Research

Exploring Dimensions, Scales, and Cross-scale Dynamics from the Perspectives of Change Agents in Social–ecological Systems.

Joost M. Vervoort [1,2,3], *Lucas Rutting* [4], *Kasper Kok* [2], *Frans L.P. Hermans* [5], *Tom Veldkamp* [6], *Arnold K. Bregt* [7] and *Ron van Lammeren* [8]

ABSTRACT. Issues of scale play a crucial role in the governance of social–ecological systems. Yet, attempts to bridge interdisciplinary perspectives on the role of scale have thus far largely been limited to the science arena. This study has extended the scale vocabulary to allow for the inclusion of practice-based perspectives on scale. We introduced "dimensions," used to describe the bare aspects of phenomena, such as time, space, and power, structured by scales and levels. We argued that this extension allows for a clearer understanding of the diversity of dimensions and scales that can be used to explore social–ecological systems. We used this scale vocabulary in a practical case study to elicit perspectives on dimensions, scales, and cross-dimensional dynamics from change agents in Dutch social–ecological systems. Through a visual interview method based in the extended scale vocabulary, our participants identified a large diversity of dimensions they saw as instrumental to understanding insights and lessons about effecting systems change. These dimensions were framed by a large number of scales to describe cross-dimensional interactions. The results illustrate the value of practice-based perspectives for the development of scale theory. We also argue that the introduction of dimensions in the scale vocabulary is useful for clarifying scale theory aimed at linking different disciplines and sectors, and that the framework and methods based on it can also provide clarity for practical scale challenges.

Key Words: *change agents, cross-scale dynamics, level, scale, social–ecological systems*

INTRODUCTION
Research on scales and cross-scale dynamics in social–ecological systems has the potential to bridge divides between different disciplinary approaches. The different conceptualizations of scales used in disciplines such as ecology, physical geography, human geography, and sociology reveal a great deal about the ways knowledge and research are structured (Gibson et al. 2000, Sayre 2005, Buizer et al. 2011).

Whereas research focusing on spatial and temporal scales has been applied in practical contexts, most work linking scales used across disciplines (e.g., ecological, economic, political scales) has been highly conceptual and focused on the development of theoretical understanding (Silver 2008, Kok and Veldkamp 2011*a*). However, interdisciplinary understanding and communication about scale interactions can help shed light on deeply rooted governance problems and identify solutions (Cash et al. 2006). Therefore, discussions about the role of scale and cross-scale dynamics should go beyond the scientific arena. Scale research should be informed by perspectives from policy and management, to develop practice-based insights and, in turn, to offer useful frameworks to help address problems of environmental governance (Kok and Veldkamp 2011*a*).

However, views on scale from actors beyond the scientific world remain largely unexplored (van Lieshout et al. 2011).

Here, we argue for a practice-based, bottom-up perspective on scale in social–ecological systems. We first redefine the scale vocabulary to make it more useful for this practice–theory interaction. Then, we elaborate on how this redefinition could help with key theoretical and practical challenges related to scale. Finally, we explore the usefulness of our extension of the scale vocabulary for tackling these challenges with an explorative case study focused on eliciting practice-based perspectives on scale and scale dynamics.

### Introducing dimensions to the scale vocabulary
Concepts associated with scale are used in many contradictory ways in different research literatures. A large number of papers exploring scales either directly rely on the definition of a scale used by Gibson et al. (2000) or refer to Cash et al. (2006). This definition states that scale refers to "the temporal, spatial, quantitative and analytical dimensions used by scientists to measure and study objects."

We would like to note that scales are not only used by scientists, and are not just tools for the study of phenomena, but are deeply rooted in the structuring of actions from personal decisions to global policies. Moreover, we believe that an understanding of, and communication of, the notions of scale and level is facilitated by introducing an additional concept, namely "dimensions." To further elaborate, we use "dimension" to refer to the unstructured aspects of reality or

[1]Environmental Change Institute, University of Oxford, [2]Land Dynamics group, Wageningen University, [3]Alterra, Wageningen University and Research Centre, [4]Institute for Interdisciplinary Studies (IIS), University of Amsterdam, [5]Communication sciences group, Wageningen University, [6]Faculty of Geo-Information Science and Earth Observation, University of Twente, [7]Laboratory of Geo-Information Science and Remote Sensing, Wageningen University, [8]Laboratory of Geo-Information Science and Remote Sensing, Wageningen University

phenomena to which scales are applied, such as time, space, power, etc. Following Gibson et al. (2000), we use "scale" to refer to the reference systems used to structure dimensions, such as the Julian calendar, the metric system, and systems to organize geographical jurisdictions. Again following Gibson et al. (2000), we define the positions on a scale as "levels." Examples of levels are countries, watersheds, ecosystems and households. See Fig. 1 for a visual schema of these definitions.

Fig. 1. Dimensions, scales, and levels as outlined in this paper.
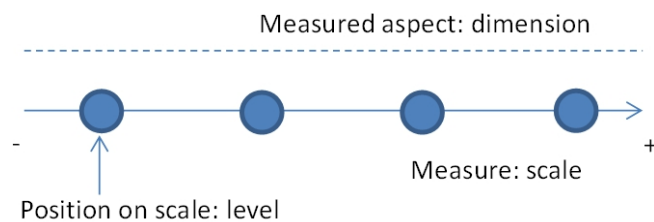
We distinguish the concept of "dimension," rather than starting with scales as the basic structure of analysis, because it allows for recognition of the multiplicity of possible scales. Scales, and what we call dimensions, are often confused and often overlap. Starting with scales as the basic concept of analysis, as has so far been done, can obscure the reality that multiple scales (e.g., metric system, customary system) can be applied to structure the same dimension (space). We argue that different scales applied to the same dimension have different consequences for analysis that might restrict or enable scientific or practical insights, and be of more benefit to some societal actors than to others. It should be noted that many studies that refer to work analyzing multiple "scales" actually explore dynamics among different levels, according to the definition used by Gibsons et al. (2000) and by us (Levin 1999, Holling et al. 2002, Hooghe and Marks 2003).

We use the term "multi-dimensional" to describe objects or phenomena framed by multiple dimensions (e.g., space, power, networks). "Cross-dimensional" dynamics refer to changes in one dimension interacting with changes in another dimension (e.g., changes in power leading to a restructuring of space). The introduction of dimensions has its consequences for our understanding of scale interactions. We can continue to use Cash et al.'s definition of "multi-scale" as referring to objects or phenomena framed by multiple scales. Similarly, we can adopt the definition of "cross-scale" interactions as occurring among different scales. However, in the definition used by Cash et al. (2006), multi-scale and cross-scale often implicitly mean multi-dimensional and cross-dimensional. In our framework, this is not the case. Scale interactions could reflect interactions between dimensions, but they could also result from multiple scales used by different actors to structure

the same dimension. An example is a state using a different jurisdictional scale to structure geographical space from non-state actors, resulting in conflict.

The introduction of dimensions does not change the use of interactions among levels, as described by Cash et al. (2006). The demarcation "multi-level" indicates objects or aspects of phenomena defined by multiple levels on a single scale, whereas "cross-level" interactions identify those interactions happening among levels on a scale.

Scale and scale dynamics: theoretical and practical challenges
Perspectives on scale differ widely among disciplines. Insights about scale dynamics originated mainly with the study of biophysical systems (Buckley 1967, Klir 1969, Holling 1986, Levin 1992, Holland 1998, Kok et al. 2001). Consequently, the main focus on scale in research has been on spatial and temporal scales (Meyer et al. 1992, Levin 1999, Kok et al. 2006). Conversely, in the social sciences, social systems are viewed as operating on a range of social scales (Giddens 1990, Westley et al. 2002). Another perspective is offered by human geographers who explore links between social and spatial scales, and see them as continuously changing based on power relations (Sayre 2005, Dahl 1989, Ostrom 1991, 1997).

Kok and Veldkamp (2011*b*) provided a range of studies that represent the state of the art in the integration of disciplinary perspectives on scale. These contributions range from the conceptual bridging of specific disciplinary gaps (Termeer et al. 2010, Buizer et al. 2011, Turnhout and Boonman-Berson 2011, Veldkamp et al. 2011) to the application of multi-scale analyses to practical case studies to show interactions between biophysical and social scales (De Blaeij et al. 2011, Van Apeldoorn et al. 2011, Van der Veen and Tagel 2011). Three challenges for current interdisciplinary research on scale in social–ecological systems can be derived from these papers and other sources. These are as follows: (1) Underlying assumptions about the structure and reality of scales should be made explicit in any attempt to bridge disciplines through different scale concepts (Manson 2008, Buizer et al. 2011). (2) Biophysical dimensions and scales still dominate scale-related research—more attention should be given to scales associated with research in other fields such as sociology, political science, economics, and human geography (Cash et al. 2006, Kok and Veldkamp 2011*a*). (3) The perspectives of non-scientist actors should be included in interdisciplinary scale debates to involve practice-based perspectives in theory development (Kok and Veldkamp 2011*a*).

Successfully tackling such theoretical challenges relates to the ability of scale research to take on practical scale-related challenges for social–ecological systems governance (Cash et al. 2006). This will help to address three factors: (1) ignorance: the complexity inherent in social–ecological systems means that there is often a lack of knowledge of key processes at and

across multiple system levels, let alone in and across different dimensions characterized by various scales; (2) mismatches: in social–ecological systems, the system dimensions that drive decisions, the scales that frame these decisions and the levels at which they are taken often affect other system dimensions in unintended and destructive ways; and (3) plurality of scale perspectives: many societal stakeholders focus on different system dimensions, use different scales to characterize these dimensions, and place the highest value on different levels on these scales.

Practice-based perspectives: change agents

In including practice-based perspectives in scale theory development, we believe it is particularly valuable to focus on the perspectives of "change agents" (Westley et al. 2006). Change agents are defined here as "actors who exert their individual agency to innovate and create sustainable, accepted change in the systems in which they operate" (Rossi et al. 2000, Moore 2011). Change agents often have to work to overcome gaps and mismatches among societal perspectives that operate across disciplines and dimensions (Westley and Mintzberg 1989, Rossi et al. 2000, Westley et al. 2006). This means that they have had to familiarize themselves with a range of ways in which the world is structured by different societal actors (Westley 2002, Moore 2011).This leads us to propose that change agents can express multi-dimensional perspectives on social–ecological systems change when guided to structure these dimensions using a diversity of scales. If this proposition is valid, change agents have particularly rich insights to offer both to scale-oriented researchers and society at large concerning interactions among dimensions, scales, and levels in social–ecological systems.

Our primary objective here is to explore how practice-based perspectives on scale, elicited through the extended scale vocabulary of dimensions, scales, and levels, can contribute to the development of interdisciplinary theory on scale dynamics. We specify this objective through three sub-objectives: (1) to identify dimensions and scales described by change agents in social–ecological systems; (2) to visualize how the dimensions and scales identified by these change agents allow them to describe how they work across dimensions and associated scales and levels; and (3) to connect these practice-based perspectives to interdisciplinary theory development on scale.

METHODS

Case study: change agents in TransForum

TransForum was a Dutch innovation institute, set up as a project over six years and ending in early 2011. Its goal was to trigger transitions toward sustainable agricultural development (Veldkamp et al. 2009). For this, 33 practical and 42 science projects were executed, incorporating different perspectives on what sustainable agro-ecological development entails (Beers et al. 2010). This wide range was chosen deliberately and in the spirit of social–ecological systems thinking and transitions theory, on the premise that the way forward is never clear, and multiple solutions might be possible (Schwartz 1991, Yorque et al. 2002, Rotmans 2005). The practical projects, involving change agents across sectors, represented a number of practical system innovations that serve as successful pilots for higher-level application (TransForum 2010), and their interaction with the science projects led to insights about knowledge co-production to tackle challenges of innovation in social–ecological systems (Van Latesteijn and Andeweg 2010). The research presented here was part of a science project on perspectives of systems change within TransForum.

Selecting change agents

We focused our research on change agents who drove "acceptable, sustainable systems change" (Moore 2011) in TransForum's practical projects. We restricted our selection of participants in the research to those involved in the 11 TransForum projects categorized as "regional development projects" to ensure that interaction between environmental and social systems was part of all projects.

Because agents of change operate in social and organizational contexts, insider perspectives are crucial for the identification of such individuals. Within Transforum, three officers were hired to stimulate cross-disciplinary and cross-sectoral interactions within TransForum and its projects. A part of these officers' mandates was to identify change agents in the TransForum projects and facilitate their activities. We consulted with these TransForum officers, asking them to identify individuals who fit our definition of change agents in the 11 TransForum regional development projects. Twenty-two individuals were identified, of which 16 individuals from 10 projects were able to participate in this research in the available time. Of these, seven were commercial project and process developers, four were practice-oriented researchers, three were public servants, and two were members of the TransForum organization. Some of these participants were formal leaders of the projects, whereas others performed different functions; "leadership" positions were not highly significant because the projects took the shape of partnerships with many stakeholders contributing comparable efforts. The projects that the participants in our research were involved in included several developing "green ports" in the Netherlands and one in Shanghai, the development of regional autonomy in sustainable agriculture, sustainable rural health care projects, the fostering of relationships between cities and the countryside, and a saline agriculture project.

### Interview method: scale repertoire

To facilitate participants' identification of dimensions and scales associated with their perspectives, we developed an interview method focused on a project storyline/future

visioning approach inspired by the repertory grid technique (Kelly 1955, Ryle 1975, van de Kerkhof et al. 2009). This interviewing technique originated in construct psychology and has recently become more popular in other contexts such as market research, intelligence, human learning, and policy analysis. This technique asks participants to frame "elements," such as people, products, and policies, on the personal "constructs" that make up their value system, such as wealth, reliability, intelligence, etc. These constructs are elicited by discussing the similarities and differences between elements and, based on that, developing the constructs as bipolar, or continual, scales (van de Kerkhof et al. 2009). Our approach, which we named the "scale repertoire," combined an adaptation of the repertory grid with a scenario storyline building in the mode of "middle-casting:" starting with a normative vision of the future, and then working toward that future from the past, with the present as a center point in the timeline. We used this temporal structure because it allowed participants to outline past change, as well as giving them the freedom to envision future developments and dynamics that exist only in their perspectives. In our approach, the "elements" were different drivers affecting events in the past and future storyline. The "constructs" represented the unstructured dimensions—and the way these dimensions were structured provided a basic characterization of associated scales. We used no predefined categories, instead allowing participants to develop the dimensions and scales that constructed their perspective in the storyline. The interviews took two hours on average.

Our scale repertoire interviews were structured as follows (see Fig. 2). (1) Narrative about past, present, future: the participant develops a normative, desirable future vision for the subject matter, for example, a project, development, or region, on a personally defined time scale. The participant explores which major changes or events have happened with regard to the subject in the past that brought it to its present state, and develops a narrative from the past through the present to the future vision. (2) Drivers: the participant determines which drivers cause changes or events to come about in the narrative. (3) Dimensions: the participant reviews the drivers associated with the past–present–future narrative as a set, and is asked to describe a dimension that can best be used to describe changes in one or more of these drivers. In the example provided in Fig. 2, a participant identifies two among a series of dimensions that, according to him or her, are most suitable as characterizing various key changes in a project. In this case, the spatial dimension describes an aspect of the changes driving the project. However, the "innovation" dimension is used to describe aspects of the project's dynamics that cannot be described by spatial changes. This process, where the participant identifies the dimensions used to describe changes, continues in a free-form fashion without demands or restrictions on numbers enforced by the interviewer. The

interview stops when the participant decides the key insights in his or her account of past and desired future changes in the project or region are adequately described between the identified dimensions. (5) Scales: the participant then structures each dimension into a simple draft scale that he or she thinks helps to describe changes in the narrative more concretely. Fig. 2 shows how the spatial and innovation dimensions can be framed by logarithmic square meters and the "number of innovation paths" as scales. (6) Dynamics: the participant draws the dynamics of the past to future storyline in terms of each of the dimensions, in a field of scales where the horizontal axis represents the time line, and the vertical axis represents a scale for any dimension that is currently in focus. The lines in the graph represent project or regional dynamics expressed along each scale (again, see Fig. 2).

Fig. 2. A simplified representation of the different steps in the scale repertoire.
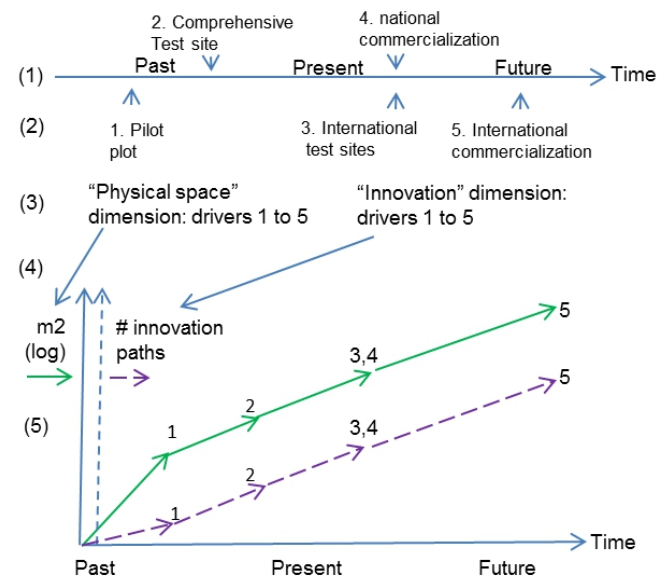
Notes:
(1) The participant describes a narrative of the history, current situation and desired future for a project or region.
(2) The participant identifies key drivers of change along the narrative timeline.
(3) The participant describes dimensions that together capture key insights and lessons in the narrative.
(4) The participant outlines scales that structure these dimensions.
(5) The participant describes the narrative along different dimensions framed by scales, thereby describing cross-dimensional dynamics.

Table 1. Relationships between the most prevalent dimensions (horizontal) and scales (vertical).

Dimensions	Scales										
	Network	Knowledge	Policy	Management	Spatial	Temporal	Vision	Innovation	Sector	Status	Role
Network	17			1	1						
Knowledge	3	14		2					3		
Policy	1		15		2	1			1		
Management	1			12					1		
Spatial					2						
Temporal				2							
Vision	5				2	1	3		1		1
Innovation			2		2			4	1		
Sector					1		1		11		
Status	1	1	1		1				1	2	
Role	1										7

Notes: The numbers refer to the number of instances in which scales from a vertical category were used by participants to frame a horizontal dimension. Many scales from the different categories are used to frame the dimension that category refers to (e.g., network scales to frame the network dimension). In other instances, scales in a category associated with one dimension are used to frame other dimensions (e.g., network scales to frame the vision dimension).

Data processing

Analysis of the spectrum of dimensions and scales

To avoid bias, three researchers each clustered the total collection of generated dimensions on similarity, and subsequently discussed categories to come to an agreement on the main dimensions. Scales were also analyzed and merged when they were essentially similar.

Exploring scales and cross-scale dynamics

An inventory was made of the scales used to structure the dimensions. By cross-referencing dimensions and scales, we evaluated how scales were applied to different dimensions. To depict the scales, we followed the visual format used by Cash et al. (2006). Cross-scale dynamics were identified with the participants and reformatted so that, rather than showing multiple dynamics against different scales on the y-axis and time on the x-axis, two scales were set against each other to show a single cross-dimensional dynamic. This translation from the initial visualization created by participants required some simplification and clarification to make the graphs more accessible. This was done by the researchers and then checked for feedback with the participants. For reference, see how a simplified version of a stakeholder-generated graph (Fig. 2) was translated to Fig 3.

RESULTS

Dimensions and scales

The interviews resulted in 156 individual dimensions and 156 scales to frame these dimensions, or an average of 9.6 dimensions/scales per participant (standard deviation = 1.8). Three researchers analyzing the dimensions for similarity came up with a set of 27 dimensions. Studies using the repertory grid technique claim that on average 16–20 participants are sufficient to capture the full spectrum of constructs—in this case, dimensions (Dunn 2001). No new

dimensions were added after 13 participants were interviewed. This gave some credibility to the conclusion that, even though the case study covered a diversity of projects, the dimensions elicited from participants were a good representation of the dimensions that framed perspectives in the case study. In contrast, because scales are dependent on the specific details of how they are structured, these could only be reduced to a set of 61 scales based on similarities. Saturation in terms of scales was observed as participants were added, but several essentially new scales were still added to the collection by the final participants.

Fig. 3. The number of innovation paths that could be taken, set against logarithmic physical space.
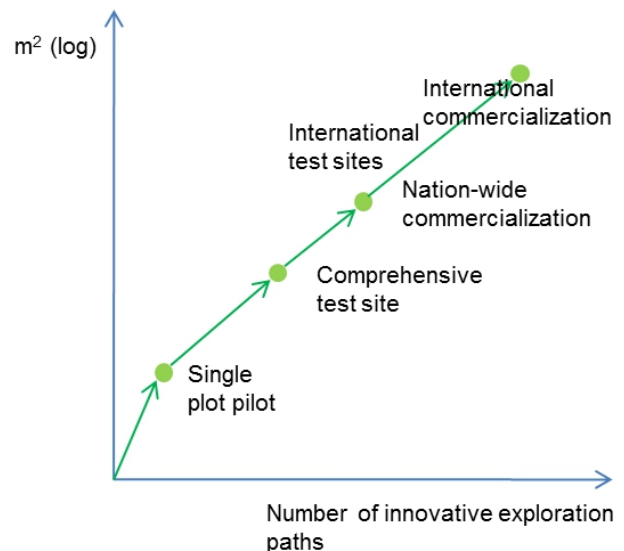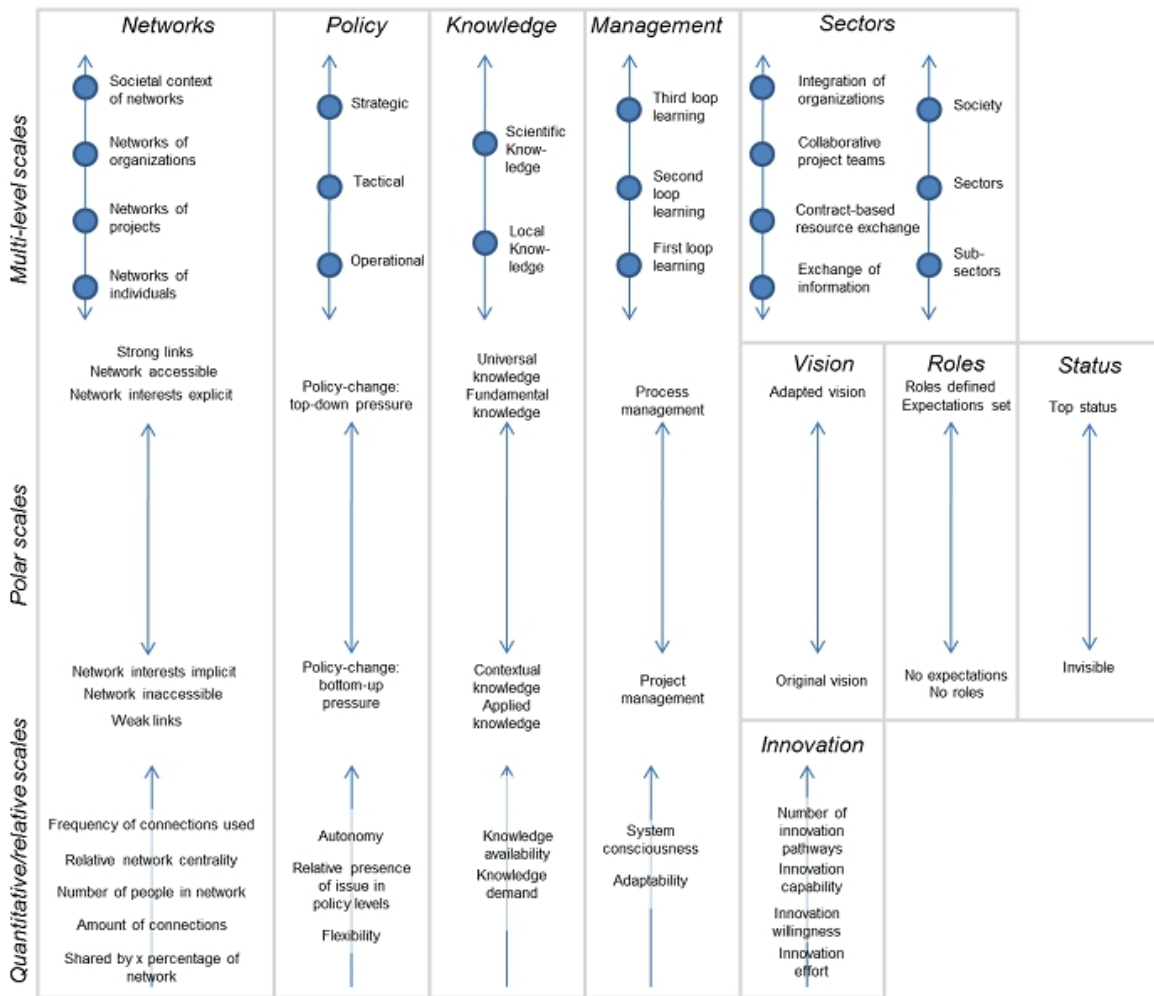
Fig. 4. Scales produced by participants using the scale repertoire.

Notes: The blue dots in the top-most category represent levels on those scales. The continuous, polarized scales are presented with different alternate polarizations. The different terms in the quantitative/relative category represent a number of different scales per dimension.

Table 1 shows a selected cross-referencing of dimensions and scales used by participants in the interviews. This table shows only those dimensions that have their own associated scales. The network dimension has the most occurrences of specifically associated scales. Network, policy, management, and sector interaction scales are the most used to structure other dimensions. Some dimensions had scales that were only associated with that dimension, whereas other dimensions were only characterized by scales that were not explicitly linked to the dimension they framed. Most dimensions were structured both by associated scales and by scales that were not associated.

Figure 4 shows a summary of scales used by participants. Each section of the figure shows the scales associated with a dimension. Three general categories can be distinguished: scales defined by separate levels, continuous scales with polar opposites, and quantitative or relative continuous scales.

Network scales were mentioned most frequently and, accordingly, the results show a large diversity among these scales. The network hierarchy, with a different composition from the example in Cash et al. (2006), was used most often. Another scale of note is the explicitness with which actors in the network express their individual agendas and interests. This describes a quality of network interactions that could

enable or restrict network development, as described by a participant. Network accessibility captures another quality of networks. The participant-generated scales associated directly with the policy dimension describe different types of policy, whether operational, tactical, or strategic, and also emphasize the description of cross-level dynamics such as top-down and bottom-up pressure, the presence of issues across policy levels, as well as issues of autonomy and flexibility. Five scales were used by participants to structure the knowledge dimension. The fact that knowledge features prominently among participants' dimensions and scales can be linked to the innovative nature of these projects, where new knowledge was implemented and developed through learning processes. Participants used five organizational management scales. Change agents dealing with organizational management in the TransForum case have had to work within highly dynamic policy, knowledge, and network environments and, therefore, learning, process management, and cross-level management feature often in the accounts of participants. Participants framed many developments in their regions and projects in terms of sectors: which were the sectors and sub-sectors that were involved, whether impacts across sectors were different, and how relationships among sectors were organized. This dimension and its associated scales was seen as essential for those seeking to create change toward sustainability across the societal spectrum. Vision was seen both a future-oriented structuring of meaning for those in the present to act on, and in this interpretation, it was framed by its own scales, but it was also seen as a trait of individuals and organizations, in which case other scales were used to define it. Four scales were used by participants to structure innovation, with the innovative properties of projects and interventions both changing and being changed by societal dynamics. Specific innovation pathways were part of this dimension, but also several scales that together express innovation potential. Table 1 shows that the status dimension was framed by multiple scales including networks, policies, (e.g., different levels of official status of organizations assigned in policy programs), jurisdictions, and sectors. In each of these framings, status received a different interpretation. The scale developed specifically for status has associations with image, visibility, and marketing. Two polar scales were defined by participants to structure the relationships of roles assigned to individuals, projects, and organizations. Problems of role definition are especially likely in environments where complexity and uncertainty are high, compounded by the large number of different perspectives and types of experiences involved (Beers et al. 2010), and both of these were abundantly the case in our participants' projects.

Cross-dimensional dynamics
The scales that the participants in the TransForum case used to frame their perspectives on past and future allowed them to draw out cross-dimensional system dynamics in specific ways.

The following depictions of cross-dimensional dynamics are examples transcribed from the participants' visual depictions as outlined previously. Figures 3 and 5 show examples of cross-dimensional dynamics described by spatial and social scales while Fig. 6 and Fig. 7 show cross-dimensional dynamics described by social scales.

Fig. 5. Sector integration set against jurisdictional space.
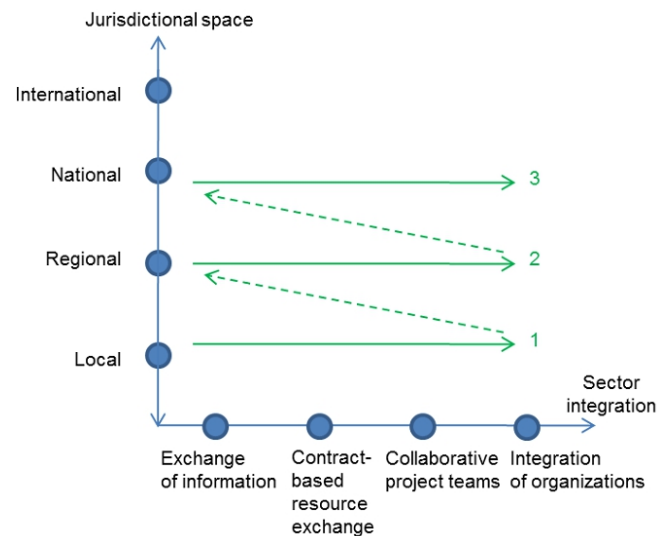

Notes: The numbers mark the order of events. (1) represents the past integration at a local level; (2) represents current efforts to achieve the same degree of integration at the regional level; and (3) represents future ambitions of taking this integration of sectors through to the national level.

Cross-dimensional dynamics described by spatial and social scales
Figure 5 shows a participant's activities to increase integration among sectors, building this integration up across jurisdictional levels. This individual has acted as a change agent by brokering between sectors related to the regional clustering of agricultural and horticultural activities and their interactions with environmental and social functions as well as logistics, knowledge development, and innovation. This image represents both the past experience this participant has had with the developing of local integration between the public and private sectors and their sub-sectors (stage 1), his current efforts to build on past successes to create a similar degree of integration between sectors at the regional level (stage 2), and his future ambitions to move from regional integration of sectors to the national level (stage 3). This elicitation of cross-dimensional dynamics in the perspective of this change agent is indicative of his orientation toward both geographical and

social dimensions and their interplay. He recognized qualitative differences between the requirements for the integration of sectors at different jurisdictional levels, as well as the differences between degrees of integration. This included his involving of different types of actors that possessed the skills specific to the requirements of those geographical and social scales.

Fig. 6. Knowledge availability and the spreading of a vision set against different network levels.
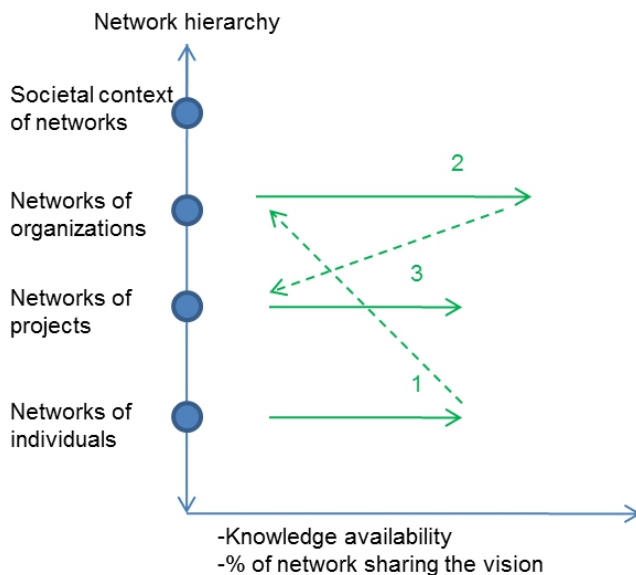

Notes: The gathering of knowledge to construct a vision (1) started at the level of individuals and their networks in this example; (2) was subsequently picked up by the organization and developed further; and (3) then dispersed among its projects.

Figure 3 shows a link between available physical space and the number of innovation paths or opportunities that could be taken, in this case for saline agriculture. A pilot plot allows for experimentation with different crops. As available space grows—e.g., test sites or commercial implementation—qualitatively different innovations can be developed, such as infrastructure and treatment innovations and marketing strategies, and the relationship between space and innovation becomes more complex.

Cross-dimensional dynamics described by social scales
Despite the geographically rooted character of the TransForum regional development projects, the majority of cross-dimensional dynamics identified by the participants in their perspectives were dynamics between social scales. We provide two examples.

Fig. 7. A continuous polar scale for role definition set against a network hierarchy with two examples.
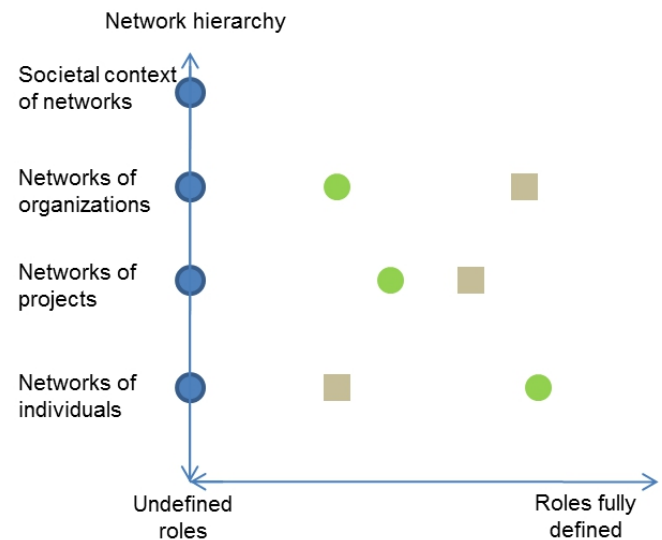
Notes: The circles represent an instance where at the level of individual networks roles are fully defined, whereas at the level of networks of projects the roles of projects are less defined and the roles of organizations are defined even less. The squares represent the opposite situation.

Figure 6 uses the knowledge availability and "percentage in network" scales set against a network hierarchy to show the spread of knowledge and vision through this hierarchy. In the scale-structured account of this participant, several like-minded and similarly positioned individuals acquired knowledge and developed a vision through their networks (stage 1). They disseminated this knowledge and the vision that was built on it into their organization, which acquired further knowledge and developed the vision at an organizational level using the resources in its network (stage 2). Both were then passed on in a top-down fashion to the networks of various projects that this organization was taking part in (stage 3). The relationship between knowledge acquisition and vision development is made with different levels in the network hierarchy. It shows how an individual acquires knowledge and develops a vision, and how these work through networks on different levels, in this case, a mix of bottom-up and top-down development and dissemination. The participant demonstrated a sense of the different dimensions associated with knowledge and vision development in the context of individual networks, practical projects and their organization, and an understanding of the qualitative differences between the levels in the network. This example

is particularly relevant considering the prevalence of the "network hierarchy" scale among the participants' perspectives in our case.

Figure 7 uses a polar scale for role definition, set against the network hierarchy to show two examples from interviews of how role definitions of individuals, projects, and organizations can differ. In one example, roles of organizations and projects in networks were clearly defined, and it is only on the individual level that we found people in the network that had less defined roles and thus more flexibility to induce change. In the other example, key individuals had clearly defined roles, but projects and organizations did not.

DISCUSSION AND CONCLUSIONS

Introducing dimensions to the scale vocabulary
Here, we have extended the scale vocabulary by introducing "dimension" to describe the unstructured aspects of phenomena or reality to which various scales are applied. We proposed that this distinction would be useful to highlight the fact that multiple scales can be applied to structure the same dimension. This has consequences both for insights into systems as well as for societal stakes associated with the structuring of knowledge and analysis. In the framework, cross-scale dynamics are not the same as cross-dimensional dynamics. Often, interactions between different scales also reflect interactions between different dimensions, but cross-scale dynamics could also refer to interactions between different scales framing the same dimension but used by different societal actors.

The use of the dimensions, scales, and levels framework has proven useful in the case study we explored. The identification of dimensions preceded the structuring of scales when using the scale repertoire with participants. This allowed participants to acknowledge certain dimensions as important, even if they were not always able to come up with a useful scale to structure them. The usefulness of the distinction between dimensions and scales was also clear in the analysis of our results, showing that, whereas in many instances, dimensions were structured according to specifically associated scales, for example, network nodes for the network dimension, or decision levels for policy, there were also many instances where dimensions were structured by scales that were not primarily associated with these dimensions.

Method: the scale repertoire
Our use of the scale repertoire in combination with the dimensions, scales, and levels framework turned out to be advantageous in many respects. The participant is not prematurely constricted by consecutive framing steps while building the narrative. Instead, dimensions, scales and associated levels are allowed to arise from the narrative. What can be seen as a weak point of this method is that the identification of dimensions is less structured than in the repertory grid technique. Also, there are no requirements for participants to structure their scales in a very detailed fashion. An argument against this criticism is that, in this way, the participants are not forced to create constructs that are artificial and not actually characteristic of their perspectives. Still, this potential tension between flexibility and structure is a point for further research on methods for the eliciting of scales that make up societal perspectives. Finally, it should be stressed that the scale repertoire focuses explicitly on subjective views of cross-scale interactions, and does not provide a way to test these perspectives.

Practice-based perspectives on dimensions and scales
We have shown that using the dimensions, scales, and levels framework and an appropriate method such as the scale repertoire, change agents can describe their perspectives using a spectrum of biophysical and social dimensions and a range of scales to describe the same dimensions. This underlines the need to consciously consider the multiplicity and multi-dimensionality of perspectives that exists among societal actors, especially actors such as our participants who are working toward sustainable and accepted systems change. Studies such as van Lieshout et al. (2011) have explored the framing of levels and scales by different actors through secondary analysis. Our findings advocate the value of having these actors structure dimensions and scales themselves.

The prominence of social dimensions and scales in our results runs counter to the dominance of biophysical and geographical dimensions and scales in the literature (Kok and Veldkamp 2011*a*). Part of this focus on social dimensions and scales could be explained by the heavily regulated and institutionalized Dutch context of the case study. However, it can also be an indication that the social dimensions—including political, economic, knowledge, and other dimensions—and not the biophysical dimensions, are seen as limiting, challenging, or providing most leverage from the perspective of change agents. It would be valuable to repeat this exercise in cases that are even more explicitly focused on physical environments and biophysical processes to see if social dimensions still dominate the accounts of the change agents.

Cross-dimensional dynamics framed by multiple scales
The range of dimensions and scales identified by the change agents interviewed in our case study has allowed them to use scales to describe specific cross-dimensional dynamics. These cross-dimensional dynamics represent the success stories and lessons the interviewees saw as crucial, as well as the visions and directions to where they saw themselves taking their work in the future. The essence of these cross-dimensional narratives would have been lost when framed only by spatial and temporal scales. For example, Fig. 4 shows the conscious attempt of the change agent to move further along the scale of integration at the lowest spatial level before aiming at a higher level, while being cognizant of the qualitatively different

Table 2. Key references of knowledge domains linked to dimensions and scales from case studies.

Dimension	Scales	Key references
Network	Affiliation hierarchy	Breiger 1974, Wasserman and Faust 1994
	Implicit vs. explicit	Crown and Rosse 1995
Knowledge	Local/scientific knowledge	Berkes and Folke 2002, Gagnon and Berteaux 2009
	Knowledge mismatches	van Eeten 1999, Hermans et al. 2010
Policy	Flexibility	Choe and Fraser 2001, Aldy et al. 2003
	Policy decision levels	Jantsch 1970
Management	Organizational learning	Argyris and Schön 1978, Flood and Romm 1996
	System consciousness	Westley 2002, Westley et al. 2006
	Process vs. project management	Meier and O'Toole Jr 2001, Edelenbos and Klijn 2009
Sectors	Inter-sector cooperation	Faulkner and Senker 1994, Casimir and Dutilh 2003, Peterson 2009, van Mierlo et al. 2009
Vision	Vision development and adaptation	Westley and Mintzberg 1989, Berson et al. 2001, van der Helm 2009, O'Connell et al. 2011
Innovation	Innovation pathways	Feder and Umali 1993, Kash and Rycroft 2002, Rycroft and Kash 2002
	Capacity, effort, willingness	McGrath 2001, McDermott and O'Connor 2002
Status	Organizational status	Podolny and Stuart 1995, Podolny and Phillips 1996, Gray and Balmer 1998
Roles	Role definitions and expectations	Sverrisson 2001

challenges that are to be found both at each level of integration and at each spatial level. The sector integration scale is instrumental to capturing this narrative.

Implications for theory development

Gibson et al. (2000) and especially Cash et al. (2006) have often been referenced to as the standard overviews of scales stemming from different disciplines. Comparing the dimensions, scales and cross-dimensional dynamics that resulted from our case study to the seminal work in these papers, we offer four key observations: (1) These studies do not give an overview of possible scales but, rather, in our view, have presented a range of different dimensions, using examples of one or multiple scales for each dimension and demonstrating the diversity of dimensions, particularly social dimensions, as guides for further research. (2) These studies and the more recent work in Kok and Veldkamp (2011*b*) advocate the need for further explorations of the spectrum of scales, and especially social scales. On the basis of our results, we would like to expand this point of view by proposing that researchers should explore a broader spectrum of a) dimensions, b) the scales associated with them, and c) differences between scales used to frame dimensions familiar to scale research. (3) This exploration entails connecting to a broader spectrum of disciplines by current scale-oriented researchers, but also an involvement in the scale debate of experts in those fields. Table 2 provides some key references from research domains that connect to the dimensions and scales found in our case studies. (5) Our results suggest that our framework and method for cross-dimensional analysis has helped change agents explicate key dynamics within the systems in which they operate. Therefore, the study of cross-scale dynamics should receive a more central focus than is currently the case. Cash et al. (2006) and Cumming et al. (2006) provide a strong theoretical basis for these explorations

that could be aided by our framework and method. The cross-dimensional dynamics described in our practical case studies show the potential value of a stronger focus not just on dynamics between environmental and social dimensions and scales but also between different social dimensions and scales.

Implications for practical scale challenges

We have mainly focused on the introduction of dimensions to the scale vocabulary to improve the link between development of interdisciplinary theory and concepts on scale and practice-based perspectives. However, the development of scale theory should ultimately aim to provide useful frameworks and analysis for the governance of social–ecological systems (Folke 2006). Exploring the practical use of the dimensions and scales elicited in our case study would be a next research step that we cannot fully address here. However, we see potential for our adapted scale framework and practice-oriented methods such as the scale repertoire beyond theory development, particularly related to the scale challenges for governance identified by Cash et al. (2006). We believe this framework can make significant contributions that address three key factors: (1) Ignorance: the dimensions, scales, and levels framework can help clarify what scales are used by societal actors, organizations, and institutions that affect social–ecological systems change and what dimensions these scales frame. Through methods like the scale repertoire, the extended framework can point to the possibility that other scales might be able to highlight aspects of issues that have so far not been visible. (2) Mismatches: the introduction of dimensions helps clarify that many scales can frame a dimension. This can propagate the understanding that scale mismatches are not unavoidable and that, opportunities and political realities permitting, different scales of organization and governance might be explored that are more conducive to sustainable cross-dimensional interactions with environments.

(3) Plurality of scale perspectives: the dimensions, scales, and levels framework is useful in identifying pluralities of scale perspectives and in helping to understand which underlying dimensions these scales frame. The scale repertoire can help elicit specific scale perspectives held by societal actors and make them accessible to others.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5098

LITERATURE CITED

Aldy, J. E., S. Barrett, and R. N. Stavins. 2003. Thirteen plus one: a comparison of global climate policy architectures. *Climate Policy* 3:373–397.

Argyris, C. and D. Schön. 1978. *Organizational learning: a theory of action perspective.* Addison-Wesley, Reading, Massachusetts, USA. http://dx.doi.org/10.2307/40183951

Beers, P. J., A. Veldkamp, F. Hermans, D. van Apeldoorn, J. M. Vervoort, and K. Kok. 2010. Future sustainability and images. *Futures* 42:723–732. http://dx.doi.org/10.1016/j.futures.2010.04.017

Berkes, F. and C. Folke. 2002. Back to the future: ecosystem dynamics and local knowledge. Pages 121–146 *in* L. H. Gunderson and C. S. Holling, editors. *Panarchy: understanding transformations in systems of humans and nature.* Island Press, Washington, D.C., USA.

Berson, Y., B. Shamir, B. J. Avolio, and M. Popper. 2001. The relationship between vision strength, leadership style, and context. *Leadership Quarterly* 12:53–73. http://dx.doi.org/10.1016/S1048-9843(01)00064-9

Breiger, R. L. 1974. The duality of persons and groups. *Social Forces* 53:181–190.

Buckley, W. F. 1967. *Sociology and modern systems theory.* Englewood Cliffs, New Jersey, USA.

Buizer, M., B. Arts, and K. Kok. 2011. Governance, scale and the environment: the importance of recognizing knowledge claims in transdisciplinary arenas. *Ecology and Society* 16(1): 21. [online] URL: http://www.ecologyandsociety.org/vol16/iss1/art21/

Cash, D. W., W. N. Adger, F. Berkes, P. Garden, L. Lebel, P. Olsson, L. Pritchard, and O. Young. 2006. Scale and cross-scale dynamics: governance and information in a multilevel world. *Ecology and Society* 11(2): 8. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art8/

Casimir, G., and C. Dutilh. 2003. Sustainability: a gender studies perspective. *International Journal of Consumer Studies* 27:316–325. http://dx.doi.org/10.1046/j.1470-6431.2003.00323.x

Choe, C., and I. Fraser. 2001. On the flexibility of optimal policies for green design. *Environmental and Resource Economics* 18:367–371. http://dx.doi.org/10.1023/A:1011170816440

Crown, D. F., and J. G. Rosse. 1995. Yours, mine, and ours: facilitating group productivity through the integration of individual and group goals. *Organizational Behavior and Human Decision Processes* 64:138–150. http://dx.doi.org/10.1006/obhd.1995.1096

Cumming, G. S., D. H. M. Cumming, and C. L. Redman. 2006. Scale mismatches in social–ecological systems: causes, consequences, and solutions. *Ecology and Society* 11(1): 14. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art14/

Dahl, R. 1989. *Democracy and its critics.* Yale University Press, New Haven, Connecticut, USA.

De Blaeij, A. T., N. Polman, and S. Reinhard. 2011. Economic governance to expand commercial wetlands: within- and cross-scale challenges. *Ecology and Society* 16(1): 33. [online] URL: http://www.ecologyandsociety.org/vol16/iss1/art33/

Dunn, W. N. 2001. Using the method of context validation to mitigate Type III errors in environmental policy analysis. Pages 417–436 *in* M. Hisschemöller, R. Hoppe, and J. Ravetz, editors. *Knowledge, power, and participation in environmental policy analysis.* Transaction, New Brunswick, New Jersey, USA.

Edelenbos, J., and E. H. Klijn. 2009. Project versus process management in public–private partnership: relation between management style and outcomes. *International Public Management Journal* 12:310–331. http://dx.doi.org/10.1080/10967490903094350

Faulkner, W., and J. Senker. 1994. Making sense of diversity: public–private sector research linkage in three technologies. *Research Policy* 23:673–695. http://dx.doi.org/10.1016/0048-7333(94)90017-5

Feder, G., and D. L. Umali. 1993. The adoption of agricultural innovations: a review. *Technological Forecasting and Social*

Change 43:215–239. http://dx.doi.org/10.1016/0040-1625 (93)90053-A

Flood, R. L., and N. R. A. Romm. 1996. *Diversity management: triple loop learning.* Wiley, New York, New York, USA.

Folke, C. 2006. Resilience: the emergence of a perspective for social–ecological systems analyses. *Global Environmental Change* 16:253–267. http://dx.doi.org/10.1016/j. gloenvcha.2006.04.002

Gagnon, C. A., and D. Berteaux. 2009. Integrating traditional ecological knowledge and ecological science: a question of scale. *Ecology and Society* 14(2): 19. [online] URL: http:// www.ecologyandsociety.org/vol14/iss2/art19/

Gibson, C. C., E. Ostrom, and T. K. Ahn. 2000. The concept of scale and the human dimensions of global change: a survey. *Ecological Economics* 32:217–239. http://dx.doi.org/10.1016/ S0921-8009(99)00092-0

Giddens, A. 1990. *The consequences of modernity.* Polity, Cambridge, UK.

Gray, E. R., and J. M. T. Balmer. 1998. Managing corporate image and corporate reputation. *Long Range Planning* 31:695–702. http://dx.doi.org/10.1016/S0024-6301(98)00074-0

Hermans, F., I. Horlings, P. J. Beers, and H. Mommaas. 2010. The contested redefinition of a sustainable countryside: revisiting Frouws' rurality discourses. *Sociologia Ruralis* 50:46–63. http://dx.doi.org/10.1111/j.1467-9523.2009.00501. x

Holland, J. 1998. *Emergence: from chaos to order.* Oxford University Press, Oxford, UK.

Holling, C. S. 1986. The resilience of terrestrial ecosystems: local surprise and global change. Pages 292–317 *in* W. C. Clark and R. E. Munn, editors. *Sustainable development of the bioshphere.* Cambridge University Press, Cambridge, UK.

Holling, C. S., L. H. Gunderson, and G. D. Peterson. 2002. Sustainability and panarchies. Pages 63–102 *in* L. H. Gunderson and C. S. Holling, editors. *Panarchy: understanding transformations in systems of humans and nature.* Island Press, Washington, D.C., USA.

Hooghe, L., and G. Marks. 2003. Unraveling the central state, but how? Types of multi-level governance. *American Political Science Review* 97:233–243.

Kash, D. E., and R. Rycroft. 2002. Emerging patterns of complex technological innovation. *Technological Forecasting and Social Change* 69:581–606. http://dx.doi.org/10.1016/ S0040-1625(01)00171-8

Kelly, G. A. 1955. *The psychology of personal constructs, volume 1: a theory of personality.* Norton, New York, New York, USA.

Klir, G. J. 1969. *An approach to general systems theory.* Van Nostrand Reinhold, New York, New York, USA.

Kok, K., A. Farrow, A. Veldkamp, and P. H. Verburg. 2001. A method and application of multi-scale validation in spatial land use models. *Agriculture, Ecosystems and Environment* 85:223–238. http://dx.doi.org/10.1016/S0167-8809(01)00186-4

Kok, K., M. Patel, D. S. Rothman, and G. Quaranta. 2006. Multi-scale narratives from an IA perspective: Part II. Participatory local scenario development. *Futures* 38:285–311. http://dx.doi.org/10.1016/j.futures.2005.07.006

Kok, K. and A. Veldkamp. 2011*a*. Scale and governance: conceptual considerations and practical implications. *Ecology and Society* 16(2): 23. [online] URL: http://www. ecologyandsociety.org/vol16/iss2/art23/

Kok, K. and A. Veldkamp. editors. 2011*b*. *Scale and Governance.* Ecology and Society Special Feature 57. [online] URL: http://www.ecologyandsociety.org/issues/view.php? sf=57

Levin, S. 1999. *Fragile dominion—complexity and the commons.* Perseus Publishing, Cambridge, Massachussetts, USA.

Levin, S. A. 1992. The problem of pattern and scale in ecology. *Ecology* 73:1943–1967. http://dx.doi.org/10.2307/1941447

Manson, S. M. 2008. Does scale exist? An epistemological scale continuum for complex human–environment systems. *Geoforum* 39:776–788. http://dx.doi.org/10.1016/j. geoforum.2006.09.010

McDermott, C. M., and G. C. O'Connor. 2002. Managing radical innovation: an overview of emergent strategy issues. *Journal of Product Innovation Management* 19:424–438. http://dx.doi.org/10.1016/S0737-6782(02)00174-1

McGrath, R. G. 2001. Exploratory learning, innovative capacity, and managerial oversight. *Academy of Management Journal* 44:118–131. http://dx.doi.org/10.2307/3069340

Meier, K. J., and L. J. O'Toole Jr. 2001. Managerial strategies and behavior in networks: a model with evidence from U.S. public education. *Journal of Public Administration Research and Theory* 11:271–293. http://dx.doi.org/10.1093/oxfordjournals. jpart.a003503

Meyer, W. B., D. Gregory, B. L. Turner II, and P. F. McDowell. 1992. The local–global continuum. Pages 255–279 *in* R. F. Abler, M. G. Marcus, and J. M. Olson, editors. *Geography's Inner Worlds.* Rutgers University Press, New Brunswick, New Jersey, USA.

Moore, M. L. 2011. Surmountable chasms: networks and social innovation for resilient systems. *Ecology and Society* 16(1): 5. [online] URL: http://www.ecologyandsociety.org/ vol16/iss1/art5/

O'Connell, D., K. Hickerson, and A. Pillutla. 2011. Organizational visioning: an integrative review. *Group and Organization Management* 36:103–125. http://dx.doi.org/10.1177/1059601110390999

Ostrom, V. 1991. *The meaning of American federalism: constituting a self-governing society.* ICS, San Francisco, California, USA.

Ostrom, V. 1997. *The meaning of democracy and the vulnerability of democracies: a response to Tocqueville's challenge.* University of Michigan Press, Ann Arbor, Michigan, USA.

Peterson, H. C. 2009. Transformational supply chains and the "wicked problem" of sustainability: aligning knowledge, innovation, entrepreneurship, and leadership. *Journal on Chain and Network Science* 9(2):71–82. http://dx.doi.org/10.3920/JCNS2009.x178

Podolny, J. M., and D. J. Phillips. 1996. The dynamics of organizational status. *Industrial and Corporate Change* 5 (2):453–471. http://dx.doi.org/10.1093/icc/5.2.453

Podolny, J. M., and T. E. Stuart. 1995. A role-based ecology of technological change. *American Journal of Sociology* 100 (5):1224–1260. http://dx.doi.org/10.1086/230637

Rossi, M. S., H. S. Brown, and L. W. Baas. 2000. Leaders in sustainable development: how agents of change define the agenda. *Business Strategy and the Environment* 9:273–286. http://dx.doi.org/10.1002/1099-0836(200009/10)9:5<273::AID-BSE254>3.0.CO;2-Q

Rotmans, J. 2005. *Societal innovation: between dream and reality lies complexity.* Erasmus University, Rotterdam, The Netherlands. http://dx.doi.org/10.2139/ssrn.878564

Rycroft, R. W., and D. E. Kash. 2002. Path dependence in the innovation of complex technologies. *Technology Analysis and Strategic Management* 14(1):21–35. http://dx.doi.org/10.1080/09537320220125865

Ryle, A. 1975. *Frames and cages: the repertory grid approach to human understanding.* Chatto and Windus for Sussex University Press, London, UK.

Sayre, N. F. 2005. Ecological and geographical scale: parallels and potential for integration. *Progress in Human Geography* 29:276–290. http://dx.doi.org/10.1191/0309132505ph546oa

Schwartz, P. P. 1991. *The art of the long view: planning for the future in an uncertain world..* Currency Doubleday, New York, New York, USA.

Silver, J. J. 2008. Weighing in on scale: synthesizing disciplinary approaches to scale in the context of building interdisciplinary resource management. *Society and Natural Resources* 21:921–929. http://dx.doi.org/10.1080/08941920-701617809

Sverrisson, A. 2001. Translation networks, knowledge brokers and novelty construction: pragmatic environmentalism in Sweden. *Acta Sociologica* 44:312–327.

Termeer, C. J. A. M., A. Dewulf, and M. van Lieshout. 2010. Disentangling scale approaches in governance research: comparing monocentric, multilevel, and adaptive governance. *Ecology and Society* 15(4): 29. [online] URL: http://www.ecologyandsociety.org/vol15/iss4/art29/

TransForum. 2010. *Duurzaam agrarisch ondernemen: Het stedelijk gebied als motor voor nieuwe bedrijvigheid; de zes gedaanten van de succesvolle agrarische ondernemer toegelicht aan de hand van negen projecten.* TransForum Agro & Groen, Zoetermeer, The Netherlands.

Turnhout, E., and S. Boonman-Berson. 2011. Databases, scaling practices, and the globalization of biodiversity. *Ecology and Society* 16(1): 35.
[online] URL: http://www.ecologyandsociety.org/vol16/iss1/art35/

Van Apeldoorn, D. F., K. Kok, M. P. W. Sonneveld, and T. (A.) Veldkamp. 2011. Panarchy rules: rethinking resilience of agroecosystems, evidence from Dutch dairy-farming. *Ecology and Society* 16(1): 39. [online] URL: http://www.ecologyandsociety.org/vol16/iss1/art39/

van de Kerkhof, M., E. Cuppen, and M. Hisschemüller. 2009. The repertory grid to unfold conflicting positions: the case of a stakeholder dialogue on prospects for hydrogen. *Technological Forecasting and Social Change* 76:422–432. http://dx.doi.org/10.1016/j.techfore.2008.07.004

van der Helm, R. 2009. The vision phenomenon: towards a theoretical underpinning of visions of the future and the process of envisioning. *Futures* 41:96–104. http://dx.doi.org/10.1016/j.futures.2008.07.036

Van der Veen, A., and G. Tagel. 2011. Effect of policy interventions on food security in Tigray, Northern Ethiopia. *Ecology and Society* 16(1): 18. [online] URL: http://www.ecologyandsociety.org/vol16/iss1/art18/

van Eeten, M. 1999. *Dialogues of the deaf. Defining new agendas for environmental deadlocks.* Eburon, Delft, The Netherlands.

Van Latesteijn, H., and K. Andeweg, editors. 2010. *The TransForum model: transforming agro innovation toward sustainable development.* Springer, Dordrecht, The Netherlands. http://dx.doi.org/10.1007/978-90-481-9781-1

van Lieshout, M., A. Dewulf, N. Aarts, and T. C. 2011. Do scale frames matter? Scale frame mismatches in the decision making process about a "mega farm" in a small Dutch village. *Ecology and Society* 16(1): 38. [online] URL: http://www.ecologyandsociety.org/vol16/iss1/art38/

van Mierlo, B., C. Leeuwis, R. Smits, and R. K. Woolthuis. 2009. Learning towards system innovation: evaluating a systemic instrument. *Technological Forecasting and Social Change* 77:318–334.

Veldkamp, A., N. Polman, S. Reinhard, and M. Slingerland. 2011. From scaling to governance of the land system: bridging ecological and economic perspectives. *Ecology and Society* 16(1): 1. [online] URL: http://www.ecologyandsociety.org/vol16/iss1/art1/

Veldkamp, A., A. C. Van Altvorst, R. Eweg, E. Jacobsen, A. Van Kleef, H. Van Latesteijn, S. Mager, H. Mommaas, P. J. A. M. Smeets, L. Spaans, and J. C. M. Van Trijp. 2009. Triggering transitions towards sustainable development of the Dutch agricultural sector: TransForum's approach. *Agronomy for Sustainable Development* 29:87–96.

Wasserman, S., and K. Faust. 1994. *Social network analysis.* Cambridge University Press, Cambridge, UK. http://dx.doi.org/10.1017/CBO9780511815478

Westley, F. 2002. The devil in the dynamics: adaptive management on the front lines. Pages 333–360 *in* L. H. Gunderson and C. S. Holling, editors. *Panarchy: understanding transformations in systems of humans and nature.* Island Press, Washington D.C., USA.

Westley, F., S. R. Carpenter, W. Brock, C. S. Holling, and L. H. Gunderson. 2002. Why systems of people and nature are not just social and ecological systems. Pages 103–119 *in* L. H. Gunderson and C. S. Holling, editors. *Panarchy: understanding transformations in systems of humans and nature.* Island Press, Washington, D.C., USA.

Westley, F., and H. Mintzberg. 1989. Visionary leadership and strategic management. *Strategic Management Journal* 10:17–32. http://dx.doi.org/10.1002/smj.4250100704

Westley, F., B. Zimmerman, and M. Q. Patton. 2006. *Getting to maybe: how the world is changed.* Random House, Canada.

Yorque, R., B. Walker, C. S. Holling, L. Gunderson, C. Folke, S. Carpenter, and W. Brock. 2002. Toward an integrative synthesis. Pages 419–438 *in* L. Gunderson and C. S. Holling, editors. *Panarchy: understanding transformations in systems of humans and nature.* Island Press, Washington, D.C., USA.