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DRAFT

HOW SCALE MATTERS: SOME CONCEPTS AND FINDINGS

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This paper summarizes very briefly a number of concepts related to how scale matters in conducting large, integrative nature-society assessments such as the Millennium Ecosystem Assessment and the assessment reports of the Intergovernmental Panel on Climate Change (IPCC). It considers issues related to both (a) how phenomena and processes differ between scales and (b) how phenomena and processes at different scales affect each other.

Such questions, of course, are related to one of the great overarching intellectual challenges across a wide range of sciences: understanding relationships between macroscale and microscale phenomena and processes (Wilbanks and Kates, 1999). Examples include biologists and ecologists considering linkages between molecules and cells on the one hand and biomes and ecosystems on the other, related to such issues as biocomplexity; economists considering relationships between individual consumers and firms on the one hand and national and global economies on the other, related to such issues as efficiency and equity; and such other scientific fields as fluidics, which considers how the behavior of fluids changes with scale and how these differences interact. In the spirit of such traditions as general systems theory, it is not uncommon to explore applications of findings in one field about how scale matters as possible hypotheses for another.

Basic Concepts

Some basic concepts about how we consider geographic scale as an aspect of nature-society assessments are summarized in Wilbanks, 2003; Wilbanks, 2002; and Millennium Ecosystem Assessment, 2003. Drawing from these references, our starting points include the following:

(1) Arrayed along a scale continuum from very small to very large, most processes of interest establish a number of dominant frequencies; they show a kind of lumpiness, organizing themselves more characteristically at some scales than others (see, for instance, Holling, 1992).

(2) Recognizing this lumpiness, we can concentrate on the scales that are related to particular levels of system activity -- e.g., family, neighborhood, city, region, and country -- and at any particular level subdivide space into a mosaic of "regions" in order to simplify the search for understanding.

(3) In many (perhaps most) cases, smaller scale mosaics are nested within larger-scale mosaics; therefore, we can often think in terms of spatial hierarchies.

(4) In some (perhaps many) cases, there are relationships between spatial and temporal scales. For instance, it appears that in many cases shorter-term phenomena are more dominant at local scales than at global scales, while long-term phenomena are the converse.

(5) As we look across mosaics at different levels of scale and spatial detail, the importance of cross-border linkages increases as the scale shrinks. This generalization clearly applies to external linkages at the particular scale of interest (e.g., multipliers in regional economics). It is not so clear that the generalization applies to the importance of <u>cross-scale</u> linkages: more important at small scales than large?

(6) Place is more than an intellectual and social construct; it is a real context for communication, exchange, and decision-making. More than a decade of research by "post-modernist" scholars has established that place has meaning for local empowerment, directly related to equity, and indeed for personal happiness in the face of space-time compression (e.g., Harvey, 1989). Scale is not just an operational abstraction. It has meaning for people and processes, related to forms of social organization.

Based partly on such concepts, it has been suggested that geographic scale matters in seeking an integrated understanding of global change processes and that understanding linkages between scales is an important part of the search for knowledge (Wilbanks and Kates, 1999; also see Kates and Wilbanks, 2003). Several of the reasons have to do with how the world works. First of all, the forces that drive environmental systems arise from different domains of nature and society. For example, Clark has shown that distinctive systems imbedded in global change processes operate at different geographic and temporal scales (Clark, 1985). Within this universe of different domains, local and regional domains relate to global ones in two general ways: systemic and cumulative (Turner et al., 1990). Systemic changes involve fundamental changes in the functioning of a global system, such as effects of emissions of ozone-depleting gases on the stratosphere, which may be triggered by local actions (and certainly may affect them) but which transcend simple additive relationships at a global scale. Cumulative changes result from an accumulation of localized changes, such as groundwater depletion or species extinction; the resulting systemic changes are not global, although their effects may have global significance. A second reason that scale can matter is that the scale of *agency* -- the direct causation of actions -- is often intrinsically localized, while at the same time such agency takes place in the context of *structure*: a set of institutions and other regularized, often formal relationships whose scale is regional, national, or global. Land use decisions are a familiar example. A third reason that scale can matter is that the driving forces behind environmental change involve interactions of processes at different locations and areal extents and different time scales, with varying effects related to geographical and temporal proximity and structure. Looking only at a local scale can miss some of these interactions, as can looking only at a global scale. For instance, as indicated above, ecological modelers such as Holling have found that managed biomes are characterized by landscapes with lumpy geometries and lumpy temporal frequencies related to the size and speed of process interactions, shaped by the fact that processes operating at different scales tend to show faster or slower dynamics (Holling, 1995).

Several additional reasons why scale matters have to do with how we learn about the world. One of the strongest is the argument that complex relations among environmental, economic, and social processes that underlie environmental systems are too complex to unravel at any scale beyond the local. A second reason is that a portfolio of observations at a detailed scale is almost certain to contain more variance than observations at a very general scale, and the greater variety of observed processes and relationships at a more local scale can be an opportunity for greater learning about the substantive questions being asked. In other words, variance often contains information rather than "noise." A third reason is that research experience in a variety of fields tells us that researchers looking at a particular issue top-down can come to dramatically different conclusions from researchers looking at that very same issue bottom-up. The scale embodied in the perspective can frame the investigation and shape the results, which suggests that full learning requires attention at a variety of scales. As one example, Openshaw and Taylor have demonstrated that simply changing the scale at which data are gathered can change the correlation between variables virtually from +1 to -1 (1979).

These reasons, of course, do not mean that global-local linkages are salient for every question being asked about nature-society systems. What they suggest is more modest: that examinations of such changes should normally take time to consider linkages between different scales, geographical and temporal, and whether or not those linkages might be important to the questions at hand.

In any case, they also suggest that integrated assessments of nature-society relationships should be sensitive to multiple scales rather than focused on a single scale:

(1) Selection of a single scale can frame an investigation too narrowly, as questions and research approaches characteristic of that scale tend to dominate and upscaling or downscaling information from other scales requires compromises that often lose information or introduce biases.

(2) Phenomena, processes, structures, technologies, and stresses operate differently at different scales. Figure 1, from Wilbanks et al., 2003, is an example from recent research.

(3) A particular scale may be more or less important at different points in a single cause-consequence continuum and therefore less appropriate for exploring some of the points. Figure 2, from Kates and Wilbanks, 2003, is an example.

(4) Institutions important for decision-making about the processes being examined operate at different scales.

(5) Therefore, no single scale is ideal for broad-based investigation, although comparative studies at a single scale can contribute important insights (e,g., Schellnhuber, Ludeke, and Petschel-Held, 2003).

Findings about Scale Differences

A number of recent nature-society assessments have helped to illuminate issues related to how scale matters in such assessments. One set of findings has to do with how observations, processes, and understandings are related to the scale of the assessment. Besides the Millennium Ecosystem Assessment, examples from a U.S. perspective include the Global Change and Local Places project of the Association of American Geographers (GCLP) (AAG, 2003); the first U.S. National Assessment of Possible Consequences of Climate Variability and Change, 1997-2000; the recent U.S. National Academy of Sciences/National Research Council report on pathways for a "sustainability transition" (NAS/NRC, 1999); and a variety of other activities, including the ongoing work of the Sustainability Sciences Project at Harvard University, the Long-Term Ecological Research (LTER) network sponsored by the National Science Foundation in the U.S., and the Land-Use/Land Cover Change project jointly sponsored by the IGBP and the International Human Dimensions Programme.

Some of the findings to date are these:

(1) Observations of many variables at a more localized scale show greater variance and volatility. In other words, larger scales lose valuable information. Figure 3, from the Canadian national climate change impact assessment (Environment Canada, 1997), was one of the earliest empirical findings of this nature in nature-society studies, supporting theoretical expectations mentioned above.

(2) Analyses and assessments at different scales tend to be associated with different research paradigms and styles. As one example, in analyses of climate change responses, work at a global or national scale tends to be characterized by quantitative analysis, using net present value metrics, while work at a small-regional or local scale tends to involve integrated assessments including significant stakeholder involvement (Wilbanks, forthcoming).

(3) Downscaling and upscaling are likely to contribute different insights, and bottom-up investigations often provide different understandings compared with top-down investigations. As one illustration, the GCLP project found that top-down assessments of potentials of technologies to reduce greenhouse gas emissions in local places tended to overestimate those potentials, because they were not sensitive to local obstacles and constraints, while bottom-up assessments tended to underestimate the potentials because they were not fully informed about directions of technological and policy changes (Kates and Wilbanks, 2003; AAG, 2003).

(4) Different scales are related to different institutional roles, and the scale of decisions is often poorly matched with the scale of the processes being decided upon.

(5) The choice of a scale and a set of boundaries is not politically neutral, even if the choice is not based on political considerations.

Even though proposing a theoretical structure at this stage in our knowledge development would seem to be premature, it is possible to imagine moving in that direction by considering a number of hypotheses that seem reasonable based on what we know so far (Figure 4 illustrates just a few of the relationships that might be explored).

Findings about Scale Relationships

Similarly, recent assessments have suggested findings about how phenomena and processes at different scales are linked with each other. Examples include:

(1) In many cases, cross-scale <u>interactions</u> are more significant than aggregate <u>differences</u> between scales (e.g., Kates and Wilbanks, 2003; AAG, 2003).

(2) Cross-scale interactions can be considered in terms of certain basic dimensions:

- Strength
- Constancy: i.e., constant or intermittent, periodic or irregular
- Directionality: i.e., mainly in one direction or the other, or mutual
- Resolution: e.g., focused or broadcast

- Context; e.g., additive or contradictory, in connection with other processes operating

- Effect; e.g., stabilizing or destabilizing, controlling or enabling

- Intent

(3) Cross-scale interactions are often associated with distinctive bridging-type institutional roles (Cash, 2001).

(4) In many cases, important kinds of data about the interactions are elusive: e.g., relationships between local phenomena and national or international corporate decision-making.

(5) In many cases, relationships are too complicated to be incorporated in hierarchy theory: personal relationships, information flow, emission dispersal, etc.

(6) In some (perhaps many) cases, increasing understanding -- at least at the current state of knowledge -- seems to call for laying out rich narrative “story lines” and then exploring the connections from multiple base points (e.g., Root and Schneider’s call for “strategic cyclical scaling:” 1995). An illustration of such a story line is Figure 5 (AAG, 2003).

Concluding Observations

Whereas a decade ago there might have been some debate about whether scale matters in far-reaching integrative nature-society analyses and assessments, this issue seems now to have been settled, with the debate shifting from the *importance* of multi-scale assessments to (at least in the case of the U.S. Climate Change Research Program) the *practicality* of science-based assessments at the regional and local scales at the current state of data, tools, and knowledge (especially the forecasting of changes and impacts at a fine-grained scale).

The challenges are (a) to show that regional and local assessments can be at least as sound scientifically as global assessments, where such initiatives as AIACC are very encouraging, and (b) to show that qualitative deliberations and stakeholder participation, which are usually more important at a local scale, can contribute to the science of nature-society assessments as well as to their political acceptability.

In the longer run, of course, we will need to develop conceptual and methodological frameworks that incorporate both scale differences and scale relationships. Figure 6 depicts the general challenge, which at this point can only be met by qualitative metascale deliberation.

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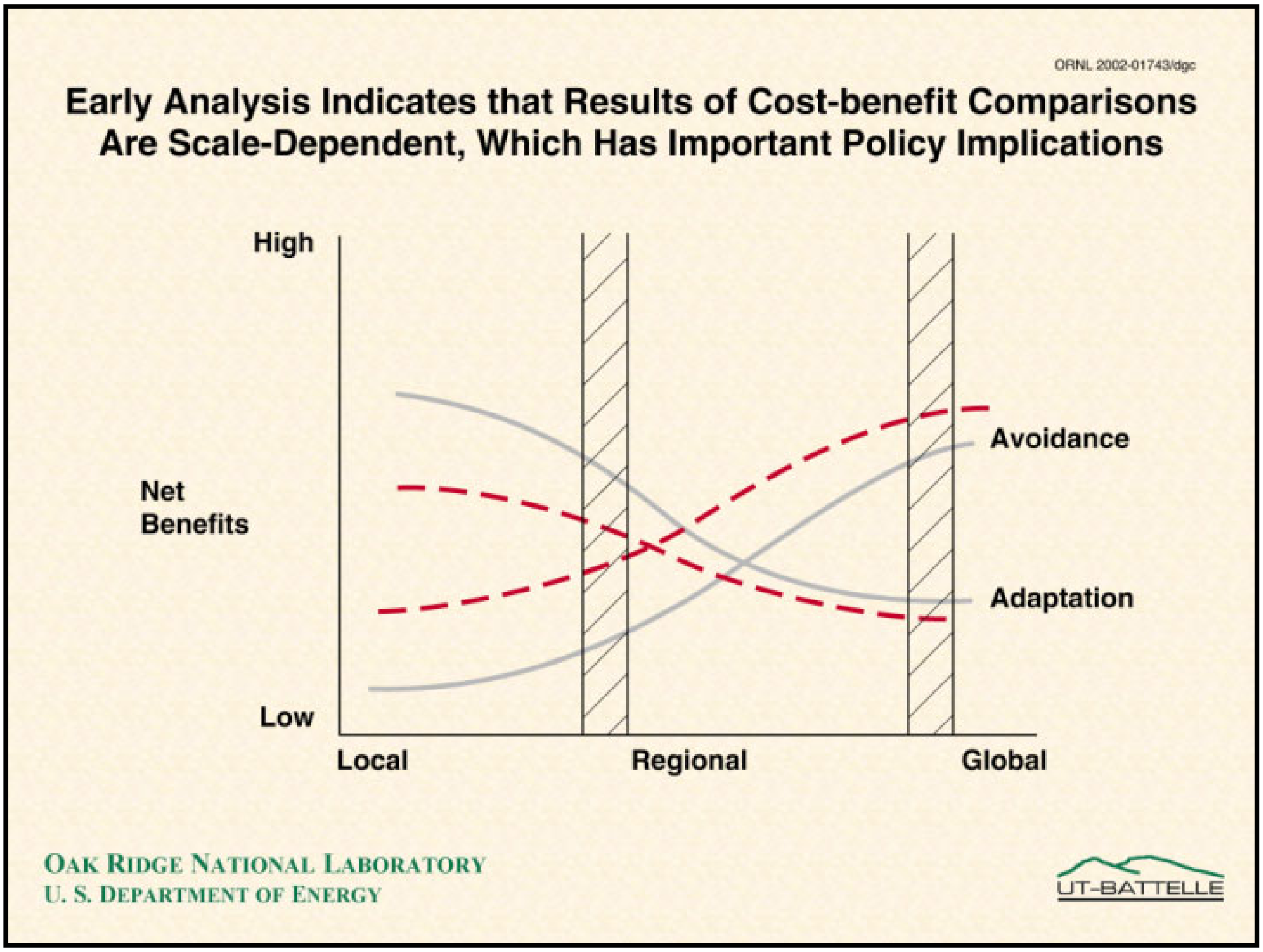
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Early Analysis Indicates that Results of Cost-benefit Comparisons Are Scale-Dependent, Which Has Important Policy Implications
High
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OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY
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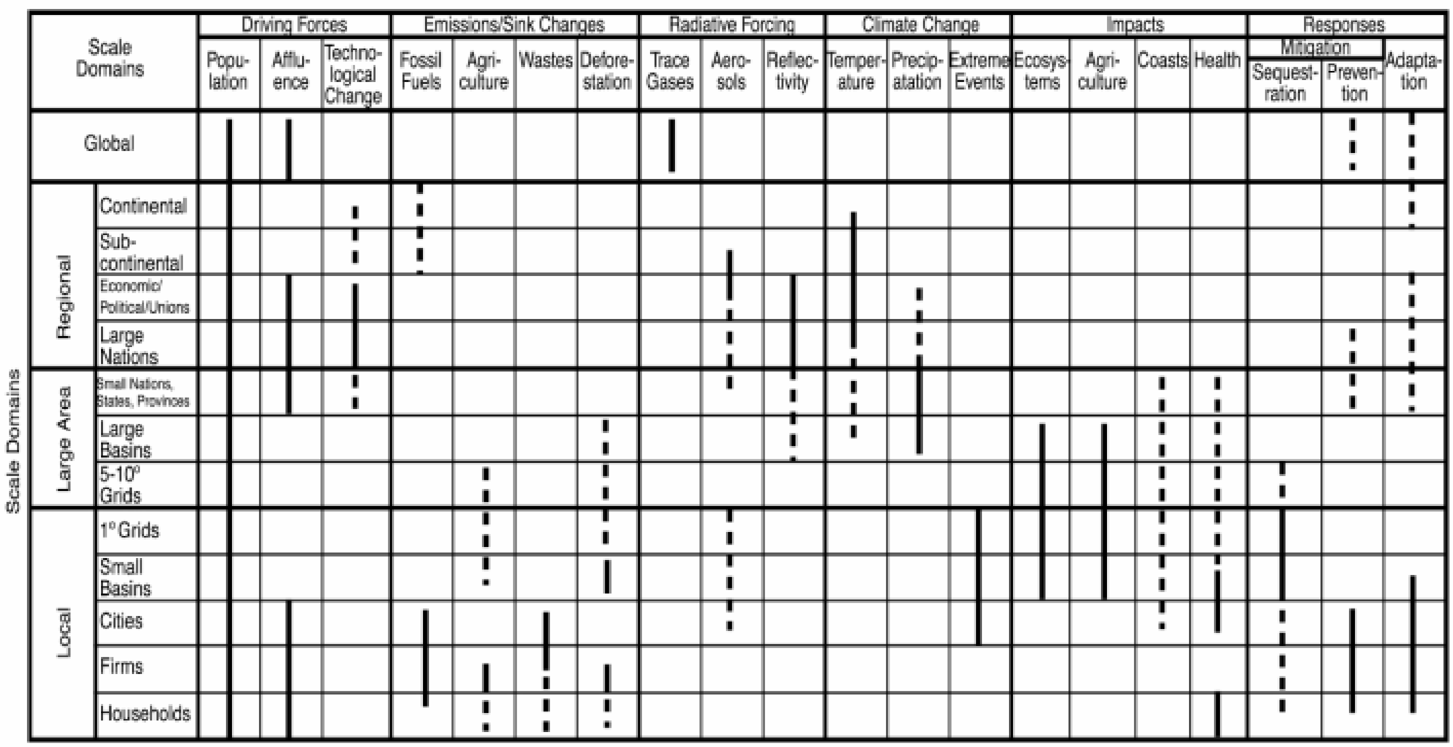

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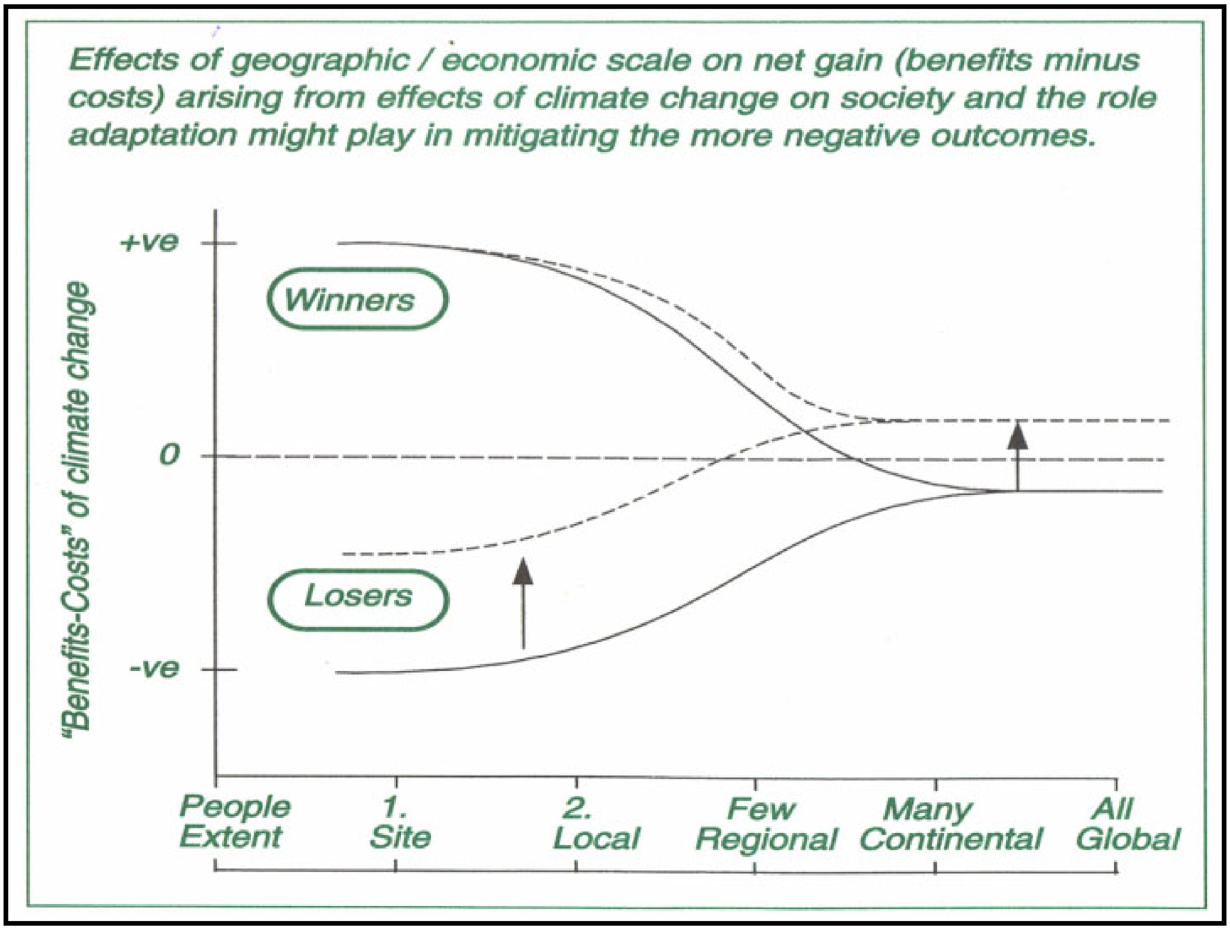
Scale Domains of Climate Change and Consequences*

Changes and Consequences**

*Depicts the scale of actions, not necessarily the locus of decision making.
**Dashed lines indicate occasional consequences or a lower level of confidence.


Effects of geographic / economic scale on net gain (benefits minus costs) arising from effects of climate change on society and the role adaptation might play in mitigating the more negative outcomes.
"Benefits-Costs" of climate change
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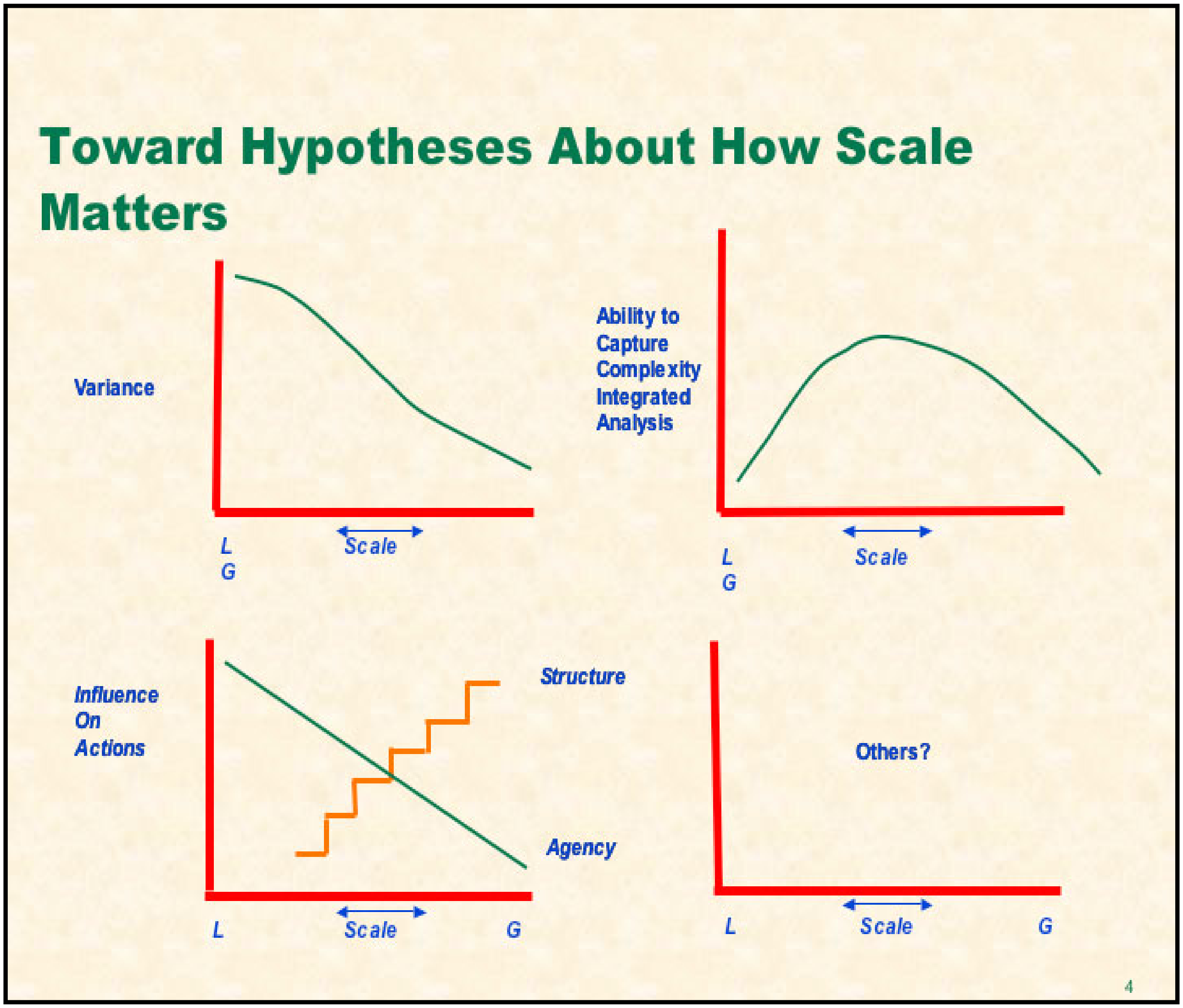
-ve
Winners
Losers
People Extent
1. Site
2. Local
Few Regional
Many Continental
All Global


Toward Hypotheses About How Scale Matters
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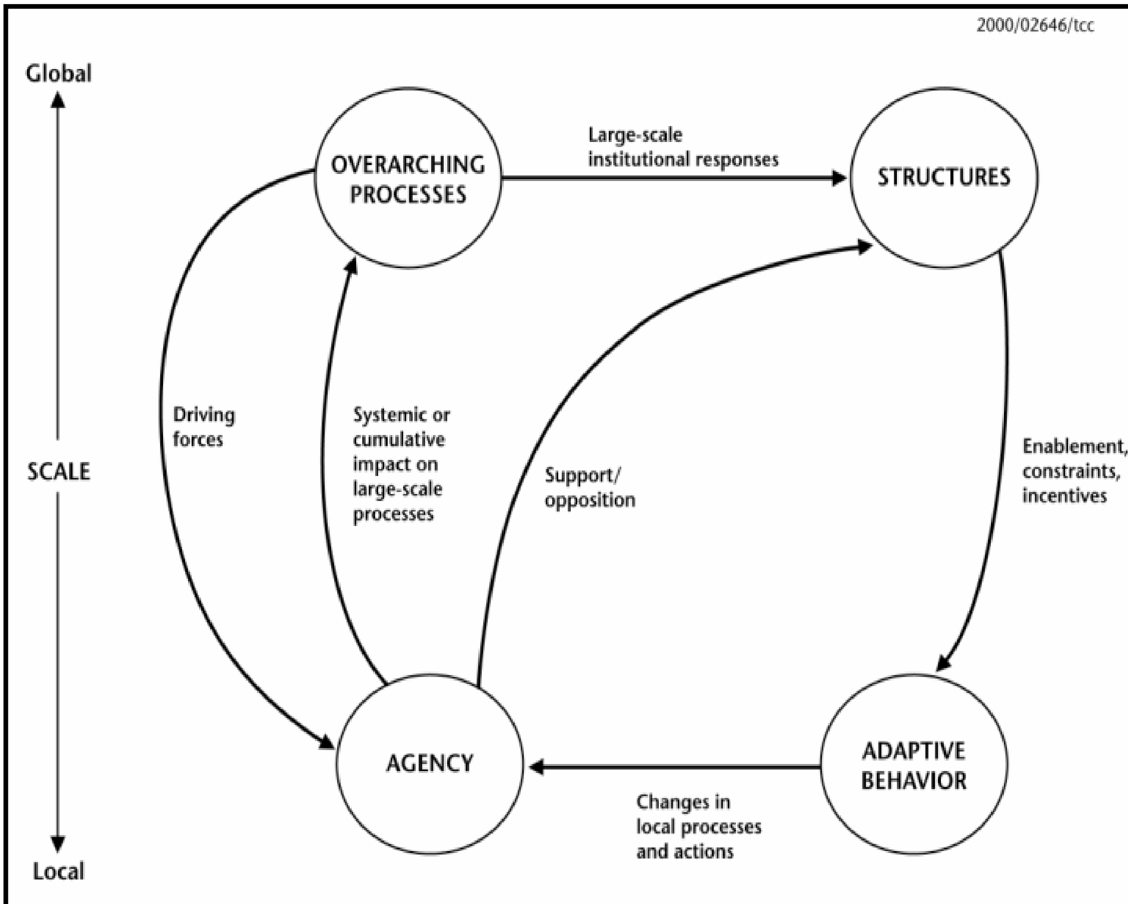
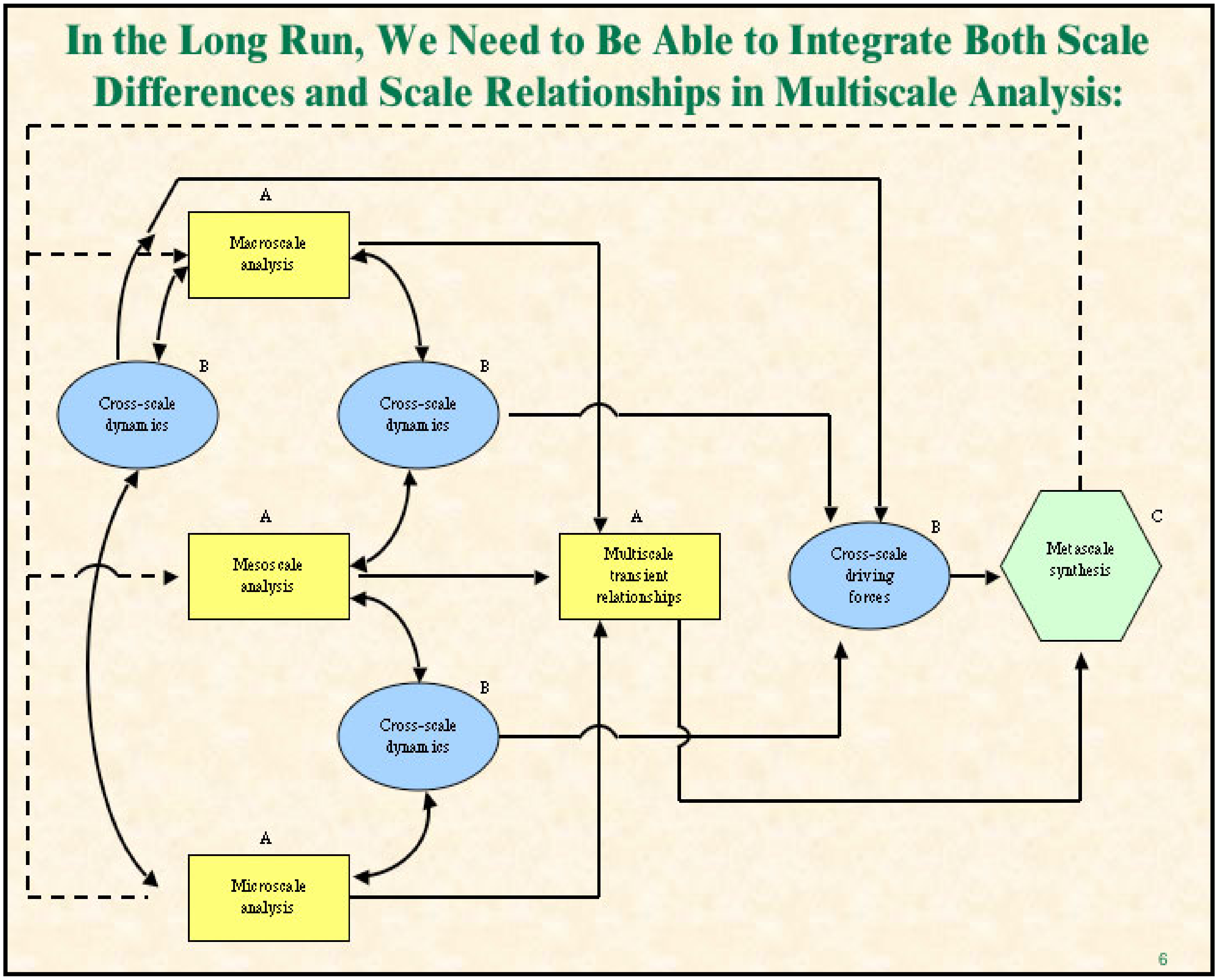


MACROSCALE/MICROSCALE INTERACTIONS IN GLOBAL CHANGE


In the Long Run, We Need to Be Able to Integrate Both Scale Differences and Scale Relationships in Multiscale Analysis:
A
Macroscale analysis
B
Cross-scale dynamics
B
Cross-scale dynamics
A
Mesoscale analysis
A
Multiscale transient relationships
B
Cross-scale driving forces
C
Metascale synthesis
B
Cross-scale dynamics
A
Microscale analysis
6