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Climate science information needs among natural resource decision-makers in the Northwest US

Elizabeth Allen [a,*], Jennie Stephens [b], Georgine Yorgey [a], Chad Kruger [a], Sonya Ahamed [c], Jennifer Adam [d]

[a] Center for Sustaining Agriculture and Natural Resources, Washington State University, United States
[b] School of Public Policy and Urban Affairs, Northeastern University, United States
[c] Gund Institute for Ecological Economics, University of Vermont, United States
[d] Department of Civil and Environmental Engineering, Washington State University, United States

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ABSTRACT

Managing water resources, air quality, forests, rangelands and agricultural systems in the context of climate change requires a new level of integrated knowledge. In order to articulate a role for university-based research teams as providers of climate services, this paper analyzes environmental change concerns and expectations about climate models among natural resources decision-makers in the Northwest US. Data were collected during a series of workshops organized by researchers from BioEarth, a regional earth systems modeling initiative. Eighty-three stakeholders from industry, government agencies and non-governmental organizations engaged with a team of academic researchers developing integrated biophysical and economic climate modeling tools. Analysis of transcripts of workshop discussions, surveys, and questionnaires reveals diverse attitudes among stakeholders about: 1) preferred modes of engaging in climate science research, 2) specific concerns and questions about climate change impacts, and 3) the most relevant and usable scope and scale of climate change impacts projections. Diverse concerns and information needs among natural resource decision-makers highlight the need for research teams to define clear and precise goals for stakeholder engagement. Utilizing the skills of research team members who have communication and extension expertise is pivotally important. We suggest impactful opportunities for research teams and natural resource decision-makers to interface and learn from one another. Effective approaches include structuring group discussions to identify gaps in existing climate change impacts information, explicitly considering changing policies, technologies and management practices, and exploring possible unintended consequences of decisions.

Practical Implications

The impacts of climate change are currently felt in managed and natural systems throughout the Northwest US. Questions about specific impacts, system feedbacks, and opportunities for adaptation and mitigation actions are highly complex. Scientific understanding of these issues continues to evolve. The need for relevant climate services information that is accessible to natural resource managers focused on water resources, air quality, forests, rangelands and agricultural systems is growing. Regional-scale information is particularly valuable because it is at this scale that many specific environmental risks and opportunities for action exist.

Within climate information initiatives, stakeholders are generally considered to be those individuals and organizations that have the interest and ability to use climate science information in their decision-making (Cash and Buizer, 2005; McNie, 2007; Hegger et al., 2012). The research initiative presented in this paper considers decision-makers who focus on water resources, atmospheric issues, forests and agricultural systems to be key stakeholders. Potential participatory roles for stakeholders within climate research are varied and can include: identifying research questions, sharing values, preferences, expectations and perceptions of risk, providing quantitative data or local expertise, commenting on research concepts, drafts and results, learning from the research process, and

* Corresponding author at: Center for Sustaining Agriculture and Natural Resources, Washington State University, 2606 W. Pioneer, Puyallup, WA 98371-4998, United States.
E-mail address: lizb.allen@wsu.edu (E. Allen).

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integrating research findings into a decision-making processes (Bìckstrand, 2003; Bucchi and Neresini, 2008). There is widespread agreement that *early* stakeholder engagement in research is more likely to ensure that problem definition and approaches to collecting data and communicating research findings are aligned with stakeholders' needs (Rowe and Frewer, 2005; Reed et al., 2009; McNie, 2012). However, specific protocols for academic modeling teams to engage with stakeholders and produce actionable model outputs have been subject to limited research and are not yet well defined (Reed et al., 2009; Prell et al., 2009; McNie, 2012; Weaver et al., 2013).

Natural resource decision-makers are a heterogeneous group with different interests, concerns and motivations; they hold a range of perspectives about the value and applicability of climate research to their work (Feldman and Ingram, 2009). Most natural resource decision-makers would agree that monitoring, or collecting empirical data about current conditions, is a source of credible information about the state of environmental systems. For example, scientific monitoring assessments and inventories are widely relied upon to document the environmental effects of federal agency actions, such as Environmental Impact Statements required under the US National Environmental Policy Act (Linkov et al., 2006).

Unlike environmental monitoring and other forms of field and laboratory research, modeling is often not well understood by decision-makers (Hartmann et al., 2002; Frigg and Hartmann, 2012; Akerlof et al., 2012). Models are, by definition, simplifications of real-world systems and processes (Frigg and Hartmann, 2012). Models enable projections about the future based on an understanding of the underlying processes at work, current information, and an assessment of likely trends (Allen et al., 2015). Some decision-makers may be predisposed to view climate change impacts modeling with suspicion because model outputs might suggest a change in practice that could be inconvenient or expensive (Akerlof et al., 2012). Or in many cases, skepticism about model outputs is rooted in the observation that weather forecasts and economic projections are ''frequently wrong'', illustrating a lack of experience with models and limited understanding about uncertainty and how model projections are generated and evaluated (Akerlof et al., 2012). Challenges associated with applying outputs from climate model simulations to decisions arise for the following reasons: 1) model results are typically stored in formats that require familiarity with computer programming, 2) outputs may be formidably large to download and analyze, and 3) outputs are often not refined to reflect conditions specific to a location of interest for individual users (Allen et al., 2015). To maximize the usability of environmental models for decision-making, effort is needed to assess decision-makers' information needs and to tailor communication strategies to be compatible with their expertise (Dilling and Berggren, 2015; Archie et al., 2012). When natural resource decision makers have sophisticated understanding of how models are developed they can better ask questions about the relevance of a model for a particular decision (Liu et al., 2008; Hallegatte, 2009; Schmolke et al., 2010).

BioEarth is a university-based integrated climate change impact modeling effort attempting to integrate economic and biophysical models to provide more usable climate change impacts information for decision-makers concerned with natural resource management regulations and policies. Six stakeholder workshops were convened for researchers to learn about concerns and information needs among natural resource decision-makers in the Northwest region of the United States. Analysis of workshop transcripts, surveys and questionnaires led to the identification of four themes related to key environmental, social and economic challenges facing the Northwest now and in the future: 1) climate change will exacerbate many existing environmental issues; 2) land use change and development are key issues facing the region; 3) scenarios of the region's future should explicitly analyze possible impacts of political and economic changes; and, 4) impacts of decisions across jurisdictions and management sectors must be considered.

Input from natural resource decision-makers played a central role in determining the direction of BioEarth model development efforts. Some of the information needs defined by stakeholders were beyond the scope of possibility for this specific research effort. However, researchers came to understand pressing environmental change questions from the point of view of regional natural resource decision-makers and gained an appreciation for the institutional context in which decision-making occurs and the constraints that natural resource decision-makers face in incorporating climate science information in management and policy decisions. Based on feedback on the BioEarth workshops shared by stakeholders, we found that research team members with a background in communication and extension performed a central role in facilitating the sharing of information between researchers and stakeholders. Informed by stakeholder input during and after workshops, we make the following recommendations for regional climate change impacts modeling teams: 1) structure discussions with regional stakeholders to identify specific information gaps and temporal and spatial scales of most interest, 2) incorporate policy changes, emerging technologies and management practices into scenarios that are modeled; 3) consider the impacts of projected land use change in combination with projected climate change impacts 4) compare the modeled outcomes of current best management practices vs. what are understood to be ''worst practices''; and 5) show straw man model outputs to stakeholders to foster discussion about assumptions embedded in the model and sources of uncertainty. These lessons learned about climate science information needs and stakeholder preferences for how model outputs are communicated are broadly relevant to the growing field of regional climate change impacts research efforts.

1. Introduction

The notion of a gap between research and decision-making has emerged as a central trope in climate science communication literature. Most potential users of climate science research are either unaware of available research, or unable to access and interpret relevant climate science (McNie, 2012; Lemos et al., 2012; Weaver et al., 2013). There are missed opportunities to link the supply of scientific information with users' demands, and hence missed opportunities for science to inform policy and decision-making (Sarewitz and Pielke, 2007; McNie, 2012).

Within the climate science research community, there is a long lineage of calls for usable science from funding agencies, stakeholder groups, and research institutions. In 1999, the US National Research Council promoted a new model of research, led by users' concerns and key questions. This was in response to growing understanding that local knowledge and practices are not only frequent *sources* of environmental concerns but are also *resources* for addressing sustainability challenges (Miller et al., 2014). Building on the history of applied research in the US cooperative extension service, a resurgence of engaged research includes focusing on place-based science, collaborating with local communities to define research questions and developing tools that link knowledge and action (US National Research Council, 1999, 2001). Providing effective climate services requires active communication and exchange of information among information producers, translators, and user communities (Dilling and Berggren, 2015).

Although the need for practical knowledge of how to foster more intensive collaboration among academic scientists and decision-makers is increasingly acknowledged, best practices for