Adapting Natural Resource Management to Climate Change: Useful Concepts and Tactical Approaches

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Abstract

Concrete ways to adapt to climate change are needed to help natural resource managers take the first steps to incorporate climate change into management and take advantage of opportunities to balance the negative effects of climate change. Because the development of adaptation tools and strategies is at an early stage, it is important that ideas and strategies are disseminated quickly to advance thinking and practice. Here we offer an example of a successful workshop that allowed quick dissemination of ideas and strategies for climate change adaptation in resource management through an interaction between scientists and managers. We share both the process used in the workshop and the outcome of facilitated dialogue at the workshop. By presenting concrete adaptation methods and demonstrating the value of a focused scientist-manager dialogue, we hope to motivate National Forests and other natural resource agencies to emulate our approach and begin the process of adapting to climate change.

Keywords: climate change, adaptation, forest management

Introduction

Climate change presents a major challenge to natural resource managers both because of the magnitude of potential effects of climate change on ecosystem structure, process, and function, and because of the uncertainty associated with those potential ecological effects. Furthermore, managers lack operational strategies to aid in adaptation to climate change. In the nascent literature on climate change adaptation, much of the focus has been on conceptual issues (Hansen et al. 2003), potential actions by governments and municipalities (IPCC 2007, Snover et al. 2007), individual resources (Slaughter and Wiener 2007, Sadowski 2008), and biological diversity (Heller and Zavaleta 2009). Recent information on climate change adaptation for natural resources provides general adaptation strategies (Millar et al. 2007, Joyce et al. 2008, Innes et al. 2009). Only a few sources contain information on adaptation to climate change that is relevant and usable for natural resource managers from a tactical or operational perspective (Ogden and Innes 2007a, 2007b, 2008). Now that most land managers have accepted that climate change is real and of great concern, more concrete ways to adapt to climate change are needed to help managers take the first steps to incorporate climate change into management and reduce the negative effects of climate change on natural resources.

The United States Forest Service administers over 78 million ha of land in 155 National Forests and 20 National Grasslands across the United States. The Forest Service also advises and partners with private and state forest land managers and the international community. The National Forest System encompasses a wide range of different ecosystems and much of the country's terrestrial biodiversity. In addition to biodiversity, other ecosystem services provided by the National Forest System include timber, grazing, municipal and agricultural water supplies, recreation, and aesthetics. Climate change will impact all of these ecosystem services provided by National Forests, perhaps most importantly, water supplies. The U.S. Forest Service is responsible for restoring, sustaining, and enhancing forests and grasslands while providing and sustaining benefits to the American people. Because of these responsibilities, federal scientists and land managers are tasked with reducing the negative effects of climate change on ecosystem function and services, while promoting and enabling beneficial aspects. Timely implementation of strategic and tactical adaptation options, with an emphasis on practical approaches that can be applied within the broader context of sustainable resource management, will be critical to meet both goals (Innes et al. 2009).

Resource managers are expected to incorporate science and climate change adaptation practices into planning, and they have the skill and local knowledge to do so. Scientists have technical knowledge but often a poor understanding of management and regulatory, policy, and collaborative social processes for resource planning and decision-making. A clear need exists for these two groups of specialists to work together to develop and implement applied adaptation projects. However, lack of formal relationships, differences in work culture, time frames, and communication styles, etc. have limited this dialog at all scales. In addition, with climate change, there is an overwhelming amount of information that managers are trying to absorb, a very steep learning curve with climate change science, and little time for learning given managers' many responsibilities. Here we offer an example of a successful workshop that allowed quick dissemination of ideas and strategies for climate change adaptation in resource management through an interaction between scientists and managers. This interaction serves as an example of what might be done to promote collaboration between scientists and managers in climate change adaptation.

We convened a workshop with a novel format to develop Web-based educational materials on climate change, and management options for adapting to climate change in the U.S. Forest Service and natural resource management in general. We chose a workshop format because other studies have reported that managers do not have sufficient time to read referred journal articles (one form of scientific outreach), and workshops provide opportunities to transfer information and facilitate interaction between managers and scientists (Barbour 2007, Youngblood et al. 2007). The workshop not only served to transfer climate change science and adaptation information, but also gave managers the opportunity to ask the 'so what' question when presented with climate change science information and heightened the managers' participation in vetting current adaptation strategies. This event was significant because of the process used, group of people assembled, and depth and utility of ideas produced. Because the development of adaptation tools and strategies is at an early stage, it is important that ideas and strategies are disseminated quickly in order to advance thinking and practice. With this purpose in mind, we share here both the process used in the workshop and the outcome of the facilitated dialogue of the workshop. In addition to describing the outcomes of interactions between scientists and land managers, the ideas put forth in this paper build on existing principles of adaptation to climate change, such as the U.S. Climate Change Science Program Synthesis and Assessment Product 4.4 (Joyce et al. 2008), Millar et al. (2007), and Bosworth et al. (2008) by providing more concrete and tactical ways for resource managers to adapt to climate change.

The workshop was conducted over a three-day period and was focused on two specific goals: 1) to develop and videotape a coordinated lecture series and related discussions on climate change, ecosystem response, and resource management in order to develop a multi-media, Web-based educational module; and 2) to promote focused dialogue on climate change and management within a select group of resource managers and scientists, and to capture the lessons learned from these interchanges. Key Forest Service and other scientists with expertise on the topics and contextual experience were invited to develop talks for videotaping. Themes were selected for the lecture series to ensure that a range of relevant topics for resource management were covered. Many of the talks were based on previous presentations, so coordination, review, and vetting were well advanced. A group of resource managers with expressed interest in climate change issues was invited as reviewers and discussants. After talks were given by the scientists, both scientists and managers discussed the talks and provided critical review. Respondents (scientists and managers) were also asked to develop questions and commentary that were used during formal videotaping. Scientists then revised their talks to accommodate the reviews and delivered the revised talk the following day for formal taping. Videotapes from the workshop have been developed into educational modules for a Web-based short course (Figure 1; Furniss et al. 2009).

In addition to producing lectures, we held a facilitated discussion session during the workshop to take advantage of the diverse group assembled and thereby advance thinking on issues related to incorporating climate into resource management. These discussions were focused on two main questions: (1) How can climate science be directly incorporated in resource management?; and (2) How can the uncertainty of future climate change and effects be evaluated and managed? The concepts and tactical approaches produced during this workshop provide some concrete ways to incorporate climate change science into resource management.

Tangible ways to incorporate climate change science in resource management

Many ideas from the facilitated dialogue focused on how climate change science can be institutionalized in government agencies involved with the management of natural resources, such as the U.S. Forest Service and the U.S. National Park Service (Table 1). Forest Service resource managers and scientists have dealt with a number of major challenges over the last few decades, including a major transition from emphasis on production of timber and commodities to ecological restoration and management for biodiversity. These past challenges leave the agency well-prepared for the shift in thinking required to meet the challenge of climate change. Institutionalization will involve incorporating climate change into many aspects of agency planning and process (Ogden and Innes 2007a, Innes et al. 2009). If climate change is institutionalized, it will be more fully considered in the National Forest planning process, at all stages of project development, and in work prioritization, funding prioritization, hiring decisions, and staff performance reviews. Ideally, barriers to dealing with the issue of climate change, such as policies and regulations that delay implementation of climate change adaptation practices, will be removed or altered without changing the benefits of aspects such as public participation in the environmental review process (Joyce et al. 2008). In addition, incentives can be created to promote advances in addressing climate change and reducing vulnerability to climate change.

Education is critical to increasing awareness of and promoting problem-solving related to climate change (Spittlehouse and Stewart 2003, Moser and Luers 2008, Littell et al. *in review*). Exposing resource managers to climate change science, promoting dialogue, and creating opportunities for education will help managers to be aware of the best available science, understand concepts associated with climate change science, acknowledge and accept uncertainties associated with future climate projections, and incorporate climate change into routine management activities (Table 2). Educating the public on climate change will have multiple benefits for natural resource agencies. For example, engaging landowners adjacent to fire-prone public lands will assist efforts to reduce wildfire hazard and severity (Baron et al. 2008). Educating the public on climate change will also promote understanding of the steps that state and federal land management agencies can take to address climate change, thus promoting support for these actions and helping to avoid costly litigation.

Scientists will play a key role in helping managers deal with climate change by providing the best available information on climate change science and the ecological effects of climate change to inform management decision-making. In addition, scientists can encourage managers to think more scientifically: to base their decisions on high-quality literature, to understand and disclose assumptions and limitations, to subject their work to critical review, and to take an experimental approach and monitor results. Managers, in turn, can help scientists be more practical, tune their scientific inquiries to the most relevant problems, and focus on solutions and the applicability of findings. Thus, iterative interactions and dialogue between scientists and managers, and forums for doing so, will be critical to incorporating climate change in natural resource management (Moser and Luers 2008, Blate et al. 2009, Innes et al. 2009). There are multiple ways to promote scientist/manager interactions, including iterative small meetings and informal discussions within communities of practice (e.g., water resources, vegetation management) (Table 3). Manager information needs can be determined with the use of surveys (e.g., Ogden and Innes 2007b). Science delivery can be enhanced by commissioning technical communication teams for natural resource agencies. Scientists and managers can also share information with others on successes and failures in climate change adaptation via the Internet or other means.

In addition to collaboration between scientists and managers, collaboration among agencies, organizations and stakeholder groups will facilitate adaptation to climate change (Baron et al. 2008, Littell et al. *in review*). Developing common plans and shared visions of resource management can result in saved time and financial resources, and more innovative, and ultimately more effective, strategies in the face of climate change (Table 4). For example, management for species such as ungulates and carnivores with home ranges larger than any single agency's ownership can be improved through collaboration among stakeholders (Baron et al. 2008, Heller and Zavaleta 2009). Collaboration can also be expanded to a united climate change outreach program, such as the proposed U.S. National Climate Service, that provides credible information on climatology, predictions of climate change effects, planning tools, and tutorials.

Many plant species will be subjected to increasing stress in a changing climate, and some species and genotypes may be unable to adapt to rapid warming. Genetic stock that is better adapted to climatic conditions of the future will be more resilient and also increase overall ecosystem resilience. For these reasons, it will be imperative that natural resource agencies reassess genetic resources (e.g., seed availability, nursery stock) with climate change in mind (Parker et al. 2000, Spittlehouse and Stewart 2003, Millar et al. 2007) (Table 5). Agencies may want to put more resources into state and federal nursery programs, expand germplasm collections (seed, pollen), restore germplasm archives (many seed storage units have been closed), and include broader representation of diverse provenances. Experimentation to determine the best provenance and species mixes to plant after disturbance in different locations can help to increase plant community resilience to both climate change and the disturbance regimes of the future.

Increased disturbance will almost certainly be associated with a warmer climate in many locations. For example, area burned by wildfire (McKenzie et al. 2004) and subjected to bark beetle outbreaks (Hicke et al. 2006) is expected to increase significantly across the western United States. Incorporating disturbance into natural resource planning, rather than treating it as an anomaly, will facilitate timely and effective management actions when disturbance events occur (Millar et al. 2007, Littell et al. *in review*) (Table 6). Using past extreme events and response to those extreme events as a context may help to structure thinking and improve response to future events. In addition, management activities that reduce the severity of disturbance, such as reduction of hazardous fuels in fire-prone forests, may help to reduce ecosystem vulnerability to a warmer climate (Dale et al. 2001, Joyce et al. 2008).

Tools and methods to evaluate and manage uncertainty

Dealing with uncertainties associated with the magnitude of changing temperature and precipitation, and the magnitude and nature of ecological effects of climate change, is one of the biggest challenges for land managers facing a changing climate. The many types of uncertainties can be overwhelming and delay adaptive responses. The second part of the facilitated dialogue, summarized below, was focused on tools and methods to evaluate and manage uncertainties associated with climate change in natural resource management.

Dealing with uncertainty requires that risks associated with uncertainty are both identified and evaluated (Table 7). Risks to ecosystems and risks associated with taking the wrong management path can be identified by asking ‘what if…?’ during planning and project development. Once risks are identified, they can be evaluated to determine which are most important to consider (i.e., set priorities). Uncertainties are important only when they are associated with high risks to ecosystems at local or larger scales. Confidences of risk (level of likeliness) can be quantified or approximated instead of quantifying uncertainty (e.g., Brekke et al. 2009).

To incorporate risk and uncertainty into management, scenarios can be developed to bracket a credible range of potential future climates and ecosystem conditions, and managers can work to develop associated strategies for dealing with those future conditions (Baron et al. 2008) (Table 8). In addition, employees/functions that assess risks associated with climate change can help managers incorporate risks into management. For example, development of tools that assess post-disturbance risks, such as debris flows following fire and heavy rain, can help managers consider and incorporate those risks into post-disturbance planning.

Conducting watershed vulnerability assessments could also help to incorporate risk into management (Table 9). An effective assessment of watershed vulnerability will require 1) the ability to identify the watersheds of highest priority for protecting watershed amenity values (such as domestic and industrial water supplies, endangered species, and recreational uses); 2) the ability to identify the watersheds in which climate-related risk to those amenity values is greatest, as well as "climate-change refugia" that are expected to see the least effects; 3) the ability to detect evidence of the nature and likely magnitudes of change as early as possible; and 4) the ability to select mitigations appropriate for the effects likely in particular watersheds. Development of a procedure for watershed vulnerability assessments would be most useful if it were capable of providing information over large areas for relatively small outlays of time and effort. This tool would be applicable both in the context of a Forest Service watershed condition assessment and as a stand-alone assessment procedure for use by anyone concerned about watershed change.

Increasing the resilience of ecosystems is one way to prepare for an uncertain future (Dale et al. 2001, Spittlehouse and Stewart 2003, Millar et al. 2007), and increasing the diversity of vegetation structures across large landscapes can help to increase ecosystem resilience to climate change (Table 10). Using a portfolio of management approaches and practices, much like a stock portfolio, can help managers to "hedge their bets," increase the diversity of outcomes on the ground, and thus increase ecosystem resilience (Millar et al. 2007, Joyce et al. 2009). Diversifying seed banks and plantings will similarly increase resilience by reducing the likelihood of forest stand failure (Heller and Zavaleta 2009).

Reducing the effects of already existing non-climatic stressors on ecosystems, such as landscape fragmentation and invasive species, will also increase ecosystem resilience to climatic changes (Baron et al. 2008, Joyce et al. 2008). Climate change is not the only issue that natural resource managers must deal with, and because of financial and time constraints, climate change may be a low priority for some natural resource managers (Moser and Luers 2008). However, embracing integrated ecosystem-based management and sustainable resource management in general (Ogden and Innes 2007a, Innes 2009), in which climate change is one of many stresses considered, could help alleviate current constraints on allocation of time and effort for managing climate change effects.

Keeping an open mind is also going to be important for managers in dealing with uncertainties of climate change (Table 11). Periodic failures will be an inevitable part of dealing with uncertainties related to climate change. However, periodic failures will be an important component of active learning as climate change effects are realized.

Discussion

Ideas generated from the workshop are consistent with the more general strategies for adaptation of natural resources to climate change outlined in recent reports. For example, the concept of promoting ecosystem resilience as an adaptation to climate change is common across existing guides to adaptation (e.g., Dale et al. 2001, Spittlehouse and Stewart 2003, Millar et al. 2007). Promoting resilience is a concept that was also highlighted in the workshop as a way to deal with uncertainties associated with climate change, and multiple ways to increase forest resilience by increasing landscape diversity and watershed health were discussed. Resilient forests and watersheds can better accommodate changing conditions, such as gradually changing temperature and precipitation, and maintain ecosystem function after a disturbance such as fire.

Even if managers are uncertain about exactly what the future holds, resilient forests will be more likely to accommodate future conditions (Innes et al. 2009) and reduce the number of situations in which land managers must respond in “crisis mode.”

Most guides to adaptation suggest using a variety of tools and management practices to deal with an uncertain future (e.g., Smith and Lenhart 1996, Millar et al. 2007, Joyce et al. 2009), similar to the suggestion of using a ‘portfolio of management approaches’ suggested here. Related and often cited adaptation strategies include flexibility and active learning, or the idea of adaptive management (e.g., Dale et al. 2001, Millar et al. 2007, Baron et al. 2008). With flexibility and active learning, tools and strategies that are most effective under a changing climate can be discovered and more widely implemented.

Reassessing genetic resources is another climate change adaptation strategy that is often suggested in guides to adaptation (e.g., Smith and Lenhart 1996, Parker et al. 2000, Noss 2001), as it was in the workshop. Appropriate species and genotypes can be planted in anticipation of a warmer climate, thus allowing resource managers to diversify the phenotypic and genotypic template on which climate and competition interact, and to avoid widespread mortality at the regeneration stage.

Several guides to adaptation recommend that education and awareness about climate change be promoted to facilitate adaptation (e.g., Smith and Lenhart 1996, Spittlehouse and Stewart 2003, Moser and Luers 2008). Similarly, in the workshop, there was much discussion about ways to promote education and awareness on climate change, both in government agencies and with the public. Education and awareness will increase capacity to analyze climate change information and use it in decision-making (Moser and Luers 2008). Scientists will play a key role in providing the best available information to managers, and effective communication between scientists and managers will be critical for successful adaptation to climate change in natural resources management (Baron et al. 2008, Joyce et al. 2008, Moser and Luers 2008). Collaboration among agencies, stakeholders, and other groups will also help develop support for and consistency in adaptation options (Baron et al. 2008, Littell et al. *in review*).

Though many of the ideas put forth during the discussion were consistent with current literature, new and different ideas for adaptation to climate change were also discussed. Many of these ideas, listed in Tables 1-11, would affect resource management more directly than the more general ideas that dominate current adaptation literature (e.g., increase ecosystem resilience). These more concrete ways to adapt natural resource management to climate change were developed as a result of the workshop setting that allowed for direct engagement between scientists and managers. The workshop was not only an efficient method for science delivery to managers, but it also allowed managers to critique existing ideas and suggest new methods for adaptation to climate change. The workshop also resulted in efficient development of online education materials for use by natural resource managers. This workshop can serve as a model others can follow for future development of adaptation options for natural resource management.

Adaptation to climate change presents organizational and cultural challenges in addition to ecological ones. Many ideas that emerged in the workshop with natural resource managers and scientists focus on institutional changes that need to occur for successful adaptation. Even if good scientific information and financial resources are available, regulations (e.g., U.S. Endangered Species Act), policy (e.g., forest harvest restrictions), and litigation (e.g., lawsuits from advocacy groups) can prevent or reduce the effectiveness of proposed adaptation activities. This will be a significant challenge for the implementation of adaptation on public lands.

Finally, with the possible exception of the Waxman-Markey climate bill that will be considered by the U.S. Senate, the Forest Service and other federal agencies that manage natural resources in the United States currently do not have a mandate for developing adaptation plans or a framework through which adaptation can be accomplished. It is challenging to motivate a geographically dispersed workforce, already stretched by heavy workloads, to expand their management and planning responsibilities to include climate change. In the meantime, leadership is being provided by individual national forests in which managers have volunteered to develop adaptation plans (e.g., Joyce et al. 2008, Littell et al. *in review*) and by *ad hoc* efforts such as the workshop described here. By demonstrating the value of a focused scientist-manager dialogue to develop educational information and adaptation options, we hope to motivate National Forests and other natural resource agencies to emulate our approach and start the process of adapting to climate change.

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Table 1.

Institutionalize climate change
• Incorporate climate change in the planning process and project development
• Incorporate climate change into work prioritization
• Conduct watershed vulnerability assessments to determine which areas are most sensitive to climate effects and which kinds of adaptations are appropriate
• Give higher priority and more funding to projects that meet climate change goals
• Hire staff dedicated to disseminating information and increasing awareness/understanding of climate change effects
• Require one specific climate change adaptation or mitigation activity per year in employee performance reviews
• Remove barriers to dealing with climate change, such as prohibitive policies and lack of funding
• Create incentives for solving climate change problems

Table 2.

Educate about climate change
• Expose managers at all levels to current climate change science and find opportunities for dialogue
• Create ability for resource managers to learn about climate change through tools, trainings and workshops
• Educate the public about climate change through information kiosks and shared learning workshops with resource managers
• Provide and mandate reading of summaries on climate change science for all agency staff
• Develop climate change curriculum material for use in existing professional training events

Table 3.

Improve information exchange and communication
• Refine information exchange between scientists and managers by holding small meetings between scientists and managers. In these meetings, managers would communicate information needs and scientists would provide information. Make this an iterative process.
• Improve technology transfer and science delivery by permanently funding a climate change science delivery team
• Initiate informal discussions on climate change at multiple levels: internally, within communities of practice, and with the public
• Increase collaboration among researchers and managers in identifying key questions for monitoring program design
• Determine resource managers' information needs with a survey and develop a strategy to meet those needs
• Hold 'pulses' in which scientists and managers engage in intensive two- to three-week meetings to discuss climate change adaptation options for a specific geographic location
• Encourage leadership, formally or informally, to share information
• Share resources (via the Internet or other means) on successes and near-successes in climate change adaptation

Table 4.

Increase collaboration among agencies, organizations and groups
• Increase interagency strategic coordination in response to climate change and work towards a shared vision of resource management
• Design joint, multi-party monitoring and assessment efforts
• Develop common plans for addressing fire and fuels, invasive species, corridors, minimizing pollution, and land use
• Develop an interagency climate service that provides information, scenarios, toolboxes, tutorials, and credible information

Table 5.

Reassess genetic resources
• Evaluate old genetic transplant/ provenance plantations for viability under current and future conditions
• Conduct controlled experiments of different provenance and species mixes after fire, and monitor at 1, 3, 5 and 10 years post-fire
• Fund state and federal nursery programs

Table 6.

Manage for disturbance and extreme events
• Incorporate disturbance into planning
• Use past extreme events and response to those events to think about and improve response to future extreme events
• Consider the effects of extreme events and disturbances on natural resources and how management can alter the vulnerability of ecosystems to these events
• Sharply increase the area of fuel treatments in fire-prone forests, and consider climate change scenarios in determining the location, type, placement and timing of fuel treatments

Table 7.

Identify and evaluate uncertainties and risks
• Ask ‘what if?’ in project development
• Match the level of analyses with risk; uncertainty is important only when it is associated with high risk
• Promote the concept of negotiated risk - identify what is scarce or scary
• Consider confidences of risk (level of likeliness) instead of quantifying uncertainty
• Pare down uncertainties to issues that can be dealt with most easily
• Identify watersheds and landscapes that are most and least susceptible to loss of ecosystem services due to climatic changes

Table 8.

Table 8.

Incorporate uncertainty and risk into management
• Manage for the unexpected
• Conduct targeted scenario planning that incorporates risk, values, and recommendations for actions
• Incorporate the concept of non-stationarity (e.g., the 50-year flood concept is changing)
• Establish an advisory group that assesses risk and uncertainty
• Develop tools to assess post-fire effects and debris-flow risk

Table 9.

Maintain and improve watershed resilience
• Protect and restore riparian forests.
• Improve or decommission roads
• Restore meadows, wetlands, and flood plains
• Maintain and restore environmental flows.
• Remove migration barriers and reestablish habitat connectivity

Table 10.

Increase landscape diversity
• Use a portfolio approach, as done with a stock portfolio, and implement a range of management practices
• Manage for ecosystem process and for landscape diversity (e.g., diversity of forest ages, structures, and species composition) while maintaining habitat connectivity
• Diversify seed banks and plantings

Table 11.

Keep an open mind
• Avoid throwing away ideas just because they have failed in the past
• Incorporate an active learning process in decision-making

Figure 1. Cover of Web-based short course for land managers developed from the described workshop. This short course is available on the Web at: www.fs.fed.us/pnw/pep/hjar.shtml.

Table 1. Methods to institutionalize climate change into natural resource management agencies.

Table 2. Methods to educate natural resources managers and the public about climate change.

Table 3. Methods to improve information exchange and communication about climate change.

Table 4. Methods to increase collaboration among agencies, organizations and groups to facilitate climate change adaptation.

Table 5. Methods to reassess genetic resources in the face of climate change.

Table 6. Methods to manage for increased disturbance and extreme events that will likely occur with climate change.

Table 7. Methods to identify and evaluate uncertainties and risks associated with climate change.

Table 8. Methods to incorporate uncertainty and risk associated with climate change into resource management.

Table 9. Methods to maintain and improve watershed resilience with climate change.

Table 10. Methods to increase landscape diversity and increase ecosystem resilience to climate change.

Table 11. Methods to keep an open mind in adapting to climate change.