policy issues are resolved, more sequestration activities may become eligible for compliance purposes. Concrete proposals to include avoided-deforestation in post-2012 agreements are currently being negotiated. For other project types, experience gained in the next few years will be critical in their inclusion in mitigation programs. Major advances are needed in several key areas: improved understanding of the ability of different activities to enhance sinks; improvements in quality, standardization, and practicality of reporting systems; avoidance of negative socio-economic and environmental impacts by carbon-sequestering projects; and close monitoring of the impact of land-based projects on emission reduction efforts (Forner 2005).

Domestic Programs Affecting Terrestrial Carbon Sequestration

In the absence of comprehensive federal action, climate initiatives have proliferated among American cities, states, and regions. States have the ability to design their own approach and, in consequence, an increasing variety of voluntary or mandatory programs, incentives, and market mechanisms are being developed and field-tested. Some of these programs can be expected to influence future national climate policies. In the meantime, they give states the opportunity to gain experience, attract investments, and position themselves for the future (Rabe 2004).

Because of the large role states and local governments play in land use, terrestrial sequestration options are key elements in their mitigation portfolios. Below are summaries of a variety of approaches that states are taking to manage carbon sinks. Activities are broken into three broad categories:

- Government Supports—Outreach & Education, Pilot Projects, Public Lands Management, and Incentives for Best Management Practices
- Climate Policies—GHG Registries, Facilitation of Offset Trading, Carbon Credit Procurement, Cap-and-Trade Programs
- Private Market Components—Carbon Procurement, Project Sponsors, Brokerages, Aggregators, Trading Platforms, and Direct Sales

The appendix provides additional information and websites on these and other exemplary activities.

Government Supports

Outreach and Education. A number of states conduct programs to educate landowners and the general public about terrestrial carbon sequestration. Establishing carbon sequestration advisory and technical committees is frequently the first step a state takes to build public understanding, consensus, and support for government action. Advisory committees are created by executive order or legislation; they may include representatives from agriculture, forestry, government, electric utilities, conservation, and academia. Committees frequently task university and/or government scientists to provide information on potential adverse impacts of global warming on state or regional water resources, environment, public health, and economy; costs and benefits of various mitigation strategies; and related questions. Reports are disseminated through various channels and used to define scientifically-credible pathways forward. A number of states and regions also sponsor periodic conferences to report on scientific and policy developments, promote public awareness, and build consensus.

- Nebraska was the first state to recognize the relationship between farming and grazing practices and carbon sequestration. In 2000, the state legislature established a Carbon Sequestration Advisory Council and funded research into minimizing emissions and increasing sequestration in forestry, agro-forestry, cropping, grazing, and livestock operations. The council's recommendations included a county-by-county baseline survey of carbon in vegetation and soils, state incentives, pilot projects, and creation of a clearinghouse of carbon brokers and carbon contracting services for landowners. The state now operates an on-line system for landowners to assess carbon options on their

lands. Other agricultural states have adopted this model for developing carbon sequestration programs.

- Nine states have established committees to develop broad climate mitigation agendas that include terrestrial sequestration. Arizona recently completed a year-long stakeholder process that resulted in 49 recommendations, including six land-based actions: quantified goals for agricultural sequestration, reduced development on agricultural and forest lands, support for locally-produced foods, reforestation, sustainable forest thinning to address fire threats and forest health, and increased commercialization of biomass energy systems. Other states have developed equally broad portfolios of activities that, collectively, produce significant reductions.
- On the West Coast, risks associated with climate change on the region's water supplies, thousands of miles of shoreline, and agricultural economies have made it a major focus of policy discussion and development. The West Coast Governors' Global Warming Initiative is an attempt to increase communication and coordination between Washington, Oregon, and California. The Initiative sponsors conferences to inform policymakers and the public about climate change research concerning the region. California has taken a lead role in sponsoring annual national forums on research and policy developments related to climate change, impacts, and adaptation, including on agricultural, forest, and water resources.

Pilot Projects. Pilot or demonstration projects are important tools for field-testing sequestration practices in different settings, gaining real-world experience with credit trading, and improving public understanding and support. Projects are frequently partnerships among governments, utilities, conservation groups, and landowner groups. They demonstrate important aspects of terrestrial sequestration, including verification of sequestration rates; monitoring and validation techniques for different practices; and alternative contracting and partnering arrangements.

- U.S. Department of Energy (DOE) sponsors seven Regional Carbon Sequestration Partnerships around the country that are conducting geologic and terrestrial pilot projects of different technologies, regulations and infrastructures for carbon sequestration. In our region, University of North Dakota Energy and Environmental Research Center (EERC) is overseeing a wetland/grassland sequestration program that will provide carbon credits produced by wetland restoration in the Prairie Potholes. The project will also develop protocols and standards that can serve as models elsewhere. Partners include Northern Prairie Wildlife Research Center, Ducks Unlimited, and Xcel Energy.
- Pennsylvania is partnering with Allegheny Energy, DOE, Pheasants Forever, and other local organizations on reforestation and sequestration pilot projects on abandoned minelands prevalent in that region. The goal of a project at Limestone Run in western Pennsylvania is to investigate restoring degraded mined sites to forest and prairie for enhanced carbon and other environmental values in the watershed. They are also studying the use of fly ash from local coal-fired power plants as soil amendments and its impact on water quality, habitat, and wetland restoration.
- Nebraska Center for Rural Affairs has sponsored farm-scale pilot projects to study results of sequestration practices at different farms and locations. Farmers in target watersheds are paid a per-acre stipend to participate in education and planning exercises that tailor and monitor sequestration practices to their operations.

Public Lands Management. Hundreds of millions of acres of terrestrial carbon sinks are in the public domain, comprising a significant proportion of North America's carbon sink. The U.S. Forest Service, Fish and Wildlife Service, National Park Service, Bureau of Land Management, 50 states, and thousands of county and municipal-level agencies manage these lands for different purposes, among them wilderness protection, habitat, recreation, timber, grazing, mining, and oil production. Interest in capturing carbon credit income to pay for restoration and ecological management projects on national wildlife refuges, state wildlife management areas, and federal and state forests is growing.

- The Lower Mississippi Alluvial Valley is the site of extensive reforestation and carbon sequestration projects in publicly-owned bottomland forests. Major efforts have been underway in Louisiana, Mississippi, and Arkansas since the 1980s to restore wetlands and forests on millions of acres of abandoned cropland to increase habitat for migratory birds and other wildlife, and to improve water quality and floodwater retention. In recent years, restoration efforts have been expedited by private and non-profit groups interested in securing carbon sequestration credits. Federal and state agencies provide technical assistance, land acquisition, financial incentives, and long-term management. National and regional conservation organizations assist in lining up private landowners and public support. Individual electric utilities or groups of utilities provide funding in exchange for carbon credits generated by their contributions.
- Ducks Unlimited works with private landowners to assess carbon options, implement restoration projects, and connect with offset credit buyers. DU negotiates contracts and easements with landowners for carbon credits.
- Trust for Public Land is acquiring, reforesting, and transferring 11,000 acres of Louisiana black bear habitat to the USFWS national wildlife refuge system. A combination of federal and private funding is being raised, including major contributions from energy companies for carbon credits.
- PowerTree Carbon Company LLC is a consortium of power companies providing financing for major reforestation projects in the southeast and elsewhere in exchange for carbon credits.
- An example of a reforestation partnership on a smaller scale is Minnesota's ReLeaf program, established in 1991, to promote energy efficiency and carbon sequestration through community forestry. The program used Environmental Trust Fund money to cost-share grants to communities, non-profits, and schools for forestry projects intended to reduce energy costs, beautify communities, and provide environmental co-benefits, including CO_2 removal. The program has supported over 360 community tree planting projects in 200 communities or counties. A shortage of funding has precluded assessments of carbon benefits (and potential credits) of the program. A similar program in New Mexico uses state general funds, tax check-off funds, and donations from private and corporate foundations.

Incentives for Best Management Practices on Private Land. Federal programs provide technical assistance and financial incentives for conservation practices benefiting carbon sinks. A major source of assistance is U.S. Department of Agriculture cost-sharing for agricultural best management practices (BMPs) affecting carbon stocks on farmed lands, wetlands, and forests in private hands. Approximately 39 million acres of marginal cropland are enrolled in the

Conservation Reserve Program (CRP) and contribute substantially to the nation's current net carbon sink. Extensive conversion of these lands to tilled cropland when contracts expire in coming years would cause re-emission of CO_2 fixed in plants and soils during the past two decades. Carbon sequestration is now used in rating CRP proposals and, in coming years, other programs may add GHG reduction and removal as priority objectives.

- USDA's Environmental Quality Incentives Program (EQIP) includes GHG as a priority resource concern within its ranking system. Current focus is on methane digesters and nutrient management.
- USDA's Wetland Restoration Program and Grassland Reserve Program provide funding for restoration and long-term easements for highly-efficient wetland and prairie carbon sinks.
- Major federal programs for protecting forest sinks are the Forest Legacy Program, Forest Stewardship Program, and Forestland Enhancement Program. Through them, the U.S. Forest Service partners with states to protect privately-owned forestland from development and to assist landowners plan and implement sustainable forestry practices.

Many states provide landowner assistance for conservation practices to improve soil and water management, biodiversity and wildlife habitat, and forest health and productivity. Policy options include grant and loan programs; property tax exemptions for BMPs on qualifying lands; purchase of conservation easements; planning and engineering assistance; full or partial direct cost payments for specified practices; equipment rentals; surveys and research; and monitoring. Some states augment conservation incentives by assisting landowners in carbon trading.

- Oregon Forest Resource Trust provides technical assistance for up to 100 % of reforestation expenses on private under-producing forestlands. The Trust and the Oregon Department of Forestry, state-owned forestlands, and non-federal landowners cooperate in a shared program that provides carbon credits (through sequestering carbon or reducing forestry-related emissions) to meet the state's climate mitigation goals. Other services by the Forest Resource Trust include: assistance to agricultural and forestry landowners to manage, register, and market offset credits derived from carbon sequestration activities; state-specific maps and model calibrations for assessing carbon resources and options; state-approved guidance to manage and market credits; and assistance in connecting buyers and sellers.
- Maine completed a Climate Action Plan in 2004 that contains 54 options to reduce greenhouse gases. Six options are forest-related: protect forestland from development; harvest timber to capture anticipated mortality; actively re-establish the state's original softwood forests; expand use of wood products; increase stocking with faster-growing trees; and increase biomass electricity feedstocks. In 2006, the focus of forestry efforts was on increasing investments in more intensive silvaculture practices to increase the value of forest products and create a GHG offset program for landowners.
- Minnesota offers numerous opportunities for assistance with conservation and protection activities affecting forests, prairies, wildlife habitat, and soil and water resources. Although initially designed for other purposes, many of the state's conservation cost-share programs, loans, grants and other instruments function as a major source of support for protection and enhancement of Minnesota's terrestrial carbon sinks. Existing programs – Reinvest in Minnesota, Agricultural BMP Loan Program, Sustainable

Woodlands Program, Native Prairie Bank Program, and Permanent Wetland Preserves – could provide the foundation for expanding carbon sequestration here.

Climate Policies

Greenhouse Gas Registries and Protocols. A number of registries in the U.S. receive and track data on GHG emissions and reductions/removals by companies, states, and others. Registries can be mandatory, voluntary, or a combination of both. Depending on their design, they can be used to track emission credit trades in cap-and-trade programs, and as repositories of project-based emission reduction or removal projects. They perform important functions by establishing an entity's baseline emissions so early adopters can register and safeguard reduction credits under future policies. Registries can provide an important analytical tool for future initiatives (i.e., identifying "low-hanging fruit" for emission reductions).

Registries use GHG accounting protocols to ensure that tons of carbon reported meet basic standards of accuracy, reliability, and verifiability. As noted above, accounting protocols vary in the level of precision, documentation, and independent validation required. Voluntary programs designed to increase participation may have lower reporting and certification requirements than programs with explicit mandates. State agencies, universities, conservation organizations, and landowners typically work together to develop or adapt accounting protocols that are practical, affordable, and sufficiently precise to meet the requirements of different exchanges and ensure public confidence.

- The U.S. DOE maintains a national voluntary registry, the Voluntary Reporting of Greenhouse Gas Program, under Section 1605b of the Clean Air Act. The registry is used by businesses participating in the federal Climate Challenge program to report GHG emissions, reductions, and sequestration. In 2004, 226 U.S. entities reported projects to reduce or sequester GHG, including carbon sequestration projects (afforestation, reforestation, urban forestry, forest preservation, modified forest management, forest plantations, wetland restoration, and conservation tillage). Over 80% of sequestration reported was from tropical forest preservation projects. The "Voluntary Reporting of GHG Carbon Management Tool" (COMET-VR) is an online tool for reporting agriculture and forestry emissions and sequestration. It calculates annual carbon fluxes based on average soil emissions and sequestration associated with historical land management practices.
- The California Climate Action Registry is a state-affiliated non-profit organization that administers one of the nation's first voluntary GHG registries. The registry encourages businesses, non-profit organizations, municipalities, state agencies, and other entities to establish GHG baselines and to take voluntary action toward increasing energy efficiency and emission reductions. In exchange, the state offers participants appropriate consideration for early actions in the event of future state, federal, or international GHG regulatory schemes. To encourage forest conservation, three protocols for registering increases in forest stocks were developed. The Forest Sector Reporting Protocol is for forest companies to use in reporting entity-wide stock changes. The Forest Certification Protocol is guidance for third-party certifiers to conduct assessments of GHG data at entity and project levels. The Forest Project Protocol is for reporting results of planned activities to remove, reduce, or prevent CO_2 emissions through reforestation,

conservation management, and conservation. Projects must promote and maintain native species and natural forests; they must be secured by perpetual easements. Third-party verification is required; on-line reporting tools exist.

- In 2006, thirty states began discussing a potential multi-state registry to provide a common platform for emissions reporting, registration, and allowance tracking. The Lake Michigan Air Directors Consortium (LADCO), including Minnesota, is participating in these discussions.

State Facilitation of Voluntary Carbon Offset Trading. Some states assist local landowners in gaining access to carbon markets. Although carbon prices in voluntary markets are considerably lower than in markets of mandatory programs, voluntary markets can provide modest incentives for adopting sequestration practices, valuable experience in market transactions, and other "early mover" advantages.

- The Illinois Conservation and Climate Initiative promotes adoption of terrestrial sequestration in agriculture by facilitating participation in private carbon markets. Landowners or producers sign five-year contracts to enroll eligible acres in the Initiative, which then aggregates enrolled acres into units of 1000 metric tons for sale on the Chicago Climate Exchange (CCX), a voluntary cap-and-trade program. Default sequestration rates are used for crediting eligible practices: conservation tillage, grass plantings, tree planting, and methane digesters. The Initiative is a joint venture of the State of Illinois, the Illinois Association of Illinois Soil and Water Conservation Districts (to educate and work with farmers), and the Delta Institute, an entrepreneurial non-profit organization managing CCX transactions.
- Montana Carbon Offset Coalition was created by the state's legislature to establish "market-based conservation" on private land by cost-sharing tree-planting projects and acquiring resulting stored carbon credits. A nonprofit organization, Montana Watershed Inc., works with watershed authorities to develop projects. In recent years, the Coalition has become a national carbon broker and assists landowners outside Montana plan sequestration projects and document results. Credits are packaged and offered for sale directly to companies seeking emission offset credits or through markets.

State Market-based Emissions Trading and Carbon Trusts. A number of states are establishing greenhouse gas reduction targets and emissions offsets programs that include forestry. These are either market-based or climate trust programs. In market-based systems, regulated entities purchase offsets from forest management projects. In climate trusts (or banks), states fund forestry projects and recoup costs by selling carbon credits. Below are descriptions of these approaches by Oregon, California, and a consortium of Northeastern states.

- In 1997, Oregon passed legislation requiring new power plants to meet a CO_2 emission target or, in lieu of that, to offset part of their emissions by paying a fee per ton of emissions into an offset fund. Under this legislation, these funds accrue to the (Oregon) Climate Trust which is used to fund CO_2 mitigation projects for new power plants. The Trust invests in transportation, manufacturing, cement production, lumber, and other sectors. Investments include projects of the Forest Resource Trust and a number of high-profile reforestation partnerships in the Pacific Northwest. One is the Deschutes River Riparian Reforestation, a fifty-year project to reforest denuded riparian areas along one of

Oregon's premier trout streams. The Climate Trust will buy offsets (estimated at 234,000 MT) generated on 1500 to 1800 acres of reforestation overseen by the Deschutes Resources Conservancy, a partnership of government and stakeholders in the basin.

- The Regional Greenhouse Gas Initiative (RGGI) is a cooperative effort by seven Northeast and Mid-Atlantic states (Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont) to stabilize and reduce regional GHG emission to 1990 levels by 2014. Individual states maintain independent climate programs and policies but, under RGGI, they will also cap CO_2 emissions of electrical power generators (25 megawatts and larger) and establish the nation's first market-based emissions trading program. The program goes into force in 2009 and has three-year compliance periods. Approximately 50% of a regulated entity's required emission reduction can be offset by purchasing credits produced elsewhere, including—if price rises above $7/ton—from outside the region.

Eligible offsets include afforestation projects (defined as transition of land from non-forest to forest). Certification for afforestation offset credits requires projects to be managed with environmentally sustainable forestry practices, promotes restoration of native forests, and is secured by a permanent conservation easement. Commercial harvests must follow forest stewardship guidelines, and offset producers must use prescribed accounting and reporting procedures. A technical working group is developing rules for including additional project types (forestry and grassland revegatation) as eligible offsets.

A multi-state GHG registry, the Eastern Climate Registry, will provide a common set of standards for reporting emissions, baselines, and reductions. This registry is in consultation with California and Midwestern states about linkages and/or harmonizing standards.

- In California, climate policy has been on the state's agenda since the late 1980s, in part because of the state's vulnerability to climate change impacts. To a greater extent than elsewhere, political and business leaders have also considered climate change and alternative energy a major economic opportunity for the state. Governor Schwarzenegger recently announced a new set of climate initiatives including aggressive emission reduction targets (25% reduction by 2020; 80% by 2050) and prospective trading agreements with the European Union and RGGI states. The California Global Warming Solutions Act of 2006 is the first state-level law to limit emissions of six greenhouse gases (identical to the Kyoto Protocol) and will regulate "any source, or category of sources, that the Air Resources Board determines as significant." The state's Climate Action Team, comprised of high-level representatives of implementing agencies, released a report quantifying how the 2020 targets will be reached. It projects that approximately 34 MMT of CO_2, or 18% of target reductions, will come from forestry activities: changes in forest management to favor longer rotations, simplified regulations, inclusion of forestry in carbon markets and a state-run carbon bank, minimized emissions from forestry practices, reduced forest conversion, urban forestry, urban biomass (waste) markets, and reforestation/afforestation projects. Recent studies indicate that ~9 million acres in California could be reforested to increase carbon stocks, potentially storing 150 to 230 metric tons of carbon per acre. The Climate Action Team is considering a specific goal of reforesting 500,000 acres of public and private lands by 2020.

Private Market Components and Infrastructure

Below are descriptions of components of the evolving international and domestic carbon offsetting infrastructure. Information on specific companies and programs is in the appendix.

Carbon Credit Procurement. Carbon investment funds use contributions by governments, private and non-profit organizations, and individuals for carbon reduction and removal projects. Carbon funds provide critical financing for start-up and operating offset projects (land acquisition or easements, construction and management costs, monitoring and reporting, and other requirements of carbon credit trading schemes). Portfolio guidelines can specify types and locations of projects and accounting procedures to attract investors. Investment funds may be open to anyone or restricted to private groups of buyers, such as consortiums of energy companies needing to offset emissions. Returns on investment are in form of carbon offset credits (one metric ton/ CO_2/year) generated by human-induced change in carbon emissions or sequestration) and may be used to meet reduction targets, re-sold, or retired as part of a climate protection program.

Project Sponsors / Credit Producers. Project sponsors are individuals and organizations that adopt practices or undertake projects to produce and sell carbon credits. They conduct feasibility studies, environmental impact and risk assessments, design and management planning, financing, project implementation, monitoring, and reporting. Typical sponsors are government agencies, conservation organizations, forestry companies, farm groups, and environmental technology firms.

Aggregators. Transaction costs related to carbon offset projects—particularly for small providers of credits derived from terrestrial carbon sequestration—can be technically and financially prohibitive. To make carbon trading more efficient and cost effective for smaller landowners, some mechanism for aggregation of credits is necessary. Forestry and farm organizations, including cooperatives involved in alternative energy, are experimenting with different roles in carbon trading.

Brokerages. Carbon brokers operate either as for-profit or non-profit organizations and provide a range of services: identifying project needs; arranging financing; determining the amount, viability, and cost of carbon credits in a particular project; and matching sellers with interested buyers. Brokerages typically build diversified portfolios of different types of offset projects to cover emission reduction needs of their clients.

Trading platforms. Environmental credit trading can be used to meet both voluntary and mandatory emission reduction targets and can potentially operate at many scales: international, national, regional, state, within a single emitter, or among a consortium of emitters. The European Union Emission Trading Scheme covers 25 countries and 12,000 to 16,000 emitters with mandatory caps; the Chicago Climate Exchange has 150 corporate, government, and non-profit partners who adopt voluntary but legally binding emission caps and buy and sell credits to meet them.

Individual trades. At present, the absence of a national regulation on GHGs means there is low demand and low prices for domestic GHG reductions. While markets and policies evolve in coming years, there are several strategies that states, companies, and other entities currently use to lay the groundwork for future trading (Zaborowsky and Reamer 2004).

- Sell directly to a private buyer with a voluntary commitment;

- Join CCX and sell credits through their exchange;
- Position for future markets by registering emission reductions with the Clean Air Act 1605b program (a voluntary GHG registry administered by the Department of Energy); one of the state or regional GHG registries;
- Work with carbon investment funds to develop and market projects.

Summary of Sector Meetings

The Minnesota Terrestrial Carbon Sequestration Project conducted a series of "early input" stakeholder meetings with agricultural, forestry, government, business, and environmental-conservation groups in the spring of 2006. The purpose of the meetings was to open dialogue with various groups about terrestrial carbon management options in Minnesota and to identify issues, interests, and priorities that could be addressed in future activities. Co-sponsoring organizations were MN Departments of Agriculture, Natural Resources, and Commerce; MN Pollution Control Agency, MN Forest Resources Partnership, Xcel Energy, and Izaak Walton League. Meetings were held in Mankato, Grand Rapids, St. Paul, and Minneapolis.

Seventy-five people attended presentations, filled out questionnaires, and participated in group discussions about (1) ideas for near-term and longer-term activities in Minnesota; (2) questions and concerns that should be addressed in future research agendas; and (3) suggestions for educational and demonstration projects. From the agricultural sector, the majority of participants were farmers ranging from organic dairy to large corn/soybean operations. Several ag-service providers, from Extension, NRCS, SWCD, and a rural bank, also attended. The forest sector group was attended by members of the Minnesota Forest Resources Partnership, including public and private forest managers. Government sector participants included state and federal agencies, cities, a metropolitan planning agency, and a metropolitan park district. Conservation representatives included regional, state, and national environmental and land conservation organizations. The business sector included major agricultural and industrial firms in the Twin Cities, environmental consulting firms, and alternative energy developers.

- There was broad consensus for pursuing a multiple-benefit approach to carbon sequestration in Minnesota. Carbon sequestration could provide both the arguments and funds for more conservation practices. Ideas included windbreaks, riparian strips to protect water quality and biodiversity, highway median strips, urban forestry, and limits on wetland conversion in urban development. Participants were also interested in quantifying co-benefits and assessing opportunities for multiple income streams from environmental services (carbon, habitat, water quality, bio-energy.)
- All groups stressed the importance of access to quantified information on potential and actual carbon sequestration benefits of different practices in different environments.
- There were frequent expressions of the need for education on carbon-related matters for land managers, government, and the public. Carbon and sequestration are difficult concepts. People need a better understanding of what carbon is and why it's important. They also need to understand what terrestrial sequestration is and how it could be applied in Minnesota. To make progress, a broad constituency for "carbon conservation" needs to be developed.
- Leveraging existing programs is crucial to getting started quickly. Suggestions included expanding Farm Bill incentives, coordinating with water quality trading programs, expanding implementation of the national, state, and county forest plans and of the Forest Legacy Program to keep working forests from being developed.

- The natural synergisms between biomass energy production and carbon sequestration were often stressed. People repeatedly urged that the sequestration potential of Minnesota's bio-energy initiative be explored and promoted.
- There is general curiosity and interest in the carbon market and opportunities to attract investment to conservation practices. There were very practical questions about how carbon trading could work, what trade-offs with productivity or other goals might exist, and how economically feasible and profitable these practices might be.
- Legal concerns surfaced about how changing government administrations and policies might put investments at risk. One policy issue of particular interest is the likelihood of federal greenhouse gas regulations. It was widely noted that until federal or state governments make reduction commitments, the strength of market mechanisms is limited.
- There were many suggestions about steps Minnesota could take to assist landowners with sequestration projects. Many centered on the idea of a carbon bank, registry, or fund that could help finance projects, aggregate credits, and handle transactions.
- Future research agendas should include development of accessible, user-friendly information on the state's carbon resources, the net carbon effects of different forestry and agricultural practices, simplified ways to monitor and verify results, and – for biomass energy – which feedstocks could provide benefits to land, waters, biodiversity, and sequestration.
- There was broad support for a group of demonstrations ("Minnesota Pilot Sites") to educate, test ideas, remove roadblocks, and attract investment. Sequestration demonstrations would likely be long-term projects, requiring a minimum of ten years. Many participants expressed an urgency to model, pilot, and evaluate different activities for broader application. All sectors expressed strong interest in participating in demonstrations of aspects of implementing a carbon sequestration initiative.

Key findings and recommended next steps

This paper has explored policies and programs affecting the protection and enhancement of terrestrial carbon sinks. Chief findings and recommendations are:

- **Finding:** Conservation and sequestration of carbon, while not geologically permanent, can provide significant benefits to climate protection efforts. IPCC estimates that terrestrial carbon sequestration has the potential to offset 10 – 20% of fossil fuel emissions over the next 50 years. This potential, however, is uncertain, because of evidence that the strength of forest and other sinks could level off and decline over the next century. Total terrestrial sequestration in the United States has declined by approximately 14% between 1990 and 2004. There is also growing concern about the vulnerability of northern peatlands to changes in temperature and precipitation. The decline or reversal of present day sinks would likely accelerate global warming and require deeper reductions in fossil fuel emissions. The magnitude of Minnesota's principal carbon sinks – forests, soils, wetlands, and peatlands – indicate that their protection and effective management is an integral part of the state's climate-related programs.
- A fundamental requirement for assessing carbon sequestration options for Minnesota is basic technical information on the state's carbon sinks, including estimated carbon stocks and fluxes, vulnerabilities, and management options for different ecosystems. Benchmarking current conditions would help identify where protection efforts are needed and where enhancement activities would provide the greatest benefits. Clear, long-term quantitative carbon sink information would create valuable information about the potential role of sequestration in mitigating CO_2 emissions in the state; create a baseline for carbon marketing and other measurement purposes; and give direction to public and private land managers, carbon project sponsors, and investors. The inventory could also provide assessment of contribution of existing programs to sequestration goals.

  Recommendation # 1a: Develop an inventory of Minnesota's carbon sinks to quantify existing and potential carbon stocks and flows of different ecosystems and regions. Create a central database to link relevant state programs and facilitate integration of carbon management into other conservation efforts.

  Recommendation # 1b: Use the carbon inventory to project potential values of regional sinks, to assess risks and mitigation strategies, and to help guide programs for public management and private investment.
- **Finding:** Terrestrial carbon sequestration offers opportunities and mechanisms for affecting large-scale sustainable management of the state's natural and agricultural resources. Well-designed and properly-sited projects have the potential to benefit the climate, regional environment, and forest and agricultural resources. Terrestrial sequestration projects that promote synergisms among environmental stewardship, adaptive management, and climate protection would maximize project benefits, improve cost-effectiveness, and improve chances of implementation and long-term public support. Leveraging terrestrial carbon sequestration with biomass and renewable energy, water quality, private lands stewardship, and public land management would incentivize integrated approaches and partnerships.

Recommendation # 2a: Create a stakeholder council to provide advice and recommendations on terrestrial sequestration strategies. Look for opportunities for private-public partnerships to ramp up existing programs

Recommendation # 2b: Identify win-win-win strategies for climate, environmental, and socio-economic goals. Encourage development of high-quality sequestration projects that integrate climate mitigation and adaptation to negative impacts of climate change.

- **Finding:** Many Minnesota farmers and foresters are interested in carbon sequestration and offset opportunities developing in other states and nations. At present, Minnesota has no identified infrastructure for assisting or educating landowners about how to access these opportunities. This is particularly true for smaller projects which can sometimes provide the greatest benefits to carbon sinks and other environmental services. As stand-alone projects, these are the most difficult and expensive to incorporate into environmental trading programs. Aggregators of portfolios can facilitate smaller projects by offering technical and financial assistance, access to markets, and reduced transaction costs associated with MMV, accounting, and other requirements needed to maintain public confidence.

  Recommendation # 3a: Provide information to Minnesota landowners and policymakers about alternative approaches to trading, registering, aggregating, investing, and banking carbon emissions credits,

  Recommendation # 3b: Evaluate and make recommendations on increasing investments in multiple-benefit terrestrial carbon sequestration, including carbon credit aggregation, carbon banks, and carbon offset funds.

- **Finding:** Long-term commitment to funding research and demonstration of sequestration options is crucial. Limited quantified data on the broad range of sequestration options, particularly on agricultural and other non-forested land, presents a hurdle for land managers, project investors, and policymakers. Of particular concern is lack of MMV tools that are technically feasible, sufficiently accurate, and not cost-prohibitive. Until corrected, this lack will either exclude desirable project types from emissions trading programs or discount their value.

  It is incumbent upon policymakers to define a strategy for using terrestrial sequestration that will demonstrably reduce the state's greenhouse gas inventory. Demonstration projects are needed not only to document how different sequestration practices affect carbon stocks and other environmental resources. They should also test economic and transactional feasibilities, public and private roles and responsibilities, and other real-world concerns related to carbon offsets. Long-term demonstrations that test adaptive management options should be included. High-profile demonstrations in different parts of the state would maximize their educational value for policymakers, land managers, and the public at large.

  Stakeholder groups express strong interest in learning more about terrestrial carbon sequestration, global warming mitigation, carbon markets, and other issues touched on in this paper. A multi-faceted program to educate landowners and decision-makers would increase adoption and effectiveness of carbon management practices. Successful models exist in many states for increasing public dialogue and knowledge needed for long-term support.

Recommendation # 4a: Develop long-term research agendas to address needed science, economic, management, and policy questions in a timely and efficient way. Convene an expert panel from academia, government, business, and stakeholder groups to assist in developing a comprehensive research agenda and funding plan.

Recommendation # 4b: A systematic approach should be used to identify demonstration projects utilizing a variety of sequestration approaches to achieve target reductions in greenhouse gas inventories.

Recommendation # 4c: Involve educators from University of Minnesota Extension, federal, state, and local agencies, and non-profit organizations to develop multi-faceted outreach and education programs.

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