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Managing United States Public Lands in Response to Climate Change: A View From the Ground Up

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Abstract Federal land managers are faced with the task of balancing multiple uses and goals when making decisions about land use and the activities that occur on public lands. Though climate change is now well recognized by federal agencies and their local land and resource managers, it is not yet clear how issues related to climate change will be incorporated into on-the-ground decision making within the framework of multiple use objectives. We conducted a case study of a federal land management agency field office, the San Juan Public Lands Center in Durango, CO, U.S.A., to understand from their perspective how decisions are currently made, and how climate change and carbon management are being factored into decision making. We evaluated three major management sectors in which climate change or carbon management may intersect other use goals: forests, biofuels, and grazing. While land managers are aware of climate change and eager to understand more about how it might affect land resources, the incorporation of climate change considerations into everyday decision making is currently quite limited. Climate change is therefore on the radar screen, but remains a lower priority than other issues. To assist the office in making decisions that are based on sound scientific information, further research is needed into how management activities influence carbon storage and resilience of the landscape under climate change.

Keywords Climate change · Carbon management · Land use · Public lands · Federal agencies · Forestry · Fuels management · Decision making

Introduction

Increases in the atmospheric concentration of CO_2 and other greenhouse gases over the past century are now recognized to be causing significant climatic changes (Solomon and others 2007). These changes include higher global average temperatures, rising sea levels, and changes in precipitation patterns, which will in turn affect ecosystems and human populations (Parry and others 2007). In addition to studying the science of climate change, scientists and others have been working to understand how carbon might be managed to mitigate climate change, and how we might adapt to future impacts.

Many countries have begun to address climate change through a number of policies and measures. International policy through the UN Framework Convention on Climate Change has mainly focused on setting targets for emission reductions, but carbon management and adaptation have been increasingly discussed. In addition to national and local level policies and mandates ranging from renewable energy standards to emissions trading schemes, voluntary projects set up by entrepreneurial companies have become important proving grounds for how measures to control greenhouse gases and respond to climate change work in practice. In short, policy to address climate change is in

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various stages of development and acceptance depending on the national context and the interest of non-state actors at various levels.

In the past two decades, several bills have been introduced in the U.S. Congress to address climate change at the national level, but none have been enacted. In the absence of a comprehensive statutory framework that would require carbon management and greenhouse gas reductions, federal policy in the U.S. has focused primarily on supporting research, development of emissions inventories, energy efficiency improvements, and voluntary reduction programs. In 2009, however, the U.S. Environmental Protection Agency used its authority under the Clean Air Act to introduce mandatory reporting requirements for greenhouse gas emissions, and began the process of regulating greenhouse gas emissions from vehicles and large stationary sources.

Even without comprehensive climate legislation, federal land managers in the U.S. have begun to respond to climate change and carbon management concerns under the multi-pronged mandates that govern the public lands. The U.S. Forest Service (FS), under the Department of the Agriculture manages 780,000 km^2 of land, much of which is covered by carbon-dense forests (Dilling and Birdsey in press). The Bureau of Land Management (BLM) within the Department of Interior manages another 960,000 km^2 of land. Public lands managed by these two agencies therefore represent a significant fraction of the land surface that could potentially be managed in service of carbon sequestration goals (Failey and Dilling 2010). Federal land managers also influence emissions of CO_2 and other greenhouse gases through oversight of the development of federally owned coal, natural gas, and petroleum resources, as well as through regulation or conduct of numerous activities on federal lands that involve fossil fuel combustion.

In addition, many of the uses of public lands that are currently valued will be impacted by climate change, and managers must consider the challenges of climate adaptation (Baron and others 2009; Joyce and others 2009). While many municipalities, agencies, and academic scholars have recognized the need to incorporate adaptation into planning and infrastructure and resource decision making, the evidence that adaptation is occurring is sparse yet increasing (Berrang-Ford and others 2011). Nonetheless this is an area of policy that is rapidly changing, and it is likely that governments, corporations and individuals will increasingly consider how the need to adapt to climate change alters decisions they must make over a variety of time scales (ICCTF 2011).

In recent years, agencies have begun to engage the issue of climate change through a variety of planning processes, new frameworks, and policy statements at the leadership level, including Executive Orders. How these documents and guidance will influence decision making at the local level is unclear, however. The local level is where many of the day-to-day decisions are made that ultimately determine how the land is managed. Agencies function under a multiple-use mandate, and so any new considerations must be weighed against other mandates for the use of resources, personnel, and the land itself. Historical legacies can also figure prominently in any decision process, such as laws and customs on public lands that have been passed down for a century or more and affect current policies through inertia and constituencies (for a thorough history of historical legacies in U.S. public lands law please see Wilkinson 1992). This study seeks to understand how federal guidance on climate change is currently being assessed and interpreted in the context of a *local* federal public lands office, the San Juan Public Lands Center in southwestern Colorado, to identify potential barriers and opportunities for responding to climate change in the public lands context.

Numerous authors have proposed frameworks for analyzing policy effectiveness and the causal mechanisms for understanding the effects of policy (e.g., Cashore and Howlett 2007, McDermott and others 2008 in the context of forest management). Cashore and Howlett (2007) separate out policy into means and ends, and three levels of analysis: goals, objectives and settings. The last level, the settings under which a policy is enacted, focuses specifically on the "on the ground" aims of policy and specific ways a policy instrument is used at the local level. The settings level has been highlighted as a critical opportunity for analysis as it is where the impacts of policies are seen on the variable of interest, for example, protection of riparian zones (Cashore and Howlett 2007, McDermott and others 2009). Auld and others (2008) have suggested that the effectiveness of an environmental policy (in their case, forest certification programs) can be tested by understanding the degree to which the policy "instrument modifies on-the-ground practices."

Several hypotheses about what promotes changes in policy have been raised in the literature. Cashore and Howlett (2007) provide a short review of some of the major drivers, and describe the tension between external perturbations to the system and features of the institutions themselves. Within the federal lands context, features of the decision making culture, wider societal goals (including environmental values) and institutional objectives (such as environmental laws) can all contribute to the emergence of settings-level policies (Ibid.). While there is still some degree of individual level discretion within a framework of organizational consistency, as Kaufman (1960) described in his seminal work on forest rangers, over the past decades new laws and cultural norms for land management agencies have sharply altered patterns of decision making (Kennedy and Quigley 1998, Koontz 2007). Federal land managers in the United States find themselves more than ever balancing competing objectives in a landscape of shifting and often conflicting public values (Luckert 2006). Cashore and Howlett (2007)

found in examining the Spotted Owl controversy in the Pacific Northwest that the most important factor shaping policy at the settings level was that the governing institutions in question, in their case the Endangered Species Act and the National Forest Management Act (NMFA) provided "durable" objectives that ultimately required changes at the settings level in response to new scientific understanding.

In this case study, we sought to examine how federal land managers might or might not be incorporating climate change into decision making at the local field office level. The office we studied, the San Juan Public Lands Center, was a shared office of the FS and BLM under the "Service First" program, which allowed cross-delegation of some authority between staff of the two agencies. When we began our study, staff at the SJPLC were actively seeking scientific advice and investing resources into understanding their options for addressing carbon management, greenhouse gas mitigation, and climate adaptation. Nevertheless, in the absence of federal legislation providing a durable objective for incorporating carbon management or climate adaptation goals into decision making, we hypothesized that the SJPLC would not yet be ready to adjust local policy "settings" in response to climate change concerns.

Our goal in this study is not to provide a definitive assessment of the effectiveness of federal level policies on decision making at the local level, as the newness of such policies likely precludes effectiveness analysis of this question (Young and Levy 1999, Gulbrandsen 2005). Rather, we seek to understand how such guidance is currently being assessed and interpreted in the context of a local federal public lands office, to identify potential barriers and opportunities for responding to climate change in the public lands context. While we might expect that there are not many, if any, prescriptive policies that would be in place thus far, we suggest that by studying a case in the formative period of how specific policies may emerge we can better understand what managers themselves might view as the tradeoffs between existing multiple use mandates and constituencies and newer directives to consider climate change in decision making. The paper first examines the various decision making influences, and then examines tradeoffs with climate change and carbon management considerations for fire and timber management, biofuels utilization, and grazing. Although focused on potential responses to climate change in the lands managed by the SJPLC, this case study raises important issues and questions to be considered more broadly for the future of carbon management and climate adaptation on public lands.

Methods

We focused on the San Juan Public Lands Center in southwest Colorado as a case study to investigate how land managers evaluate tradeoffs when making decisions about publicly owned lands and their uses. The case study method is particularly appropriate for our question, as climate change and carbon are only just emerging as management considerations, and we were interested in studying these decisions as "a contemporary phenomenon in its real-life context" (Yin 2003, p. 13). The SJPLC provides leadership for BLM and FS field offices and ranger districts in Durango, Pagosa Springs, Bayfield, and Dolores (Fig. 1) and for the Canyons of the Ancients National Monument. Overall approximately 175 federal employees are involved in the management of the land encompassed by the SJPLC in these offices, districts and headquarters. SJPLC is responsible for approximately 9600 km^2 of public lands in southwest Colorado and administers mineral estate underlying more than 4000 km^2 of private and tribal lands. Management decisions from these offices have far-reaching impacts over a wide variety of lands that are rich in natural and cultural resources. Lands administered from the SJPLC range from grass and shrublands to alpine tundra, with elevations ranging from 1500 to over 4200 m (Fig. 2). Of the 9700 km^2 area covered by the most recent Draft Land Management Plan/Environmental Impact Statement, more than 1700 km^2 are designated wilderness, and an additional 470 km^2 of non-designated lands are managed as wilderness. Private lands and communities are also dispersed throughout the area. The SJPLC itself is located in Durango, CO, a growing community with a population of greater than 15,000.

The case study focused on three different categories of land management activities (timber and fuel reduction, biofuels, and grazing), in order to explore a range of specializations and types of decisions in the SJPLC's jurisdiction. Our data consists of 15 semi-structured interviews, published reports from the BLM and the FS, as well as information presented by scientists and decision makers at the *Workshop on Adapting to Climate Change on the San Juan National Forest* held in Durango, CO on May 12, 2010. This workshop was organized by the SJPLC for the purpose of discussing and understanding how local climate is likely to change in the future and what it means for water, wildfire, and ecosystems. About 35 people attended from the BLM and FS, the University of Colorado, and the National Oceanic and Atmospheric Administration.

We conducted semi-structured interviews of 15 officials responsible for those types of decisions at various levels of government (field office, regional, and state) and with a range of different areas of expertise. Interviews were conducted in March and April 2010. Semi-structured interviews were most appropriate in this case study as we were interested in clarifying the central factors involved in decision making and how they related to new opportunities for carbon management (Schensul and others 1999, p. 150).

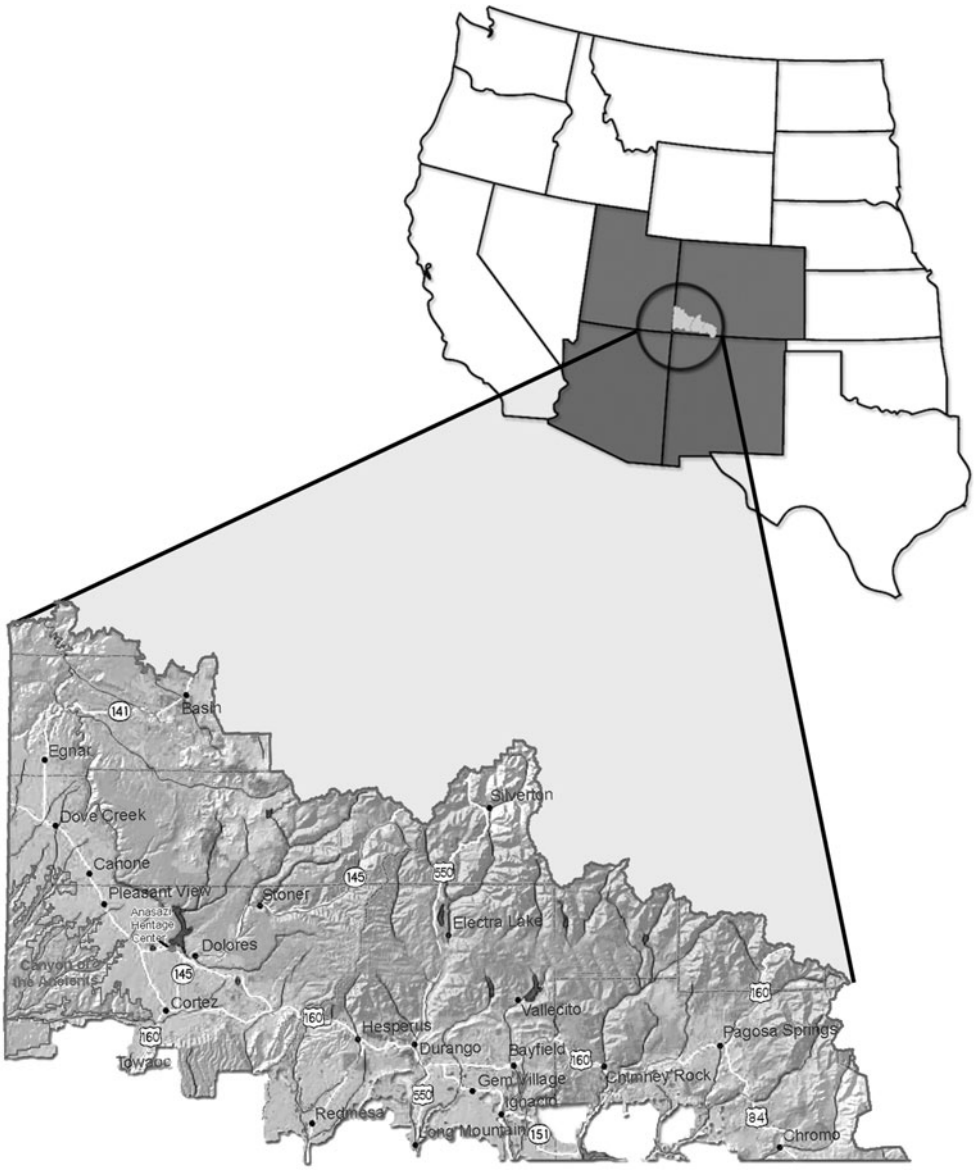

Fig. 1 Location of the San Juan Public Lands in Colorado near the four corners region in the Western United States

All participants were chosen based on their involvement in public land management or based on their expertise in climate change impacts or mitigation. Some interview participants had direct decision-making authority, while others were not decision-makers, but were planners, researchers, and technical specialists. Using snowball sampling, participants from that study suggested colleagues who could offer relevant insights.

In conducting the interviews, we expanded upon a set of previously developed questions and also allowed for more open-ended discussion (Dilling and Failey in review). By using semi-structured interviews, we were able to gain insight into various influences on decisionmaking and the implications for climate change and carbon management. Questions for decision makers covered experiences with controversial decisions, different types of influences on those decisions, the approach used to consider the advantages and disadvantages of alternatives under consideration, and prioritizing land uses. Our interviews asked about how climate was being considered in general in decision making, but also highlighted the area of carbon management as that was our initial area of focus. Specialists and scientists were asked about their respective specializations and the implications of climate change for sectors within their areas of expertise. Many of these individuals provide data and information to decision makers and those processes were probed through the interviews as well. Interview notes were transcribed, grouped into a matrix by interviewee type and topic, and analyzed according to themes such as types of management activities (e.g., timber management, biomass energy, grazing), use of information and uncertainty, carbon management or climate, and tradeoffs (Miles and Huberman, 1994,

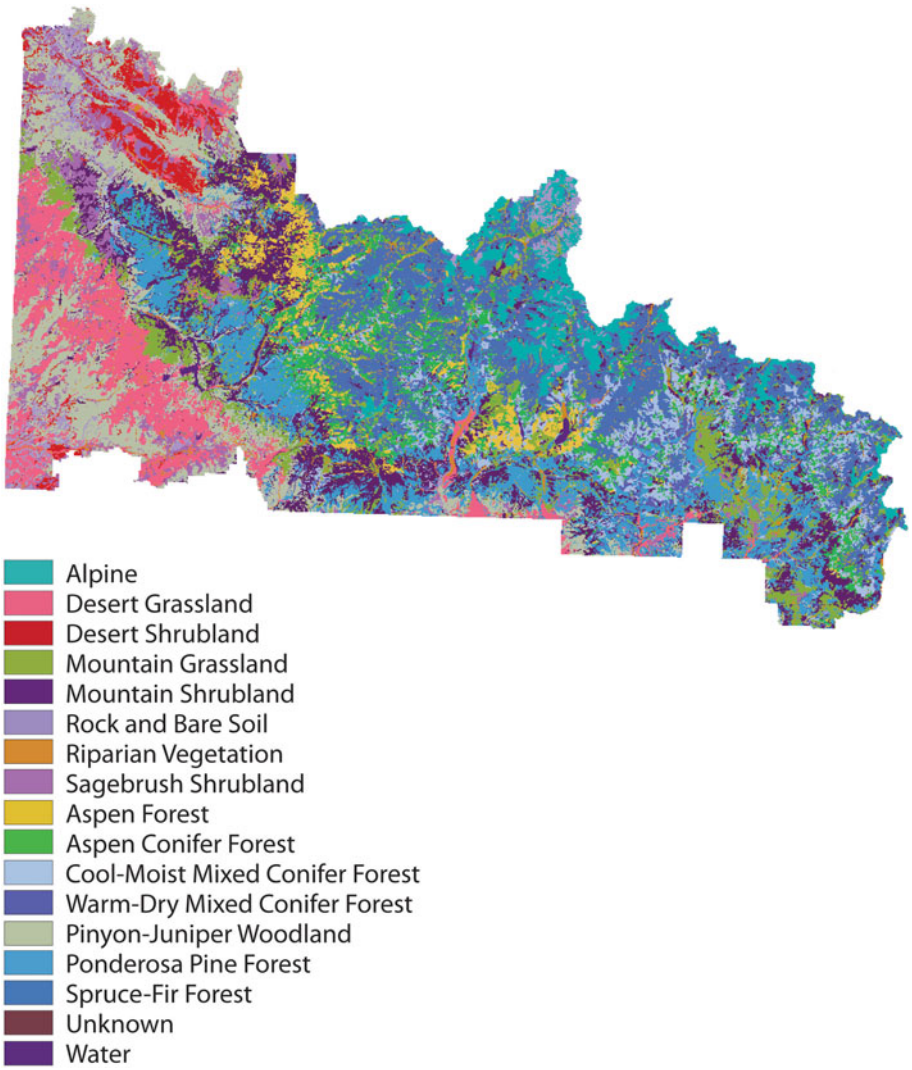

Fig. 2 Map of vegetation types within the San Juan Public Land region. Data provided by the US Forest Service (R2veg data) from their existing vegetation database from San Juan Public Lands website (http://www.fs.fed.us/r2/sanjuan/)

p. 93). The prevalence of emergent themes across interviews was identified and analyzed using this matrix.

Our study was focused more generally on responses to climate change, with some emphasis on carbon management. After our interviews were conducted, in October 2010, the Interagency Climate Change Adaptation Task Force developed a set of climate adaptation and policy goals, and additional activities on climate change adaptation are underway (ICCATF 2011). Our results therefore do not include these most recent developments on adaptation at the SJPLC.

Case Study Findings

The National Policy Landscape

Laws and guidance documents at the national level are extremely important for broadly determining how U.S. public lands are managed. The Forest Service operates under a mandate for multiple land uses and sustained yields of renewable resources, as set forth by the Multiple Use and Sustained Yield Act of 1960 and the National Forest Management Act (NFMA) of 1976. The NFMA imposes requirements for forest planning, including assessment of environmental impacts and public participation. Forest management plans must provide for diversity of plant and animal communities, and for sustainable management of water resources. Similarly, the BLM administers lands under its control with a multiple use mandate established by the Federal Land Policy and Management Act (FLPMA) of 1976. The BLM's multiple use mandate may encompass recreation, mining, energy development, grazing, wildlife habitat, and wilderness values. Within FS or BLM lands, Wilderness Areas are managed for conservation, recreation, scenic, and educational or scientific value, per the 1964 Wilderness Act. Use of motorized vehicles is generally prohibited in Wilderness Areas, except by federal

agencies as needed for wilderness management. Logging is prohibited and mining and mineral leasing highly restricted, but grazing is authorized within limits needed to protect wilderness values. As with other federal agencies, both the FS and BLM are subject to planning and environmental assessment requirements under the National Environmental Policy Act of 1969.

Over the past decade, the Executive Office of the President, the Department of Interior, which houses the BLM, and the Forest Service have all issued orders or guidance dealing with climate change and/or carbon management. In October 2009, President Obama issued Executive Order 13514 (2010), requiring federal agencies to measure, report, and reduce greenhouse gas emissions, set targets for improving sustainability, energy and water use efficiency, etc., and identifying risks and vulnerability to climate change. In February 2010, the Council on Environmental Quality issued draft guidance for federal agencies to address greenhouse gas emissions and climate impacts in environmental assessments and impact statements under NEPA (Sutley 2010). However, the draft guidance excluded land and resource management actions, due to the lack of an established protocol for assessing their effects on emissions and sequestration of carbon.

General guidance on responding to climate change has also been promulgated by the individual land management agencies. In January 2001, Secretary of Interior Bruce Babbitt signed Secretarial Order 3226, requiring each bureau and office within the Department to "consider and analyze potential climate change impacts" in planning and prioritization exercises. That order was amended in January 2009 by Secretary Dirk Kempthorne, but reinstated in its original form in September 2009 by Secretary Ken Salazar (Secretarial Order 3289, 2009). Salazar's Order also endeavors to increase coordination of climate change response strategies within the Department and across other federal agencies, and initiates projects related to carbon storage and reductions in greenhouse gas emissions and energy use.

The 2010–2015 Strategic Plan for the U.S. Department of Agriculture includes the goal to "ensure our national forests and private working lands are conserved, restored, and made more resilient to climate change, while enhancing our water resources" (USDA 2010). Within the Department, the Forest Service developed a Strategic Framework for Addressing Climate Change (USFS 2008), followed by a National Roadmap for Responding to Climate Change (USFS 2011). The Framework calls for consideration of climate change in FS planning. It encompasses both "facilitated adaptation", which refers to actions to adjust to and reduce the negative impacts of climate change on ecological, economic, and social systems; and actions to reduce emissions and enhance sinks of greenhouse gases. In the case of ecological systems, adaptation is defined as "enhancing the capacity of forests and grasslands to adapt to the environmental stresses of climate change and maintain ecosystem services" and is typically viewed as regional and site-specific (USFS 2008). The 2011 Roadmap identifies some specific priorities such as actively managing for carbon storage, facilitating demonstration projects, and encouraging the use of biomass for power and materials substitution.

In addition, for more than a decade the agencies have had a stated goal to manage for resilience. The BLM defines resilience as "the capacity of an ecosystem to maintain or regain normal function and development following disturbance" (BLM 2001). Resilience is helpful in order for systems to be able to absorb change without a fundamental shift of state, although some shifts will be "inevitable" in the face of climate change (Baron and others 2009). Finding the balance that promotes resource utilization while maintaining resilience of the landscape is thus the daunting and rather ill-defined task presented to land managers at the field office level. Going forward, decision-makers will need to evaluate the trade-offs and weigh the costs and benefits of alternatives to make decisions about how to promote ecological resilience in the face of climate change.

Decision-Making at the Field Office Level

The agency staff we interviewed generally concurred in the view that federal land management policy within both the FS and BLM commonly starts with Washington establishing broad polices and guidance. From there, state offices provide more specific guidance (8),[1] but the field offices are where the details are elaborated and specific decisions are made (11). A program planner with the FS stated that "the FS and BLM have a lot of general laws, but when it comes to a single management area, things get more specific," with their site-specific plans spelling out the details of how land will be managed under the general framework of the agency (10).

Proposed projects undergo extensive review at the field office level, through which environmental and other impacts are assessed under NEPA with the fullest amount of information possible and with opportunities for comment and input from interested constituencies. According to one BLM manager, and as required by NFMA and the Multiple Use-Sustained Yield Act, a key factor to be considered when screening proposed projects is whether each project would be "viable or sustainable based on the resources" available to the agency (9). Managers also consider potential negative impacts. In both the BLM and the FS technical specialists and program staff have the responsibility to provide the specialized knowledge

[1] Numbers in parentheses correspond to information obtained through interviews. See list of interviews after the references.

necessary on science, policies and regulations in order to help managers understand their options, and sometimes make direct recommendations (8 and 10). Ultimately the decision maker is responsible for analyzing and validating information presented in each case. Potential impacts must be carefully analyzed for each alternative when considering projects such as prescribed burns, energy extraction, or beetle prevention treatments at the field office level. Among the factors to be considered are impacts on species, wilderness, local communities, cultural resources, and the economy. Direct impacts as well as cumulative impacts that are incremental over time are considered. As an associate manager at the field office indicated, it is also critical to fully disclose these impacts (9).

As might be expected in a multiple use situation, there is often tension between competing and not necessarily compatible land uses. In the SJPLC, land managers in the BLM and FS give high priority to public concerns about recreation and preservation of wild and scenic areas. At the same time, they face pressure from expanding development and infrastructure projects and the area's growing wild-land-urban interface (WUI). Allocating land to meet the needs of development, conservation, and preservation creates what an associate manager with the BLM calls "a balancing game" with a large amount of discretion when it comes to management decisions (9).

Once made, decisions are not always popular. Decision makers are subject to pressures from various sources, including environmental groups, the broader public, elected officials responding to their constituents, and from other agency staff (9). Because of the many opinions that are to be taken into account, managers have many discussions during the planning process and also have review periods for significant decisions in order to draw input from the varying opinions of the public. A branch chief with the BLM emphasized that "public lands have different advocates" and unpopular decisions are inevitable due to their conflicting interests (8).

Interview respondents also indicate that funding is a strong internal constraint on project selection, including for actions that might be taken to address potential climate change and carbon management. Costs, effectiveness and efficiency of land treatments are thus significant considerations. Treating all of the land managed by the field office for insects, disease, and wildfire susceptibility would be prohibitively expensive and the reality is that some areas are more feasible to treat than others.

Local Office Decisions and Climate Change

A USFS specialist at the Colorado regional office states that future revisions of resource and land management plans in both the state (BLM) and regional (FS) field offices will be required to address climate change impacts and scenarios (14). Despite the lack of specific policy guidance for managing carbon or assessing climate change impacts and implications, managers and specialists within both agencies assert that a lot of "thinking" on the issue is occurring (1). In order to initiate an effective change in policy to address climate change and carbon management, according to one of the interview participants, there is a greater need for improved organization, more specialists, and stringent goals to guide site-specific projects (11).

A frequent theme from our interviews was the notion that climate change and carbon management were on the radar screen and were on the list of concerns that managers were aware of, but were not by any means "at the top of the list" (3). Moreover, several individuals mentioned that climate change was not currently a driving factor in decision making for management of the land itself, but nearly everyone mentioned some sort of familiarity with climate change, and felt that they were considering it in some way in their daily job. Strictly speaking, according to one interview subject, "there are no policies that promote carbon management" (15). Requirements or mandatory policies might be necessary in order for carbon management to be more widely considered in decision making, given the priorities and resource limitations already in place for land use management (11). One manager stated quite simply, "it's not a big factor in the majority of those issues [oil and gas leasing, recreation, and cultural preservation decisions] (7). Issues such as land use change and disturbances in general were mentioned as more important than carbon management (1). On the other hand, climate change and carbon management in particular may be of interest to some in terms of being a way to fund activities that would otherwise not be funded, should carbon markets or other funding mechanisms emerge (1).

Nonetheless, several actions are underway that are directly a result of concern over climate change, and within the scope of what has already been promulgated as administrative policy or guidance. First, all agencies must contribute inventories of carbon sources and sinks on their lands as part of U.S. obligations under the UN FCCC, so many offices provide data already or are considering how to collect data for a more accurate inventory in the future (11 and 13). In addition, some interviewees mentioned the office is investing in low-carbon emissions vehicles for their fleets (13, 14). Several individuals also mentioned bringing climate change considerations into the updates of the long-term plans that govern broad scale decision making (10, 14).

As mentioned earlier, managers are well attuned to the topic of managing for resilient ecosystems. When asked about actions that were being taken to respond to climate change, several respondents answered in terms of what

they were doing to promote resilient landscapes and healthy forests (3, 5, 9, 14). These respondents expressed the view that forest treatments such as thinning, prescribed burns, and other management tools might be used to promote a resilient landscape and therefore help in adapting to climate change and/or managing carbon. However, while it may be that a resilient forest is a well-adapted forest in terms of climate change up to a certain point, there is also an argument that climate change will "push certain ecosystems and species beyond their capacity to recover" (West and others 2009).

Despite the sense that resilience would be a good goal to strive for in the face of climate change, it was also acknowledged that "we can't make decisions knowing for a fact what is going to happen in 10 years" (3). The literature thus far on management of public lands and adaptation stresses that managers must face the fact that we are entering a more uncertain future, both in terms of the climate and in terms of the capacity to respond (Baron and others 2009; Joyce and others 2009; West and others 2009). Characteristics such as flexibility, planning for a range of outcomes, adaptive management, and scenario construction are likely needed (West and others 2009).

Furthermore, projects that alter the land to enhance resilience or alleviate or avoid climate change impacts may come into conflict with other environmental or public concerns. For example, interview respondents indicated prescribed burns and mechanical thinning that land managers believe can promote resilience of forests and grasslands are opposed by some members of the public, who cite concerns about smoke, landscape disturbance and potential for losing control of fires (4, 5). Even if it were clear scientifically which management actions to recommend in the face of climate change, these other public concerns pose another challenge to managers hoping to implement effective land use decision making.

Trade-Offs of Climate and Carbon Management with Other Management Aims

In this section, we review how climate and carbon management-related issues are currently being considered in some of the most important management sectors for the SJPLC: timber and fire management, biomass utilization, and grazing and rangeland management.

Timber and Fire Management

Policies emphasizing fire suppression have historically dominated local management plans at the SJPLC. Echoing recent research findings (Parker and others 2006) a supervising forester argues that exclusion of fire has largely contributed to forest homogeneity at high altitudes, making the landscape more susceptible to drought, disease, and outbreaks of pests like the mountain pine beetle (5). More recently, forest managers have had increased ability to use tools like mechanical thinning and prescribed burns to reduce the density of forest stands. As explained by a BLM manager (9) and supported by recent research (Youngblood and others 2009), achieving a mosaic of age classes and vegetation diversity is one key concern of land managers in order to better prevent stand-replacing fires. Among other factors, the Healthy Forests Restoration Act was enacted in 2003 in order to expand projects reducing fuel hazards on federal lands (CRS 2008).

Wildland Fire Use (WFU) is a management technique that uses naturally ignited fires to accomplish resource management objectives to improve forest health (USDA 2007). Fire managers at the SJPLC use prescribed burns and WFU as tools for promoting forest health. In conjunction with use of fire, there is also need for mechanical work with finer detail such as individual tree removal (5). Other examples of the timber management tools used at the SJPLC include harvesting small-diameter trees to promote more vigorous growth of surrounding trees, and regenerative planting that contributes to wider size-age class distribution within the forest (9).

With the expansion of the wildland urban interface, more communities are considered to be at high risk from wildfire, increasing the demand for fuel management projects (Nicholls and others 2008). Public land within the WUI is near residential communities and subdivisions, where prescribed fire is not always a viable option. As explained by a forest supervisor (5), prescribed burns near developed land are risky for the public, structures, and for the firefighters involved. Smoky conditions so close to residential communities are disliked by the public, and may violate state air quality standards, making it more difficult to approve prescribed burns in the WUI than for treating land outside of these areas. Thus while it is often the more expensive form of treatment, within the WUI mechanical thinning is often the more viable treatment option.

The BLM has adopted a fuels-reduction plan for the WUI lands administered by the SJPLC that would increase the number of mechanical thinning projects to reduce the risk of catastrophic wildfire (BLM 2004). The environmental assessment cited the risk of a significant effect on air quality in the event of a large wildfire without the use of fuels-reduction projects. A fire manager in southwest Colorado recognized that these fuel-reduction projects are costly, especially in the WUI, but stressed that these projects are growing increasingly important to long-term forest health and safety of growing populations in the area (4).

Forests in southwest Colorado tend to have historical disturbance regimes that include frequent, low severity

fires (Hurteau and others 2008). A century of fire suppression and timber extraction has led to denser forests, with higher numbers of smaller diameter trees and larger fuel loads supporting larger, more intense fires (Hurteau and North 2010). However there is disagreement about whether these forests store more carbon now in comparison to the past—some researchers argue that because these forests have fewer mature, large trees they have lower carbon storage compared with historical levels (North and others 2009). Others suggest that current levels of carbon storage are higher than historical levels because of fire suppression (Harmon and Marks 2002; Reinhardt and Holsinger 2010).

Old, dense forests are prone to stand-replacing fires, which can result in large, abrupt CO_2 releases and loss of carbon retention (Wiedinmyer and Neff 2007; Hurteau and others 2008; Dore and others 2010). Thinning is thought to reduce the risk of stand-replacing fires and the corresponding sudden release of large amounts of carbon to the atmosphere (Hurteau and others 2008; Dore and others 2010; Reinhardt and Holsinger 2010). However, the effects of thinning and fuels treatment on overall carbon balance are complex. The ultimate effect of thinning and fuels treatment on carbon stocks is affected by the initial state of the forest, the types of treatments conducted (e.g., mechanical thinning versus prescribed burning), and the time period over which one compares the carbon balance (North and others 2009; Hurteau and North 2010). Some researchers suggest that while thinning and other mechanisms to reduce fire risk reduce the overall carbon stocks in the forest by a moderate amount in the short run, if the treated forest subsequently supports the growth of larger mature trees it may end up storing as much carbon as it did before treatment, in a landscape that is less susceptible to large stand-replacing fires (North and others 2009; Reinhardt and Holsinger 2010). Because the carbon balance continues to change as the forest recovers long after the fire event, there is much uncertainty about how long it might take for the carbon balance to be back in equilibrium (Dore and others 2010; North and others 2009; Kashian and others 2006). In addition, the fate of thinned material influences the overall carbon impact, e.g., by sequestering carbon if the material goes into long-lived products such as timber or displacing fossil fuel emissions if used to produce biomass energy (Harmon and Marks 2002).

Another key consideration for forest and fire managers is the cost of fuels reduction projects. In the SJPLC, costs of removing dead and small diameter trees are often not offset by timber sales or covered by federal government funding. Although federal policies and legislation such as the Healthy Forests Restoration Act encourage fuels reduction practices, thinning projects are only federally funded if timber sales will generate revenue to cover the project costs (Hurteau and others 2008). A program staff member with the FS cited the sharp reduction in the demand for timber as a problem for the agency to cover costs of fuels reduction activities (10).

In the event of major disturbances to the landscape, land managers may consider restoration projects, which focus on promoting new forest growth and can be a means of replenishing or increasing carbon stores. As noted by a regional forest service planner, however, trees grow relatively slowly in Colorado and thus take decades to recover from stand-replacing fires (15). An ecologist who was interviewed made a similar point, also noting that Colorado's arid climate leads to low rates of carbon storage (1; see also Hicke and others 2007). Thus in southwest Colorado it is unlikely that large scale replanting or reforestation projects would be widely used, due to unfavorable economics, lack of agency resources, an arid environment, and public opposition to large-scale manipulation of national forests.

Meanwhile, forest management focuses on mandates to foster healthy forests, resilient forests, or forests that are more resistant to catastrophic fires. Managers in our study often cited prescribed burns or mechanical thinning as potentially aiding in sequestering carbon, but acknowledged there is much that is not yet known. How carbon storage goals interact with goals relating to the ultimate resilience of the forest is still uncertain. Some researchers argue that restoring forests to the historical high frequency – low intensity fire regimes that have dominated the Colorado region may support a more resilient landscape as well as contributing to carbon goals (e.g., Hurteau and others 2008). One ecologist noted that there was still a lot of debate on the effectiveness of thinning and fuel treatment and was personally "pretty convinced it is not helpful for carbon" (1). He also noted the large expense in treating an area when one is not certain where the next fire will be. A deputy forest supervisor explained, "We need more data…and more research on the relationship of decisions to climate change… Are we having a net impact?" (3). Despite the uncertainty with respect to impacts on the carbon balance, several land managers in southwest Colorado who we interviewed felt that thinning practices are necessary to promote forest resilience in the long term in the face of climate change (3, 5, 10).

Biomass Utilization

Reducing fuels in forest stands is an important component of the FS strategy for improving forest health. On the other hand, the benefits are countered by the high costs of mechanical thinning and prescribed burns, and the low timber value of small diameter trees and other thinned materials. To help address this problem, federal policies, including the Healthy Forest Restoration Act and

appropriations for the Department of the Interior, have contributed funding and program direction for the purpose of implementing more biomass utilization projects. Several interviewees mentioned increasing biomass utilization as a carbon management strategy that should be pursued in the SJPLC (3, 5, 10, 14, 15).

The FS has taken several steps to increase funding and opportunities for biomass utilization across the country. These include programs such as the Woody Biomass Utilization Grant Program, which was created in 2005 in order to "help reduce forest management costs by increasing the value of biomass and other forest products generated from forest restoration activities" like mechanical thinning projects (Levan and Bilek 2007). This grant program provided funding for a dowelling mill in order to increase the use of small-diameter material in the San Juan Public Lands area. Because the use of small-diameter material became more economical, the revenue generated from local fuels-reduction programs was estimated at $200–$300 for every acre treated by local FS operations (Levan and Bilek 2007). A program staffer with the FS noted that other grants encouraging biofuel or biomass power plants serve as one mechanism to promote fuels reduction projects on national forests (10).

As another example of biomass utilization, a private entity is planning to construct a biomass power plant in Pagosa Springs, CO, the location of one of the SJPLC field offices. This power plant will convert small-diameter trees into gas to be used for energy (McGuire 2010). To ensure the availability of fuel for the power plant, the company intends to establish a contract with the FS and also with private owners in the San Juan area to acquire wood from thinning projects (Ibid). The new market for small-diameter trees is expected to offset treatment costs for some FS thinning projects (Ibid).

Despite the removal of carbon-storing biomass from the landscape, advocates expect biomass utilization projects to promote the sustainability of the national forests in a more cost-effective manner. Notwithstanding the controversy among researchers (see section above) one of the specialists interviewed argued "if you do it through thinning, you increase the health of what is standing; a lot of people would see that as increasing carbon storage over the long term" (10). In conjunction with promoting long-term stand resilience through thinning projects and restoration activities, increased production and use of forest products for power production has potential to offset CO_2 releases from combustion of fossil fuels. An ecosystem specialist and planner with the FS predicts that the potential increased market for thinned materials and the potential for beetle-killed timber to be used for biomass-based energy can have a positive impact on protecting current sinks in remaining stands, displacing fossil fuels, and improving the local economy (14). At present, wood residue generated from fuel reduction treatments is often piled and burned after a mechanical thinning is done, according to a planner involved with the FS. He said it would be ideal to have a market for that wood to be used for energy, instead of having to dispose of it through inefficient burning, which results in a loss of carbon and net CO_2 emissions (15).

Grazing and Rangeland Management

Properly managed rangeland has been estimated to hold the potential to offset 3.3% of CO_2 emissions produced from fossil fuels in the U.S. (Fynn and others 2009). However, carbon storage potential is highly variable; the West's arid rangelands are often characterized by low seasonal productivity and shallow soils and correspondingly low carbon storage potential (Follett and Reed 2010). That, coupled with large fires and drought, has caused rangeland to sometimes become a source of carbon rather than a store (Conant and others 2007). As one of the dominant uses of western rangeland, livestock grazing has the potential to alter carbon storage by modifying the availability of light, water, and nutrients while simultaneously altering the functional diversity of plant communities (Derner and others 2006). Livestock also produce methane, a potent greenhouse gas. The effect of grazing on vegetation and soil carbon storage is unclear. Some studies indicate grazing-induced processes can bring vegetation back more vigorously if proper management practices are used, such as allowing plants a respite after grazing to allow for sustained growth (Trlica 2006). Other ways to promote carbon stores may include controlling invasive species and reintroducing grasses, legumes, and shrubs on degraded lands (Fynn and others 2009). At present, however, the effect of different management practices on carbon storage in rangeland soils is quite uncertain, due to limitations in modeling and observational capabilities (Brown and others 2010).

None of the interview subjects who were asked about linkages between carbon management and grazing practices saw carbon management in rangelands as a significant current consideration (e.g., 3, 6). However, a supervisor identified this as an important research topic for facilitating carbon management efforts (3). A rangeland management specialist for the FS also indicated they are considering climate change impacts with respect to endangered species and invasive species on rangelands managed by the SJPLC (6). According to both the supervisor (3) and the FS rangeland specialist (6), grazing may decline in the area due to a number of other factors, irrespective of climate change concerns. The number of grazing permits issued by the San Juan Public Lands Center has been reduced in recent years, due primarily to a shift in the socioeconomic climate of the West that is characterized by reduced ranching and the expanding WUI.

Implications for Decision Making, Research and Policy

There is strong awareness of climate change among public land managers we spoke to at SJPLC and other FS and BLM offices in Colorado, but as of spring 2010 only limited actions had been taken that directly considered climate change. These included supporting EPA emission inventories, "greening" the vehicle fleet, and updating long-term management plans. New ideas such as increasing the production of biomass energy were also receiving consideration. In general, however, climate-related issues and actions were not at the top of the list of priorities.

The finding that only limited action had been taken by the SJPLC generally supports our hypothesis that they would not yet be ready to adjust local policy "settings" in response to climate change concerns. The policy landscape for carbon management and climate adaptation remains highly unsettled. In particular, while the potential is recognized, there are no direct requirements to recognize or credit terrestrial carbon sequestration; policy frameworks for carbon management are still in the entrepreneurial stage. To date, for example, the Council on Environmental Quality has only requested comments on issues related to land management for carbon sequestration (Sutley 2010). As federal agencies move forward with directives to consider both carbon management and climate adaptation, there is a need for better-defined targets, measures of progress, and guidance on how these issues should be incorporated into local decision making.

In contrast, in 2010 there were already "objectives" level mandates and relatively clear guidance for planning updates, emissions inventories and fuel-efficient vehicle purchases, so the fact that the SJPLC was taking action on these fronts is consistent with expectations from prior policy implementation studies. Planning updates are required by NEPA and other laws governing public lands and have been recognized by the Administration as needing to consider issues related to climate change (Sutley 2010). EPA requires emissions inventories for greenhouse gases, partly in response to mandates of the U.N. Framework Convention on Climate Change. And, the Obama Administration has specifically identified purchasing more fuel-efficient vehicles as a priority (Sutley 2010).

As observed in previous studies of policy implementation, SJPLC interviewees highlight competing priorities and resource limitations as two key challenges for addressing climate change and carbon management at the field office level. It is clear that public lands managers are already balancing many different objectives within the framework of their agencies' multiple-use missions and constituencies. These objectives do shift to accommodate new opportunities and concerns; however, as of spring 2010, climate change and carbon management had not yet come to the fore. Among competing objectives in the area managed by the SJPLC, oil and gas leasing has rapidly expanded over the past decade, and recreation and tourism have become more common activities, whereas traditional activities such as grazing are declining. Fire management, which has long been important in western forests, poses multidimensional challenges as staff must consider reducing fuel loads, protecting expanding communities at the WUI, promoting forest health from an ecological perspective, and complying with air quality regulations. Managers also operate in a resource-limited environment, in terms of both staff and funds. Many of the projects that might otherwise be considered do not wind up being economically feasible, or are simply not done because they take low priority. This may pose a barrier to further incorporating climate change considerations into decision making if these resource limitations cannot be addressed.

Uncertainty in the science of how management activities affect carbon storage or resilience to climate change is a further hindrance to decision makers at the local level being able to take proactive steps on these issues. Land managers interviewed for this study expressed interest in learning more about how climate change might affect ecosystems and how the various practices used to manage land might affect ecosystem resilience and carbon storage. However, despite active research in this area, it remains uncertain how resilience to the impacts of climate change or carbon sequestration goals are affected by everyday decisions such as fuels reduction or grazing management. Further research is needed to examine what types of management actions are warranted in the face of uncertain, changing climate and how they trade off with other land management objectives and requirements.

Research that seeks to inform decision making related to climate change on public lands will be most useful if it is conducted within a framework that incorporates the various tradeoffs and multiple uses being considered. Because managers are not currently, and may never in fact be able to manage public lands solely for climate resilience or carbon purposes, information that seeks to guide decision making must be presented in the context of this broader suite of considerations. Understanding the context in which information is used for decision making is a common requirement for "usable science," or science that can be effectively used in decision making (Dilling and Lemos 2011).

Additional developments on the policy front after our data were collected may make a difference in the future to actions on the ground. In 2010, after our interviews for this study were completed, the Forest Service introduced a "Climate Change Performance Scorecard" where each National Forest and Grassland area must record their progress on integrating climate into their decision making and unit activities (USFS 2010). This Scorecard asks National

Forests and Grasslands on an annual basis to indicate whether or not certain activities are occurring such as assessing carbon stocks, conducting monitoring, assessing vulnerability and so on. In addition, in 2011 new tools such as a drought vulnerability model, a carbon storage map, and an alpine monitoring system were developed for the SJPLC to provide input on changing land management strategies such as adjusting grazing allotments and planting trees in the face of climate change (ICCATF 2011). These are interesting developments and it remains to be seen how decisions and tradeoffs will be made in these cases.

This case study, while only a snapshot of one public lands center, gives a glimpse into some of the issues that can emerge as land managers begin to incorporate climate change into their decision making. The issues identified for the SJPLC may also warrant attention in other locations and agencies. However, there are likely to be significant regional differences in approaches to climate adaptation and carbon management that warrant further research. For example, the national forests of the Pacific Northwest have a much different carbon signature, and more viable timber industry, and may therefore support more aggressive carbon management efforts. As national policies and guidance are further defined in coming years, and as on-the-ground implementation steps proceed, it would be useful to compare field offices in the Northwest with those in the intermountain West to better understand potentially site-specific tradeoffs that influence or block action on climate change and carbon management. Our case showed that managers at the SJPLC are quite interested and willing to think about these issues, but this may not be the case everywhere.

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2. Interview with project manager at the National Science and Technology Center, BLM, March 4th 2010
3. Interview with BLM manager at the SJPLC, April 15th 2010
4. Interview with fire management officer at the SJPLC, April 27th 2010
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