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Managing carbon in a multiple use world: The implications of land-use decision context for carbon management

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ABSTRACT

Human land use contributes significantly to the growth of greenhouse gases in the atmosphere. Changes in land management practices have been proposed as a critical and cost-effective mechanism for reducing greenhouse gas emissions and promoting the storage of additional carbon in vegetation and soils. However many discussions of the potential for land use to mitigate climate change only take into account biophysical factors such as vegetation and land cover and neglect how the agency of land owners themselves affects whether additional carbon storage can be achieved. Unlike many potential REDD opportunities in developing countries, land management in the U.S. to enhance carbon sequestration would occur against a backdrop of clearly defined, legally enforceable land ownership. In addition, more than a third of the land surface in the U.S. is managed by federal agencies who operate under legal guidelines for multiple use and is subject to demands from multiple constituencies. We set out to investigate how the goal of enhancing carbon sequestration through land use is perceived or implemented in one region of the U.S., and how this goal might intersect the existing drivers and incentives for public and private land use decision making. We conducted a case study through interviews of the major categories of landowners in the state of Colorado, which represents a mixture of public and privately held lands. By analyzing trends in interview responses across categories, we found that managing for carbon is currently a fairly low priority and we identify several barriers to more widespread consideration of carbon as a management priority including competing objectives, limited resources, lack of information, negative perceptions of offsetting and lack of a sufficient policy signal. We suggest four avenues for enhancing the potential for carbon to be managed through land use including clarifying mandates for public lands, providing compelling incentives for private landowners, improving understanding of the co-benefits and tradeoffs of managing for carbon, and creating more usable science to support decision making.

1. Introduction

Carbon management through changes in land-use is a prominent topic in discussions surrounding the mitigation of climate change (Gibbs et al., 2007; Boyd, 2010). Human land-use change is the second largest contributor of increasing carbon dioxide in the atmosphere through land clearing for agriculture and other activities, and can mediate the uptake of carbon as well (Le Quéré et al., 2009). Studies have estimated that relatively large amounts of additional carbon could be stored through deliberate management of the land surface, when taking into account the historical rate of conversion of land from forest to agriculture and previous degradation of soils from agriculture (Kinsella, 2002; Heath et al., 2003; Lal et al., 2003; Sperow et al., 2003; Paustian et al., 2006; Richards et al., 2006).

Several types of land management practices can enhance carbon storage on land, either in vegetation itself or in soils (CCSP, 2007). The greatest amount of carbon in vegetation on land is found in forests, and practices such as halting deforestation, planting trees or using different forestry practices have the potential to sequester substantial amounts of carbon on a global basis (House et al., 2002; Jackson and Baker, 2010). Changes in practices in the agricultural sector such as reducing or ceasing tillage of soil, changing crop rotations and amendments, using cover crops, and changing rice cultivation practices can help to prevent the loss of soil carbon as well as causing more carbon input to soil (Post and Kwon, 2000; CCSP, 2007, p. 113).

Over the past few decades, therefore, society has been moving to considering deliberate management of carbon and establishing means for carbon governance (Dilling, 2007). With the recognition of land carbon sinks in Article 3.3 of the Kyoto Protocol in 1997, a

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number of forest-related offset projects were undertaken around the world using a variety of mechanisms, including the Clean Development Mechanism (CDM), the World Bank BioCarbonFund, and various voluntary pilot programs (Corbera et al., 2009; Caplow et al., 2011). In the past few years, international policy interest in forest protection and its carbon benefits has galvanized around REDD (Reducing Emissions from Deforestation and Degradation) and REDD has become a formal part of policy negotiations under the UN Framework Convention on Climate Change (Corbera et al., 2010; Agrawal et al., 2011).

Many of the case studies conducted thus far on projects related to REDD have occurred in the developing world in the tropics (Caplow et al., 2011). Despite the presence of substantial land carbon sinks in the northern hemisphere and elsewhere outside of the tropics (Goodale et al., 2002), fewer studies have been conducted on carbon and land-use decision making in the northern hemisphere and the U.S. in particular (although see Poudyal et al., 2010; Gosnell et al., 2011; Ellenwood et al., 2012).

No matter where carbon management is being attempted, carbon management goals are not imposed on a blank slate. Land is already intensively managed by a host of actors for a variety of purposes over much of the globe (Foley et al., 2005). Therefore, the potential for deliberate management of land to enhance carbon sequestration must be evaluated through the lens of human decision making and behavior (Failey and Dilling, 2010). Lambin et al. (2003) suggest that factors driving land use can be distinguished in many different ways: as proximate or underlying, as slow or fast, and as biophysical or human drivers. Drivers for land-use decision making in the private sector include broad trends such as market prices for commodities, policy levers such as incentives and subsidies, and biophysical factors such as climate and water supply (Lambin et al., 2001, 2003). In some countries, a substantial portion of the land surface can also be managed by government agencies rather than the private sector. Fig. 1 (adapted from Riebsame et al., 1994) provides a conceptual overview of the underlying drivers of land-use decision making in a U.S. context.

The potential for carbon management to be more widely implemented therefore depends on how private sector and public sector actors perceive carbon management goals, and how carbon management interfaces with their existing drivers and interests. Studies of payments for ecosystem services (PES) programs in general do not tend to focus on the factors that drive people's participation (Kosoy et al., 2008) or of the perceptions of individuals in important institutions managing the land in REDD-related projects specifically (Brown et al., 2011). We therefore set out to understand the existing drivers and incentives for public and private sector land owners and the extent to which carbon management goals were compatible with those drivers in a U.S. context. Since much of the REDD-related literature is also focused on the scientific characterization of the potential for lands to enhance carbon sequestration, we also investigated the role of scientific information in supporting decision making. We chose to focus our study on the state of Colorado in the United States, where there is a wide variety of land ownership types.

Colorado is home to privately held land (57%), a high proportion of public land managed by a variety of federal land agencies (36%), state government land (5%) and municipal governments (1%), with 1% managed by Native American tribes (Failey and Dilling, 2010).

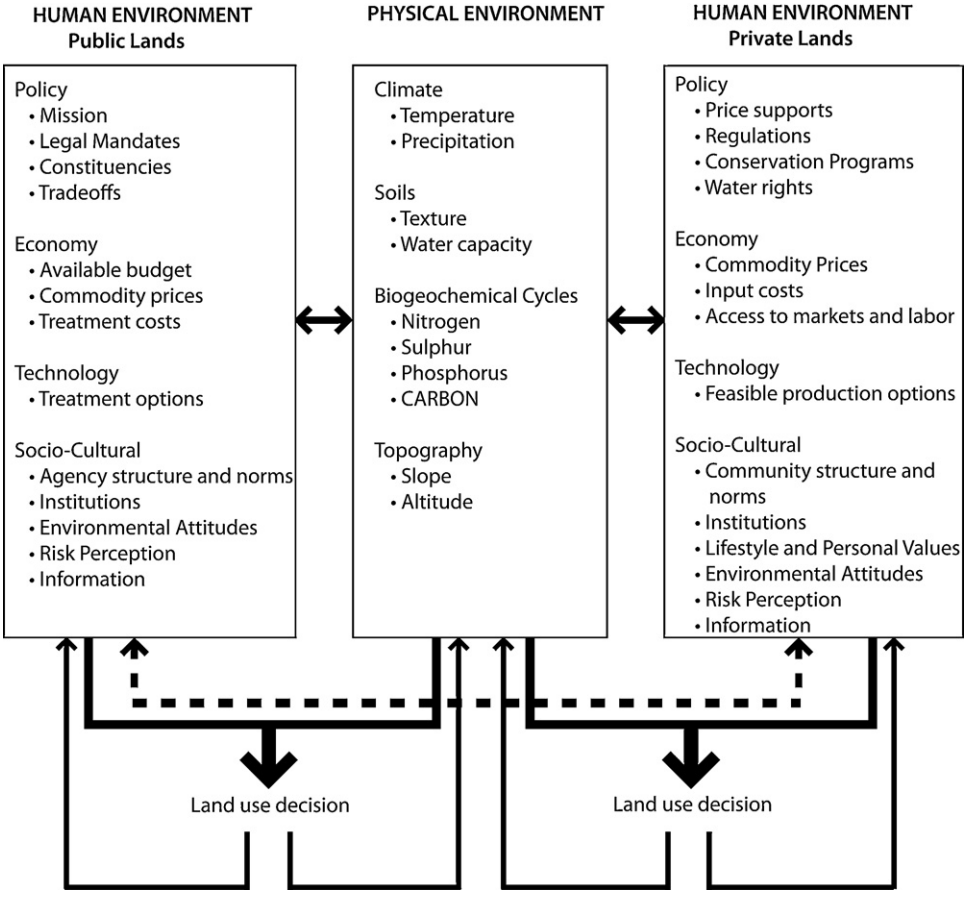

Fig. 1. Conceptual representation of underlying physical and human environment drivers of land use decision making and feedbacks. Human environment drivers are separated into those influencing public land managers and those influencing private land managers, as those human drivers can be quite different.
Adapted from Riebsame et al. (1994).

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Colorado encompasses of a diversity of vegetation types including forests, grasslands, rangelands and agriculture, distributed unequally across ownership categories.

Colorado also represented an interesting context for carbon-related decision making as there were opportunities for Colorado farmers and ranchers to enroll their acres in a voluntary carbon market known as the Chicago Climate Exchange (CCX) under contracts typically brokered and aggregated into groups in Colorado by various Farmers Union organizations. CCX is now a voluntary carbon credit registry owned by Intercontinental Exchange and is no longer actively exchanging carbon offsets (see https://www.theice.com/ccx.jhtml).

In this paper we examine the private and public sector contexts for decision making and the role of information in supporting decision making for carbon management in a case study of Colorado. First, we report the state of awareness and activities regarding carbon management among public and private land owners. Next, we analyze the current drivers and incentives of land-use decision making for public and private lands. We then describe the potential barriers we observed to expanding activities related to carbon management on public and private lands, including competing objectives, limited resources, lack of information, perceptions and attitudes toward carbon management, and the lack of a policy signal. Finally we present results and analysis on how carbon management goals might become more widely incorporated into land-use decision making. We also discuss the implications of these results for the broader international context of land use as a carbon management strategy.

2. Methods

To understand the decision making context for public and private land managers in light of the emerging goal of carbon sequestration, we conducted a case study on decision makers in the state of Colorado, United States. The case study method is particularly appropriate for this research, as the context of climate change and carbon as a management goal is only still emerging, and we were interested in studying these decisions as "a contemporary phenomenon in its real-life context" (Yin, 2003, p. 13).

We conducted semi-structured interviews with 31 public and private land managers across the state, including 15 interviews with federal land managers (U.S. Forest Service (USFS), Bureau of Land Management (BLM), Natural Resources Conservation Service (NRCS)), 12 interviews with private land owners, three with state and county officials, and one interview with several representatives from a Native American tribe (Table 1). Interviewees were selected to include the major categories of direct decision makers on the land, whether public or private. In addition, informal conversations with carbon aggregators were held before and after the study to discuss questions of fact about how the market was structured. The private land owners included farmers on both dryland and irrigated agricultural land, ranchers who both owned and leased land, and one forest land holder.

We conducted interviews in the spring and summer of 2008 with individuals at their place of work or in their homes. Interviews lasted at least one hour, and up to a half a day. Interviewees were selected in several ways. Many of the farmers and ranchers were recruited through Conservation District meetings attended by one of the authors (EF). Subjects were approached and told about the study, and agreed to arrange an interview with us at a later date. Individuals working at the USFS, BLM, or NRCS were contacted using information available online. Human subjects protocols were followed and participants were provided informed consent information.

Table 1
List of interviews, all took place in Colorado in a variety of locations around the state.

1. BLM Field Manager, April 16, 2008
2. USFS District Ranger, April 16, 2008
3. Private Land owner, April 25, 2008
4. Private Land owner, April 25, 2008
5. BLM Field Manager, May 2, 2008
6. Private Land owner, May 6, 2008
7. Private Land owner, May 7, 2008
8. Private Land owner, May 14, 2008
9. Private Land owner, May 14, 2008
10. BLM Planner State Level, May 15, 2008
11. BLM Planner State Level, May 15, 2008
12. Private Land owner, May 19, 2008
13. USFS Forest Supervisor, May 29, 2008
14. USFS Planner Regional Office, May 30, 2008
15. County Division Director, May 30, 2008
16. USFS Program Lead, June 5, 2008
17. BLM Planning Lead, June 5, 2008
18. USFS Program Lead, June 5, 2008
19. Center Official, June 5, 2008
20. Project Lead, June 5, 2008
21. Center Official, June 5, 2008
22. Center Official, June 5, 2008
23. Group interview of Tribal Lands Resource Managers, June 6, 2008
24. Specialist, Department of Wildlife, State of Colorado, June 18, 2008
25. Specialist and program coodinators, Natural Resource Conservation Service, June 26, 2011
26. Private Land owner, July 8, 2008
27. Private Land owner, July 10, 2008
28. Private Land owner, July 15, 2008
29. Private Land owner, July 15, 2008
30. Private Land owner, July 17, 2008
31. County Commissioner, August 7, 2008

Interviews were semi-structured around the following five categories of questions: (A) awareness and actions related to carbon markets or managing carbon; (B) the primary factors influencing land-use decision making; (C) the degree of latitude decision makers had to undertake new management practices; (D) information use and sources of information; and (E) demographics, and details about the particular land area under management, e.g. how much land and what type of land. Semi-structured interviews were most appropriate in this case study as we were interested in clarifying the central factors involved in decision making for each land owner type and how they related to new opportunities for carbon management (Schensul et al., 1999, p. 150).

In most interviews two researchers were present to take notes; interviews were not recorded. Interview content was then transcribed and analyzed by organizing each interview into a matrix by type of manager and statements made in response to each question category described above (Miles and Huberman, 1994, p. 93). Emergent themes were also incorporated into the matrix to discern how prevalent they were across interviewees. For this paper, we present our results mainly on the two main categories of land ownership types; private land owners and federal agency land managers. Private lands and federal public lands represent over 90% of the land area in Colorado.

3. Results and discussion

3.1. Awareness of carbon as an issue

Our results suggest that in 2008, while both the public and private sector were aware of carbon sequestration as an issue and potential consideration, neither group seemed to be strongly vested in activities to actively manage carbon.

Public agencies: In 2008, public lands decisions makers in the federal agencies were definitely aware of the issue of carbon

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sequestration, and of the potential for carbon to be managed more deliberately. While there were general directives stating that climate change should be considered in decision making on federal public lands in place in 2008, there was not yet specific guidance either in terms of legislation or administrative policy that specified how climate was to be considered. For example, in 2001, Department of Interior (DOI) Secretary Babbitt issued executive order #3226 stating that agencies must "consider and analyze potential climate change impacts" in decision making, but this may not have influenced many decisions at the local level until approximately 2007, when more people within DOI agencies such as BLM became aware of its existence (interviews 11, 5, 10, 18). In 2008, at the local district or ranger office level in the Colorado region, we did not find decision processes yet taking into account the impacts of land management on carbon, either to store additional carbon or to prevent release of stored carbon. Several managers at both the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) mentioned the lack of firm direction, stating that offsets were "not on the radar screen" or that things were "pretty vague" or that they were only "dabbling" in the issue of carbon management (interviews 10, 11, 13, 14). For example, one supervisor had put in an unsuccessful proposal to include some of his Forest's lands in the Chicago Climate Exchange program, but this was the exception rather than the rule (interview 14). Further guidance was generally expected from agency headquarters Washington, DC—there was a sense that "something was trickling down on global warming", and a "lot of stuff on carbon *might* happen" but that specific directions were not yet clear (interviews 1 and 2).

This level of awareness was similar in other levels of government we spoke with. For example, in one Colorado county recognized for its progressive approach to setting emission reductions goals, the county commissioners had not yet taken a policy position on including carbon offsets as part of their emissions reductions portfolio, and the issue was not yet high on the policy agenda (interview 31). A county program director put it this way: "We are doing some things that are positive for carbon. But we didn't get there for carbon reasons" (interview 15). For example, the county was revegetating former agricultural lands with native plant species, but in order to improve habitat for wildlife rather than carbon purposes, even though conversion of cultivated agricultural land back to native grassland has been shown to increase carbon storage in soils (Conant et al., 2001).

Private land owners: Private land owners were not uniformly informed about the issue of carbon sequestration, and we encountered a wide range of responses to our inquiries about whether they were familiar with carbon management or offsets as a concept. A small number of interviewees had not only heard of carbon management, but had their acres enrolled in one of the above-mentioned aggregator programs for carbon credits at the time (interviews 3 and 4). The majority of farmers and ranchers had heard of carbon programs, either through their local Farm Bureau representative or news outlets, but had decided not to enroll or were still considering whether or not to enroll their acres (interviews 6, 8, 9, 12, 26, 27, 28). A few interviewees had simply not heard of the issue of carbon management but were interested to hear more while also expressing some skepticism (interviews 7, 29, 30).

3.2. Current drivers of decision making

Any new goal, such as managing land to enhance carbon sequestration, will be superimposed onto an existing decision landscape. We present here some of the major contextual factors that we observed to be driving decision making.

Public lands: While space precludes us from describing the full suite of influences and incentives operating for public lands managers, one of the most important contexts for decision making at the federal Bureau of Land Management (BLM) and U.S. Forest Service (USFS) is their multiple use mandate. Established by U.S. law, the multiple use framework requires BLM and USFS to manage lands for many types of goals, including recreation, timber and other resource extraction, species protection, wilderness preservation, fire management, and so on (Loomis, 1993). Some agencies do have a more narrow mandate, such as the U.S. Park Service, which does not allow resource extraction or off-road vehicle use, for example, but the vast majority of public land in the United States is managed by agencies charged with a multiple use mandate (Loomis, 1993).

Each designated public lands area is governed by an overarching plan that is revisited every 15 or 20 years and that spells out in broad terms the various permitted uses and their general locations within the management boundaries. Within this overall guidance plan, it is the task of the federal lands managers working for each agency to balance among competing uses when making specific decisions for how to conduct their own management activities or what to allow on public land and under what conditions. Typical decisions in Colorado might include allowing a timber sale, granting oil and gas leasing, permitting grazing of cattle or sheep, granting a concessionaire the right to lead rafting trips down a river, and so on. Decision makers must triangulate among what resource values exist, where the values are compatible, and where activities can be sited. Some of the types of impacts that are evaluated in a particular project decision include impacts on endangered species, public safety, aesthetic characteristics, economic considerations, quality of recreational experience, health of forests and tradeoffs among competing uses (interviews 1, 5, 11and 16, Ellenwood et al., 2012; Dilling et al., in press; Archie et al., in press).

In addition to operating under the legal and administrative structures established by the multiple use mandate, federal public lands managers also must follow processes established in U.S. law under the National Environmental Policy Act (NEPA). NEPA requires that agencies consider the environmental impacts of decisions along with other ramifications, and requires an open, public process that allows comment and provides transparency regarding the choices on the table and the reasoning behind a decision. Nearly every federal land manager that we spoke with mentioned the importance of NEPA in their permitting process and the importance of public input to that process (interviews 1, 2, 5, 10, 11, 13, 16, 17, 20, 21, 22). Because federal public lands are managed in a multiple use context and thus subject to a range of potential interests, every major decision is potential open to scrutiny and challenge. Lawsuits challenging major decisions are not uncommon, and thus many decisions are made with the threat of litigation in mind (interview 21).

Economic factors also weigh strongly on decision making on public lands. While public lands are not managed as a profit-generating enterprise, they must operate within a budget allocated each year by the federal government or state or local government.

Private lands: As with most commodity producers, economics and commodities' markets greatly affect landowners' decisions of what crop to grow and how to manage the land (interview 3). While not every individual was concerned about the level of profitability of their farm or ranch, every person we spoke to mentioned the cost of maintaining their land, the cost of farming or ranching equipment, the prices they could get for their products, or the role of markets. Some individuals were not concerned about profitability since they held employment off the farm and were holding onto the land out of "sentimentality" (interview 27). As another farmer remarked: "you don't make a lot of money running

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a farm, the value of the land is in selling it" (interview 12). This may reflect a situation specific to our group of interviewees who were exclusively family-owned and run operations, rather than larger agribusiness operations more common in other parts of the U.S.

Economics are not the only factor, of course, as climate, soil type and access to water are equally important in setting the parameters for what can be grown. Colorado is a semi-arid state, especially in the eastern half where most of the private land and agriculture exists. Gaining access to water is expensive, whether through building wells and tanks or buying water rights. Those who have senior water rights have a great advantage over those with junior rights, as senior water rights holders are legally entitled to obtain their water first, which can be a make-or-break situation in times of scarcity (interviews 9, 12). Climate is also important for its influence on erosion—windy conditions can cause a tremendous loss of soil cover (interviews 9, 12).

Federal and state policies are also highly influential on the choices and options available. Some examples of particularly influential policies include: the federal Crop Insurance Program; the U.S. Farm Bill, including policies regarding ethanol and other biofuels; access to and/or subsidies for new technology; grazing opportunities for ranchers on public lands; the Conservation Reserve Program; and state agricultural lands tax policies (interviews 9, 25, 28). Access to new technology for cropping and seed availability also influences for example the types of crops and the need for additional labor, overall costs, and so on (interviews 9, 28).

3.3. Barriers to carbon management

We next turn to results from our questions on the degree of latitude decision makers have to incorporate new goals into decision making, and in particular, whether barriers exist to increasing engagement with carbon management-related goals.

3.3.1. Competing objectives and limited resources

Public lands: On the one hand, one might imagine that carbon management fits neatly into a multiple use management context, as it would seem to simply be adding one more goal to the list. However, in practice, there are already strong governing mandates to fulfill legal or constituency demands for various uses as discussed above. Given the limited resources available with which to manage the multiple uses, adding on an additional consideration may be difficult. While not mentioned as an insurmountable hurdle, funding or the cost of new projects was often mentioned as a necessary factor in moving forward on a new activity (interviews 17, 21, 11, 19, 22).

In addition, in many cases, it was unclear how carbon management goals might enhance or detract from these other, established uses of the land (interviews 2, 5, 13, 14, 16, 18, 19, 21, 22, 31). While some felt carbon management objectives would dovetail nicely with existing priorities, others considered that some of their objectives may even be in conflict with carbon goals and therefore may not gain "much traction" on public lands (interview 14). While forests are currently a significant carbon sink, some may perceive that forests currently "have too much carbon" due to the build up of carbon from fire suppression policies in the past (interview 14). Trying to store more, or preserve what is there may then be perceived as conflicting with the goal of restoring to a "healthy" forest state.

Private lands:

Economics: As mentioned above, profitability is an important driver for many (but not all) family ranches and farms. As such, options that constrain profit or at least do not enhance it are not favored. Most farmers and ranchers would have no economic incentive to manage for carbon on their lands in the absence of policy or payment programs that would do so. At the time of this study, there was only a voluntary policy providing incentive to farmers and ranchers to manage their lands to sequester carbon, the aforementioned CCX program. As a voluntary and experimental program without a national price on carbon to incentivize participants, carbon prices on the CCX hovered for most of its history around $1 or $2 per metric ton of CO_2-equivalent emissions, reaching a high of approximately $7 a ton only when legislation for cap and trade seemed to have a possibility of being made law. Nonetheless there are some lessons that can be drawn from how farmers and ranchers interacted with this program to understand the broader view of these types of incentives and how they intersect with land owner decision making.

Carbon incentive program—payments: From the perspective of private land owners, fledgling carbon programs in the private sector seem to have several drawbacks that may have limited the overall enrollment in these programs in 2008. First, the payments for carbon at the time of our interviews were said to be too low to provide much incentive to enroll or especially to change practices, at perhaps $1–$2 per acre (about 4000 m^2) enrolled (interviews 3, 4, 6, 28), reflecting the voluntary nature of the market. Some interviewees, however, thought that even this small amount could be helpful to farmers who, oftentimes, are simply trying to hang onto land which may be only marginally profitable (interview 12).

Carbon offset program—restrictions and recordkeeping: Second, the actual requirements and restrictions regarding land management were a barrier for some. Several farmers mentioned that record-keeping requirements may be prohibitively time-consuming for such a small economic return (interview 3). As one rancher said, "the carbon program isn't worth the bother or the payment" (interview 6). Protocols are complicated (over 30 pages each) and have quite specific requirements that may exclude many common existing practices or land use situations in Colorado such as fallowing or not being able to rotate cattle sufficiently (interviews 3, 6, 9, 28; Chicago Climate Exchange, 2009a,b,c).

Carbon offset program—fairness: One rancher felt that there were too many restrictions on who could enroll in the program for carbon—not all ranches are eligible, and they found it a disincentive that carbon credit prices differed by location (interview 4).

Carbon offset program—uncertainty: There was uncertainty about the repercussions if one fell out of compliance with the standards set forth in the contract. One landowner wondered, for example, if the offset payments would then be retracted or a fine levied (interview 9). In addition, some were concerned about the longevity of the program and incentives, citing the example of the Conservation Reserve Program (CRP), a U.S. federal program which provides substantial payments for removing marginal lands from production. Lands enrolled in the CRP program were being plowed under at high rates at the end of contracts when the prices for commodities such as corn were sufficiently high (interviews 12, 27), thereby negating gains for conservation and soil erosion. Whether these factors might affect future carbon offset contracts remains to be seen.

Carbon offset program—compatibility: Finally, most producers must follow specific requirements if enrolled in the federal Crop Insurance Program and file records with the U.S. Department of Agriculture's Farm Service Agency (FSA). The FSA sets a great deal of policy for how producers work their land so that they may remain eligible for crop insurance, support payments and loan payments. If carbon offset crediting practices are not consistent with practices set forth by the FSA and other agencies producers will not likely be able to enroll their acres in the offset program.

In sum, low prices for carbon, restrictions on use of land, onerous reporting requirements, uncertainties about penalties and

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incompatibilities with existing policies may limit the adoption of carbon offset programs among producers. These findings are consistent with the disincentives reported by the Iowa Farm Bureau under the original CCX program such as term credits, high transactions costs, and lengthy contracts (Iowa Farm Bureau, 2009). In a study focused on ranchers in the U.S. Southwest, Gosnell et al. (2011) found similar economic as well as technical and psychological barriers to transitioning to more "carbon-friendly" management practices.

3.3.2. Lack of information

Because carbon management is a relatively new objective and quite a technically complex one, we asked questions about the role of scientific information in the decisions made by land owners in Colorado. The lack of information does emerge as a potential barrier, but results suggest some differences in what is lacking for public and private land managers.

Public lands: Many public lands managers expressed that they do not have adequate information on how various management options that they have at their disposal affect carbon sequestration. Furthermore, changing management practices is often a contentious process, and under NEPA, managers feel they must have solid scientific information to help back up their decision (Interview 21). When asked about the role of information and what type of information was important in decision making, public lands managers tend to use words like "reliable," "unbiased," and "the best available science" (interviews 1, 10). Decisions cannot be based on speculation, "what ifs," or anything that seems "hysterical" (Interview 18). Peer-reviewed literature that can stand up under legal challenge is seen as the gold standard (interview 18) especially when court trials become "a battle of science" (interview 16). Even so, one "can never make a decision bulletproof or ironclad" in the face of future challenges, although this seemed to be a common goal of many of the agency staff we spoke with (interview 19).

Several managers emphasized that they did not have sufficient information on the ramifications of various management alternatives on the carbon balance, such as reducing the fuel load or making wood products (interviews 14, 19, 21). One Forest Service District Ranger was well aware that "forests are a great place to sequester carbon," but had questions about how to manage forests to maximize carbon, asking "should we leave the slash on the ground, or leave it as a whole tree"? (interview 2). Unfortunately some of the objectives such as timber production and fuels management techniques do not have straightforward correlations with carbon content, which poses a challenge to providing effective decision support information (Hurteau et al., 2008; North et al., 2009; Dore et al., 2010; Reinhardt and Holsinger, 2010; Hurteau and North, 2010; Ellenwood et al., 2012).

Private lands: Private land owners tend to get their information from a range of sources, including trade magazines, neighbors, agricultural consultants, and agency employees, but rarely if ever get information directly from scientists themselves or peer-reviewed publications (interviews 3, 4, 6, 7, 8, 9, 12, 26, 27, 28, 30). Most of our farmer and rancher interviewees did not mention information as a particular lack, although some mentioned that they didn't know what to think about carbon management as yet. Those who had heard of programs were well-informed about the specifics of the programs and how they might work with their own land management practices. The uncertainty about how practices affected the carbon balance was not a direct issue—practices were prescribed by the contracting broker (as established by CCX) and so there was not likely much of a need to seek information on what practices best enhance carbon sequestration.

3.3.3. Perceptions of carbon offsetting

Attitudes are an important determinant of land-use decision making (Riebsame et al., 1994) and can thus represent an opportunity or a barrier to managing for carbon. We report in this section on those attitudes that might represent a barrier to expanding the role of the public or private sector in managing for carbon.

Public lands: While many public lands managers we talked with saw carbon management as a worthy goal, some public land managers held perceptions of carbon management that could lead to hesitation in prioritizing the issue. Beyond the issue of uncertainty in how much carbon might be stored by deliberate activities, some worried about the permanence of carbon stored in biospheric reservoirs. Permanence refers to how long carbon is kept out of contact with the atmosphere—a more "permanent" means of sequestering carbon would indicate that the carbon is stored out of contact with the atmosphere for a longer period of time (Dilling et al., 2003). One specialist expressed concern about the potential loss of extra carbon stored from fire, pests, etc. (interview 13). As one staff advisor put it, "What happens if the forest burns? We're still struggling with what to do" (interview 16). On the other hand, he felt that many of the means taken to reduce forest fire danger seemed to be compatible with carbon storage, such as removing ladder fuels (vegetation that can help a fire reach the forest canopy), reducing the fuel load, and preventing crown fires.

In addition to concerns about permanence, some public land managers did raise questions about additionality, or whether it was right to credit existing activities when there was no additional carbon stored. As the staff advisor said: "we're finding that most of them [things to do to increase carbon storage] we're already doing. If the money is there for carbon offsets, what would we do differently?" (interview 16). As one program leader asked "Can you take credit for something that has always been there [i.e. forests, for example]"? (interview 18). A Forest Supervisor echoed this question, asking "should we be getting credit?" (interview 21). A county-level program director also expressed these sentiments: "it's good to store carbon. But I'm not sure if we want to get credit so that someone else can pollute" (interview 15). It should be noted that this skepticism about offsets may still exist even if programs can establish that there is true additionality. We did not attempt to distinguish these points of view. Clearly, some are concerned about whether these types of offsets are the best way to address the problem of climate change mitigation.

Private lands: There may also be some resistance to carbon management that stems from landowners' perceptions about the outcomes of carbon offset programs and the values the landowners hold. Some of the private land owners expressed negative perceptions of carbon offsets that relate to the theme of concerns about additionality. One farmer said he just "doesn't see how that is going to work." He asserted that he knows that most of the crop he grows and uses for feed goes right back into the system, "into the atmosphere" (interview 6). Another expressed skepticism regarding benefit of the program to climate, expressing the view of many opposed to offsets: "So people are paying us for carbon credits so they can keep polluting somewhere else? How is this going to help anything?" (interview 12). While some farmers felt that it would be most successful if they could be paid for things they were already doing (interview 4), another stated clearly he did not want the program to be "paying for things that are already happening" (interview 27). As yet another farmer put it, "it is hard to reconcile paying for something that people are already doing so that someone [else] can pollute" (interview 28). One aggregator expressed a different perspective on this point, saying that offsets are an opportunity for landowners who are managing their lands responsibly to be paid for providing a service that they would

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otherwise be providing "for free" (anonymous, personal communication, May 23, 2011).

3.3.4. Lack of policy signal

Public lands: Another reason that carbon management may be difficult to incorporate into decision making on the ground was the lack of definitive federal policy. Many managers did not feel they had sufficient information or guidance to know how to incorporate climate change into their everyday decisions (2, 5, 10, 11, 18).

In addition to the lack of specific policy at the local level constituting a barrier, the uncertainty in the political situation with respect to climate change can also cause concern. The U.S. political environment with respect to climate change has become more polarized along political party lines in recent years (Dunlap and McCright, 2008). While local federal managers are career civil servants, and not political appointees, some public sector individuals simply did not feel they were supported in making decisions that incorporated climate-change information, either in terms of support for showing leadership in the area or in terms of seeking out science that might support decisions. As one program lead stated "I don't want to stick my neck out without a national policy. There is not enough solid information yet" (interview 18). Subsequent informal conversations after interviews were completed suggest that this fear of acting too proactively may persist even if the administration changes, as there is always a chance of an administrative policy reversing with a change in administration.

Private lands: While there was general support in the U.S. Farm Bill encouraging practices on private lands that would sequester carbon in soils, in 2008 there were no payments from the federal government that would have incentivized carbon sequestration on private lands. Carbon is mentioned as a priority in the 2008 U.S. Farm Bill (Titles 2, 7 and 8), but only in the context of technological innovation, developing guidelines for market participation, research and public benefits of forestry.

4. The potential for expanding carbon management on the land

4.1. Clarity of guidance and mandate for public land managers

While there was generally high awareness among the public land managers we spoke with about the issue of carbon sequestration and the role that their decisions might play in the carbon balance, there was not a lot of clarity about what to do to manage land to enhance carbon sequestration. There was also a general sense that the issue was simply not yet high enough on the priority list at the agencies that resources should be devoted to carbon management or that it should be considered routinely in making decisions.

Since our interviews were completed, however, further developments have occurred in the national policy landscape related to climate change. The Council on Environmental Quality (CEQ) that coordinates federal executive branch policy on environmental issues, issued a memo outlining how agencies should consider the emissions aspects of climate mitigation, although they asked only for comment on developing a potential protocol for land-use management for carbon sequestration (Sutley, 2010). Climate change has been increasingly emphasized at the U.S. Department of Agriculture (USDA, 2008, 2010a), and the USFS has also recently implemented a "Climate Change Performance Scorecard" to track progress on incorporating climate change into decision making, including monitoring carbon stocks on public lands (USDA, 2010b). The Department of Interior (which houses both the BLM and the National Park Service) has established several new Climate Change Centers, and the DOI has prepared a plan for responding to climate change impacts (Department of Interior, 2011).

These developments notwithstanding, our results suggest that if enhancing carbon sequestration becomes a policy goal, managers at the local level in federal agencies will need more specific guidance for how and to what extent to incorporate carbon management as a goal in decision making. Given the variability in carbon stocks and the differences that various management options can make for carbon storage potential, such guidance will likely need to be regionally specific and flexible to accommodate a multiple use context. In addition, managers will need a clear signal that carbon management is a priority and that they do not feel it is a risk to their careers to move ahead with actions to manage carbon.

With the exception of a few pilot projects on public lands elsewhere in the country, public lands have not generally been a part of the voluntary carbon market (Dilling et al., in press). It is however, well recognized that public lands play a critical role in maintaining carbon stocks, and that good stewardship practices are essential. Some agency managers in Colorado suggested that new, innovative policy should be developed for how to incentivize carbon storage on public lands.

4.2. Compelling incentives for private land managers

At present, there seems to be little incentive for private landowners to consider carbon as an additional driver in their decision making, especially if it would require them to change practices. The economic return is low in a voluntary market, and the practices and recordkeeping burden associated with typical carbon offset programs are a deterrent for some potential participants. While some modeling has been done of the price of carbon necessary to entice more broad participation by land owners (Lewandrowski et al., 2004; McCarl and Schneider, 2002), it would be informative to test through empirical studies what kind of payment would be necessary to elicit a change in practices among those who do not already conform to the carbon management guidelines. In the absence of economic incentives, it seems unlikely that many landowners will change their practices solely motivated by the goal of storing additional carbon.

On the other hand, carbon offset programs could be appealing for those already in compliance with the requirements for earning credit. For example, Gosnell et al. (2011) found that of all the 28 ranchers she interviewed who had enrolled in the CCX carbon offset programs, none had to change their practices to comply with the offset protocol. However, if practices do not change, this raises the question of whether such programs are truly additional with respect to climate goals.

4.3. Better understanding of the co-benefits of enhancing carbon sequestration

For both public and private lands, certain management practices can provide co-benefits for carbon-related goals that provide other benefits such as fuels management, preventing soil erosion and ensuring healthy forests. No-till agriculture, for example, both promotes soil carbon sequestration and prevents erosion and water loss (Post and Kwon, 2000). Other programs such as fire mitigation on public lands or more extensive changes to cropping systems are more uncertain with respect to their carbon benefits, and thus we simply do not currently know whether or not these programs can be a "win-win" with respect to carbon (Breshears and Allen, 2002). In still other situations, existing practices or policies may directly conflict with the goal of storing more carbon on land (or with the way the policies are constructed; e.g. Hurteau et al., 2008). The potential for additional

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carbon storage on land must be understood, therefore, in terms of how it fits with existing goals and practices. If enhancing carbon sequestration on public and private land is a policy priority, more research into the co-benefits and practicalities of supporting multiple goals including enhancing carbon sequestration with existing land management options is warranted.

If carbon sequestration practices also can improve the health of the land, that may represent a win-win for many producers. Many of the farmers and ranchers with whom we spoke cared deeply about preserving the health of the land they manage and the environment as a whole. From one rancher's perspective, "anything that can improve the health of the soil is good, and if carbon does that, great" (interview 7). While he was not sure about the ultimate fate of carbon markets or what to think of the idea, one producer indicated that he would enroll in the program "if he is going to be doing some good" (interview 12).

4.4. Creating usable science for land-use decision makers

At least for public land managers, the lack of relevant information on the effects of alternative actions on the carbon balance in the lands they manage appears to be an obstacle to incorporating carbon sequestration goals into routine decision making. Previous work has shown that for information to be effective in influencing decision making it must be seen as credible, relevant and legitimate (Cash et al., 2003).

What constitutes credible science in this context? Many of the agencies mentioned that they rely heavily on the scientific literature, and on information produced by other agencies. On the other hand, although university research can have high credibility and be seen as more unbiased it may sometimes not be acceptable for the planning process if it is seen as too experimental, as stated by one specialist "if they [the public, decision makers, other agencies] haven't heard of it, they won't trust it" (interview 11).

Information must also be relevant. What is relevant can depend on who the decision maker is. As one specialist put it: "As a scientist, I want to know all the details. Planners want to know what will be controversial. Managers want to know what's political, so they can do risk management" (interview 11). Relevance can also relate to many other qualities of the information including scale, content, and timing of results. As one manager of tribal lands said: "We can't wait 30 years for the research" since actions are already being taken to respond to management challenges (interview 23).

Finally, information must be legitimate. Legitimacy refers to being respectful of all of the parties involved and being fair in representing opposing views and interests (Cash et al., 2003). For example, one specialist warned that he is "leery of self-serving science" citing examples of researchers who use a justification such as climate change to support ongoing research that is not directly answering the questions managers wanted to know (interview 11).

These findings suggest that in order to support land managers' needs for information related to carbon management, programs and scientists must become more attune to the process of producing information as well as the ultimate decision context in which information might be used. However, in this study we heard that "researchers don't always act as if they are aware of the decision space" (interview 14). How can scientists become aware of the "decision space"? One way is to focus on creating ongoing opportunities for researchers and decision makers to work together, rather than separating the process of knowledge generation from its use (Lemos and Morehouse, 2005; Sarewitz and Pielke, 2007; Dilling and Lemos, 2011).

5. Conclusions

The interest in promoting carbon sequestration on land through land-use management has grown in the international policy community in recent years. Carbon sequestration through improved land-use practices has the potential to sequester tremendous amounts of carbon in terrestrial biomass and soils. One of the challenges that is only recently receiving attention is how to incentivize the behavior of land managers themselves so that these potentials can actually be realized. We examined the existing decision context of public and private land owners in the U.S. state of Colorado to understand what currently drives land-use decisions, and how carbon management goals might be playing out against that backdrop.

We found that land managers in both the private and public sectors were generally aware of the potential to manage land to increase carbon sequestration, but that not many actions were yet underway to do so. The incentives and requirements for land-use decision making are not yet well matched to the emerging call to manage carbon more deliberately. Public lands managers are already coping with many competing objectives for public lands, and operating in an environment with little certain knowledge about how management actions in their region affect the carbon balance. Private land owners do not yet see a financial incentive to change practices to store more carbon, and existing practices are not always in line with maximizing carbon storage. Public and private land managers have mixed feelings about prioritizing carbon management as a land-use goal—on the one hand they see value storing as much carbon as possible on land, but at the same time they question some of the assumptions about whether carbon offsets are truly beneficial for the climate in the long run.

Looking toward the future, there are several opportunities to potentially expand carbon management on public and private lands. A clear policy signal that carbon management is a priority, both for public lands and private lands, is likely to provide a stronger incentive for land managers to become involved. Public lands managers do not yet have clear guidance on how to incorporate carbon into decision making at the local level. A policy signal can also incentive private land owners to prioritize carbon if that signal translates into high enough financial incentives to overcome barriers such as having to change practices or increased recordkeeping. Further research on the co-benefits of management actions that also sequester carbon would help to inform decisions, especially on public lands. Finally, creating opportunities to understand the context of decisions involving carbon management can enhance the likelihood that the information generated by research can actually be usable by decision makers.

It remains to be seen whether our findings hold true for land owners in other parts of the U.S. with different growing conditions, practices, and traditions. Parts of the Pacific Northwest and Southeast have much denser forests with higher biomass, and the Midwest has much larger expanses of non-irrigated agriculture. Presumably these features of the landscape would make a difference to the way that carbon is credited, and to the options available for changing practices. A broader geographical study would be needed in order to ascertain how applicable our results are to the larger national picture.

This study also has implications for the wider debates on land use as a means of achieving additional carbon sequestration. The challenges identified thus far in REDD research in a developing country context include providing adequate monitoring of effective sequestration (Agrawal et al., 2011), supplying sufficient economic incentives for participation in the REDD program (Potvin et al., 2008; Caplow et al., 2011), ensuring that REDD programs do

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not trample the rights of local people or reverse gains in land tenure reform (Larson, 2011; Beymer-Farris and Bassett, 2012) and preventing a carbon-centric scheme from overriding other valued outcomes such as biodiversity protection and food security (Agrawal et al., 2011; Mustalahti et al., 2012). While uncertain land tenure is not an issue in Colorado, many of these other issues emerged in our study, including concerns about additionality and reversibility, competing or incompatible management goals, and lack of knowledge about which management actions actually sequester additional carbon. This suggests that even in a situation of relative stability in governance regimes, managing land to achieve additional carbon sequestration can be a challenge.

In sum, our study raises several questions about what might be necessary in order for land managers to consider carbon in their land management decision making in any widespread way. Incentives, information, policy drivers and existing practices all play a role in this emerging area. Estimates of the technical potential for enhancing carbon storage must go hand in hand with knowledge of decision maker priorities and constraints in order to craft effective policy.

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