Two types of global environmental change

Definitional and spatial-scale issues in their human dimensions

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Clarification of several issues in the human dimensions of global environmental change is essential to the creation of a balanced research agenda. Global environmental change includes both systemic changes that operate globally through the major systems of the geosphere–biosphere, and cumulative changes that represent the global accumulation of localized changes. An understanding of the human dimensions of change requires attention to both types through research that integrates findings from spatial scales ranging from the global to the local. A regional or meso-scale focus represents a particularly promising avenue of approach.

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continued on page 15

The long sweep of human history reveals an escalating trajectory of alterations and transformations of Earth – of the geosphere–biosphere that sustains life as we know it.[1] This trajectory has not been uniform, however, but has been punctuated by periods of rapid increase in the scales and rates of change, usually concentrated within specific regions of the world.[2] The most recent of these broad, episodic 'outbreaks' of transformation, mainly in the last half century, differs from its predecessors in magnitude, pace, and kind. It is truly global in scope, has progressed with unprecedented speed, and involves major and novel changes in the basic biogeochemical flows of the geosphere–biosphere. The changes carry the potential, as anticipated by Vernadsky and others, of altering the great systems of these spheres.[3] Nevertheless, this episode shares at least two features with those in the past: much of the human activity that drives these transformations is highly regionalized, as are the environmental consequences, and alterations of the landscapes of Earth remain a significant component of change.[4]

These characteristics of human-induced alterations of Earth raise issues that have yet to receive adequate attention in the emerging discourse on global environmental change.[5] Important among those issues are the meaning of 'global', and the spatial scales of analysis to be used in the study of human-induced environmental change. Clarification of these issues is imperative for the maturation of emerging research agendas. As the study of global environmental change expands to include its human dimensions,[6] it will inevitably engage various fields of study with traditions and perspectives that do not necessarily follow those of the natural sciences.

Before we address these two issues, a brief note is warranted about the meaning of 'environment'. Some segments of the social sciences and humanities use the term to refer to the social environment or circum-

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Table 1. Types of global environmental change.

Type	Characteristic	Examples
Systemic	Direct impact on globally functioning system	(a) Industrial and land use emissions of 'greenhouse' gases (b) Industrial and consumer emissions of ozone-depleting gases (c) Land cover changes in albdeo
Cumulative	Impact through worldwide distribution of change	(a) Groundwater pollution and depletion (b) Species depletion/genetic alteration (biodiversity)
	Impact through magnitude of change (share of global resource)	(a) Deforestation (b) Industrial toxic pollutants (c) Soil depletion on prime agricultural lands

continued from page 14

mous reviewers, and for discussions with members of various national (US) committees dealing with global change and the Institute of Geography, USSR Academy of Sciences.

[1]Vladimir V. Annenkov and Leos Jelecek, eds, 'Historical geography of environmental changes', *Historical Geography*, Vol 27 (special edition), Institute of Czechoslovak and World History, Czechoslovak Academy of Sciences, Prague, 1988; George Perkins Marsh, *Man and Nature; or, Physical Geography as Modified by Human Action*, Charles Scribner, New York, 1864; William L. Thomas, Jr, ed, *Man's Role in Changing the Face of the Earth*, University of Chicago Press, Chicago, IL, 1956; B.L. Turner II, William C. Clark, Robert W. Kates, John F. Richards, Jessica T. Mathews and William B. Meyer, eds, *The Earth as Transformed by Human Action*, Cambridge University Press, Cambridge, 1990 (forthcoming).

[2]Robert W. Kates, B.L. Turner II and William C. Clark, 'The Great Transformation', in Turner *et al*, *op cit*, Ref 1.

[3]V.I. Vernadsky, *La biosphere*, Felix Alcan, Paris, 1929.

[4]William C. Clark, 'The human dimensions of global environmental change', in Committee on Global Change, *Toward an Understanding of Global Change*, National Academy Press, Washington, DC, 1988, pp 134–200; William C. Clark, 'Managing Planet Earth', *Scientific American*, Vol 261, No 3, 1989, pp 46–54; Michael Glantz, ed, *Forecasting by Analogy: Societal Responses to Regional Climatic Change*, Summary Report, Environmental and Societal Impacts Group, National Center for Atmospheric Research, Boulder, CO, 1989; National Aeronautics and Space Administration (NASA), *Earth System Science: A Closer View*, NASA, Washington, DC, 1988; B.L. Turner II,' The human causes of global environmental change', in R.S. DeFries and T.F. Malone, eds, *Global Change and Our Common Future: Papers from a Forum*, National Academy Press, Washington, DC, 1989, pp 90–99.

continued on page 16

stances of human life. In this use, environment includes '[w]hatever is outside the immediate focus of study', and includes not only the material conditions external to the individual – the interior of the home or workplace or the neighbourhood – but the non-material as well – household or workplace relations and settings.[7] In this sense, environment represents the 'nurture' side of the 'nature *v* nurture' dichotomy. This broad meaning of environment is not the one that prevails in the natural sciences and in those social science fields closely linked to them, where the term refers exclusively to the physical conditions of Earth – the components and systems of the geosphere–biosphere (eg soil, flora, or climate), even if altered by human action. The study of global environmental change, including its human dimensions, clearly employs this second meaning of environment. This is so because physical change itself constitutes a fundamental problem, and because the problem needs to be bounded, at least in its initial stages.

Two types of global environmental change

'Global' has at least two meanings, but unlike those for environment, both are appropriate for the study in question. In the first, or systemic meaning, global refers to the spatial scale of operation or functioning of a system (Table 1). A physical system is global in this sense if its attributes at any locale can potentially affect its attributes anywhere else, or even alter the global state of the system. This meaning has had universal acceptance, if only implied, and has dominated much of the discourse to date. Much of the initial attention of the International Geosphere–Biosphere Programme (IGBP) has been focused on atmospheric and marine systems – those in which human-induced perturbations may alter the conditions of the systems themselves.[8] Well known examples include the increase in the so-called 'greenhouse' gases that may lead to changes in the heat balance of the atmosphere and oceans, giving rise to new climatic zones and sea levels. The facts that the atmospheric concentration of methane has, owing to human inputs, doubled over the past 300 years, and that one-half of all the carbon mobilized by humankind has been released since the middle of the twentieth century, illustrate the need for attention to systemic change.[9]

Globally systemic changes need not be caused by global-scale activity; only the physical impacts of the activity need be global in scale, manifested through the systemic adjustments that follow. The industrial sources of CO_2, for example, are highly concentrated on Earth's

continued from page 15

[5]Martin F. Price, 'Global change: defining the ill-defined', *Environment*, Vol 31, No 8, 1989, pp 18–20, 42–44; Martin F. Price, *The Human Aspects of Global Change*, Final Report, Environment and Societal Impacts Group, National Center for Atmospheric Research, Boulder, CO, 1990.

[6]These include international efforts such as the World Climate Impact Study Program (United Nations Environment Program/World Meteorological Organization), the Man and the Biosphere Programme (United Nations Educational, Scientific and Cultural Organization), the Human Dimensions of Global Change Committee (International Social Science Council), and the Human Dimensions of Global Change Program (International Federation of Institutes for Advanced Study and United Nations University). National-level panels and committees in the USA alone include the Committee on Global Change (National Research Council-NRC), the Human Dimensions of Global Environmental Change Committee (Commission on Behavioral and Social Sciences and Education, NRC), and the Committee for Research on Global Change (Social Science Research Council). In addition, 'global change' research programmes have emerged in a number of universities and national laboratories. For more complete listings of groups and organizations related to the human dimensions of global environmental change, see Clark, 1988, *op cit*, Ref 4 and Price, 1990, *op cit*, Ref 5.

[7]See, for example, Allan Schnaiberg, *The Environment, from Surplus to Scarcity*, Oxford University Press, Oxford, 1980, p 9.

[8]Special Committee for the International Geosphere–Biosphere Program (IGBP), *A Plan of Action*, Report No 4, IGBP Secretariat, Stockholm, 1988; Committee on Global Change, *op cit*, Ref 4; Price, 1990, *op cit*, Ref 5.

[9]Thomas E. Graedel and Paul Crutzen, 'Atmospheric trace constituents', in Turner *et al*, *op cit*, Ref 1; Richard A. Houghton and David L. Skole, 'Carbon', *ibid.*

[10]Carbon Dioxide Information Center (CDIC), *Communications*, Oak Ridge National Laboratory, Oak Ridge, TN, 1989.

[11]Our terminology for this second type of change has been a subject of considerable discussion among those with whom we have consulted. Globally 'systemic' captures the essence of the changes of the first kind – direct connections to the great systems that sustain the geosphere–biosphere. Its counterpart, globally 'non-systemic', may be an accurate term, but is an awkward one. Alternative terms, however, capture facets of environmental change other than its globally non-systemic nature. We have selected globally 'cumulative' change to emphasize the spatial or substantive magnitude of the change that must be reached through addition to constitute globally significant impacts on the geosphere–biosphere.

continued on page 17

surface. Currently, seven industrialized countries possessing 11% of the world's population produce 40% of carbon dioxide emissions.[10] Yet carbon dioxide, once released into the atmosphere, diffuses through the troposphere, probably leading to global warming. Other cases may require a widespread, perhaps worldwide, distribution of human activity to trigger systemic change, as in the climatic consequences of albedo change brought about by land-use transformations.

In the second – the cumulative – sense, 'global' refers to the areal or substantive accumulation of localized change (Table 1).[11] A change is global in this sense if it occurs on a worldwide scale, or represents a significant fraction of the total environmental phenomenon or global resource. This meaning is not new; it underlies the consideration of solid earth processes and terrestrial ecosystems, especially loss in biodiversity, by the US Committee on Global Change (National Research Council/National Academy of Sciences and US affiliate to the IGBP).[12] Changes of the cumulative type include those that 'are local in domain, but which are widely replicated and which in sum constitute change in the whole human environment'.[13] They involve both the landscapes or 'faces' of Earth, such as forest, grassland, and wetland conversions, and those biogeochemical flows that remain below the globally systemic scale in their movement, such as sulphur and nitrogen oxides, tropospheric ozone, and water pollution.

If cumulative changes reach a global scale, it is typically as the consequence of worldwide or widespread human activity that may not be directly registered on the major geosphere–biosphere systems. The loss of soil at one locale does not cause physical adjustments in world soil conditions. Nevertheless, global soil losses, currently estimated to destroy the productivity of as much as 60 000 to 70 000 km^2/year, stimulate global-scale expansion of agricultural land at the expense of forest and pasture and the intensified use of synthetic resource substitutes on the degraded lands.[14] Anthropogenic impacts on freshwater are typically confined within individual basins and aquifers, but widespread shortages caused by excessive withdrawal (per capita use of water is estimated to have increased fourfold over the past 300 years) or pollution may sum up to a globally critical situation.[15]

'Systemic' and 'cumulative' as used here characterize the physical changes produced by human activities. The activities causing these changes have been designated 'proximate sources' and 'driving forces'.[16] Proximate sources are the near-final or final human activities, such as biomass burning or industrial emissions, that directly affect the environment, whereas driving forces constitute a complex, multi-tiered set of actions and rationales (eg population change, urbanization, land tenure, technological change) that give rise to proximate sources. Any proximate source may contribute to either or both types of global change, systemic or cumulative. For example, biomass burning leads to systemic change through CO_2 releases and albedo changes, and to cumulative change through its impacts on soils and biotic diversity. Indeed, systemic and cumulative change are so intertwined in some cases that they must be examined in tandem (eg wetland conversion/atmospheric methane/atmospheric warming).

The greater attention given to human-induced globally systemic change *v* cumulative change to date is understandable given its relative historical novelty,[17] its potentially life-threatening nature, our poor understanding of the physical processes involved, and the widespread

concern over global climatic change. But if the human dimensions of global environmental change are to be understood, attention to cumulative change is essential. It is generally agreed within the natural science community itself that certain types of cumulative change are critical in their own right (eg loss of biotic diversity) and that some types of cumulative change are intimately tied to globally systemic change (eg forest loss). Understanding the 'human dimensions' of globally systemic change moves us yet further into the cumulative realm because so many facets of our experiences are embedded in that realm and because these two types of change are so clearly related in both causes and effects. For example, understanding global land-use change, which is cumulative, is essential to understanding global climatic change, which is systemic. Moreover, society registers, perceives, and responds to environmental change of any kind largely through the localized environmental conditions of the cumulative type.

A final distinction is useful to emphasize the importance of addressing cumulative change. In addressing the human dimensions of change, the 'geocentric' focus of natural scientists should be supplemented by an 'anthropocentric' perspective that evaluates physical changes primarily in terms of their importance to society. Both systemic and cumulative change, of course, can be addressed from either perspective. This distinction, however, contributes to enlarging and clarifying the range of concern over global environmental changes and may identify some globally systemic changes as less important than some cumulative ones. From the anthropocentric point of view, significant global environmental change is any change of worldwide or major significance to human society. From this perspective, the dominant problems in global environmental change may be cumulative ones. A holistic perspective that integrates the geocentric and anthropocentric perspectives may prove the most valuable for global change studies.[18]

Defining the bounds of human-dimension studies

How do we distinguish the study of global environmental change from that of environmental change in general? We must recognize that the distinction is arbitrary in as much as systemic and cumulative environmental changes stem from and affect human activities on all spatial scales. But whereas the endeavours of both the natural and social sciences will surely draw upon understanding and knowledge from all scales of change and associated nature–society relationships, practical considerations direct certain fields of research to emphasize certain forms of environmental change and, hence, related human activities in the initial phases of study.

The distinctiveness of current environmental change is the increasing ability of humankind to affect or alter directly the basic physical systems that sustain the geosphere–biosphere. Globally systemic change, therefore, is the obvious point of departure for the IGBP and its national affiliates.[19] The human linkages here tend to emphasize those activities – production and consumption in the industrialized world – that most directly affect the biogeochemical flows of those systems. As noted, however, systemic change cannot be adequately understood apart from the cumulative changes related to it.

One key to the initial focus of study, therefore, is the identification of the specific kinds of cumulative environmental changes that contribute

continued from page 16

[12]Committee on Global Change, *op cit*, Ref 4, 1988; for an earlier instance, see C.L. Wilson and W.H. Matthews, *Man's Impact on the Global Environment: Report on the Study of Critical Environmental Problems*, Massachusetts Institute of Technology Press, Cambridge, MA, 1970.

[13]Harold C. Brookfield, *Sensitivity to Global Change: A New Task for Old/New Geographers*, Norma Wilkinson Memorial Lecture, University of Reading, Reading, UK, 1989.

[14]Boris Rozanov, Viktor Targulian and D.S. Orlov, 'Soils', in Turner *et al*, *op cit*, Ref 1.

[15]Mark I. L'vovich and Gilbert F. White, 'Use and transformation of terrestrial water systems', in Turner *et al*, *op cit*, Ref 1.

[16]Turner, *op cit*, Ref 4.

[17]For example, the anthropogenic contribution to most greenhouse gases is a phenomenon of the second half of the twentieth century. In contrast, this contribution to changes in many aspects of Earth, such as forest loss and species extinction, is a phenomenon of much longer standing. See Kates, Turner and Clark, *op cit*, Ref 2.

[18]The terms geocentric, anthropocentric, and holistic are drawn from Price, who concludes that geocentric meanings have dominated the development of global change studies to date. See Price, 1990, *op cit*, Ref 5.

[19]William C. Clark, 'The human ecology of global change', *GeoJournal*, Vol 20, No 2, 1990, pp 143–150.

most directly to systemic change, such as those altering land uses and their impacts on land cover and hydrological cycles. For the most part, this method of bounding global change studies – identifying systemic change and those cumulative changes most clearly linked to it – has been that followed by the US Committee on Global Change, if only implicitly. Social scientists would benefit greatly from assessments detailing the strength and directness of the contribution of the myriad of environmental changes to systemic change. Such an effort is currently inhibited, however, by inadequate understanding within the natural sciences of many specific kinds of environmental change, and thus their relationships to globally systemic change are not well known.

A second focus for the social sciences should use the anthropocentric perspective on global environmental change as a means of balancing the natural science emphasis on the geocentric perspective, with the goal of merging the two into a holistic one.[20] The choice of topics within this focus should be guided not by linkages to systemic change *per se* but by the anthropocentric significance of the physical transformations. This perspective will further illuminate the role of cumulative change in global environmental change in general, perhaps demonstrating it to be of importance equal to or greater than that of globally systemic change.

Spatial scales of human-dimension studies

To address adequately the human dimensions of global environmental change poses a formidable challenge. A reconciliation of two competing trajectories in the social sciences will be required – of those tending towards understanding through broad, macro scale social forces that affect nature–society relationships with those tending towards understanding through the complexity of these relationships in their local space–time contexts. The macro approach searches for those forces whose operation across the globe makes possible general explanations that have broad applicability for understanding and dealing with global change. The micro approach asserts not only that the human activities that drive and mitigate environmental change and the human impacts of global change vary significantly by region or place, but also that historical or local contextual factors are so influential that understanding must be grounded in the specifics of the case.[21] Elements of this approach characterize Soviet studies of anthropogenic landscape modification, which have examined in detail the regional interactions between human activities and regional biogeochemical processes and underlying landscape changes.[22]

Study of the human dimensions of global change requires that such scale issues be broached, if only because the world community will demand a foundation on which to tackle environmental problems on all spatial scales. Clearly the macro and meso scales require analysis, because we know less about them and because so many of the nature–society processes are shared among locations. On the other hand, studies at the micro scale will provide a major opportunity for holistic analysis not possible or extremely difficult on larger scales.[23]

At the macro scale (global and continental), attention must be paid to the intricate associations between worldwide trends in social and environmental phenomena. What variables, for example, are associated with deforestation at a global scale, and what facets of society underlie them? Relevant variables surely include population and technological

[20]See Price, 1989, *op cit*, Ref 5.

[21]Martin L. Parry, T.R. Carter and N.T. Konijn, eds, *The Impact of Climatic Variability on Agriculture, Vol 1: Assessments in Cool Temperate and Cold Regions* and *Vol 2: Assessments in Semi-Arid Regions*, Kluwer, Dordrecht, The Netherlands, 1988.

[22]Vladimir M. Kotlyakov, J.R. Mather, Galina V. Sdasyuk and Gilbert F. White, 'Global change: geographic approaches (a review)', *Proceedings, National Academy of Sciences*, Vol 85, 1988, pp 5986–5991; John R. Mather and Galina V. Sdasyuk, 'Global change: some concepts and problems of geographical research', *GeoJournal*, Vol 20, No 2, 1990, pp 8–94.

[23]Likewise, understanding the human dimensions requires attention to variable temporal scales. Perspectives drawn only from the present or current situation mask alternatives illustrated through a longer historical perspective. For example, the current episode of global population growth, although unique in its magnitude, is not unique but the third such in the history of humankind, and the relationships between this growth and changes in technology and socioeconomic organization as they have affected environmental change offer invaluable insights (see Edward S. Deevey, Jr, 'The human population', *Scientific American*, Vol 203, No 3, 1960, pp 194–204; Thomas Whitmore, Douglas L. Johnson, B.L. Turner II, Robert W. Kates, and Thomas Gottschang, 'Long-term population change', in Turner *et al*, *op cit*, Ref 1. Similar important insights can be drawn from examinations of nature–society relationships over smaller time scales (see *op cit*, Ref 2). The differing time scales of interacting physical and social processes also warrant attention (see William C. Clark, 'Scale relationships in the interaction of climate, ecosystems, and societies', in K.C. Land and S.H. Schneider, eds, *Forecasting in the Natural and Social Sciences*, D. Reidel, Dordrecht, The Netherlands, 1987).

change, level of and inadequacies in market development, and socio-economic organization, although the specific terminology varies by study.[24] Examination of variables at this scale of analysis imposes innumerable data problems which must be overcome and which will require a level of resources that the social sciences do not yet command (nor does it match even that proposed for the natural sciences).[25]

Examining these individual relationships alone, however, is not sufficient. Exploration should also be made of the development and usefulness of a systemic framework for understanding nature–society relationships that parallels globally systemic environmental change. At issue here are societal attributes which operate as a worldwide system and which are associated with global environmental change. Several candidates for study exist, such as global industrialization or flows of investment or information, but much work is needed to determine the overall workings of these systems and the strength, directness, and spatial scales with which they interact with environmental change.[26] Examinations using a macro approach should illuminate processes of interdependence and interaction that might be masked on smaller spatial scales of study.

In contrast to this 'global scale' approach, there is a rich tradition of nature–society studies on smaller spatial scales, such as regions or places.[27] These place-specific studies inform us that site and situation create a multitude of ways by which Earth is sustained, altered, or transformed, allowing for a more complete understanding of the way in which global forces are played out in specific places and cultures. The meso-level or regional scales offer a powerful entry into understanding global change, since they connect micro- and macro-level processes. They illustrate the unevenness of the processes and impacts of change, even of the systemic kind, and yet do not focus our attention so narrowly that linkages to the global scale or broader patterns are obscured. Particularly useful are regional comparative studies that seek both the similarities and differences in various facets of the human dimensions of change, such as the role of population growth in deforestation under different socioeconomic, political, and technological conditions.[28] This approach allows studies to be topical, but at the same time holistic.

Spatial variability is not only important in detailing the nature of change by locations; it also suggests the probability that critical nature–society relationships in global change, including the important variables within them, may vary with the spatial scale of the analysis. In some instances, subglobal conditions will parallel the global; in others, nested sets of explanations will be required that fit the local condition to the regional and the regional to the global. It is precisely these types of connections that must be carefully articulated, not only to understand the human dimensions of global change, but also to match on the social side the sophistication of the physical-science inputs to the various modelling and projection efforts called for by the international and national global change committees.

In addition, attention to such issues of scale will illuminate other facets of the human dimension, such as the pathways to human-induced environmental change, systemic or cumulative. For example, initial studies[29] suggest three pathways: intraregional, inter- or transregional, and regional–global (Figure 1):

- 'Intraregional' change is produced within a region by human

[24]William C. Clark, 1988, *op cit*, Ref 4; Turner, *op cit*, Ref 4.

[25]The current budgets proposed by the US government are a good example. See *Our Changing Planet: the FY 1991 US Global Change Research Program*, A Report by the Committee on Earth Sciences (to accompany the US President's Fiscal Year 1991 Budget), Washington, DC, 1990. It must be recognized, however, that the social sciences lag behind the natural sciences in the development of coordinated research agenda.

[26]While interest in global change issues is high and growing rapidly, it appears that considerable segments of the social sciences and specific disciplines have provided rather muted responses to the burgeoning field, at least in regard to what they have the potential to contribute. Geography is a good example. Its earth science, nature–society, and cartographic/geographic information branches have responded vigorously (see Kotlyakov *et al*, *op cit*, Ref 22; Mather and Sdasyuk, *op cit*, Ref 22), while its space–society branch has not. It is precisely this last segment of geography that has long-standing traditions in the study of the importance of spatial scale to understanding social phenomena and that is engaged in studies of global industrialization and other such 'systemic' qualities of the social world. The knowledge and expertise of these segments of the social sciences will be vital for the study of the social side of global change.

[27]See, for example, John W. Bennett, *Northern Plainsmen: Adaptive Strategy and Agrarian Life*, Aldine, Chicago, IL, 1969; Karl W. Butzer, *Early Hydraulic Civilization in Egypt: A Case Study in Cultural Ecology*, University of Chicago Press, Chicago, IL, 1976; William Cronon, *Changes in the Land: Indians, Colonists and the Ecology of New England*, Hill and Wang, New York, NY, 1983; Robert McC. Netting, *Balancing on an Alp: Ecological Change and Continuity in a Swiss Mountain Community*, Cambridge University Press, Cambridge, 1981; Piers Blaikie and Harold Brookfield, *Land Degradation and Society*, Methuen, London, 1987; Richard P. Tucker and John F. Richards, eds, *Global Deforestation and the Nineteenth-Century World Economy*, Duke University Press, Durham, NC, 1983; Turner *et al*, *op cit*, Ref 1, chapters 28–39.

[28]Towards this end, it is surprising how few worldwide comparative studies of regions have been undertaken in the social sciences, especially studies directed towards nature–society problem solving.

[29]Turner *et al*, *op cit*, Ref 1. The three pathways outlined here parallel the spatial scales of the three generations of environment–development concern identified in William C. Clark and C.S. Holling, 'Sustainable development of the biosphere: human activities and global change', in Thomas F. Malone and J.G. Roederer, eds, *Global Change*, Cam-

continued on page 20

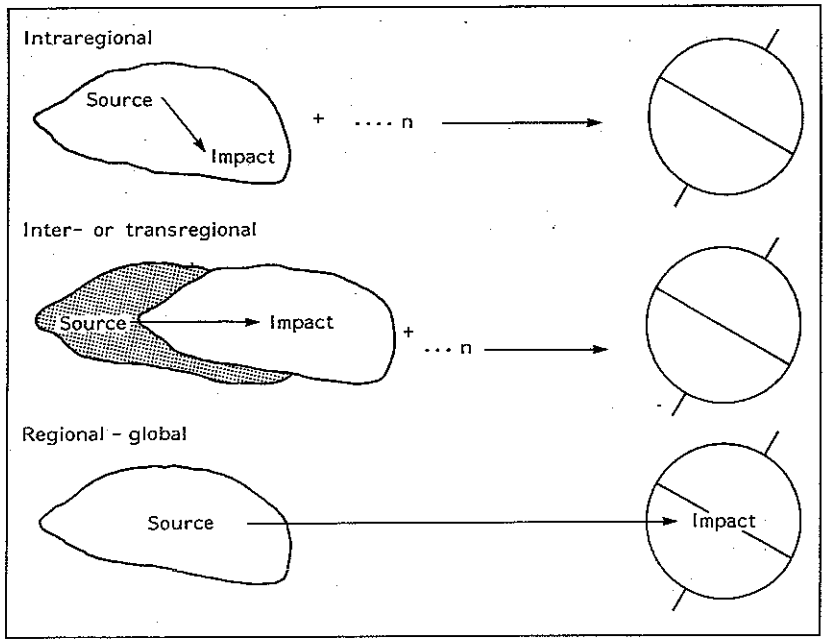

Figure 1. Regional pathways to global environmental change: systemic and cumulative.

proximate sources that also occur within the region. It may, by an additive process, reach sufficient magnitude that some aspect of the regional environment is transformed, while not registering direct physical effects on other regions. Examples include loss of biomass or species, or groundwater depletion. This path can lead to global environmental change only if it is replicated on a sufficient spatial scale or involves a significant portion of the world's resource.

- 'Inter-' or 'transregional' change is produced in one or more regions by human activities or changes taking place in another region or other regions. Examples might include acid rain, the impact of wetland conversion on migratory species, or the contamination by upstream activities of a major riverine network. By itself, interregional change is neither globally cumulative nor systemic, although it may, as with the intraregional pathway, reach the globally cumulative level if widely duplicated elsewhere.
- 'Regional–global' change includes those cases in which the activity in a region or set of regions contributes directly to systemic global change, such as methane releases from changes in wetlands or chlorofluorocarbon (CFC) emissions from industrial activities.[30] This pathway almost invariably involves interruptions or additions to the biogeochemical flows of the geosphere–biosphere.

The category to which a particular change will be assigned will depend on the spatial scale of the region that is adopted for analysis, on the nature of the process itself, and on the location of the proximate source of change relative to the regional boundaries chosen. Suppose, for instance, that areas as large as the continents are employed as the basic regional units. Then most human impacts on freshwater (eg pollution of and withdrawal from rivers) will fall into the intraregional category, as will sediment transfer and even such atmospheric impacts as acid rain, unless they occur near the regional boundary. If the subnational state or provincial unit is adopted as the rough scale of regional division, on the

continued from page 19
bridge University Press, Cambridge, 1985, pp 474–490.

[30] In contrast, global–regional change can be recognized in those instances in which change in a global system alters the regional environment. The physical consequences of even a uniform global change of this kind will vary according to the nature of the regional environments experiencing it, and the human impacts will also depend on the social dimensions of the region.

other hand, then many of these impacts will shift into the inter- or transregional category, because they routinely overflow the bounds of these smaller units.

The classification of some other processes will be largely unaffected by the scale adopted, particularly those physical changes largely anchored in place (eg mineral depletion or soil salinization), which will consistently fall under the intraregional category, and those highly fluid changes that are globally systemic (eg CO_2 and CFC emissions) and are assigned to the regional–global class. These problems notwithstanding, the role of such exercises is to determine whether typologies of pathways or other facets of environmental change are related to broader patterns in associated human driving and mitigating forces and responses to global change in general.

These pathways address the spatial patterns of the physical linkages between proximate sources and environmental changes. They are also relevant to the spatial scales of social linkages that run from the deeper human driving forces of change to the human actions that constitute proximate sources. Consideration of these driving forces further highlights the significance of the regional approach. Examples are market-based demand and local population pressures, which vary in strength across the globe and by resource and environmental setting, in addition to influencing environmental changes that are distant from them (interregional or regional–global change). Several well known examples can be cited. Albedo changes in the North American Great Plains are, in part, a response to agricultural land-use changes which, in turn, supply national and international (but not local or subnational) agricultural demands.[31] Albedo changes in the West African Sahel, by contrast, are a response to land-use changes created by the intersecting dynamics of international markets and local subsistence needs.[32]

Considered from a geocentric perspective, the physical scale of an environmental problem – intraregional, interregional, or regional–global – may seem to dictate the proper scale of management, with only the last category requiring globally coordinated social responses. The systemically interconnected nature of many social processes, however, enlarges the range of physical changes that have, or can have, effects wider than their direct spatial reach. Regulation of localized forms of industrial pollution can diminish a country's attractiveness to global investment. The depletion of resources at one locale can increase pressure on other sources of supply. Localized environmental disasters or degradation may prompt migration to other areas. And, of course, the social and cultural differences across space would mediate differently the human impacts of even a uniform global physical change.

Conclusion

The arguments advanced here address problems implicit in the rapidly growing literature on global environmental change. Clarifying basic distinctions and definitions at an early stage may prevent much later confusion, particularly given the need to incorporate the expanding research effort on human dimensions with the better established environmental fields. Indeed, it is interesting how little of the effort on global environmental change (eg literature, symposia, committee and workshop reports) to date has addressed these issues.

The term 'global environmental change' can refer legitimately to

[31]Brian Blouet and Frederick Luebke, eds, *The Great Plains: Environment and Culture*, University of Nebraska Press, Lincoln, NE, 1979; H-J. Späth, 'Dryland farming in the central Great Plains: Sedgwick County, Northeast Colorado', in B.L. Turner II and S.B. Brush, eds, *Comparative Farming Systems*, Guilford Press, New York, NY, 1987; William E. Riebsame, 'The United States Great Plains', in Turner *et al*, *op cit*, Ref 1; Donald Worster, *Dust Bowl: The Southern Great Plains in the 1930s*, Oxford University Press, Oxford, 1979.

[32]R.W. Franke and B.H. Chasin, *Seeds of Famine: Ecological Destruction and the Development Dilemma in the West African Sahel*, Allanheld and Osmun, Montclair, NJ, 1980; Michael Mortimore, *Adapting to Drought: Farmers, Famines and Desertification in West Africa*, Cambridge University Press, Cambridge, 1989; Michael Watts, *Silent Violence: Food, Famine and Peasantry in Northern Nigeria*, University of California Press, Berkeley, CA, 1983.

either of two types of change: globally systemic change that occurs within a fluid worldwide physical system, and globally cumulative change that reaches the global scale through the worldwide aggregation of more localized changes. A well founded research programme on the human dimensions of global change requires balanced attention to both types. While considerable attention must be given to cumulative changes that link strongly and directly to systemic changes, a broadening of the scope of human-dimensions research may well lead to the identification of sets of 'independent' cumulative change of such significance that they also must become part of the core of global change studies.

These two types of change, in both their physical and their human dimensions, may vary significantly by spatial scale, and should be addressed at a range from the macro to the micro. For the reasons noted, however, the macro- and meso-scale approaches deserve special attention. Ultimately, studies that examine human driving forces and societal responses on differing scales, and the linkages among scales, appear to hold particular promise for deeper insights and theory building.