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Reconciling the supply of and demand for carbon cycle science in the U.S. agricultural sector

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ABSTRACT

When asking the question, "How can institutions design science policies for the benefit of decision makers?" Sarewitz and Pielke [Sarewitz, D., Pielke Jr., R.A., this issue. The neglected heart of science policy: reconciling supply of and demand for science. Environ. Sci. Policy 10] posit the idea of "reconciling supply and demand of science" as a conceptual tool for assessment of science programs. We apply the concept to the U.S. Department of Agriculture's (USDA) carbon cycle science program. By evaluating the information needs of decision makers, or the "demand", along with the supply of information by the USDA, we can ascertain where matches between supply and demand exist, and where science policies might miss opportunities. We report the results of contextual mapping and of interviews with scientists at the USDA to evaluate the production and use of current agricultural global change research, which has the stated goal of providing "optimal benefit" to decision makers on all levels. We conclude that the USDA possesses formal and informal mechanisms by which scientists evaluate the needs of users, ranging from individual producers to Congress and the President. National-level demands for carbon cycle science evolve as national and international policies are explored. Current carbon cycle science is largely derived from those discussions and thus anticipates the information needs of producers. However, without firm agricultural carbon policies, such information is currently unimportant to producers.

1. Introduction

When scientific endeavors aim to perform research in support of specific groups of decision-makers, and through this support to benefit society, the commonly invoked "linear model", where funding of undirected basic research leads to maximal benefit, has neither been accurately descriptive, nor suitably prescriptive (Pielke and Byerly, 1998). Given this criticism of the dominant model, the important question becomes, "How can governments design science policies that contribute to beneficial societal outcomes?" Several authors have attempted to provide input, or an answer, to this question (see Cash, 2001; Etzkowitz and Leydesdorff, 2000; Funtowitcz and Ravetz, 1993; Gibbons et al., 1994; Herrick and Sarewitz, 2000; Kitcher, 2001; NAP, 2006; OMB, 1993; Ravetz, 1986; Stokes, 1997). Competing explanations of how science might contribute to benefit can find evaluation with empirical evidence. This article explores one method for evaluating an institution's science programs by focusing on the U.S. Department of Agriculture's (USDA) carbon cycle science programs.

McNie (this issue) provides justifications for considering the problem of supplying "good" scientific information. The

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myriad calls for useful information, decision support, societal benefit, or outcome-focused work (Brown, 1992; Ehlers, 1998; Mayden, 2002; NRC, 1999; OMB, 1993; USCCSP, 2003), and for public participation (Beierle and Cayford, 2002), along with increased expectations of participation (Wagle, 2000; Welp, 2001) and the growth of institutions for reinforcing links between science and societal benefit (McNie, this issue) dictate expanding our options for achieving such linkages.

One condition contributing toward effective science is that the information itself must be credible. Additionally, the resultant knowledge must be salient, or relevant to decision maker needs, and users should perceive the knowledge production process as legitimate (Bocking, 2004; Brown, 1992; Cash and Clark, 2001; Cash et al., 2002, 2003; Guston, 2001) Policy options that promote salience, legitimacy, and credibility may also correspond to successful policies under Sarewitz and Pielke's (this issue) conceptualization of ''reconciling supply and demand'', but these three criteria might not be the only constraints on producing effective science. Deducing whether an institution's policies lead to matches between supply of science and demand for information could lead to greater ability to fulfill calls for enhanced societal benefit from federal science programs.

Does USDA carbon cycle science help agricultural decision-makers? Do efforts to generate carbon cycle information meet users' demands? Utilizing the idea of reconciling supply and demand, this paper explores such questions. Beyond assessing USDA science policies, an assessment of supply and demand in this institution provides an example of how the concept of reconciling supply and demand can work. Furthermore, lessons learned, and the method itself, could find use in assessments of other government programs and scientific institutions in the United States or internationally. Given that the concept of reconciling supply and demand helps clarify this case, the work provides justification for pursuing this framework.

Several authors have explored the relationships between agricultural science projects and beneficial outcomes for farmers. One study of model development for use in Australian farms (Carberry et al., 2002) found that the participation of farmers in research increased the ability of developers to commercialize their tools. Research has also shown increased value from collaboration with users (Gadgil et al., 2002; Siepen and Westrup, 2002), and from active management of science-policy boundaries (Cash et al., 2002). However, collaborative processes do not guarantee success (Korfmacher and Koontz, 2003), and other factors can also affect a program's outcome, such as the geographic scale of the research (Cash and Moser, 2000), and the creation of realistic expectations by politicians (Lemos et al., 2002). Thus, investigating the whole policy context, along with the potential for collaboration, is important to gain a comprehensive view of how supply of science might match demand.

This paper investigates how USDA attempts to develop its research portfolio in support of agricultural decision-making, which we define as decisions made that effect the management of agricultural lands, labor, or products. Following an explanation of methods, the paper describes the parties involved in USDA carbon cycle science, and the ways in which these parties participate in the supply/demand process. An explanation of how the Agricultural Research Service (ARS) sets priorities follows, with illustrative case studies of ARS activities that highlight supply/demand relationships. The paper concludes with an assessment of how USDA activities might map onto one tool for conceptualizing supply and demand, the missed-opportunity matrix, and a discussion of how the supply and demand concept works in this case.

2. Methods

Sarewitz and Pielke (this issue) argue that science-policy makers can make decisions with better outcomes if they understand how supplies of information relate to user demands. The authors provide examples of well-articulated, well-defined demand functions that have affected science programs (Cash and Clark, 2001; Epstein, 1996; Lerner, 2001; Morgen, 2002; Rosenberg, 1997; Wagle, 2000) and justifications for funding science that meets the needs of users (Kitcher, 2001), Sarewitz and Pielke propose the ''missed-opportunity matrix'' as a tool for assessing supply and demand relationships in particular situations.

The matrix consists of a two-by-two grid, with one axis representing supply and the other representing demand (Fig. 1). The *x*-axis of the grid, or the demand side, poses the question, ''Does the decision maker need information?'' The *y*-axis asks, ''Does the agency target its agenda to the information needs of the decision maker?''.

The matrix's top left and bottom right quadrants represent cases in which the supply matches demand. On the top left, users have access to the information they need from the supply side. On the bottom right, decision makers do not need information from the agency, and the suppliers do not supply any. This could mean that the particular user group is not an appropriate target for the agency. Supply matches demand in these scenarios. In the other two quadrants, a need for reconciliation exists. When assessment finds a missed opportunity, making supply match demand may require the introduction of new strategies. Changes in how the program prioritizes science, the audience it targets, or how suppliers assess demand could increase the chances of reconciliation.

For the purpose of obtaining information necessary to use the missed-opportunity matrix, we obtained programmatic detail from agency documents, published articles and reports, databases, and interviews. In the spring of 2005 we conducted interviews with nine ARS staff members. The interviews

		Demand: Can User Benefit from Research?	
		YES	NO
Supply: Information Being Produced?	YES	Sophisticated users taking advantage of well-deployed research capabilities.	Unsophisticated users, institutional constraints, or other obstacles prevent information use.
	NO	Research agendas may be inappropriate.	Research agendas and user needs poorly matched.

Fig. 1 – The missed-opportunity matrix for reconciling supply and demand.

Table 1 – Mission statements and other documents that justify USDA global change research

Institution	Mission
USDA	'provide leadership on food, agriculture, natural resources ... based on ... the best available science'' (USDA, 2002, p. 2)
USDA component of USGCRP	''develop management practices that can take advantage of beneficial effects of global change and mitigate or adapt to adverse effects'' (USGCRP, 2006)
Cooperative State Research, Education, and Extension Service (CSREES)	Advance knowledge for agriculture, the environment, human health and well-being, and communities by supporting research, education, and extension programs'' (CSREES, 2006a)
CSREES Global Change and Climate Program	''Information for citizens and public officials to evaluate the environmental and socioeconomic impacts of policy options for sustainable resource management'' (CSREES, 2006b)
ARS Global Change National Program	''develop and provide adaptation, mitigation, and management strategies to the individual farm, ranch, and rural community, and to natural resource decision-makers to allow them to derive optimal benefit from the positive aspects of global change and deal effectively with the detrimental effects'' (ARS, 2003)
USDA component of USGCRP	''responding to the President's directive to develop accounting rules and guidelines for carbon sequestration projects'' (USGCRP, 2006)

followed a semi-structured format, after the methods of Rubin and Rubin (1995), to garner information and perspectives concerning who makes decisions on what science is important, what efforts are made to meet user needs, and what competing demands may exist for the research. Interview subjects on the supply side include scientists and science-policy makers at the national level, along with scientists and research leaders at the regional offices. These interviews identify potential users on the demand side, as perceived by ARS employees. Important topics of inquiry included the existence of methods for involving users in the decision process, the justifications for the current methodologies, what projects get funded, and why the projects that are funded are being pursued.

3. Demand for USDA science

The USDA's research, including research focused on understanding the impacts of agriculture on the environment (Ruttan, 1982), has historically made significant contributions to agricultural development. As a participant in the U.S. Global Change Research Plan (USGCRP), the USDA has undertaken research on carbon cycle science and carbon management. USDA-USGCRP research averaged $54M[1] per year between 1995 and 2005, which is 3.3% of total USGCRP expenditures, and was 3% of USDA's 2005 research funding (AAAS, 2006). Examination of mission statements and other pertinent documents invites the conclusion that the agency promises beneficial outcomes to decision-makers including farmers, resource managers, and consumers (Table 1). These statements closely match justifications for USDA and ARS within congressional floor statements (Gutknecht, 2003; Hoyer, 2003; Stenholm, 2003; Visclosky, 2003) and legislation (7USC3101). However, promises to benefit specific groups do not in themselves justify an agency's work, but they can be used as criteria for judging its activities. The challenge lies in connecting these promises of supply to real benefits.

Documents identify groups of participants on the demand-side of carbon cycle research including policy-makers at the national level, natural resource decision-makers (including state-level actors), agricultural producers and producer groups. Examining the needs of each of these groups, and how USDA acts to meet them, can provide a better idea of where the USDA might succeed in its mission to serve all of these users.

3.1. *National activities*

In its proposal to reduce greenhouse gas intensity[2] by 18% (Office of the Press Secretary, 2002) the Bush administration directed the USDA to (1) provide recommendations on targeted incentives for agricultural sequestration of greenhouse gases and (2) develop accounting rules and guidelines for crediting sequestration projects, in consultation with the Department of Energy (DOE) and Environmental Protection Agency (EPA). DOE, in collaboration with USDA, is currently updating the Voluntary Reporting of Greenhouse Gases Program, in which any of these entities can document emission reductions or carbon sequestration (Energy Information Administration, 1996).

The Secretary of Agriculture stated, ''USDA will factor in greenhouse gas benefits when we set priorities within our conservation programs. These steps will allow our offices and the states to consider carbon sequestration ... when allocating funds, ranking their activities and providing support and technical assistance'' (USDA, 2003a). Inclusion of greenhouse gas impacts in the Environmental Quality Incentives Program ranking system (H.R. 2646, sec. 1240H), which is tied to conservation payments, is among the new practices proposed. Federal payments for conservation practices require development of conservation plans, which producers create with the Natural Resources Conservation Service (NRCS). No governmental institution has established methods of assessment for carbon sequestration.

These policy statements raise questions about eligibility (which producers, regions, and practices should be eligible?), value (how do greenhouse gas benefits compare with other conservation benefits, and how much benefit is a voluntary

[1] Consumer-price index-adjusted 2000 dollars.

[2] Intensity refers to the emissions per unit of U.S. gross domestic product.

program likely to bring?), and protocols for estimating and/or documenting activities. USDA science could facilitate development of policies with information about relative magnitudes of net greenhouse gas emissions or sequestration (NRCS, 2005), how those vary geographically (Jawson et al., 2005), what influence emissions might have on agricultural management (Amthor, 1998), and the economics of payment programs for carbon sequestration (Lewandrowski et al., 2004).

3.2. *Producers, producer groups, and non-governmental organizations*

Some agricultural producers have expressed interest in soil carbon sequestration as a potential source of income. One group, the Pacific Northwest Direct Seed Association, signed a contract with a Louisiana energy company (Entergy) to adopt conservation tillage practices in order to sequester carbon.

A limited number of groups have voiced interest in emissions reduction or carbon sequestration. We reviewed state and national corn, wheat, and organic farmer producer association websites for statements on carbon sequestration, global change, and greenhouse gases/best management practices. While website contents do not provide a definitive guarantee of policy, they do imply that these are issues the organizations spend time on. Less than 10% of groups mention global change impacts or greenhouse gases/best management practices, while 25% mention sequestration. National organizations for corn, wheat, and organic growers each mentioned all three areas. The National Wheat Growers Association listed 'exploring how farmers can profit from carbon sequestration' as policy and planned to "monitor carbon sequestration initiatives in order to ensure the greatest benefit to growers at the local level" (National Association of Wheat Growers, 2006). The American Corn Growers Association has taken a similar stance, and has called upon the USDA to "establish minimum values for carbon sequestration, based on scientific university studies ... including crop variances and production practices" (American Corn Growers Association, 2004).

Several other non-governmental organizations, such as the Environmental Resources Trust, and the Oregon Climate Trust participate in carbon trading activities for carbon mitigation. Others, like The Nature Conservancy, endorse application of carbon sequestration credits to support conservation activities on agricultural lands.

Information about carbon sequestration is relevant to ongoing activities of producer groups and NGOs. However, while such groups may demand more or better information about how practices impact carbon stocks,[3] concerns tend to focus on potential future revenue from carbon sequestration, and not on immediate, practical information for sequestration. The primary questions in which producers are interested fall into three categories: amount of carbon, income potential, and contract details (Antle et al., 2002; CSTPR, 2004).

3.3. *Business and industry*

The Chicago Climate Exchange (CCX) is a voluntary "multinational and multi-sector marketplace for reducing and trading greenhouse gas emissions" (CCX, 2004). CCX identified agricultural carbon sequestration as one of their initial offset project categories, and derived payment schedules for soil offsets with assistance from the Iowa Farm Bureau. Research into the effect of different management practices on sequestration could change the activities that CCX recognizes and the amount of credit farmers receive for such activities. Below, we point out that current volume and price of CCX carbon may not dictate large expenditures of scientific effort on this front.

3.4. *States*

While states do not have control over USDA actions, they are one level of the natural resource decision makers that USDA mission statements identify. Many of the 40 states that have developed greenhouse gas inventories include emissions from the agricultural sector (EPA, 2004). Twenty-seven states have developed Action Plans to mitigate the impacts of climate change. Several states have assessed the potential for carbon sequestration in agricultural soils. Producers in Nebraska supported allocation of funds to generate information about soil carbon stocks and sequestration potentials in agricultural lands and have sustained their efforts through the University of Nebraska.[4] An EPA compilation of 20 state-level resolutions shows that all 20 intend to generate baseline emission data or to establish parameters for greenhouse gas registries (EPA, 2004). Ten states maintain that development of assessments should consider agricultural carbon cycling. One-third of the states call for inclusion of agricultural carbon sequestration. Carbon cycle science could inform states about the ramifications of changing climate, but at the state level much of the interest relates to sequestration.

The various prospective user groups for USDA science have many priorities beyond those related to climate; understanding impacts of and potential responses to global change, including carbon management activities, is low on the list of expressed priorities for many of them. Furthermore, meeting an expressed demand, even in the cases where the USDA has to respond to a user, such as the U.S. President, does not necessarily increase the information's potential to provide aid in decision-making. Examining the relationship between USDA science and agricultural producers is important because, for much of the work within USDA's provenance, a decision to implement research results will affect operations of people working within agriculture.

4. ARS research prioritization

The ARS is organized into two divisions. One consists of those groups responsible for "Program Planning, Coordination, and Support", while the other consists of "Research Implementation and Information Delivery." All of the ARS laboratories fall within this second group. Much of the research funded by USDA takes place on long-term National or State Agricultural Experiment Stations. Cash (2001) found that research on such stations, with the participation of extension agents, facilitates two-way communication between information producers and

[3] G.R. Smith, personal communication.

[4] See http://cropwatch.unl.edu/main.htm#C_sequestration.

users. The main interaction between actors at local research stations and planners, in terms of development of overall research goals and prioritization, is with the National Program Staff. ARS holds planning workshops, which bring together scientists, Program Leaders, and users, and leads to the development of a 5-year action plan that states the program's research direction. National Program Leaders also assess the research projects for relevance to the program goals. ARS managers intend National Program and program component reviews to "ensure the quality, relevancy, effectiveness, and productivity of the work being done in each National Program" (USDA, 2003b). Every research project's relationship to its goals and objectives meets evaluation in annual progress reports.

For global change, the initial workshop to identify priorities, held in 1999, consisted primarily of scientists, but also included representatives from the non-profit sector, agriculture, and agricultural industry (ARS, 1999). Following the workshop, the ARS developed an action plan, a scientific plan, and an implementation plan in succession. At the end of the 5-year period, National Program teams evaluate the program's scope and accomplishments and begin the next 5-year cycle. The second Global Change National Program Workshop probably will not occur until 2007 or 2008 (N. Kessler, pers. commun.), thus prolonging the first cycle.

ARS employees frequently cited the planning workshop as a central means for evaluating demand. While other, similar meetings do exist, such as the USDA-sponsored biannual meetings intended to bring together biologists, land managers, and policy makers to review the state of agricultural carbon science (Mickler, 2004), the workshops are the primary formal mechanism within ARS. One scientist described the process for the Soil Resource Management program (Follett, 2005b). "And they [invited users] sat in a little workshop before we really got down to nuts and bolts, and they told us what was helping them, what their needs were. They were trying to be forward looking, and this included farmers. They left us with their list of needs and then we sat down and we tried to interpret those into products that we might deliver, anything from computer models to equipment, such as sensors to information and so forth. And then we work-shopped that and we'd list the product and we'd list what it would take to deliver that product ... and then we listed the ARS locations that could work together to work towards delivering that product." Follett equated this process with the one for global change, "then we're doing the same type of thing. GRACEnet [discussed below] is trying to address some of these things in terms of what types of management practices will accomplish under ... different scenarios." Follett's describes a process that could plausibly contribute to matching of supply with demand. His description covers assessment of the users' needs (or at least, those users that are present), and an attempt by ARS to match scientific products to these needs. However, this does not guarantee that the ARS staff's decision on what products are most useful matches actual needs of users, or if the research units succeed in delivering a useful product.

Regarding project-level accountability, Jawson (2005), former National Program Leader for the Global Change program, said that peer reviewers ask the scientist what impact the research will have on information users, and according to one scientist who is involved in the review process (Hatfield, 2005a), ARS has become more assiduous about revisiting what the scientists say about impacts, and evaluating the project on these terms. Review panels for competitive funding within and outside of USDA base their ratings in part on broader impacts and outreach. Often, program managers ask non-scientists to review these components of research proposals. Teams of outside scientists also perform peer review on the scientific merit of the work.

In the Global Change program, requests for information do not tend to come from individual farmers (Jawson, 2005). According to Jawson, "For most of these people, climate change is on the radar screen, but its not something they deal with when they think about day-to-day needs. (2005)." Ron Follett agreed, "I'm not sure how high on the radar screen global change is to a lot of them. It may not even be on their radar screen" (2005), and also called it a "non-issue" from the perspectives of farmers, "Global climate change is a Washington D.C. policy maker issue. It's not a farm issue." This lack of interest does not mean that individual producers find climate change science information to be useless, but it may imply that they find it less pertinent than other issues. However, many of the previously listed user groups do express interest in aspects of global change research and make requests of the ARS.

5. Specific interactions between ARS and users

Beyond the requirements of the ARS to supply the federal government with science lies the goal of making a contribution to the "individual farm, ranch, and rural community." The following section describes past interactions and potential interactions between the ARS and users of global change research. The cases chosen do not consist of a representative sample of all ARS carbon cycle projects. Instead, they correspond to those cases interviewees supplied as examples of interactions with users. Through these interactions, we can assess how the Global Change National Program may meet the needs of users. The first two examples provide an illustration of ARS projects that aim to meet the needs of local decision makers, despite finding impetus at the national level. Following are two examples of work with local decision makers that originated in local-level interactions. All four examples provide perspectives by ARS scientists on the demand for their science, and how interactions with the demand side occur.

5.1. *GRACEnet*

In 2004, ARS staff conceived of and began GRACEnet (Greenhouse gas Reductions through Agricultural Carbon Enhancement network). The project aims to develop "agricultural strategies that will enhance soil C sequestration and reduce greenhouse gas emissions and to provide a scientific basis for possible C credit and trading programs that could be used to ... improve environmental quality" (Jawson et al., 2005). The GRACEnet project is part of the ARS endeavor to fulfill the Presidential Directive of 2002 demanding research into sequestration. An article (Jawson et al., 2005) attributes

the research's justification to interest from land managers in receiving payments for carbon, along with the environmental and production benefits of storing carbon in soils. When asked to characterize the recipients of the research, one scientist said that the "main focus ... is to get information to producers so that they can implement practices" (Franzluebbers, 2005).

Although GRACEnet aims at benefit for agricultural producers, it may be difficult for the agency to know if it is being successful in this approach. On the issue of evaluating the success of a project, Franzluebbers said, "I really don't know, exactly ... certainly we can document that there have been changes in management by producers from one point in time to another point in time. Perhaps the research contributes to that." (2005) People at the regional level who were working on GRACEnet and related projects also pointed to the National Program Staff, along with policy makers at the national level, as the people who would be assessing success (Follett, 2005b; Franzluebbers, 2005). It is not known how much the National Program staff will use the opinions of producers in evaluation, although the 5-year planning workshops do provide a venue in which this could occur.

5.2. CQESTR

The CQESTR model is one of several decision support systems (DSSs) ARS is designing to aid farmers with carbon-related activities. ARS staff in Oregon developed the CQESTR model for the purpose of predicting the amount of carbon sequestration that would occur on a parcel of land. According to one of CQESTR's designers (Albrecht, 2005), the U.S. State Department and the NRCS intended to use the model to show other countries in the Kyoto Protocol negotiation process how carbon sequestration in agricultural soils may be viable. However, Albrecht characterizes this original rationale, where the users are national-level policy makers, as a misconception of the real situation, which was that the European Union's reason for resisting sequestration was the emissions advantage it would give to countries with large rural areas, such as the U.S. and Australia. Thus, the original justifications for CQESTR became moot.

However, an "adjunct reason" (Albrecht, 2005) for developing CQESTR was the possibility that the government would alter the Farm Bill to allow payments to farmers for sequestration. If this occurs, Albrecht identifies the NRCS as the primary user of the model, for the purpose of quantifying the amount of carbon that a producer sequesters under a specific management practice. At one point, a software company that believed there would be "vigorous trading" (Albrecht, 2005) of carbon credits contacted the Pendleton unit about the possibility of a Cooperative Research and Development Agreement (CRDA) between the company and the ARS for the purposes of making the software more user-friendly and distributing it commercially. However, the CRDA never occurred, due to a reassessment by the company that the venture would not be profitable. In addition to its possible use by farmers and the NRCS, the developers of the model envision its use for predicting the carbon sequestration that might occur at GRACEnet research sites as a research aid.

Albrecht does not consider widespread use of the model to be likely unless producers are receiving payments, "if it's going to affect their bottom line significantly, they might take the time to modify their tillage operations to comply with CQESTR predictions. If it doesn't, they might not" (2005). Albrecht also said, "We have had interaction with producers because they're interested in the model development and they're interested in what it's potential might be. For them to sit down and say 'gosh, I think this is neat. Show me how to do this. I want the model for hands-on work at my farm.' That sort of interest has been very limited." Albrecht characterized some user groups, such as the National Carbon Council and the Pacific Northwest Direct Seed Association, as showing greater interest than individual farmers. One article (McCown et al., 2002), which analyzed several published cases on DSSs, provides reasons that CQESTR could find use if farmers receive incentive. DSS developers often experience problems with implementation by farmers, McCown (2002) concluded that DSSs used as supplementary tools, instead of substitutes for decision processes, and that were used by an expert intermediary in a relationship with the farmer to facilitate learning instead of prescribing action, tend to be more successful.

5.3. Iowa Farm Bureau

As a member of CCX, the Iowa Farm Bureau has a pecuniary interest in carbon cycle science. The Iowa Farm Bureau works to sell carbon sequestration credits from state farmers on the exchange. According to Hatfield (2005b), the Farm Bureau approached ARS employees at the Ames, IA research unit with questions about how carbon sequestration would change with differing management strategies, how stable a management strategy would have to be to sequester carbon, and how policing of practices could occur. Additionally, the Bureau asked about quantification of carbon in the soil, including the measurement of relatively small changes, where in the soil profile the carbon would reside, and differences in sequestration dependent on soil type. Hatfield wrote that the ARS responded by providing "more detailed information to the group to help them make decisions about potential soil management practices for carbon credits" (2005a).

The interaction between the Farm Bureau and ARS does mark a matching of user demand with science supply, since the Iowa Farm Bureau did have questions that the ARS research aims at answering. However, it is not known whether any feedback to ARS research goals and operations occurred as a result of this interaction.

The current trading scheme uses a single number, 0.5 metric tonnes per acre (or 1.2 metric tonnes per hectare) (Iowa Farm Bureau, 2005), which does not accurately represent how much carbon is put into the soil in every acre in different contexts. While an idea of how much carbon enters the soil is necessary to obtain this number, it is not clear that a large effort by the USDA, which could conceivably obtain a more precise number, will bring much added value to this user without a changed market. Because the U.S. does not regulate carbon, the trading price was below a dollar per metric tonne in December 2003, and in August 2005 fluctuated between a high of $2.02 per metric tonne and a low of $1.68 per metric tonne of vintage 2005 carbon (CCX, 2005). At this price a farmer

can expect about two dollars per hectare of land devoted to conservation tillage. While this is a benefit, it is less than other, non-climate related factors, such as fuel saved by not plowing. Through 2004, the Iowa Farm Bureau had been responsible for the enrolling of over 32,000 ha (Iowa Farm Bureau, 2005). Since the scope of monetary benefit to the producers has been limited, putting abundant funding into refining estimates or putting more explicit numbers on conservation tillage cannot be justified in the current market. However, members of the Iowa Farm Bureau have expressed interest in better models for economic evaluation of carbon sequestration (CSTPR, 2004), and the possible emergence of new payment options could alter things. Financially, the usefulness of carbon cycle information to producers is largely contingent upon future policies at the national level.

5.4. *Minnesota Corn Growers*

John Baker, a research leader at the Soil and Water Resource Management Unit, briefly described an interaction that occurred between ARS employees and the Minnesota Corn Growers Association (Baker, 2005c), After ARS scientists initiated contact, the Corn Growers invited ARS scientists to a meeting, where ARS staff described their projects (Baker, 2005a). The ARS also invited association members to attend the National Program Planning Meeting in the Soil Resource Management National Program, and the Corn Growers sent two people to the meeting. The research that Baker performs falls into the Global Change, Water Quality and Management, and Soil Resource Management National Programs.

The Minnesota Corn Growers sent people to the soil program's national meeting, and Baker thinks it is likely that they will also participate in the Water Quality and Management National Program Planning Meeting. However, Baker wrote, ''I don't know if they would participate in the Global Change Workshop or not. They have to be able to justify any travel expenses to their membership, so there has to be a clear connection to production problems'' (Baker, 2005b). This highlights a possible disparity between the needs of the producer on a more immediate, production-oriented scale, and any long-term benefits that the Global Change program might be able to provide users. In other words, some farmers may perceive the carbon cycle activities that relate to the more traditional study of organic material and soil resources as more beneficial than work that is only applicable to dealing with the consequences of climate change or future benefits from carbon sequestration. As the scope of research into soil carbon sequestration expands into the precise quantification of carbon in soil and the relationship between increasing soil carbon and other greenhouse gas emissions, some groups of information users, such as the Minnesota Corn Growers association, may have greater interest in more conventional questions of soil carbon management.

6. Reconciling supply and demand at USDA

When questions of responsivity arise concerning the relationship between USDA and national-level decision makers, the answer appears to be that USDA is responsive to their needs, in that Congress and the president can prompt action since the USDA is ultimately accountable to them for continued authorization of activity and appropriation of funds. An example of this is the President's 2002 call for more work on quantification of carbon sequestration on farms (Office of the Press Secretary, 2002). This directive provides the USDA with a strong justification for pursuing work into carbon cycling. While there are benefits that could eventually come to farmers from the Global Change National Program, it appears from the interviews that ARS scientists believe that, the average farmer has a number of priorities that come before those of mitigating climate change or adjusting to the consequences. Thus, they make statements that global change is ''not on the radar screen'' (Follett, 2005a), or is lower on the list of priorities.

The missed-opportunity matrix can represent the situation of the ARS Global Change National Program. First, for ARS research that falls within the Global Change National Program, but which also applies to general issues of carbon management, a simplified missed-opportunity matrix may depict the situation (Fig. 2), where the highlighted sections represent likely outcomes:

This could be scientific information that Kimble et al. (2003) refer to as the ''win-win'', where farmers might find carbon management information useful even if there are no climate-related reasons to pursue it. Without climate change, the incentives of enhanced soil, water, and air quality that could accompany may be enough to make the information relevant. Both the ''yes'' and ''no'' on the producer axis are highlighted because some carbon cycle science could work towards these goals, while other science may only be applicable in a case where carbon cycle science is needed for management related to global change, or if national policy changes.

Another version of the missed-opportunity matrix (Fig. 3) describes the case of carbon cycle science specific to global change and carbon sequestration, including models such as CQESTR that may only see widespread use if policy change occurs.

In this case, there may be a match between the scientific agenda of the ARS and the needs of the user, but only in the case where policy changes. Both CQESTR and GRACEnet target users' informational needs as a response to a national-level impetus. Thus, the matrix outcome relies chiefly on actions at the national level, and not on relationships between ARS staff and producers. Salience is not achievable by any action of the ARS.

	Demand: Can User Benefit from information on carbon management strategies?		
		YES	NO
Does the agency target its carbon cycle agenda to the information needs of the producer?	YES	"win-win" research provides soil management benefits to farmers.	Unsophisticated users, institutional constraints, or other obstacles prevent information use.
	NO	Research is specific to global change, can only provide benefit with policy change.	Research agendas and user needs poorly matched.

Fig. 2 – Missed-opportunity matrix for carbon management (from Sarewitz and Pielke, this issue).

		Does the producer need information on carbon management strategies for global change reasons?	
		Policy change on payment for sequestration (YES)	No policy change (NO)
Does the agency target its global change agenda to the information needs of the producer?	YES	Producers benefit through knowledge that enables payment	Global change is not a priority for farmers until tied to the bottom line
	NO	Research is specific to global change, can only provide benefit with policy change.	Research agendas and user needs poorly matched.

Fig. 3 – Missed-opportunity matrix for carbon cycle specific to global change.

While more research into carbon sequestration accounting may become a higher priority if prospective change in the policies for carbon sequestration come to pass, the other aspects, such as work on climate impacts, that are either more predictive, or that will not be incentivized by government policy in the near future, can lead to more questions for the ARS in its attempts to meet the needs of decision makers. One question concerns the explicitly expressed needs of users versus the future needs of the users as perceived by the scientific experts and policy makers. Basically, how much weight do you put on either of these perceptions? In such cases, scientists might believe they are working towards the top-right quadrant, where they will create sophisticated users by acting towards an unspoken future need. If the question at the top of the matrix changed from ''Does the decision maker need information...?'' to ''Does the decision-maker want information...?'' the outcome could be different, and a missed-opportunity would be the result.

7. Conclusions

While there are benefits that could eventually come to farmers from the Global Change National Program, it appears from interviews with some USDA scientists that, outside of some user groups, the average farmer has a number of priorities that come before that of either mitigating carbon dioxide or adjusting to climatic consequences. The USDA attempts to work with users on all levels, and includes them in the planning process formally and informally. This inclusion seems to be an important part of the process, and one that could be transferable to other agencies, since it provides scientists with ideas on whose needs they are meeting. One remarkable result of the interviews was that many of the interviewers had come to the conclusion that doing global change work that would satisfy producers was more difficult than meeting the needs of national-level policy makers. However, the other important lesson to take from this is that the existence of awareness, interaction, and social capital at the agency level does not guarantee success. Thus, the perception of some USDA scientists that global change research is ''not on the radar screen (Follett, 2005a)'', or is lower on the list of priorities (Jawson, 2005; Albrecht, 2005) for producers, may be accurate. For this reason, the biggest barrier to reconciliation may be the lack of current benefit to farmers coming from pursuit of climate change research. Until the promise to change agricultural payments becomes a reality, the primary demand for research specific to the prospective payments is potential demand.

While the results of the missed-opportunity matrix and the ''reconciling supply and demand'' method, are inconclusive due to the uncertain nature of the current policy regime, one can see that it does illustrate where the missed-opportunity lies. Considering work done on carbon sequestration options, the missed opportunity is created by the fact that ARS is performing mandated research that anticipates a policy change that may not occur. While it is not certain that supply would match demand if the policy did change, certain ideas present themselves for how ARS might alter its strategies to move closer to a match between supply and demand. For example, there is a subset of global change work, such as some work on organic matter in soil, that Kimble et al. refer to as the ''win-win'' (Kimble et al., 2003), which consists of climate change science that would also be useful to producers if climate change were non-existent. These ''win-win'' scenarios might be similar to what people refer to as ''no regrets'' adaptation measures (Smit et al., 2000), since they do not depend on some uncertain future event (in this case, policy change) to bring benefit to producers. Additionally, more focus on helping farmers to deal with both shorter-term climate variability and longer-term changes, could increase the resiliency of the system for producers and consumers.

While many of the mission statements and authorizing legislation for the USDA tie farmer benefit to societal benefit, 'win-win'' or ''no regrets'' science may make this link more clear. Paying farmers to sequester carbon could technically mitigate a small percentage of U.S. carbon emissions (Lal et al., 1998), but pursuing research that might enable sequestration projects, and, if not, can lead to more sustainable agricultural practices, can produce long term benefit for agriculturalists, environmentalists, and the consumers of agricultural products. The ''win-win'' path is only one way to increase matches between suppliers and users, but it is one that may be open to USDA within its current mandate, and thus might allow the organization to use the flexibility it has to pursue its mission.

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