Chapter 2
Climate Adaptation

Science and Collaborative Decision Making

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Abstract Climate change adaptation is at the intersection of science, communities, and a decision-making context characterized by multiple spatial and temporal scales and high levels of uncertainty, complexity, and dynamism. Potential approaches to adaptation include shared governance, adaptive management, establishing improved system indicators and metrics, and assessing ecosystem services benefits. Addressing climate change also requires evaluating the role of scientists in the decision-making process.

2.1 Introduction

Climate change and its effects on people and places present a medley of potential effects—sea level rise, thawing permafrost, changes in precipitation patterns, increased frequency of high-intensity rainfall events, impacts on flora and fauna, and many other changes to the environment. These changes have been well documented [11].

At the Interior Department, I chaired the Climate Change Task Force. The Task Force examined how climate effects might unfold across 500 million acres of Interior-managed lands, affecting resources and infrastructure at 2,400 locations with 165,000 facilities. The Task Force explored both adaptation and mitigation options. Its deliberations were situated at the confluence of science, technology, communities, management, and policy.

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There's a passage in the children's book, *Alice in Wonderland*, by Lewis Carroll, in which the heroine Alice stands at a fork in the road.

Alice looks up to see the grinning Cheshire Cat. She asks the cat, "Would you tell me, please, which way ought I to go from here." The cat replies: "That depends a good deal on where you want to get to." For communities grappling with a changing climate and its effects, their response to the Cheshire Cat might be that they are striving for risk reduction and sustainability (however defined).

The challenge is, of course: How? Where? What? Who? When? From the vantage point of a policy maker, I offer a few thoughts on the intersection of science, communities and decision making. Through that lens, I'll highlight four features of the climate change tableau that complicate decision making and affect how we think about institutions, information, and actions. These features are not wholly unique to climate change. However, they are distinctive in their breadth, depth, pace, and scale at which they are manifested in the climate change context. These four features include:

- Multiple spatial and temporal scales of the climate change problem set
- High levels of uncertainty about those effects, particularly regionally and locally
- The interconnected complexity of the changes underway that result from multiple variables, non-linear interactions, a hyper-volume of interacting axes, and links among issues, across landscapes, between people and place, and even across time
- The highly dynamic context in which multifaceted climate change effects intersect with demographic, economic, and land use changes

2.2 Discussion

Consider the first feature of the climate change context—the multiple spatial and temporal scales of change. Many climate effects transcend the boundaries of political institutions. Sea level rise, for example, along the Gulf of Mexico, affects multiple communities, even multiple states. Climate effects transcend boundaries and span different time horizons. Some effects are significant and near-term, such as currently observed changes in sea-ice in the Arctic region. Others are long-term and iterative, as may occur in the responses of some wildlife to climate change.

What are the implications of this first feature for decision makers? Nations and their communities will need institutions and decision processes that facilitate coordination across jurisdictional boundaries and among public and private land managers. They will also need both horizontal and vertical interaction among multiple governing units. Such interaction is not new. Indeed, the governing framework in many nations involves some sharing of public decision making and a vertical distribution of governing roles and responsibilities.

But these forms of federalism and regional decision making may require a different character to respond effectively to the challenges of a changing climate. Social scientist Kirk Emerson describes “collaborative federalism,” with joint decision making among multiple governing units [2]. The model she describes is one of “shared governance,” not divided decision-making authorities and responsibilities in which governing functions and issues are segregated and parceled out among different levels and units of government.

The concept of shared or collaborative governance may be applicable at the regional scale among local, interacting jurisdictions that are striving to coordinate policy and action where responding to climate effects requires cross-jurisdictional action. But collaborative federalism presents challenges. As the Lincoln Institute (Cambridge, Massachusetts) has pointed out in its discussions of regionalism [8]: How might one convene and motivate a cross-jurisdictional polity?

Policy makers also face practical challenges associated with limits on their authorities to expend funds outside jurisdictional boundaries. Yet such expenditures may be important. Consider source water protection in which relevant lands may lie outside a city’s, or even a nation’s, boundaries. Or consider the need to sustain cool, instream water temperatures or augment instream flows along an entire watershed. Or consider beach replenishment along coasts, in which sediment deposition may be required outside a city’s boundaries to secure the desired protections.

Two central challenges confront efforts to facilitate multi-jurisdictional governance. Fundamentally, policy makers face the challenge of how to achieve a decision scale “big enough to surround the problem, but small enough to tailor the solution” [8]. Second, policy makers face a challenge of how to share both goal-setting and financing across governing units and among the public and private sectors.

Within this context of shared governance, federal agencies may shift their roles from that of provider to facilitator—what Steve Stockton of the U.S. Army Corps of Engineers (USACE) refers to as the “Home Depot Model”—“you do it, we help.”

Cross-boundary governance options include both structural and nonstructural tools. Structural tools include the creation of dedicated agencies, districts, and institutions. Nonstructural tools include service agreements, partnerships, joint programs, and other informal coordinating arrangements. Both may be relevant, depending on regional issues and circumstances. Cross-national political, cultural, social, and economic distinctions will shape and limit the possibilities of shared governance.

In the U.S., we see many emergent models of cross-jurisdictional collaboration. In southeastern Wisconsin, 28 municipalities with separate stormwater management authorities have joined in a public-private partnership to create a trust to coordinate stormwater management in an area encompassing six watersheds [9]. In the Tualatin Basin of Oregon, water managers combined four wastewater permits and one stormwater permit into a single cluster and partnered with the farmers in the county and the U.S. Department of Agriculture to plant trees within the watershed to reduce water temperatures [9]. Both partnerships are issue-specific. Very few U.S. examples present models of multipurpose, cross-jurisdictional government.

A second feature of climate effects complicates decision making: the high level of uncertainty regarding these effects, particularly at regional and local scales. This characteristic of climate change effects makes ongoing learning imperative and highlights the significance of adaptive management and what the National Academy of Sciences has referred to as a "deliberation with analysis" decision model [7].

Adaptive management in the context of resource management refers to a decision-making model in which:

1. Goals are set, a process that is fundamentally about values and invokes the importance of legitimacy, relevance, and feasibility as key filters.
2. Action options are developed and intentionally designed as experiments to evaluate scientific assumptions and action effectiveness.
3. Ongoing monitoring is undertaken.
4. Results are reviewed.
5. Adjustments to management practices are based on the monitored results and analysis.

In a review of adaptive management, the National Academy of Sciences in the U.S. reports that experience to date indicates limits to the applicability of adaptive management [7]. Specifically, this approach may be most feasible where four conditions are met. Adaptive management may be most effective when:

- Temporal and spatial scales are relatively small.
- Dimensions of uncertainty are bounded so that option experiments can yield clear results.
- Costs, benefits, and risks of experimentation are acceptable and course corrections are tolerated.
- Institutional support exists for flexibility and adjustments.

These features may not apply to many climate issues and contexts. Thus, some analysts suggest a "deliberation with analysis" model may be more relevant [7]. This model refers to decision processes that provide for:

1. An iterative formulation of a problem, which is not solely a technical matter
2. Identification of interests and values relevant to defining objectives and addressing the problem
3. Development of a shared understanding of risks
4. Crafting of options and possible responses using this shared knowledge

Recognizing the limitations of how adaptive management has been practiced, USACE is developing a model of "enhanced adaptive management" that situates adaptive management within a decision framework of goals set through collaboration and evaluated using scenario planning. This framework would overcome some of the limitations described by the National Academy in its critique of how and when adaptive management might be a useful management tool. Depending on the particular climate issue, different decision models may be appropriate.

The ubiquity of uncertainty underscores the need for flexibility, resilience, iteration, and adaptive responses in decision tools and action options. High uncertainty also underscores the central role of science and technical expertise in decision making about whether, when, and how to respond to the effects of a changing climate. But the centrality of science and technical expertise raises a conundrum of what some have referred to as the “technocracy versus democracy” quandary.

Climate change issues are highly technical and complex. But policies and adaptation decisions may significantly affect people and involve tradeoffs. These differential effects on people heighten the relevance of community collaboration and present a fundamental question. How is it possible to increase public involvement in decision making when the scientific and technical issues associated with some climate effects challenges are so complex? What are the roles of scientists and technical experts?

The role of science in decision making is fluid and varying. The relationship of scientists to decision making unfolds along a continuum of low engagement to high engagement. That continuum is described by Denise Lach and her colleagues as clustering into five potential roles for scientists [6]. At one end of the spectrum with minimal engagement is a reporting role in which scientists report research to decision makers. A slightly more active engagement includes reporting and interpretation of scientific information. Third is a role in which scientists report, interpret, and then integrate their scientific information and analysis into policy or management options. Beyond this integration, some scientists may actually advocate particular policy or management options. At the far end of the spectrum are circumstances in which scientists participate in making policy choices.

What is the appropriate role of scientists? How can relevant science inform policy and management decisions? The joint fact-finding model described and used by the U.S. Geological Survey and others holds some potential more strongly to link scientists, decision makers, and publics affected by policy decisions [5]. Under that model, articulated and practiced by former U.S. Geological Survey scientist Herman Karl and others, scientists, decision makers, and citizens collaborate in the scoping, conduct, and employment of technical and scientific studies to improve decision making.

Such collaborative settings may be especially significant in enhancing prospects that scientific and technical information will be incorporated into resource policies and management. Studies on knowledge use show importance of iterative dialogue and the importance of decision contexts and mechanisms (such as joint fact finding) that link researchers to users. Such iterative dialogue can also provide for adaptive research outputs, the two-way flow of information, and actual uses of knowledge.

The user context also can significantly affect whether and how scientific and technical information are used. In part, USACE’s enhanced adaptive management model is designed to provide this context and these linkages. Substantial research indicates that mere reception of knowledge by users does not imply use. A lack of interaction between researchers and their intended audiences can present a significant problem that limits the relevance and perceived credibility of research that is intended to inform public policy decisions.

The context of uncertainty invokes other important questions about science and policy. How much certainty about a particular cause/effect sequence or about projected futures is enough? Scientists use the protocol of a 95% confidence level as the bar necessary to affirm scientific results in a research context. Policy makers use a different bar—for policy makers or managers, how much uncertainty is acceptable invokes the reply: "It all depends." It depends on the legal or policy context that might dictate immediate action despite uncertainties [9].

Think of water management in the West. Water managers don't know with certainty the timing, amounts, and storm frequencies that a changing climate might bring to the West. But managers may need to take steps to alter water management despite these uncertainties. Thus, the question of what level of certainty is sufficient to take management action is, in part, a policy decision.

Though much more might be said of the science-policy interface, a third feature of the climate change problem set—the interconnected complexity of climate change effects—also challenges decision makers. Consider a case in the Netherlands regarding sea level rise and river flows. In the Dutch "Room for the River" project, managers indicate that, on one hand, they need to plan for higher river flows through improved drainage [4]. On the other hand, sea level rise interferes with water drainage. Improved flood protection and water management, therefore, require considering both river flows and sea level. One issue cannot be addressed independently of the other.

This interconnectedness raises challenges of agency silos in which responsibilities for issues are divided. It also raises challenges for metrics: how might managers develop cross-issue indicators to measure outcomes on integrated basis?

Scientists and others in the Everglades and elsewhere have begun to develop "dashboard" indicators and winnow down a welter of indicators into accessible, smaller subsets. These efforts strengthen the science-management interface. But consider two challenges. Metrics are often calculated in terms of location-specific targets for, say, species populations. Are these the right metrics? Do location-specific population targets cause us to lose sight of the forest for the trees? Many metrics are focused on particulars rather than an integrated whole. Quantum physicist David Bohm once observed: "To fragment is to divide things up that are at a more fundamental level actually connected" [1].

To enhance ecosystem health, resource managers need a combination of system process indicators and population metrics. This challenge raises a corollary issue: resource management requires both "richness"—detailed knowledge of specific ecosystem components—and "reach"—a broad knowledge of interacting components and natural systems [3, 10]. In short, good resource management requires both specific and integrated information. Resource managers also need interpretation—what do indicators mean? I am reminded of a caution once offered by economist Thomas Sowell, who remarked: "Information everywhere but knowledge is rare."

But let us now turn to the last feature of climate change effects: dynamism. Climate effects are highly dynamic, with the pace of change sometimes dramatic (as in current trends with Arctic sea-ice melting).

Like the characteristic of uncertainty, the highly dynamic nature of climate change effects implies the need for adaptation. It may also heighten the need for policy options centered on resilience or robustness. More specifically, resource managers need management options that provide functionality across a broad range of conditions.

Consider water management and flood protection. In the case of coastal protection, traditional flood and storm surge protection has relied on "gray" infrastructure such as dikes and levees. This infrastructure may perform well under certain conditions. Yet increasing the performance of this gray infrastructure to withstand more frequent and more intense storms may be exorbitantly expensive in many cases relative to solutions that supplement existing gray infrastructure with green infrastructure like beach nourishment, wetlands restoration, and sea marsh protections. The latter mix of options may provide greater functionality and more resilience across a broader range of conditions than traditional infrastructure. Moreover, such green infrastructure may provide habitat protection, enhanced water quality, and other co-benefits.

Or consider reservoirs, which, traditionally, have been built for the dual purposes of water storage and flood control. With an increased frequency of high-intensity rainfall events or prolonged droughts, revising reservoir operations to maximize water storage capacity in combination with restoring flood plains to serve the flood protection role may offer communities greater resilience than building ever-larger reservoirs that operate as dual-purpose systems. Comparing these options renders consideration of "Nature's Capital"—ecosystem benefits—especially relevant.

Calculation of such benefits should not be confused with ignoring what some refer to as the intrinsic value of nature. Ecosystem benefits assessment and the intrinsic value of nature are not dichotomous concepts.

Instead, the challenge resides in selection of methodologies associated with assessing intrinsic values. Because such values are not traded in a marketplace, assessing such values requires use of tools such as contingent valuation—exercises in assessing what people "would" pay to sustain natural places and ecosystems. Disagreements often arise regarding the selection and use of such tools.

Challenges also reside in determining the role of such ecosystem benefits valuations within an overall decision framework. Specifically, how much weight does one place on such valuations—or cost-benefit valuation in general—in resource management and infrastructure investment decisions?

2.3 Conclusion

The governance, information, and adaptation challenges presented by climate adaptation responses invoke no single set of policy and institutional answers. But risk reduction and sustainability will require a confluence of science, collaboration, and new forms of governances. These three dimensions of problem solving are important to enhance decision-making effectiveness, accountability, and legitimacy.

Twenty-first century governance, as the Lincoln Institute in Cambridge, Massachusetts, has pointed out, may reveal a new lexicon of collaboration, shared power, networks, consensus, and iteration. All these features, for policy makers, make decisions provisional, and they diffuse responsibilities. This sort of diffuse, provisional decision making is difficult to reconcile with traditional notions of accountability.

With this backdrop, I conclude by returning to an earlier issue—the broad relationship of science and decision making. The intersection of science and decision making presents difficult questions. Science is critical to understanding causes and effects, filling knowledge gaps, projecting future outcomes, modeling alternative options, and assessing restoration results. Many climate adaptation issues are sufficiently scientifically complex that science at the decision table may help pinpoint the possible and define the doable. Scientists may help decision makers and managers shape and evaluate options through iterative conversations. They may help decision makers define the "problem set" but this input requires strengthening the iterative processes by which information needs are articulated and information is generated, communicated, and used. But what information do decision makers need? Scientists ask: "how does the world work?" [9] Scientists' reputations are often built upon the dissection and discernment of complexities and new frontiers. They often provide "deep knowledge" and highly specialized knowledge. Policy makers and managers have a different set of tasks and knowledge needs. Policy makers ask: what values do we care about? What priorities should we set? What actions should we take to address those priorities? Fundamentally, these questions involve the "people factor."

At one level, the very nature of these questions invokes the importance of citizen engagement. Situation complexity requires complex decision-making processes of coordination, partnerships, and collaboration. But, in other respects, managers need simplicity. At an operational level, managers (and policy makers) need information that allows for nimble, sometimes quick action. They need a general sense of progress or signals of impending problems. They need easily accessible, readily comprehended information. Policy makers and managers need general benchmarks, easy-to-use models and decision support tools. Within a resource management context, this tension between the aims of the scientist and the needs of the manager sometimes eludes resolution.

As nations and communities ponder these issues, governing institutions, and the intersection of science and decision making, the words of Bertrand Russell offer a fitting caution:"Sometimes we need to hang a question mark on things long taken for granted."

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