How Can We Improve the Usefulness of Carbon Science for Decision Making?

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KEY FINDINGS

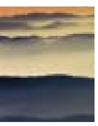
- Decision makers are seeking more comprehensive information on the carbon cycle and on carbon management options across scales and sectors. Carbon management is a relatively new concept not only for decision makers and members of the public, but also for the science community.
- Improving the usefulness of carbon science in North America will require stronger commitments to generating high quality science that is also decision-relevant.
- Research on the production of policy-relevant scientific information suggests several ways to improve the usefulness of carbon science for decision making, including co-production of knowledge, development of applied modeling tools for decision support, and use of "boundary organizations" that can help carbon scientists and decision makers communicate and collaborate.
- A number of initiatives to improve understanding of decision support needs and options related to the carbon cycle are under way, some as a part of the Climate Change Science Program (CCSP).
- Additional pilot projects should be considered aimed at enhancing interactions between climate change scientists and parties involved in carbon management activities and decisions.

5.1 INTRODUCTION: THE CHALLENGE OF "USABLE" CARBON SCIENCE

This chapter answers two questions:

- How well is the carbon cycle science community doing in "decision support" of carbon cycle management, *i.e.*, in responding to decision makers' demands for carbon cycle management information?
- How can the carbon cycle science community improve such decision support?

Chapters in Parts 2 and 3 of this report identify many research priorities, including assessing the potential for geological storage of carbon dioxide (CO_2), quantifying expansion of the North American carbon sink, and identifying the economic impact of carbon tax systems. This chapter focuses on improving communication and collaboration between scientific researchers and carbon managers, to help researchers be more responsive to decision making, and carbon managers be better informed in making policy, investment, and advocacy decisions.



Humans have been inadvertently altering the Earth's carbon cycle since the dawn of agriculture, and more rapidly since the industrial revolution. These influences have become large enough to cause significant climate change (IPCC, 2007). In response, environmental advocates, business executives, and policy-makers have increasingly recognized the need to manage the carbon cycle deliberately. Effective carbon management requires that the variety of people whose decisions affect carbon emissions and sinks have relevant, appropriate science. Yet, carbon cycle science is rarely organized or conducted to support decision making on managing carbon emissions, uptake and storage (sequestration), and impacts. This reflects that, until recently, scientists have approached carbon cycle science as basic science and only a relatively small, although growing, portion of non-scientist decision makers have demanded carbon cycle information. Consequently, emerging efforts to manage carbon are less informed by carbon cycle science than they could be (Dilling *et al.*, 2003). Applying carbon science to carbon management requires making carbon cycle science more useful to public and private decision-makers at all levels, from national and international policymakers to the executives and employees of corporations to the millions of individuals whose myriad consumer and household decisions are central to human impacts on the carbon cycle. In particular, scientists and decision makers will need to identify the information most needed in specific sectors for carbon management, adjust research priorities, and develop mechanisms that enhance the credibility of the information generated and the responsiveness of the information-generating process to address stakeholder's views (Lahsen and Nobre, 2007; Mitchell *et al.*, 2006; Cash *et al.*, 2003). Combining some "applied" or "solutions-oriented" research with a portfolio that also includes basic science would make carbon science more directly relevant to decision making.

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5.2 TAKING STOCK: WHERE ARE WE NOW IN PROVIDING DECISION SUPPORT TO IMPROVE CAPACITIES FOR CARBON MANAGEMENT?

How effective is the scientific community at providing decision support for carbon management? The Climate Change Science Program (CCSP) Strategic Plan defines decision support as: "the set of analyses and assessments, interdisciplinary research, analytical methods, model and data product development, communication, and operational services that provide timely and useful information to address questions confronting policymakers, resource managers, and other stakeholders" (U.S. Climate Change Science Program, 2003).

Who are the potential stakeholders for information related to the carbon cycle and what are the options and measures for altering human influences on that cycle? Most people constantly, but unconsciously, make decisions that affect the carbon cycle through their use of energy, transportation, living spaces, and natural resources. Increasing attention to climate change has led some policy makers, businesses, advocacy groups, and consumers to begin making choices that consciously limit carbon emissions[1]. Whether carbon emission reductions are driven by political pressures or legal requirements, by economic opportunities, or consumer pressures, or by moral or ethical commitments to averting climate change, people and organizations are seeking information that can help them achieve their specific carbon-related or climate-related goals[2]. Even in countries and economic sectors that lack a consensus on the need to manage carbon, some people and organizations have begun to experiment with carbon-limiting practices and investments in anticipation of a carbon-constrained future.

[1] For examples, see Box 5.1

[2] For example, carbon science was presented at recent meetings of the West Coast Governors' Global Warming Initiative and the Climate Action Registry [http://www.climateregistry.org/EVENTS/PastConferences/; http://www.climatechange.ca.gov/events/2005_conference/presentations/]

In designing and producing this report, we engaged individuals from a wide range of sectors and activities, including forestry, agriculture, utilities, fuel companies, carbon brokers, transportation, non-profits, and local and federal governments. Although we did not conduct new research on the informational or decision support needs of stakeholders, a preliminary review suggests that many stakeholders may be interested in carbon-related information (see Box 5.1).

5.3 CURRENT APPROACHES AND TRENDS

Interest in, and attention paid to, carbon information has increased incrementally over the last 20 years. Future levels of interest are likely to depend on perceived risks from carbon emissions as well as on whether and how mandatory and incentive-based policies related to carbon management evolve. As efforts at deliberate carbon management become increasingly common, decision makers from the local to the national level are increasingly open to or actively seeking carbon science information as a direct input to policy and investment decisions (Apps *et al*., 2003). The government of Canada, having ratified the Kyoto Protocol, has been exploring emission reduction opportunities and offsets and has identified specific needs for applied research (Environment Canada, 2005). For example, Canada's national government recently entered a research partnership with the province of Alberta to assess geological sequestration of CO_2, to develop fuel cell technologies using hydrogen, and to expand the use of vegetative matter (biomass) and biowaste for energy production (Western Economic Diversification Canada, 2006).

Some stakeholders in the United States are actively using carbon science to move forward with voluntary emissions offset programs. For example, the Chicago Climate Exchange brokers agricultural carbon credits in partnership with the Iowa Farm Bureau[3]. Many cities and several states have established commitments to manage carbon emissions, including regional partnerships on the east and west coasts, and non-governmental organizations and utilities have begun to experiment with pilot sequestration projects (Box 5.1). In Europe, for example, mandatory carbon emissions policies have resulted in intense interest in carbon science by those directly affected by such policies (Schröter *et al*., 2005).

In the United States, federal carbon science has very few mechanisms to assess demand for carbon information across scales and sectors. Thus far, federally-funded carbon science has focused on basic research to clarify fundamental uncertainties in the global carbon cycle and local and regional processes affecting the exchange of carbon (Dilling, in press). Most federal efforts are organized under the CCSP. The National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) manage almost two-thirds of this effort and their missions are limited to basic research, not decision support (CCSP, 2006; Dilling, 2007). Research efforts have also been undertaken at the Department of Energy (DOE), the Department of Agriculture (USDA)[4], and the Department of Interior's Geological Survey (USGS/DOI). Significant technology efforts are underway in the Climate Change Technology Program (CCTP), a sister program to the CCSP focused on technology development. Increasing linkages among these programs may increase the usefulness of CCSP carbon-related research to decision makers. For over a decade, the National Oceanic and Atmospheric Administration (NOAA) Climate Program Office has invested in research and institutions intended to improve the usability of climate science, although that investment is small relative to the investment in climate science itself and has focused on the usability of climate, rather than carbon cycle, science.

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Until recently, the concept of "carbon management" has not been widely recognized—even now, most members of the public do not understand the term "carbon sequestration" or its potential implications (Shackley *et al*., 2005; Curry *et al*., 2004). However, the carbon cycle science community is beginning to recognize that it may have information relevant to policy and decision making. Thus prominent carbon scientists have called for "coordinated rigorous, interdisciplinary research that is strategically prioritized to address societal needs" (Sarmiento and Wofsy, 1999) and the North American Carbon Program's (NACP) "Implementation Plan" lists decision support as one of four organizing questions (Denning *et al*., 2005).

That same plan, however, states that the scientific community knows relatively little about the likely users of information that the NACP will produce. Indeed, the National Academy of Sciences' review of the CCSP stated that "as the decision support elements of the program are implemented, the CCSP will need to do a better job of identifying stakeholders and the types of decisions they need to make" (NRC, 2004). Moreover, they state that "managing risks

[3] http://www.iowafarmbureau.com/special/carbon/default.aspx

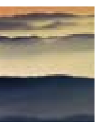
[4] For example, the Consortium for Agricultural Soil Mitigation of Greenhouse Gases (CASMGS) was recently funded by the USDA to provide information and technology necessary to develop, analyze, and implement carbon sequestration strategies.

BOX 5.1: Sectors and Stakeholders Expressing Interest and/or Participating in the SAP 2.2 Process

This list of sectors is neither exhaustive nor is it based on a systematically rigorous assessment, but is meant to demonstrate the wide variety of stakeholders with a potential interest in carbon-related information.

Agriculture: Tillage and other farming practices significantly influence carbon storage in agricultural soils. Managing these practices presents opportunities both to slow carbon loss and to restore carbon in soils. Farmers have been quite interested in carbon management as a means to stimulate rural economic activity. Since much of the agricultural land in the United States is privately owned, both economic forces and governmental policies will be critical factors in the participation of this sector in carbon management. (Chapter 10 this report).

Forestry: Forests accumulate carbon in above-ground biomass as well as soils. The carbon impact of planting, conserving, and managing forests has been an area of intense interest in international negotiations on climate change (IPCC, 2000). Whether seeking to take advantage of international carbon credits, to offset other emissions, or to simply identify environmental co-benefits of forest actions taken for other reasons, governments, corporations, landowners, and conservation groups may need more information on and insight into the carbon implications of forestry decisions ranging from species selection to silviculture, harvesting methods, and the uses of harvested wood. (Chapter 11 this report).



Utilities and Industries: In the United States, over 85% of energy produced comes from fossil fuels with relatively high carbon intensity. The capital investment and fuel source decisions of utilities and energy-intensive industries thus have major carbon impacts. A small but growing number of companies have made public commitments to reducing carbon emissions, developed business models that demonstrate sensitivity to climate change, and begun exploring carbon capture and storage opportunities. For example, Cinergy, a large Midwestern utility, has experimented with carbon-offset programs in partnership with The Nature Conservancy. (Chapter 6 and 8 this report).

Transportation: Transportation accounts for approximately 37% of carbon emissions in the United States, and about 22% worldwide. Governmental infrastructure investments, automobile manufacturers' decisions about materials, technologies and fuels, and individual choices regarding auto purchases, travel modes, and distances all have significant impacts on carbon emissions. (Chapter 7 this report).

Government: In the United States, national policies currently rely primarily on voluntary measures and incentive structures (U.S. Department of State, 2004; Richards, 2004). Canada, having ratified the Kyoto Protocol, has direct and relatively immediate needs for information that can help it meet its binding targets as cost-effectively as possible (Environment Canada, 2005). The Mexican government appears to be particularly interested in locally relevant research on natural and human influences on the carbon cycle, likely impacts across various regions, and the costs, benefits, and viability of various management options (Martinez and Fernandez-Bremauntz, 2004). Below the national level, more and more states and local governments are taking steps, including setting mandatory policies, to reduce carbon emissions, and may need new carbon cycle science scaled to the state and local level to manage effectively. For example, nine New England and mid-Atlantic states have formed a regional partnership, also observed by Eastern Canadian provinces, to reduce carbon emissions through a cap and trade program combined with a market-based emissions trading system (Regional Greenhouse Gas Initiative—RGGI—www.rggi.org). (Chapters 4 and 14 this report).

Non-Profits and Non-Governmental Organizations (NGOs): Many environmental and business-oriented organizations have an interest in carbon management decision making. Such organizations rely on science to support their positions and to undercut the arguments of opposing advocates. There has been substantial criticism of "advocacy science" in the science-for-policy literature, and new strategies will need to be developed to promote constructive use of carbon cycle science by advocates (Ehrmann and Stinson, 1999; Adler *et al.*, 1999).

and opportunities requires stakeholder support on a range of scales and across multiple sectors, which in turn implies an understanding of the decision context for stakeholders" (NRC, 2004). Successful decision support (*i.e.*, science that improves societal outcomes) requires understanding of who the users are and of the kind of information they are likely to deem relevant and bring to bear on their decision making. Without such knowledge, information runs the risk of being "left on the loading-dock" and not used (Cash et al., 2006; Lahsen and Nobre, 2007).

Some programs within CCSP may shed light on how to link carbon science to user needs. NASA has an Applied Sciences program that seeks to find uses for its data and modeling products using "benchmarking systems," and the USDA and DOE have invested significant resources in science that might inform carbon sequestration efforts and carbon accounting in agriculture and forests. However, these programs have not been integrated into a broader framework self-consciously aimed at making carbon cycle science more useful to decision makers.

Funding agencies, scientists, policy makers, and private sector managers can improve the usefulness of carbon science programs in North America by increasing their commitments to generating decision-relevant carbon cycle information and by integrating those programs more fully into forums and institutions involved in carbon cycle management. The participatory methods and boundary spanning institutions identified in the next section help both refine research agendas and accelerate the application of research results to carbon management and societal decision making.

5.4 OPTIONS FOR IMPROVING THE APPLICABILITY OF SCIENTIFIC INFORMATION TO CARBON MANAGEMENT AND DECISION MAKING

Studies of the creation and use of knowledge for decision making have found that information must be perceived not only as credible, but also as relevant to high priority decisions and as stemming from a process that decision makers view as responsive to their concerns (Mitchell *et al.*, 2006; Cash *et al.*, 2003). Even technically and intellectually rigorous science lacks influence with decision makers if decision makers perceive it as not addressing the decisions they face, as being biased, or as having ignored their views and interests.

Research on the production of policy-relevant scientific information suggests several strategies that can maintain the integrity of the research endeavor while increasing its policy relevance. Although communicating results more effectively is clearly important, generating science that is more applicable to decision making may require deeper changes in the way scientific information is produced. Carbon cycle scientists and carbon decision makers will need to develop methods for interaction that work best in the specific arenas in which they work. At their core, strategies will be effective to the extent that they promote interaction among scientists and stakeholders in the development of research questions, selection of research methods, and review, interpretation, and dissemination of results (Adler *et al.*, 1999; Ehrmann and Stinson, 1999; NRC, 1999; NRC, 2005; Farrell and Jaeger, 2005; Mitchell *et al.*, 2006). Such processes work best when they enhance the usability of the research while preserving the credibility of both scientists and stakeholders. Transparency and expanded participation are important for guarding against politicization and enhancing usability.

Examples of joint scientist-stakeholder development of policy relevant scientific information include:

- *Co-production of research knowledge (e.g., Regional Integrated Sciences and Assessments)*: In regional partnerships across the United States, university researchers work closely with local operational agencies and others that might incorporate climate information in decision making. New research is developed through ongoing, iterative consultations with all partners (Lemos and Morehouse, 2005). Co-production of research knowledge involves efforts to reach out to, educate, and involve stakeholders in programs that facilitate a dialog of researchers and stakeholders consulting with and engaging each other in identifying near-term research questions and longer-term research trajectories.

- *Institutional experimentation and adaptive behavior* (*e.g., adaptive management)*: Adaptive management acknowledges our inherent uncertainty about how natural systems respond to human management, and periodically assesses the outcomes of management decisions and adjusts those decisions accordingly, a form of deliberate "learning by doing" (*cf.,* Holling, 1978). Adaptive management principles have been applied to several resources where multiple stakeholders are involved, including management of river systems and forests (Holling, 1995; Pulwarty and Redmond, 1997; Mitchell *et al.*, 2004; Lemos and Morehouse, 2005).
- *Assessments as policy components* (*e.g., recovering the stratospheric ozone layer)*: Assessments that were credible, relevant, and responsive played a significant role in the Montreal Protocol's success in phasing out the use of ozone-depleting substances. A highly credible scientific and technical assessment process with diverse academic and industry participation is considered crucial in the Protocol's success (Parson, 2003).
- *Mediated modeling*: Shared tools can facilitate scientist-user interactions, help diverse groups develop common knowledge and understanding of a problem, and clarify common assumptions and differences. In mediated modeling, participants from a wide variety of perspectives jointly construct a computer model to solve complex environmental problems or envision a shared future. The process has been used for watershed management, endangered species management, and other difficult environmental issues (Van den Belt, 2004).
- *Carbon modeling tools as decision support*: Although the United States government has not yet adopted a carbon management policy, some federal agencies have begun to develop online decision support tools, with customizable user interfaces, to estimate carbon sequestration in various ecosystems and under various land-use scenarios (see the NASA Ames Carbon Query and Evaluation Support Tools, http://geo.arc.nasa.gov/sge/casa/cquestwebsite/index.html; the U.S. Forest Service Carbon Online Estimator, http://ncasi.uml.edu/COLE/;and Colorado State's CarbOn Management Evaluation Tool, http://www.cometvr.colostate.edu/).

Over time, well-structured scientist-stakeholder interaction can help both scientists and decision makers (Moser, 2005). Scientists learn to identify research questions that are both scientifically interesting and relevant to decisions, and to present their answers in ways that audiences are more likely to find compelling. Non-scientists learn what questions science can and cannot answer. Such interactions clarify the boundary between empirical questions that scientists can answer (*e.g.*, the sequestration potential of a particular technology) and issues that require political resolution (*e.g.*, the appropriate allocation of carbon reduction targets across firms). Institutional arrangements can convert *ad hoc* successes in scientist-stakeholder interaction into systematic and ongoing networks of scientists, stakeholders, and managers. Such "co-production of knowledge," can enhance both the scientific basis of policy and management and the research agenda for applied science (Lemos and Morehouse, 2005; Gibbons *et al*., 1994; Patt *et al*., 2005a).

That said, such interactive approaches have limitations, risks, and costs. Scientists may be reluctant to involve non-scientists who "should" be interested in a given issue, but who can add little scientific value to the research, and whose involvement requires time and effort. Involving private sector firms may require scientists accustomed to working in an open informational environment to navigate in a world of proprietary information. Scientists may also avoid applied, participatory research if they do not see it producing the "cutting edge" (and career enhancing) science most valued by other scientists (Lahsen and Nobre, 2007; Lemos and Morehouse, 2005). Public and private carbon cycle science programs, as well as universities and research institutes, more generally, can help address these obstacles by recognizing that they exist and altering incentive structures to reward innovation in applied research through endowed chairs, fellowships, research grants, and the like.

Some stakeholders may lack the financial resources, expertise, time, or other capacities necessary to meaningful participation. Some will distrust scientists in general, and government-sponsored science in particular, for cultural, institutional, historical, or other reasons. Some may reject the idea of interacting with those with whom they disagree politically or compete economically. Stakeholders may try to manipulate research questions and findings to serve their political or economic interests. In addition, stakeholders often show little interest in diverting their time from other activities to what they perceive as the slow and too-often fruitless pursuit of scientific knowledge (Patt *et al*., 2005b).

Where direct stakeholder participation proves too difficult, costly, unmanageable, or unproductive, scientists and research managers need other methods to identify the needs of potential users. Science on the one hand, and policy, management, and decision making on the other, often exist as separate social and professional realms, with different traditions, norms, codes of behavior, and reward systems. The boundaries between such realms serve many useful functions but can inhibit the transfer of useful knowledge across those boundaries. A boundary organization is an institution that "straddles the shifting divide" between politics and science (Guston, 2001). Boundary organizations are accountable to both sides of the boundary and involve professionals from each. Boundary spanning individuals and organizations may facilitate the uptake of science by translating scientific findings so that stakeholders find them more useful and by stimulating adjustments in research agendas and approach.

Boundary organizations can exist at a variety of scales and for a variety of purposes. For example, cooperative agricultural extension services and non-governmental organizations (NGOs) successfully convert large-scale scientific understandings of weather, aquifers, or pesticides into locally-tuned guidance to farmers (Cash, 2001). The International Research Institute for Climate Prediction focuses on seasonal-to-interannual scale climate research and modeling to make their research results useful to farmers, anglers, and public health officials (*e.g.*, Agrawala *et al*., 2001). The Subsidiary Body for Scientific and Technological Advice of the United Nations Framework Convention on Climate Change serves as an international boundary organization that links information and assessments from expert sources (such as the Intergovernmental Panel on Climate Change [IPCC]) to the Conference of the Parties, which focuses on setting policy[5]. The University of California Berkeley Digital Library Project *Calflora* has explicitly designed their database on plants to support environmental planning (Van House *et al*., 2003).

Though attractive in principle, boundary organizations may not be effective in practice. They may fail to be useful if they are not responsive to both the stakeholders and scientists they seek to engage. They may be captured by one particular stakeholder or science interest. Their usefulness may decline over time if they are unable to keep pace with the salient issues of the principals on either side of the boundary.

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Even where boundary organizations do facilitate the translation of scientific expertise for policy, other significant challenges exist in the use of knowledge. People fail to integrate new research and information in their decisions for many reasons. People often are not motivated to use information that supports policies they dislike or that conflicts with pre-existing preferences, interests, or beliefs, or with cognitive, organizational, sociological, or cultural norms (*e.g.*, Douglas and Wildavsky, 1984; Lahsen, 1999; Yaniv, 2004; Lahsen, 2007). These tendencies are important components of a healthy democratic process. Developing processes to make carbon science more useful to decision makers will not guarantee its use, but will make its use more likely.

5.5 RESEARCH NEEDS TO ENHANCE DECISION SUPPORT FOR CARBON MANAGEMENT

The demand for detailed analysis of carbon management issues and options across major economic sectors, nations, and levels of government in North America is likely to grow substantially in the near future. This will be especially true in jurisdictions that place policy constraints on carbon budgets, such as Canada, United States' states comprising the Regional Greenhouse Gas Initiative, or the U.S. State of California. Although new efforts are underway in some federal agencies, carbon cycle science in the United States could be organized and carried out to better and more systematically meet this potential demand. Effective implementation of the goals of the Climate Change Science Program "requires focused research to develop decision support resources and methods" (NRC, 2004). Relevant science could evaluate the impacts, technical feasibility, and economic potential of the wide range of existing and newly-developed options that are likely to be proposed in response to growing regional and national interest in carbon management.

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5 http://unfccc.int/2860.php

Creating information for decision support should differ significantly from doing basic science. In such "use-inspired research," societal need is as important as scientific curiosity (Stokes, 1997). Scientists and carbon managers need to improve their joint understanding of the top priority questions facing carbon-related decision making. They need to collaborate more effectively in undertaking research and interpreting results in order to answer those questions.

A first step might involve developing a formal process "for gathering requirements and understanding the problems for which research can inform decision makers outside the scientific community," including forming a decision support working group (Denning *et al*., 2005). The NRC has recommended that the CCSP's decision support components could be improved by organizing various deliberative activities, including workshops, focus groups, working panels, and citizen advisory groups to: "1) expand the range of decision support options being developed by the program; 2) to match decision support approaches to the decisions, decision makers, and user needs; and 3) to capitalize on the practical knowledge of practitioners, managers, and laypersons" (NRC, 2004).

5.6 SUMMARY AND CONCLUSIONS

The carbon cycle is influenced through both deliberate and inadvertent decisions by diverse and spatially dispersed people and organizations, working in many different sectors and at different scales. To make carbon cycle science more useful to decision makers, we suggest that leaders in the scientific and program level carbon science community initiate the following steps:

- Identify categories of decision makers for whom carbon cycle science is a relevant concern, focusing on policy makers and private sector managers in carbon-intensive sectors (energy, transport, manufacturing, agriculture, and forestry).
- Evaluate existing information about carbon impacts of actions in these arenas, and assess the need and demand for additional information. In some cases, demand may need to be fostered through an interactive process.
- Encourage scientists and research programs to experiment with incremental, as well as major, departures from existing practice with the goal of making carbon cycle science more credible, relevant, and responsive to carbon managers.
- Involve experts in the social sciences and communication as well as experts in physical, biological, and other natural science disciplines in efforts to produce usable science.
- Consider initiating participatory pilot research projects and identifying existing boundary organizations (or establishing new ones) to bridge carbon management and carbon science.