Scale and cross-scale dynamics: governance and information in a multi-level world

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This paper represents the efforts of a group of scholars from multiple disciplines to synthesize current theoretical and empirical efforts to understand scale and cross-scale dynamics in solving environmental and resource management problems. Over the last year+, W. Neil Adger, Fikret Berkes, David Cash, Po Garden, Louis Lebel, Per Olsson, Lowell Pritchard, and Oran Young, have collaborated to produce a suite of papers on scale and cross-scale dynamics (see titles of these papers below). We met in Montreal in October 2003 to discuss our papers and collectively outline this overview paper.

As such, this paper is designed to synthesize the work represented in the papers listed below. Given the timing of when first drafts of the papers were completed, this current synthesis draft does NOT adequately provide this synthesis. It highlights the major themes that run through the papers but does not yet effectively integrate the findings and conceptual development that is contained in the papers. We hope that feedback from the Alexandria meeting (where a number of these papers will be presented) will help us truly synthesize existing understanding for the next draft of this synthesis paper.

We look forward to comments!

-David Cash

Papers to be submitted in a scale and cross-scale dynamics special issue of *Ecology and Society*:

Scale and cross-scale dynamics: governance and information in a multi-level world (David W. Cash, W. Neil Adger, Fikret Berkes, Po Garden, Louis Lebel, Per Olsson, Lowell Pritchard, and Oran Young)

The political economy of cross-scale networks in resource co-management (Neil Adger)

From community-based resource management to complex systems: the scale ussue and marine commons (Fikret Berkes)

The politics of scale in the assessment and management of environmental change (Louis Lebel)

Social networks and cross-scale social learning for improved ecosystem management in southern Sweden (Per Olsson, Lisen Schultz, Carl Folke)

Hierarchies and panarchies: Scale (mis)matches in ecosystem and political processes (Rusty Pritchard)

Vertical interplay among scale-dependent resource regimes (Oran Young)

1 INTRODUCTION

In October 1998, Hurricane Mitch, one of the strongest hurricanes in recorded history, made landfall on the eastern shores of Central America. Within several days, over 10,000 people were dead, hundreds of thousands displaced, and long-term changes in ecosystems and social systems had begun. Hurricane Mitch and its aftermath can be framed in a variety of ways: as a natural disaster, a vulnerability problem, a north-south divide problem, an emergency response problem, a poverty problem, a land management problem, or a forecasting problem. An additional way of characterizing it, however, is with a conceptual perspective that cuts across these others and increasingly occupies the thinking of scholars, policy makers and managers: as a problem of **scale**.

Global climatic patterns resulted in a large tropical storm, that covered millions of square kilometers. Acute rainfall from the tropical storm fell in areas where the large amount of precipitation resulted in the destabilization of steep landforms in specific places (on the order of several square kilometers or less) and mudslides that buried entire villages. Vulnerability of local communities was heightened by national development policies (or lack thereof). Aid for victims was coordinated at the international level, but there were difficulties in transferring goods and services to local communities. The existent capacity to forecast the large-scale event had little impact on local decision making. Finally, there is the possibility that the aggregate result of individual behaviors that result in carbon dioxide emissions have changed the global climate system and influenced the probability that a storm of Hurricane Mitch's magnitude would develop.

Hurricane Mitch is not an isolated incident, but represents a class of complex problems that are at the heart of the study and practice of resource management and development. There is a long litany of failures in policy and management related to not accounting for issues of scale and cross-scale dynamics in human-environment system: fisheries collapses, transboundary pollution problems, vulnerability to repeated extreme events (e.g., flooding, drought), inability to address human-induced disease outbreaks, etc.

The study and practice of understanding and managing human-environment interactions increasingly recognize the importance of scale and cross-scale dynamics[1]. Challenges arise from the facts that biophysical phenomena and the processes of human causation and response are intricately linked, but incompletely understood, and the scales and levels at which they manifest are frequently mismatched. A number of disciplines have stressed the importance of scale in ecological, social, and human-environment interactions, and they have begun to investigate selected cross-scale processes, but these processes prove to be complex and few strong generalizable propositions have emerged from these fields to date. Furthermore, there is little understanding of the role that knowledge plays in supporting effective policy-making and management of human-environment interactions that span different scales (Kates, 2001; Cash, Clark, Alcock et al., 2003).

[1]Definitions from (Gibson, Ostrom and Ahn, 2000):
Scale: the spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon.
Levels: The units of analysis that are located at the same position on a scale. Many conceptual scales contain levels that are ordered hierarchically, but not all levels are linked to one another in a hierarchical system.

Despite these challenges, the call for dealing with scale and cross-scale dynamics is increasing. The output of the World Summit on Sustainable Development in 2002 was emblematic of these calls. In its Implementation Plan, the parties to the summit agreed to "Encourage relevant authorities *at all levels* to take sustainable development considerations into account in decision-making, including on national and local development planning, investment in infrastructure, business development and public procurement [emphasis added]."(United Nations, 2002, Section III.18). In a fifty page document the phrase "at all levels" appears 81 times, in an apparent acknowledgement that the most difficult challenges of sustainable development will require at least the admission that these problems have causes and solutions that span multiple levels.

Can we tease apart what "at all levels" means, and derive structured ways of thinking about problems of scale? In this paper, we synthesize existing literature and our own research, provide a framework for analyze scale-related issues, and propose hypotheses of institutional solutions for understanding and solving complex human-environment problems.

2 THE CHALLENGES

In the academic literature and in practical applications, four major challenges seem to characterize problems defined as scale problems in social-ecological systems: 1) mismatch between scales of human systems and scales of natural systems; 2) the tendency to define issues at one scale; 3) mismatch between scales of knowledge and scales of management; 4) ignoring cross-scale interactions in the human-environment system; and 5) ignoring linked issues or domains (indirectly scale-related, since many issues display scale-dependency) (Gibson, Ostrom and Ahn, 1997; Cash and Moser, 2000).
[A meta-level challenge related to all of these is that scale and its attendant concepts are socially constructed and dynamic, and thus a shifting and difficult target to analyze... discussion on this to be added.]

Scale mismatch in human-environment systems

This is perhaps the archetypal scale problem, a problem of fit – human institutions that do not map coherently on to the ecological scale of the resource, either in space or time. In these kind of mismatch problems the authority or jurisdiction of the management institution is not coterminous with the problem. Transboundary pollution problems, migratory fisheries problems, and aquifer management conflicts fall in to this category. More recently, the temporal scale dimension of mismatch has been addressed. Temporal scale mismatches arise, for example, in cases where short electoral cycles conflict with long-term planning needs (Folke, Pritchard, Berkes et al., 1998; Young, 2003).

Defining issues at one scale

A second challenge relates to how an issue is framed. Defining a problem as purely a "global" problem or purely a "local" problem often leads to failure. Consequences and potential nuanced solutions to global environmental issues are made invisible by their definition as "global only" and hence the "solutions" are not found and the problem polarizes (Goldman, 1998; Wilbanks and Kates, 1999; Adger, Benjaminsen, Brown et al., 2001). Likewise, narrow temporal scale definitions of problems also can have similar outcomes. Issues identified as short-term or long-term exclusively tend to polarize debate and ignore causes and solutions that occur simultaneously at different scales. The tendency to define problems at single scales is also what contributes to the difficulty of defining success and effectiveness in complex problems – those evaluative terms can be highly scale dependent.

Mismatch between scales of knowledge and scales of action

One of the fundamental challenges in linking knowledge and action is matching the scale of what is known about the world, and the scale at which decisions are made and action taken (Kates, 2001). This is seen in the dual problems of large-scale scientific knowledge that has little relevance to local decision makers (global climate models are at a resolution that is not useful to sub-national decision making), or local, tacit or indigenous knowledge that is not seen as valid by national or international actors (e.g., artisanal fishing knowledge that is not taken into account in international treaties on fisheries) (Berkes, 2002; Gadgil, Olsson, Berkes et al., 2002).

Ignoring global/local dynamics and long-term/short-term dynamics

Consistent with, but somewhat more complex than the previous problems of mismatch, are the challenges associated with ignoring cross-scale dynamics within spatial and temporal dimensions (Holling, 1986; Clark, 1987; Holling, 1995). A class of these kinds of challenges in the management arena are illustrated by national policies that adversely constrain local policies, local actions that aggregate into large-scale problems, and short term solutions that aggregate into long-term problems. [@@ need more here are ecological global/local dynamics and long-term/short-term dynamics. Rusty?].

Ignoring linked issues or domains

The fact that social and ecological issues have largely been analyzed, understood and managed separately is increasingly being recognized as one of the fundamental pitfalls in improving human well-being (World Bank, 1999; Annan, 2000; Walker, Carpenter, Anderies et al., 2002). This is the case as well, when understanding management of specific issues as well. There is a growing realization that institutional structures and policy that carve the social-ecological system into seemingly manageable pieces of water, food security, forests, fisheries, etc., in fact, ignore the most important aspects of a resource or environmental problem – its links with other issues. It has become obvious, fore example, in may irrigated agriculture systems that water quality and water quantity issues can not be analyzed and managed separately [@@ cite]. While not directly an topic about scale, linking issues becomes a scale problem to the extent that many issue display scale-dependence and cross-level interactions with other issues (Young, draft).

3 FRAMEWORK

Driven by these five challenges, and attempting to synthesize a changing and diverse literature, we propose a framework for analysis of scale for complex problems found at the nexus of environment and development. We think of the following two dimensions of the framework as critical concepts to explore in understanding and managing complex systems.

3.1 Dimensions of the problem: space and time

1st dimension: Spatial Scale

Ecological phenomena occur over a continuous range of levels, although particular levels may be most important for particular processes. For example, complex cellular processes govern the decomposition of plant matter lying across a deforested tract of Amazonian rainforest, releasing carbon dioxide into the atmosphere. Once released to the atmosphere, molecules of carbon dioxide rapidly merge into a somewhat uniform global mix of gases regulating the Earth's greenhouse effect. Global climate change may result from an amplified greenhouse effect. Thus, global systematic changes and phenomena are linked to and regulated by a complex mix of local processes and vice versa.

A similar argument can be made for social phenomena and processes that roughly correspond to characteristic spatial scales, ranging from individuals to families to the population of a nation or the world. Social scales can also be defined in the context of clearly bounded and organized political units (e.g., towns, counties, states or provinces, and nations) with linkages between them being created by constitutional and statutory means. These scales tend to be lumpier or more clearly separated than scales of biophysical phenomena, but similarly hierarchical organized. The linkages between social phenomena at different levels is made complex, however, because people are also connected via non-governmental institutions and social networks that are less strongly correlated with spatial scales (e.g., through markets and industries, clans, religions, professions, voluntary associations.

Some authors deal with spatial scale and institutional scale separately. Institutional scale and spatial scale do not always correlate. Switzerland and Russia are both at the same institutional scale (nations), yet are very different in terms of the spatial extent by which they are defined. Yet, for analytic purposes, there is utility in thinking about them along the same dimension, with care given to address the times when there is little correlation.

When discussing spatial scale, the term "level" is useful in identifying the unit of analysis. Characterizing the interactions across levels is at the core of the cross-level (often called "cross-scale") analysis that we discuss later. Thus, we are interested in the interactions between U.N. treaties (the global level), national governments (national level) and municipalities (local level) or General Circulation Models (global level); regional climate forecasts (regional level); and watershed weather events (local level).

2nd dimension: Temporal Scale

As spatial scale can be thought of as divided into different "levels", temporal scale can be thought of as divided into "timeframes", or divided using language such as long-term and short-term or fast and slow. Thus biogeophysical and social phenomena happen at a range of different timeframes: fast cellular metabolism, slow genetic changes, population dynamics that happen over generations (of course, depending on the species that could mean minutes to centuries), extremely rapid erosion events (as was seen with Hurricane Mitch), and extremely long duration in global climate dynamics (as might be manifest in a greater probability of Hurricane Mitch); the 24 hour news cycle, electoral events that happen on the order of multiple years, the lifetime of bureaucratic agencies, the long timeframe of large cultural shifts (e.g., religious, economic, etc.). [This section will be fleshed out more with, for example, interactions between fast and slow events; triggers, thresholds, etc.]

3.2 Interactions of spatial scale and temporal scale

[In this section we will outline current thinking on interactions of spatial and temporal scale. It will be particularly important to relate these interactions back to the central challenges...It is, after all, largely because of these interactions, and social systems' inability to understand or deal with these interactions that results in the challenges outlined in Section 2 ; Use **Figure 1** to illustrate]

4 INSTITUTIONS FOR MANAGEMENT AND KNOWLEDGE IN A MULTI-LEVEL WORLD

4.1 Institutional interplay

[This section will be drawn largely from recent work by Oran Young, including a paper that is being submitted as part of this effort: "Vertical Interplay among Scale-Dependent Resource Regimes". Below are sections lifted directly from his paper. In the final draft this text will reflect an integration of Young's writing and the empirical contributions of the other papers in the set.]

Cross-level, scale dependent interplay

"On this account, cross-level interactions among resource regimes occur when there is vertical interplay between or among regimes located at higher and lower levels on the jurisdictional scale. In many cases, such interactions will involve interplay between management systems located at adjacent levels (e.g. interactions between state-level regimes administered by the Alaska Department of Fish and Game and national-level regimes administered by the U.S. Fish and Wildlife Service). But this is not always the case. To take a concrete example, there are important cross-level interactions between the traditional practices of local, Native hunters engaged in the harvest of bowhead whales for subsistence purposes and the global regime for whales and whaling that has evolved under the terms of the 1946 International Convention on the Regulation of Whaling."

Patterns of cross-level, scale-dependent interplay

Dominance
Separation
Merger
Negotiated agreements

System Change

Hypothesized mechanisms
Authority/leverage paradoxes
Illusions of decentralization
Dueling discourses
Cognitive transitions
Blocking coalitions

Consequences of cross-level, scale-dependent interplay
Ecological stability/instability
Social welfare/efficiency
Equity/justice

"I have argued in this article that under conditions prevailing today cross-level interactions among scale-dependent resource regimes are common occurrences. At a minimum, this line of analysis suggests three observations that those responsible for administering resource regimes should consider carefully. First, it is dangerous to focus attention exclusively on one level or to assume that higher-level arrangements will take the form of macrocosms of lower-level arrangements and vice versa. This raises questions about the usefulness of propositions about resource regimes derived from studies that address a single level on the scale of jurisdiction. Second, although the consequences are not always negative, it is easy to see that cross-level interactions among scale-dependent regimes will often give rise to serious problems framed in terms of considerations like ecological stability, efficiency, and equity. As a result, managers and policymakers need to be particularly vigilant in identifying such problems and be prepared to take corrective actions when these problems become severe. Third, there is much to be said for analyzing alternative arrangements in advance and for preparing to launch desirable alternatives during momentary windows of opportunity, even though the impact of path dependence ensures that the prospects for reforming existing arrangements are ordinarily dim. There is no point in treating cross-level interactions among scale-dependent regimes as a kind of pathology to be cured. But we can and should make a concerted effort to improve our understanding of this phenomenon and to prepare in advance to take advantage of transient opportunities to restructure existing patterns of cross-level, scale-dependent interactions."

4.2 Institutions and asymmetries of power

[The following text contains the kernel of our discussions about asymmetries of power from an institutional perspective]

In many resource situations, there are direct incentives for individuals and organizations to engage in co-operation. These same incentives apply to the formulation and evolution of cross-scale linkages. While to date in the paper we have focused on the benefits of cross-scale interactions for the effectiveness of the resource system, we also need to recognize the patterns of individual incentives and the asymmetries that incentive structures bring about. It is well established that conventional co-operation between actors in resource situations occur and persist even in the absence of shared goals or objectives. Linkages between actors for resource management have transactions costs, but can benefit all parties. To characterize the issue, in the case where actors perceive a benefit, they act co-operatively (Sandler, 1997). Linkages in general then develop their own momentum and persistence even in the absence of perceived benefit. This has various been explained by social pressure, or mutual enforcement (Barrett, 2003; Dasgupta, 2003).

In the same way, linkages between institutions develop across scales. They do so in some part because of self-interest. In many cases cross-scale linkages develop to access information and provide benefit to linking agents through the use of this information. In terms of scientific knowledge in particular, access to externally validated information brings about greater legitimacy. Access to credible science has been central to strategies of environmental advocacy groups as well as government agencies in a host of conflictual decisions (see recent GM Nation and surrounding debates in the UK – (Freckelton, Sutherland and Watkinson, 2003).

4.3 Institutional mechanisms and cross-level linkages in knowledge: Boundary management

As noted above, knowledge is often held, stored, and perceived differently at different levels. The result is often a dissonance across levels about what is perceived as salient, credible, and legitimate knowledge. This can be illustrated in the case of sustainable water resources, with a focus on spatial/jurisdictional scale and the institution\al boundaries that separate levels. The multi-level nature of a problem like aquifer depletion, brings these kinds of differential attributions into sharp focus because issues such as saliency, credibility, and legitimacy can exhibit strong scale-dependence, and attribution of these three qualities can be relatively easily identified and associated with specific levels: what is salient, credible or legitimate to state level actors might be different from and antithetical to what is salient, credible or legitimate to local actors. A state level water plan that might be salient to state actors ("aggregating over the state, this is how water can best be allocated"), might not be salient to local actors ("the state water plan does not address our local problem, in fact it causes new problems.") Regulations set by a states' department of water resources, while legitimate to state actors ("after all, the state owns the water"), would not be legitimate actions in the eyes of local landowners ("we've hand no input into rules that affect our livelihoods.") Assessment of the aquifer undertaken by a states' geological survey, while credible to state actors ("the state geological survey has the best geologists in the state, plus it's been peer reviewed"), would not be credible in the eyes of local landowners ("they don't understand the specific conditions here.") (Cash, in review).

Thus, one challenge for institutions dealing across multiple levels, timeframes or domains is to more effectively create knowledge that is salient, credible and legitimate across levels and timeframes and domains. [This will need to build on and relate to the issues of interplay and asymmetries of power outlined in Sections 4.1.1 and 4.1.2, above). We can refer to solving this challenge as the boundary management function, and we can refer to organizations that explicitly focus on this intermediary function as **boundary organizations** (Guston, 1999; Cash, 2001; Guston, 2001): organizations which play an intermediary role between different arenas (levels, domains) and facilitate the co-production of knowledge. Whether formalized in organizations specifically designed to act as intermediaries, or present in organizations with broader roles and responsibilities, several proposed institutional functions and characteristics seem to be important for effectively harnessing science and technology for sustainability by ensuring salience, credibility and legitimacy across boundaries. These include: 1) accountability to both sides of the boundary; 2) use of "boundary objects"; 3) participation across the boundary convening; 4) convening; 5) translation; 6) coordination and complementary expertise; 7) mediation. One goal of this research is to test to what degree these features lead to effectiveness in linking science to decision making, what institutional mechanisms support these functions, and how these functions influence the salience, credibility and legitimacy of information.

Accountability: A critical institutional mechanism which helps assure legitimacy across boundaries is accountability to both sides of the boundary (Guston, 1999). When the actors in a boundary organization are dually accountable, they must take into account the interests, concerns and perspectives on both sides of the boundary. In the Great Plains case this is seen for water district managers who are hired (and fired) by a locally elected board, but also must take actions that are consistent with state regulations enforced by state agencies and the courts. This is also seen for county extension agents (CEA) who are hired by a locally elected board and are accountable to the academic department to which they are affiliated at the state university. Such accountability confers legitimacy on the actions of these players, and is especially useful when they play coordinating roles by linking their organizations to others.

Use of Boundary "Objects": In the field of science studies, "boundary objects" has become a useful concept to describe items that “sit between two different social worlds, such as science and non-science, and they can be used by individuals within each for specific purposes without losing their own identity" (Star and Griesemer, 1989; Guston, 2001, p. 400). In the cases we examined, these are hydrologic, fisheries or climate models, forecasts, and assessment reports. They are "objects" over which disparate perspectives can argue and agree, and they can serve as a focal point for common understanding. It is through boundary objects that farmers and economists, state and local officials, emergency managers and climate modelers, economists and chemists, and fishers and marine biologists can come to the table to work upon collaborative tasks. Such collaborative building of a model or forecast or report increases the probability that salient information will be produced by engaging the end-user early in the production of information. They potentially increase credibility by bringing needed (though perhaps disparate) expertise to the table. And they potentially increase legitimacy by providing greater access to the process for multiple perspectives and greater transparency. However, given that they may be “used by individuals within each for specific purposes without losing their own identity”, they can also allow different actors to value the boundary objects in different ways – ways that suit their interests, and ways that allow tradeoffs between salience, credibility, and legitimacy to be tempered. A local water manager on Guam can view climate forecasts as a tool to make a quick decision about how to allocate resources, while a scientist can view a forecast as a way of better understanding a complex natural system. Such a dynamic allows both credibility to be maintained (a primary concern of the scientist) at the same time that salience and legitimacy are maintained (primary interests of the end-user.)

Participation across the boundary: In systems that effectively link knowledge and action, participation from both sides of a given boundary seems critical (Guston, 1999). In the cases we examined, effectiveness is associated with systems that engage multiple actors across multiple boundaries. Cases that did not do this (e.g., the lack of engagement of farmers in southern Africa, modelers from state agencies in Texas, farmers as recipients of "scientific" breeding programs) have special difficulty producing salient information or technology, but also experience difficulties producing legitimate and credible information for critical actors. A boundary organization is one kind of organizational structure that facilitates participation across the boundary. While more research needs to be completed on the role of individuals, preliminary findings suggest that it is often individuals who have legitimacy or credibility on both sides of a boundary that are especially useful in making this bridge (e.g., the hydrologist who becomes a manager; the CEA who had experience as a farmer; the farmer who becomes a crop scientist, etc.) [@@ connect this to later text on leadership by Olsson.]

Convening connotes the process of bringing parties together for face-to-face contact. This is hypothesized to be an important function, as it forms the background for relationships of trust and mutual respect. Convening can also provide the foundation for providing the three other functions outlined below. In studying this function, we sought information on how and in what contexts actors from different spheres were brought together.

Translation: Some of the most central challenges when crossing boundaries are about differences in jargon, language, and discourses that are scale dependent. This challenge is seen in southern Africa ENSO prediction where forecasters are struggling with how to present probabilistic information in a way that is understandable to farmers or managers (O'Brien, Sygna, Naess et al., 2000; Patt, 2000). Through the Pacific ENSO Applications Center's (PEAC) ongoing iterative meetings with modelers and users, users have been able to be educated about how different forecasting information can be presented and interpreted, and users have been able to suggest to modelers what kinds of products are the most useful. In doing so, PEAC plays a central role in translating information between the multiple parties. Likewise, El Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT - the International Maize and Wheat Improvement Center) specialists are able to help translate crop breeding information to local farmers, and traditional farming information and needs to breeders. Such translation capacities are facilitated by the kinds of people described above – people, who as individuals, bridge boundaries and are comfortable conversing in multiple “languages”.

Coordination and complementary expertise: Assessing and addressing complex sustainable development issues requires multiple perspectives, disciplines, and interests (Kates, 2001; Folke, Carpenter, Elmqvist et al., 2002). For assessment activities, coordination is often necessary to take advantage of complementary expertises and conceptual frameworks (e.g., one cannot understand how the change in fisheries will influence local communities without expertise in both marine biology and economics). Likewise, to implement actions, coordination is necessary to avoid multiple entities producing divergent or mutually incompatible policies (state water policy and local water regulations should be mutually supportive.) Our findings suggest that those systems that actively coordinate different entities within the system are better able to take advantage of complementary expertises and produce actions that are more harmonious across different groups (levels, agencies, etc.) In the Great Plains, the vast modeling expertise and resources from a federal agency like USGS can be integrated with local data collection through the coordinating efforts of the CEA. Neither USGS nor the water district could produce credible and salient models of the aquifer that would have locally-specific information if the two expertises were not coordinated. Likewise, traditional farming knowledge and modern scientific breeding techniques are married through the coordination of CIMMYT specialists – an outcome that produces legitimate and salient technologies for farmers, without sacrificing the need for standardization by scientific plant breeders.

Mediation and a selectively permeable boundary: If what comprises and characterizes boundaries between science and decision making, across levels, and across disciplines is negotiated (Jasanoff, 1987), then a critical role in managing boundaries seems to be that of active mediation. As in any negotiation where there are conflicting interests, different perspectives and different ways of understanding, mediation can provide the means by which gains from trade can be made and win-win outcomes can be supported. In our cases, mediation reduces the potential tradeoffs and conflicts between increasing salience, credibility, or legitimacy. As water district managers and county extension agents mediate the collaboration between farmers and modelers they succeed at making the information products salient to users, while at the same time assuring that scientists have control of their research and use peer review to maintain the credibility of their research. Likewise, PEAC's mediation between climatologists and managers in the structuring of forecasts results in the production of information where salience and credibility can be increased complementarily. Managers get timely information about variables that matter to them (when will a drought start), and researchers can build more robust climate models by integrating large-scale with locally collected data. In such a way, the mediator acts to make the boundary selectively porous, allowing bridging the boundary for some purposes (e.g., getting user research needs to researchers), but keeping the boundary solid for others (e.g., keeping the scientific process out of politics).

5 DYNAMICS

[This has been the least formulated section and is presented only in outline form]

Possible hypotheses to guide this section:

H: Change toward cross scale governance requires a crisis;
H: Intentional design of mechanisms to mediate across scales are more likely to lead to incremental change;
H: Systems that are explicitly designed to facilitate an on-going, dynamic process of experimentation, evaluation and learning are more effective than those focused on one-time findings or interventions.

5.1 Dynamics and institutions

5.1.1 Scale moving – strategic or accidentally organizing at different levels than institutions are used to.

5.1.2 Scale jumping – shopping for influence at higher levels leaving out the line manager.

5.1.3 Speed of interplay – high amplitude/high frequency

5.2 Dynamics and characteristics of the resource

5.2.1 Speeds of renewal

5.3 Dynamics and agency

5.3.1 Leadership

5.3.2 Transfer of leadership

5.4 Dynamics and triggers

5.4.1 How to encourage innovation and creativity, particularly in periods when the system is not in crisis?

5.4.2 Does cross scale management help to anticipate surprise?

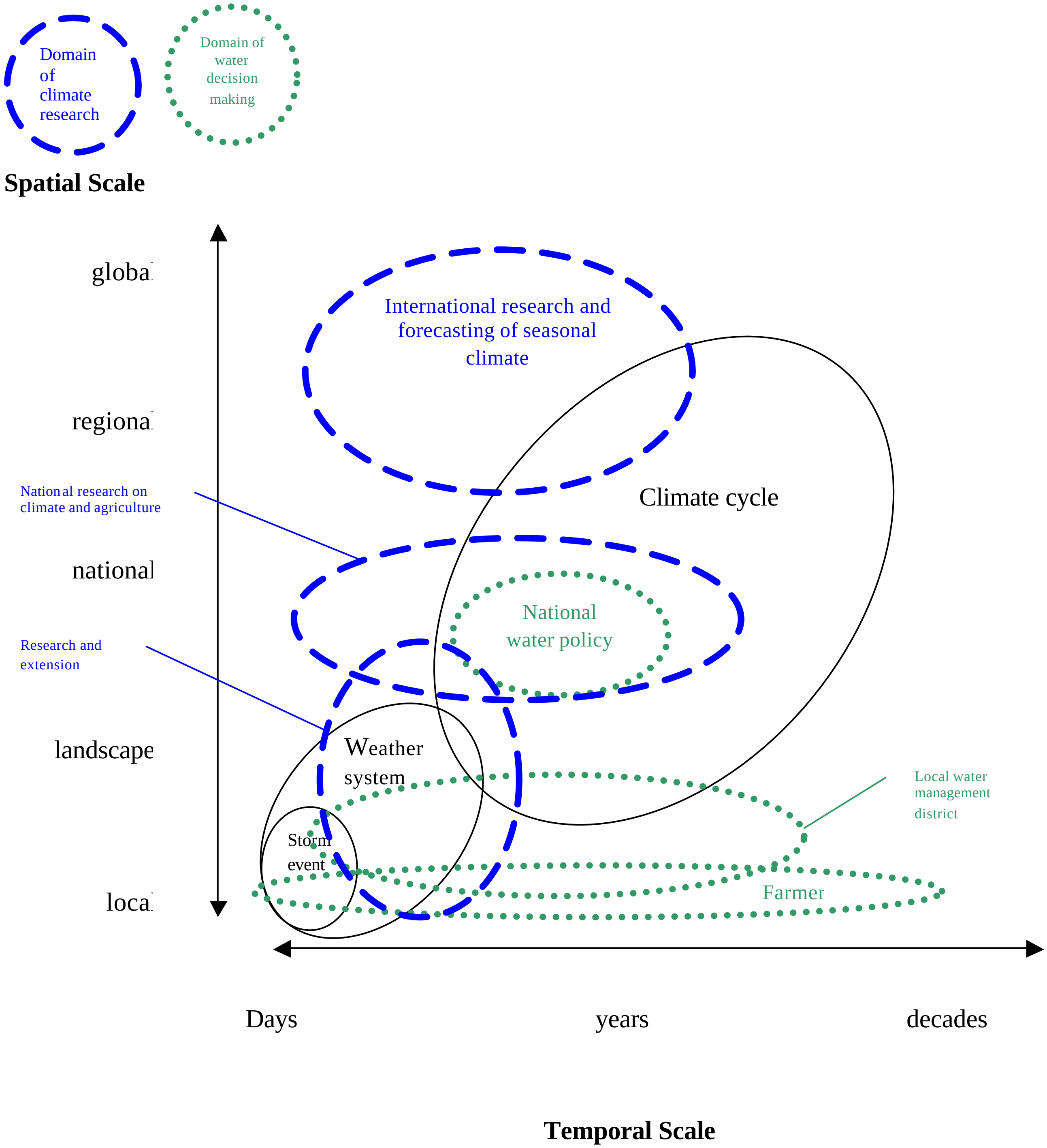
6 SYNTHESIS

[Return to how this illuminates a problem like Hurricane Mitch and helps us understand how to implement calls for addressing environment and development "at all levels" (WSSD).

Potential value of this framework?

Outstanding research questions.]

Figure 1 Interaction of spatial scale, temporal scale and domain.
This schematic diagram can be used to illustrate the spatial and temporal dimensions of biogeophysical phenomena (the climate-related system in solid black line); and the interaction of two human domains (climate research - blue long hashed line; and water management (green dotted lines). In this case, gaps exist in the human systems **across levels** within domains (e.g., international climate research does not link with national or subnational research or forecasting, and national water policy does not link with local water management) and across domains. (This diagram is based on original figure by Clark (Clark, 1987), and recent additions by Lebel.)



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