

Rio Grande Basin and the Modern World: Understanding Scale and Context

Joseph A. Tainter

Abstract—Environmental problems are social issues, embedded in economic and political contexts at the local, regional, national, and global levels. Placing environmental issues on the scale from local to global clarifies conflicts between the level at which problems originate and the level at which they must be addressed. Local issues today often originate in sources distant in time and space, increasing the difficulty of discerning and addressing them. Conflicts in environmental management can be approached by understanding their broader context and the appropriate level at which to manage them.

Scaling and Social Context

Environmental problems are really social issues. Environmental matters do not exist on an independent plane in the biophysical world. Ecosystems, being systems, adjust automatically to what we call disturbances, and cannot care about such matters as species composition, ground cover, or water flow. An environmental phenomenon becomes a problem only because people perceive it to be. Variation in human perception gives rise to environmental concerns, the research by which we comprehend them, and the confrontations or negotiations by which we resolve them.

To understand that environmental problems are really social issues is also to understand that they have scalability that is characteristically fractal. As we consider environmental issues ranging from local to national to global, we find that the problems fundamentally retain the same form, the same parts, and the same relations among parts. Always, for example, there is conflict between immediate human livelihood and long-term environmental resiliency. The fact that the problematical relationship between humanity and the environment tends to repeat the same patterns and issues helps us to develop a context to understand both what we experience in the Rio Grande Basin today and the broader processes in which we participate. A perspective that is comparative and historical helps to clarify both the situation of the Rio Grande Basin and the meaning of the ecosystem approach to management. The discussion is far-ranging, and is meant to illustrate the diversity of the knowledge that we need to understand any region today.

In: Finch, Deborah M.; Whitney, Jeffrey C.; Kelly, Jeffrey F.; Loftin, Samuel R. 1999. Rio Grande ecosystems: linking land, water, and people. Toward a sustainable future for the Middle Rio Grande Basin. 1998 June 2-5; Albuquerque, NM. Proc. RMRS-P-7. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Joseph A. Tainter is Project Leader, Rocky Mountain Research Station, U.S. Department of Agriculture, Forest Service, Albuquerque, NM.

The era since World War II has been particularly transformative in many places, of which it is useful to relate one example. Until World War II communities in this area were relatively isolated and closed. Within a community everyone knew everyone else, the information pool was homogeneous, and decision-making was primarily consensual. There were few differences among people, either technical, social, or economic. The system of land use had been in operation for a very long time. People knew the area intimately, and their subsistence practices were suitable to the environment and sustainable over the long term.

Roads were introduced in the period just after the war, leading to increased contact between villages and with the outside world. This brought new influences and information about the world at large, and new opportunities and ways of doing things. Within villages both the pool of information and community organization began to differentiate. Villages lost some autonomy as they came to be embedded in larger systems at the regional and national levels. As urban ways of living penetrated the countryside, people began to acquire manufactured goods and cash became increasingly important.

The last 50 years have seen much emigration from the villages, as people have moved to the outside world to find work. Social and economic differentiation accelerated, so that no longer could everyone know everything about everyone else. Personal and group interests began to conflict. Subsistence practices changed also. Transformations in cattle grazing meant that fire stopped being used to keep upland pastures clear of competing vegetation. This led to an overgrowth of undesirable woody plants and to erosion.

The natural environment, and how it is used, have been central to the people's cultural heritage. Yet forests in the region are now controlled by the government, and there is frequent conflict between forestry officials and local residents. Organizations external to the area now promote projects to develop the local economy. The great beauty of the area is to be marketed by far-off urban residents to other urban residents. These outsiders bring an ethos in which heritage is to be preserved rather than lived. Forests are to be maintained largely for urban values. The architectural style is to be preserved even though local people can no longer afford it, and no longer have free access to raw materials in the forests.

As local self-sufficiency declined, the region has become more and more dependent on the commercial economy and the government. Today many people, particularly older ones, are supported by government payments. Being embedded in larger systems means that the transformation from autonomy and self-sufficiency to dependency and environmental deterioration is probably irreversible in the near future (Green and others 1998, van der Leeuw and others n.d.).

This is a description of changes, not within the Rio Grande Basin (though it could almost be), but in the region of Epirus in the northwest of Greece. We recognize the account and respond to it because, with a few changes in minor details, it could easily describe what has happened in the Basin over the past 50 years. How is it that two distant and unrelated places could exhibit such strikingly parallel developments?

The answer lies in understanding the scalability of economic and environmental change. The description of Epirus sounds not only like the Rio Grande Basin, but also like many other places that have been transformed in recent decades. These places tend to change along parallel courses because they have become embedded in a global economic system in which participation is rarely optional. To a degree that is generally not understood this system guides the development of localities that were previously unconnected. Places like the Rio Grande Basin or Epirus, once largely autonomous and self-sufficient, may never again control their own destinies.

Social Memory, Hierarchy, and Heterarchy

Epirus exemplifies the problem of scaling in environmental management. The problem concerns the levels at which environmental problems arise, and the levels at which we consider and devise solutions to them. Often these levels exist in blissful ignorance of each other. Take climate change as an example. The Intergovernmental Panel on Climate Change (IPCC) periodically issues reports synthesizing scientific information on this topic. Its most recent report in 1995 was in three volumes, one of which concerned the social and economic dimensions of climate change (Bruce, Lee, and Haites 1995). It is a remarkable compilation, which addresses such pressing matters as adaptation and responses, equity, decision-making frameworks, and economic considerations. Yet within its learned chapters one looks fruitlessly for discussions of scaling, or for sensitivity to the matter, or even, at the very least, for awareness of it.

Scaling in this case concerns the level at which humans respond to environmental change, or attempt to manage it. As befits an organization chartered by the United Nations, IPCC considers adaptation and responses primarily at the level of nations, and within nations, at the level of cities. Discussions of equity, for example, usually turn on relations of developed nations to those in transition. Adaptation is discussed in terms of responses that *nations* might undertake, such as steps to protect coastlines and low-lying areas. Certainly these matters are important, but they are not the considerations of most people who will be affected by climatic or other environmental change. The major part of humanity's adaptation will come at the local level, at a community or regional scale, among people who do not participate in international deliberations and who know nothing of such concepts as international or intergenerational equity, opportunity costs, return on investment, or net present value.

Environmental responses at the local or regional level, including the Rio Grande Basin, reflect the accumulated knowledge of people who have occupied a territory for generations, and who have learned through long experience

how to respond to change (McIntosh, Tainter, and McIntosh n.d.). Environmental responses at this level are based on knowledge of which national governments, and international organizations such as IPCC, are typically unaware. Carole Crumley, for example, has studied traditional farming and gardening practices in the Burgundian region of France (Crumley n.d.). Millennia of experience with local conditions have given these people knowledge to farm sustainably. Yet as the French government accedes to international demands for open markets, local production systems are being destroyed. The result for the French government is tractor parades of angry farmers through Paris. In Burgundy the consequences are more serious: to compete in international markets these farmers must expand their scale of production. Hedgerows are being destroyed to allow for larger fields, and centuries-old conservation practices are being abandoned. Closer to home, similar problems generated by the North American Free Trade Agreement have damaged subsistence farmers in southern Mexico, and contributed to the grievances fueling the rebellion in Chiapas. Meanwhile, in the Rio Grande Basin, we seem increasingly to worry about farmland preservation less as a fundamental aspect of our lives, and more as a quaint curiosity, part of our conception of a picturesque landscape.

In a world that has become globally interconnected we will increasingly experience conflict between action at the local level and actions at higher levels. Environmental action at the local level, among people who have occupied a region for much time, is initiated on the basis of what has been termed *social memory* (McIntosh, Tainter, and McIntosh n.d.). Social memory is the mechanism by which local-level societies retain, transmit, and modify knowledge of the environment, its past changes, and successful responses to those changes. Social memory is encoded in the very things that form the basis of life in small communities: cosmology, myths, rituals, stories, and drama. Social memory is active in all communities, even those that are part of nations with scientific traditions. The Burgundians studied by Carole Crumley (n.d.), for example, encode knowledge of environmental variation in sayings and aphorisms that guide how they prepare and tend vegetable gardens. Gardening in turn serves as a repository of knowledge and experience about broader environmental variation. On the other side of the world, China possess perhaps the oldest continuous tradition of social memory (Hsu n.d.). Proverbs predict how one state of weather leads to another, while pragmatic observations on the environment are encoded in poems and songs. These traditions have been transmitted for centuries. The people of the Rio Grande Basin have had a similarly rich tradition of environmental knowledge, extending over a century in the case of Anglo-Americans, for several centuries among Hispanos, Apaches, and Navajos, and even longer among Puebloans.

A physical remnant of this tradition can be found south of Tijeras Canyon, along an old state highway that runs parallel to but largely hidden from the current road. It was a narrow, curving road, meant to be driven at slow speeds. Amidst rock art of the 14th century there is a sign from earlier this century, hand painted on a limestone cliff. It advertises, in a characteristically New Mexican combination of Spanish and English, that "Curandera cures all." Whoever this *curandera* was, she carried a long tradition

about the medicinal use of local plants. It is an example of what we call social memory. Her tradition still exists, though many New Mexicans, newly arrived and working for some modern institution, will be unaware of it. It is a tradition that can no longer galvanize social action to the extent that it once did.

Responses to environmental challenges can be categorized by the channels through which they are initiated. In broad terms these channels can be termed *hierarchical* and *heterarchical*. The meaning of hierarchy is widely understood. In a social context it refers to people or institutions that are ranked relative to each other, and connotes authority and power. Heterarchy, a term coined by Carole Crumley (1979: 144), means just the opposite: a social condition in which people or institutions are unranked relative to each other, or can be situationally ranked in a number of ways. Of course most societies today incorporate elements of both hierarchy and heterarchy. The communities of central and northern New Mexico in the 18th century could be viewed as a heterarchy, but they were in turn linked hierarchically through Santa Fe to the government in Mexico City, and ultimately to the Spanish Crown. The villages of Epirus in the 1930s similarly formed a local heterarchy, linked weakly to the national government in Athens.

Hierarchy and heterarchy differ in the speed and scale at which they respond to challenges, in the rates at which they change, and in their appropriateness for different situations. We usually think of hierarchies in an active sense: passing laws, setting policies, issuing orders, or establishing budgets. Higher levels do constrain lower levels in this way, but much of the time they do so in ways that are not intuitively obvious. Higher levels often constrain those further down by *not* acting, or by acting slowly (Allen and Starr 1982, Allen and Hoekstra 1992, Ahl and Allen 1996). Elites limit the behavior of subordinates by being unresponsive. While the lower levels in a social hierarchy go about the high-frequency business of daily life, the higher levels slowly issues edicts or grant appeals.

In human societies as in most living systems, information flows to higher levels and controls operate downward. Higher levels respond not to the primary forces felt by lower levels, but to information about those forces. Information flowing upward is always filtered, becoming ever more abstract and disconnected from its source, while at the same time higher levels are notoriously unresponsive to signals from below. What hierarchies do respond to is horizontal social signals—messages from or about other elites. A Russian colleague, for example, once described to me how Mikhail Gorbachev behaved in the waning days of the Soviet Union. As the union crumbled about him, and its citizens and security forces battled in the streets, the information that mattered to Gorbachev was not the needs of lower levels but his reputation in the minds of Western leaders. Along analogous lines, in August 1996 there was much discussion of establishing a high-speed rail line between Moscow and St. Petersburg. At the same time the local rails within St. Petersburg were so dilapidated that in places they ran over mud. The upper levels of civil administration in St. Petersburg responded to horizontal signals from civic elites in Moscow, while responding callously to local distress.

This may sound like hierarchy is merely a useless parasite, utterly unsuited to solving local problems. In fact

hierarchy has distinct advantages that heterarchy can never match. The advantages of hierarchy are that it can act quickly, uniformly, and over large areas. Hierarchy conveys the authority to mobilize communities to act, and to act expeditiously. Hierarchy can mobilize resources for an effective response, and can ensure that resources are distributed equitably. What hierarchy typically cannot do is to respond quickly and effectively to signals from below about new or unusual problems. Our own disaster-relief agencies, for example, have become adept at responding to flooding in the Mississippi Basin, but take excruciatingly longer to address a more unusual problem such as a catastrophic snowfall in southeastern New Mexico. National governments may unwittingly undermine traditional production systems, such as in Burgundy, because they respond to horizontal social signals, while information from below must always struggle upstream.

Heterarchy, while not so effective at mobilizing quick, large-scale responses, is better able to acknowledge and incorporate varieties of experience. Heterarchical systems work either by consensus, or by *ad hoc* consensual leadership. While the process of adjusting to new circumstances in a heterarchy is unavoidable slow, it derives legitimacy from consensus. It is based on local experience and social memory. Those who have developed a heterarchical consensus are intrinsically committed to implementing it. Yet heterarchy, like hierarchy, is by itself incomplete. While heterarchy has the advantage of incorporating diverse experiences and ensuring legitimacy of decision-making, it falters where conditions call for rapid or uniform responses, or where problems arise from outside a local context. Social memory is also far from faultless. Fekri Hassan relates a story of an advisor to the Egyptian government, who insisted that he had detected a pattern to the Nile floods of seven years of high water, seven years of low, and six years of intermediate levels. In fact the advisor had detected no such thing, and admitted privately that his model was inspired by the Koran. The inspiration is actually far older than the Koran. The advisor, probably unknowingly, perpetuated a long tradition of Egyptian social memory, which has a documented history of over four thousand years, and which is reflected in the Biblical tale of seven years of plenty followed by seven years of famine (Hassan n.d.). Local social memory, formed through heterarchies, may sometimes be a suitable guide for action, but it can also be nothing more than fable.

Scale, Context, and Landscape Change

This meandering discussion has come in a roundabout fashion to one of the fundamental dilemmas of our time: whether to confront our problems top-down, through our national government or even international conventions, or from the bottom up, based on local experiences. This dilemma, as we know, frames much of our national debate, and in various guises dominates our headlines. The dilemma becomes poignant as we realize that for the most part there are no answers or solutions that are unambiguously right or wrong. Neither hierarchy nor heterarchy is invariably appropriate or misguided. Their usefulness depends on circumstances. In a world that is interconnected at many

levels—in which the air of Albuquerque can be turned to haze by fires in southern Mexico, (such as in the third week in May, 1998), in which warming of equatorial waters increases profits for Mesilla lettuce farmers while it increases disease in the San Juan Basin—we realize that ever-closer scrutiny of our problems will likely reveal only finer and finer shades of gray. This underscores again the centrality of scaling and context, and particularly the problems that inevitably arise when there is a contradiction between the level at which problems are generated and the level at which they must be addressed.

My colleague Tim Allen is fond of saying that if fish were scientists, the last thing they would discover would be water (for example, Allen, Tainter, and Hoekstra n.d.). His point is that the most difficult matter to comprehend is the context that constrains us. It is always difficult to understand something larger than ourselves, and that is what context is (Allen and Hoekstra 1992). In a global marketplace in which the fiscal crisis in Asia may influence the level of water use in microprocessor manufacturing, and ultimately how long farmers in the Rio Grande Basin will be able to irrigate alfalfa, trying to understand our context is surely one of the most important things we can do.

The dilemma we ultimately face is that our context is increasingly distant, impersonal, unaware of us, and uncaring. In the eighteenth century the Spanish Crown probably also seemed distant, impersonal, unaware, and uncaring, but it also had little influence in the day-to-day lives of New Mexicans. Today New Mexico may be affected by decisions made on Wall Street, in Tokyo, or in the Persian Gulf, or even by the actions of angry mobs in Indonesia. The control of our local affairs is more and more in external hands.

Although the universality with which this is happening is peculiar to our era, there are precedents for it. It is worth reviewing one of these precedents briefly, for it allows us to see the long-term consequences of a locality losing control of its destiny. In the civilizations of the ancient Mediterranean, agriculture was the basis of wealth and power. The ideal landscape was one of peasant farmers producing food for the cities, sons for the armies, and taxes for the state. This was the energetic basis of the Greek city-state, and it formed a landscape in which events and processes were substantially under local control.

This began to change when Alexander the Great conquered the Near East toward the end of the fourth century B.C. The large Hellenistic kingdoms that formed in the wake of his conquests hired large armies of Greek mercenary soldiers. Suddenly Greek peasants had opportunities on an unprecedented scale to earn gold and silver serving as soldiers in Syria or Egypt, rather than farming laboriously for meager subsistence in the poor soil of Greece. The Greek countryside began increasingly to lose population from the second century B.C. When the Romans came to Greece they expropriated so much treasure that for small farmers there was a liquidity crisis. They could not earn money to pay their debts and began to lose their lands to the wealthy. The Greek landscape of peasant proprietors changed to one of ostentatious villas, owned by oligarchs who used the land less intensively—for exportable cash crops such as olive oil, wine, or livestock, and to raise prize horses and cattle. By the second century A.D. writers described the Greek countryside as unkempt and underpopulated—a sad reflection of its

former productivity. Ironically, cities flourished in this era, as oligarchs put their wealth into building public monuments. The magnificent ancient cities of the Mediterranean Basin, which we admire so much today, were partly built on the basis of rural depopulation. Greece has, in some ways, never recovered from this.

By the third century A.D. the Roman Empire was fighting for its own survival against Germanic peoples from the north and the Persians from the east. It financed its wars largely from taxes on land. It came to require that taxes be paid whether a plot of land was cultivated or not, and so tried to force underutilized lands back into production. The Greek landscape came to be repopulated, but not by a free peasantry. Farmers from the fourth century on were legally tied to their lands, or attached as tenants to great estates. These obligations were hereditary, a foretaste of the social conditions of the Middle Ages (Alcock 1993, Allen, Tainter, and Hoekstra n.d.).

The unfortunate story of the Greek landscape is one of changing context. In the era of city-states the Greek landscape developed under local control, responded to local needs, and supported the local population—much as the landscape of the Rio Grande Basin did until recently. Developments far off brought Greek independence to an end. As political units grew in size and scale, the context for the Greek landscape shifted first to the entire Near East, then to the Roman Empire and the Mediterranean Basin, then beyond the borders of the empire to the pressures exerted from central Europe and central Asia. Similarly we participate now in a Rio Grande landscape that came in the 19th century to be embedded in distant processes at national and continental scales, and in the 20th century in the international arena. We might wonder whether we have any more power to control our landscape today than the Greeks did 2,000 years ago.

Ecosystem Management: Understanding Context

As the context for the Greek landscape shifted to ever-larger arenas, in a process that extended over centuries, the Greeks lost the ability to understand what was happening to them. To lack comprehension of one's context, or the ability to influence it, makes for a depressing tale. It is also a common tale. In the first century B.C. (to give a final historical example) the Romans financed their continuous foreign and civil wars with very high production of silver coins. The metal was produced from silver-bearing lead ores, and the smelting process caused atmospheric lead pollution that circled at least the entire northern hemisphere and left a signature in the Greenland ice cap (Hong and others 1994). It is a remarkable story of context. As Marc Antony and Cleopatra dallied in the eastern Mediterranean, the silver coins they minted to pay their armies caused American Indians in the Rio Grande Basin to breathe air polluted by levels of lead not seen again until the Industrial Revolution.

The prehistoric New Mexicans of that era could not, of course, have understood this process, if they were even aware that something in their air was wrong. They could not know their context. I relate this story, and that of the Greek landscape, to show how fortunate we actually are in the

midst of all our challenges. As we have lost direct connection with our context we have also gained the ability to understand it, and that is the first step toward influencing it. We have the capacity, more than the people of any previous era, to know where we are in long-term historical processes (Tainter 1988, 1995), in the international economy, and in global environmental concerns.

We face, as I have sketched, contradictions between the levels at which problems are generated and at which they must be addressed. Many of us would no doubt prefer that local environmental problems be addressed on the basis of local experience, social memory, and heterarchy, and be resolved sustainably on the basis of local resources. Yet challenges arising from such things as atmospheric circulation patterns or international monetary flows bring us to a world of problem-solving where we depend on hierarchy, centralized solutions, and external subsidies. In such a world we will always face conflict between local and centralized problem-solving. Our approach to this conflict should start by taking advantage of the remarkable levels of knowledge that are available about our national and international context. Resolving problems locally requires equal doses of knowledge about the Basin itself and about the world at large. It is unrealistic to expect that our context will ever know us sufficiently well to avoid the sort of problem that the French government caused in Burgundy. It is our responsibility to understand our context.

As the processes at work in the world call for broader and broader realms of knowledge, most of us specialize in narrower and narrower pursuits—this or that species, or watershed, or cultural group. Accordingly we fail to see connections that ultimately we must understand, connections that form the essence of ecosystem management. How many of us would recognize that welfare reform, to take one example, is pertinent to ecosystem management? How many of us realize that for rural areas there is a fundamental contradiction between welfare reform and environmental conflict? As judicial decisions deprive rural people of their livelihoods, more and more will move to cities. Rural traditions of local knowledge, social memory, and heterarchy will decline, while the hierarchical, centralized cities will grow larger, more congested, and more polluted. Environmental protection in one area may simply shift environmental problems elsewhere.

To have the capacity to understand our context is meaningful only if we take advantage of it. We are challenged not only to develop the ability to see connections between disparate things, but more fundamentally, to change how we think so that it becomes normal and unremarkable to do so. This is the only way that the problems of the Rio Grande Basin will be understood, the best way that conflicts can be resolved, and the only way that we can discern the appropriate, ever-shifting balance among local, national, and international solutions. As the Forest Service and other agencies have developed the concept of ecosystem management in recent years, many have wondered what the term means. I suggest that it should mean precisely these matters of scale, context, and interconnection. These link the biophysical and social realms in a bond that we can dissolve artificially in specialized scientific analyses or in environmental litigation, but which can never be dissolved in actuality.

Acknowledgments

I am pleased to express my appreciation to Dr. Deborah Finch for the invitation to present this paper as a plenary address in the symposium "Rio Grande Ecosystems: Linking Land, Water, and People" (Albuquerque, 2-5 June 1998), and to Dr. T. F. H. Allen and Dr. Dale Brockway for comments on an earlier draft.

References

- Ahl, Valerie; Allen, T. F. H. 1996. *Hierarchy Theory: A Vision, Vocabulary, and Epistemology*. New York: Columbia University Press.
- Alcock, Susan E. 1993. *Graecia Capta: The Landscapes of Roman Greece*. Cambridge: Cambridge University Press.
- Allen, T. F. H.; Hoekstra, Thomas W. 1992. *Toward a Unified Ecology*. New York: Columbia University Press.
- Allen, T. F. H.; Starr, Thomas B. 1982. *Hierarchy: Perspectives for Ecological Complexity*. Chicago: University of Chicago Press.
- Allen, T. F. H.; Tainter, Joseph A.; Hoekstra, Thomas W. n.d. *Supply-Side Sustainability*. New York: Columbia University Press (in preparation).
- Bruce, James P.; Lee, Hoesung; Haites, Erik F., eds. 1996. *Climate Change 1995: Economic and Social Dimensions of Climate Change*. Cambridge: Cambridge University Press.
- Crumley, Carole L. 1979. Three locational models: an epistemological assessment of anthropology and archaeology. In: Schiffer, Michael B., ed. *Advances in Archaeological Method and Theory* 2: 141-173. New York: Academic Press.
- Crumley, Carole L. n.d. From garden to globe: linking time and space with meaning and memory. In: McIntosh, Roderick J.; Tainter, Joseph A.; McIntosh, Susan Keech, eds. *The Way the Wind Blows: Climate, History, and Human Action*. New York: Columbia University Press (in press).
- Green, S. F., G. P. C. King, V. Nitsiakos, and S. E. van der Leeuw. 1998. Landscape perception in Epirus in the late 20th century. In: S. E. van der Leeuw, ed. *The Archaeomedes Project: Understanding the Natural and Anthropogenic Causes of Land Degradation and Desertification in the Mediterranean Basin*, pp. 329-359. Luxembourg: Office for Official Publications of the European Communities.
- Hassan, Fekri. n.d. Environmental perception and human responses in history and prehistory. In: McIntosh, Roderick J.; Tainter, Joseph A.; McIntosh, Susan Keech, eds. *The Way the Wind Blows: Climate, History, and Human Action*. New York: Columbia University Press (in press).
- Hong, Sungmin; Candelone, Jean-Pierre; Patterson, Clair C.; Bouton, Claude F. 1994. Greenland ice evidence of hemispheric lead pollution two millennia ago by Greek and Roman civilizations. *Science* 265: 1841-1843.
- Hsu, Cho-yun. n.d. Chinese attitudes toward climate. In: McIntosh, Roderick J.; Tainter, Joseph A.; McIntosh, Susan Keech, eds. *The Way the Wind Blows: Climate, History, and Human Action*. New York: Columbia University Press (in press).
- McIntosh, Roderick J.; Tainter, Joseph A.; McIntosh, Susan Keech. n.d. Climate, history, and human action. In: McIntosh, Roderick J.; Tainter, Joseph A.; McIntosh, Susan Keech, eds. *The Way the Wind Blows: Climate, History, and Human Action*. New York: Columbia University Press (in press).
- Tainter, Joseph A. 1988. *The Collapse of Complex Societies*. Cambridge: Cambridge University Press.
- Tainter, Joseph A. 1995. Sustainability of complex societies. *Futures* 27: 397-407.
- van der Leeuw, S. E.; ARCHAEOEMEDS Research Team. n.d. Land degradation as a socio-natural process. In: McIntosh, Roderick J.; Tainter, Joseph A.; McIntosh, Susan Keech, eds. *The Way the Wind Blows: Climate, History, and Human Action*. New York: Columbia University Press (in press).