Chapter 5. How Can We Improve the Application of Scientific Information to Decision Support Related to Carbon Management and Climate Decision-Making?

Coordinating Lead Authors: Lisa Dilling[1] and Ronald Mitchell[2]

Lead Author: David Fairman[3]

Contributing Authors: Myanna Lahsen,[4] Susanne Moser,[5] Anthony Patt,[6] Chris Potter,[7] Charles Rice,[8] and Stacy VanDeveer[9]

[1]University of Colorado/National Center for Atmospheric Research (NCAR); [2]University of Oregon; [3]Consensus Building Institute, Inc.; [4]Affiliated with University of Colorado, on location in Brazil; [5]Institute for the Study of Science and the Environment, NCAR; [6]Boston University; [7]National Aeronautics and Space Administration, Ames; [8]Kansas State University; [9]University of New Hampshire

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KEY FINDINGS

- Information is lacking on emerging needs and demands for carbon cycle related data and analyses across scales and sectors. In fact, carbon management is a relatively new concept for most decision-makers and members of the public.
- Improving the usefulness of carbon science in North America will require more explicit commitments to generate decision-relevant information.
- Research on the production of policy-relevant scientific information suggests a number of options, from co-production of knowledge to uses of modeling tools in decision support structures and certain uses of “boundary organizations.”
- A number of initiatives to improve understandings 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).
- Further participatory pilot experiments should be considered to enhance interactions between climate change scientists and parties involved in carbon management activities and decisions.

INTRODUCTION: THE CHALLENGE OF "USABLE" CARBON SCIENCE

Humans have been inadvertently altering the Earth's carbon cycle since at least the dawn of agriculture, and more rapidly since the industrial revolution. Recent climate science has shown that these influences are large enough to cause significant climate change (IPCC, 2001). In response, environmental advocates, business executives, and policy-makers have increasingly recognized the need for deliberate management of the carbon cycle. Effective carbon management would seem to require that relevant, appropriate science be communicated to the wide variety of people whose decisions affect carbon cycling. Yet, thus far, carbon cycle science has rarely been organized or conducted in ways that directly support decision making on managing carbon emissions, sequestration, and impacts. There are two main reasons: (1) carbon cycle science has been conducted primarily as basic science[1] and (2) non-scientists have only recently begun to demand carbon cycle information for decision making. As a result, the emerging efforts to consciously manage carbon occur in the virtual absence of information and insights on whether these efforts are appropriate, sufficient, or implemented effectively relative to the needs to reduce carbon emissions and atmospheric concentrations (Dilling *et al*., 2003). To make carbon cycle science more relevant to public and private decision makers, scientists and decision makers will need to clarify what information is most needed in specific sectors and arenas for carbon management, adjust research priorities as necessary, and develop mechanisms that enhance the credibility and legitimacy of the information being generated—in short, they will need to collaborate to make carbon cycle science and analysis more "usable" (Mitchell *et al*., forthcoming; Cash *et al*., 2003). Such a component of more "applied" or "solutions-oriented" research could be combined with a basic science portfolio to make carbon science more directly relevant to decision making.

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

The first question to address then is what might we consider "decision support?" There are many different uses of the term. We adopt the definition of decision support included in the U.S. Climate Change Science Program (CCSP) Strategic Plan: "Decision support resources refers to 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 options and measures? Most people constantly if 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 in these sectors to begin

[1] Carbon cycle research has been applied to agricultural soil management for a number of years; however, the focus has been on improving agricultural productivity, not limiting carbon concentrations in the atmosphere.

making more conscious choices to limit carbon emissions.[2] Whether driven by normative commitments to averting climate change, by political pressures or requirements to reduce carbon emissions, or by economic opportunities and consumer pressures, actors in these sectors are beginning to seek out information that can help them achieve their specific carbon-related goals, including those that relate to or affect the carbon cycle and the climate.[3] Even in countries and economic sectors where no consensus exists on the need to manage carbon, some entities have begun to experiment with carbon-limiting practices and investments in anticipation of a carbon-constrained future.

As part of the process of 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 needs of these stakeholders for information and decision support capabilities, a preliminary review of their interests and activities suggests that there are many stakeholders potentially interested in carbon-related information (see Text Box 1).

CURRENT APPROACHES AND TRENDS

As we enter an era of deliberate carbon management, 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 delineated needs for applied research (Government of Canada, 2005). A few prominent stakeholders in the U.S. are actively using carbon science to move forward with voluntary emissions offset programs such as the Chicago Climate Exchange, which brokers, among other mechanisms, agricultural carbon credits in partnership with the Iowa Farm Bureau.[4] Cities and states, including large regional partnerships on the east and west coasts, are beginning to show interest in managing emissions and carbon-related science (Text Box 1). In addition to these select visible, active stakeholders for carbon-related information, there may be many other potential stakeholders in the U.S. across sectors and scales (Text Box 1). Whether or not interest in carbon information emerges broadly in these constituencies may well depend on whether and how mandatory policies involving carbon management evolve, and what incentives might be put in place. In Europe, for example, mandatory carbon emissions policies have resulted in intense interest in carbon science from interested stakeholders who are directly affected by such policies (Schröter *et al*., 2005).

[2] For examples, see Text Box 1
[3] 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/]
[4] www.iowafarmbureau.com/special/carbon/default.aspx

In the U.S., the federal carbon science enterprise does not have many mechanisms to assess emerging demands for carbon information across scales and sectors. Thus far, federally-funded carbon science has focused predominantly on basic research in order to elucidate some of the fundamental uncertainties in the global carbon cycle and local and regional processes affecting the exchange of carbon (Dilling, in review). Most of the effort at the U.S. federal level is organized under the Climate Change Science Program (CCSP). Almost two-thirds of this effort is managed by the National Aeronautics and Space Administration and the National Science Foundation, whose missions are explicitly focused on basic research, not decision support per se (U.S. Climate Change Science Program, 2006; Dilling, in review). There are research efforts at a relatively lower level of investment at the Department of Energy and the U.S. Department of Agriculture under the CCSP[5] as well as significant technology efforts under the Climate Change Technology Program (CCTP), a sister program to the CCSP focused on technology development. Increasing linkages between these programs may enhance the ability of CCSP carbon-related research to serve decision support needs.

Until perhaps the past decade, carbon management as a concept was not widely recognized—even now, most members of the public do not know the term "carbon sequestration" or understand its potential implications (Shackley *et al*., 2005; Curry *et al*., 2004). In more recent years, however, the carbon cycle science community has increasingly recognized that it may have more direct relevance to issues of policy and decision making, calling for "coordinated rigorous, interdisciplinary research that is strategically prioritized to address societal needs" (Sarmiento and Wofsy, 1999). The North American Carbon Program's (NACP) "Implementation Plan" lists decision support as one of four organizing questions (Denning *et al*., 2005).

As stated in that same plan, however, little is known in the scientific community about the likely users of decision support information that might emerge from a program such as the NACP. 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" (National Research Council, 2004). Moreover, they state that "managing risks 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" (National Research Council, 2004).

There are two programs within the CCSP framework that may inform this question of how to link carbon science to user needs more explicitly in the coming years. NASA has an Applications program

[5] 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.

that seeks to find uses for its data and modeling products using a "benchmarking systems" approach, and USDA and DOE have invested significant resources in science that might inform future carbon sequestration efforts and carbon accounting in agriculture and forests. Conducted as separate efforts, the programs have not yet been integrated into a broader framework aimed at making carbon cycle science more useful to decision makers within the CCSP carbon research agenda, but certainly may contribute to such a strategy if developed.

Improving the usefulness of carbon science in North America will require more explicit commitments by scientific research funding agencies, scientists, policy makers and private sector managers to generate decision-relevant carbon cycle information. The participatory methods and boundary spanning institutions identified in the next section may be helpful both in refining research agendas and accelerating the application of research results to carbon management and societal decision making.

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

Studies that have examined the creation and use of knowledge for decision making have found that information must be perceived not only as *credible* (worth believing), but also as *salient* (relevant to decision making on high priority issues) and *legitimate* (conducted in a way that decision makers believe is fair, unbiased and respectful of divergent views and interests) (Mitchell *et al*., forthcoming; Cash *et al*., 2003). Even the most technically and intellectually rigorous science may fail to influence decision makers if it does not address the decisions they face, or if it is conducted in a way that they perceive as biased or unresponsive to their concerns.

Research on the production of policy-relevant scientific information suggests strategies to maintain the integrity of the research endeavor while increasing its policy relevance. Although communicating results more effectively is important, generating science that is more applicable to decision making may require modifying the way scientific information is produced. Carbon cycle scientists and carbon decision makers will need to develop methods for interaction that work best in their specific application. At their core, all of these strategies promote scientist-stakeholder interaction 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; National Research Council, 1999; National Research Council, 2005; Farrell and Jaeger, 2005; Mitchell *et al*., forthcoming). Such processes work best when they enhance the research and its utility while preserving the credibility of both scientists and stakeholders. Transparency and 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 nine regional partnerships across the U.S., university researchers partner with local operational agencies and others that might incorporate climate information in decision making. New research is developed in consultation with all partners in an ongoing, iterative process (Lemos and Morehouse, 2005).
- *Institutional experimentation and adaptive behavior* (*e.g., adaptive management)*: Adaptive management is a powerful concept that acknowledges the inherent uncertainty of responses of natural systems to human management, and seeks to periodically assess the outcomes of management decisions and adjust policy decisions and new actions accordingly, a form of deliberate "learning by doing" (c.f. Holling 1978). Adaptive management principles have been applied for resources with multiple interests at stake, such as management of large river systems as well as forests in the Pacific Northwest (Holling 1995; Pulwarty and Redmond, 1997; Mitchell *et al*., 2004; Lemos and Morehouse, 2005).
- *Assessments as policy component* (*e.g., recovering the stratospheric ozone layer)*: Assessments that were credible, salient and legitimate played a significant role in the successful implementation of the Montreal Protocol which phased out the use of ozone-depleting substances. The presence of a highly credible scientific and technical assessment process with diverse participation from academics and industry scientists is credited as a key factor in the Protocol's success (Parson, 2003).
- *Mediated modeling*: Shared tools can facilitate scientist-user interactions, help diverse groups orient around a problem and illuminate common assumptions as well as differences. Mediated modeling involves a guided process in which participants from a wide variety of perspectives jointly construct a computer model that can be used in solving complex environmental problems, or envisioning a shared future. The process has been successfully used for watershed management, endangered species management and a host of other difficult environmental issues (Van den Belt, 2004).
- *Carbon modeling tools as decision support*: As carbon management within the United States is increasingly considered at the national level, some federal agencies have begun to develop decision support tools to help estimate carbon sequestration in various ecosystems and under various land use scenarios. These pilot-phase tools are available online and feature a customizable user interface (see examples such as the NASA Ames CQUEST, Carbon Query and Evaluation Support Tools, http://geo.arc.nasa.gov/website/cquestwebsite/; the U.S. Forest Service COLE, Carbon Online Estimator, http://ncasi.uml.edu/COLE/; and Colorado State COMET-VR, CarbOn Management Evaluation Tool, http://www.cometvr.colostate.edu/).

Over time, well-structured scientist-stakeholder interaction can bring substantial benefits to both scientists and decision makers (Moser, 2005). Scientists learn to identify research questions that are both scientifically interesting and relevant to decisions, and to frame their answers in ways that audiences are more likely to find compelling. Non-scientists learn more about what questions science can and cannot answer. They also 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).

Such interactive approaches to research also 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 consumes considerable time and effort. Involving private sector firms may require scientists accustomed to working in an open informational environment to navigate in a world in which much information is proprietary. Scientists may also choose not to pursue applied, participatory research if they do not see it producing the "cutting edge" (and career enhancing) science most valued by other scientists (Lemos and Morehouse, 2005).

On the stakeholder side, some may lack the financial resources, expertise, time, and other capacities needed for meaningful participation. Some will distrust scientists in general and government-sponsored science in particular due to cultural, institutional, historical, or other factors. Some may reject participation in open and public processes in which they must interact with those with whom they disagree politically or compete economically. In some cases, stakeholders will try to manipulate research questions and findings to serve their political or economic interests. Perhaps most importantly, stakeholders often show little interest in diverting their time (or that of their employees) 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 exist to a large extent as quite separate social and professional realms, with quite different traditions, norms, codes of behavior, and reward systems. The boundaries that exist between them serve many useful functions but may also inhibit the transfer of useful knowledge across those boundaries. According to Guston (2001), a boundary organization is an institution that "straddles the shifting divide" between politics and science. Boundary organizations are accountable to both sides of the boundary and involve professionals from each, as well as those serving in a mediating role. Such "boundary spanning" individuals and organizations can often facilitate the uptake of science by translating scientific findings so that stakeholders find them more user-friendly and by stimulating adjustments in research agendas and approach. Boundary organizations can exist at a variety of scales and for a wide variety of purposes. Cooperative agricultural extension services and NGOs that successfully convert large-scale scientific understandings of weather, aquifers, or pesticides into locally-tuned guidance to farmers are classic examples of boundary organizations (Cash, 2001). The International Research Institute for Climate Prediction focuses on seasonal-to-interannual scale climate research and modeling so that their research results are useful to farmers, fishermen, and public health officials (e.g., Agrawala *et al*., 2001). The Subsidiary Body for Scientific and Technological Advice (SBSTA) of the United Nations Framework Convention on Climate Change serves also as a boundary organization at an international level. The SBSTA serves as a link between information and assessments provided by expert sources (such as the IPCC) and the Conference of the Parties (COP), which focuses on setting policy.[6] The University of California Berkeley Digital Library Project Calflora project has sought to ensure that an extensive database on plants is designed and implemented in ways that support environmental planning (Van House *et al*., 2003).

And of course, there are other significant challenges to the use of knowledge, even when created through self-conscious efforts like those just delineated. People fail to integrate new research and information in their decisions for many reasons. Besides obstacles already mentioned, people often are not motivated to use information that implies or supports policies they dislike; that conflicts with pre-existing preferences, interests, or beliefs; or that conflicts with cognitive, organizational, sociological, or cultural norms (e.g., Douglas and Wildavsky, 1984; Lahsen, 1998; Yaniv, 2004; Lahsen, forthcoming). These tendencies are important components of a healthy democratic process. Developing processes to make carbon science more useful to decision makers will not guarantee that it gets used but it will make it possible and more likely that it will.

RESEARCH NEEDS TO ENHANCE DECISION SUPPORT FOR CARBON MANAGEMENT

There is likely to be substantial and growing demand for detailed analysis of carbon management issues and options across major economic sectors, nations and levels of government in North America. This is especially likely in jurisdictions that place policy constraints on carbon budgets, such as within the states comprising the Regional Greenhouse Gas Initiative, or the State of California. Although some new

[6] http://unfccc.int/2860.php

efforts are underway in parts of agencies, carbon cycle science, at least in the U.S., could be organized and carried out in ways that better meet this potential demand in a more systematic fashion. As noted by the National Research Council (2004), effective implementation of the goals of the program, as a part of the Climate Change Science Program, "requires focused research to develop decision support resources and methods." While such recommendations were stated for the whole of the program, they are pertinent to carbon-related science as one of the major components.

The process of creating information to support decision making should be significantly different from the process of creating "basic" or "fundamental" scientific knowledge. The primary driver for such "use-inspired" research is societal need, not scientific curiosity alone (Stokes, 1997). To improve the application of scientific information to support carbon and climate-related decisions, scientists and non-scientist carbon managers need to improve their joint understanding of the top priority questions facing carbon-related decision making. They also need to collaborate more effectively in undertaking research and interpreting results in order to answer those questions. The scale of information provided and its specificity to regional or local concerns are often important considerations for the salience of information (Cash and Moser, 2000).

As a first step, a formal process could be developed "for gathering requirements and understanding the problems for which research can inform decision makers outside the scientific community," including the formation of a decision support working group (Denning *et al*., 2005). To move forward on creating an effective decision component of the CCSP program, the NRC recommends organizing a variety of deliberative activities, such as workshops, focus groups, working panels, and citizen advisory groups, with the goals being 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" (National Research Council, 2004). The current status of decision support activities across the CCSP will be assessed by several other SAP processes, complementary to this one, specifically SAP 5.1, 5.2, and 5.3 (organized under the heading of "Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change").

SUMMARY AND CONCLUSIONS

The carbon cycle is influenced through deliberate and inadvertent decisions on the part of diverse and spatially dispersed actors, located in many different sectors and at different scales. Scientific information and analysis can lead to better-informed decision making across many sectors and levels of action, if decision makers recognize that information and analysis as relevant and legitimate. To make carbon cycle science more useful to decision makers, we suggest the following steps, to be initiated by leaders in the scientific and program level carbon science community:

- Identify specific categories of decision makers for whom carbon cycle science is likely to be salient, focusing on policy makers and private sector managers in carbon-intensive sectors (energy, transport, manufacturing, agriculture and forestry)
- Identify and evaluate existing information about carbon impacts of decisions and actions in these arenas, and assess the need and demand for additional information. In some cases, demand may need to be nurtured and fostered through a two-way interactive process.
- Encourage scientists and research programs to experiment with both incremental and major departures from existing practice with the goal of making carbon cycle science more salient, credible, and legitimate to carbon managers.
- Involve not just physical or biological disciplines in scientific efforts to produce useable science, but also social scientists and communication experts.
- Consider initiating participatory pilot research projects and identifying existing boundary organizations (or establishing new ones) to bridge carbon management and carbon science.

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[BEGIN TEXT BOX]

Sectors Expressing Interest and/or Participating in the SAP 2.2 Process. This list of sectors is not an exhaustive list nor is it based on a rigorous assessment, it is meant to demonstrate the wide variety of potential stakeholders with an 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 demonstrated significant interest in carbon management as ways 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).

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, land-owners, and non-profits might 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).

Utilities and Industries: In the US, 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).

Transportation: Transportation accounts for approximately 37% of carbon emissions in the U.S., and about 22% worldwide. In transportation, governmental infrastructure investments, automobile manufacturers' decisions about materials, technologies and fuels, and individual choices on auto purchases, travel modes and distances all have significant impacts on carbon emissions. (Chapter 7)

Government: In the US, 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 (Government of Canada, 2005). The Mexican government appears to be particularly interested in locally-relevant research on natural and anthropogenic 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] (see Chapters 4 and 14).

Non-Profits and Non-Governmental Organizations: 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*., 2001).

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