PART 1
Climate and Culture

Chapter 1

Human Agency, Climate Change, and Culture: An Archaeological Perspective

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Introduction

In 1914, the geologist and explorer J. W. Gregory inquired if the earth was drying up. He surveyed various sources of data from Scandinavia to China and concluded that there was, in general, no evidence of climate change in historical times. Furthermore, Gregory noted that there was a great deal of controversy concerning paleoclimatic interpretations and the probable causes of climate change. Today, our knowledge of climate change in historical times has improved immensely (Mayewski et al. 2004; Shulmeister et al. 2006), yet we are still not clear about the magnitude, scale, timing and frequency of climatic changes, and are unable to provide conclusive evidence of the causes of certain paleoclimatic events (for news on current research on past global changes see the PAGES project [Past Global Changes]).[1] We are also far from certain of the probable impact of climate change on the trajectory of human history. H. H. Lamb (1982), in his seminal volume *Climate History and the Modern World*, reviews in detail both the lack of sufficient paleoclimatological data and, more importantly, the limitations of our methodologies and our interpretative strategies.

Climate change is no longer a matter solely of academic interest. People throughout the world are now aware of the impact of climate change on contemporary societies. For example, when the Sahelian droughts in the 1970s caused severe famines threatening the lives of millions of Africans, most scholars agreed that the droughts were, in part, caused by human activities, such as land use, overgrazing, overfarming, inappropriate irrigation, and inadequate governmental policies (Hulme 2001; Reynolds and Smith 2001; Zeng 2003). This spurred debate over the exact role of human activities in land degradation and droughts and ushered in an increasing appreciation of human agency in environmental change.

This chapter elucidates the intractable and complex interrelationship between climate and human societies with a plea to overcome simplistic notions of determinism and indeterminacy. Climate, as I show through case studies in Southwest Asia and North Africa, played a major role in the origins of agriculture, the emergence of state societies, and the temporary breakdown of the centralized organization of complex state societies. However, the impact of any climatic event depends on the local ecological setting and the organizational complexity, scale, ideology, technology, and social values of the local population. It is only through long-term archaeological and historical analysis, as well as detailed examination of the social dynamics on local and regional scales within an interregional framework, that we can begin to detect the differential impact of the same climatic event.

I wish here to emphasize the rigor needed to make any assertion of the causal role of climate. It is misleading, for example, to list the frequency of radiocarbon age determinations as a proxy to climate change, or to cull a selection of a few archaeological cases from different regional and temporal contexts to underscore the role of climate in the "collapse" of civilizations on the basis of dubious chronological determinations, climatic reconstructions, and cultural interpretations. Frequencies of radiocarbon age measurements of archaeological occurrences are not directly a function of intensity of human occupation, but more so of a series of formation processes as well as the intensity of archaeological research and dating objectives. It is important to infer climatic events from well-dated geological and environmental proxies. Archaeologists also need to pay attention to the screening of radiocarbon data to ensure that they accurately date the event under consideration. Precision in this can be improved by the use of multiple measurements and statistical analysis. In this chapter, I report events based on radiocarbon age determinations as calibrated radiocarbon years before present (cal BP).

At present, new drilling methods to obtain samples, dating, and analytical techniques have improved our current understanding of climate change. Data retrieved over the last two decades have shown that climate change is not always gradual or cyclical, but that dramatic shifts in climate can take place rapidly (Allen and Anderson 1993; Street-Perrott and Perrott 1990). Such rapid events occur within less than a century and the change can be quite severe (Adams, Maslin, and Thomas 1999; Rahmstorf 2001; Taylor 1999). One of the most remarkable transitions, which had a major impact on the history of humankind, was the end of the last major cold spell, a period known as the Younger Dryas. A large part of this global switch from cold to warm climate took less than twenty years: "There was no warning. A threshold was crossed, and the climate in much of the world shifted abruptly from cold to warm" (Taylor 1999, 323). Abrupt climatic events are not just rapid; they are also breaking points, thresholds resulting from strongly nonlinear responses to "forcing"[2] (Rahmstorf 2001, 2). Rahmstorf singles out an event, dated to 8,200 years ago during the Holocene that shows a spike in arctic ice cores, which affected the North Atlantic. He also recognizes the abrupt desertification of the Sahara 5,500 years ago with evidence from Atlantic sediments off northeastern Africa that show a sudden and dramatic step-function increase in wind-blown dust, indicative of the drying of the African continent. Similarly, the last ice age, like previous ice ages, was punctuated by abrupt climatic transitions.[3]

I also wish to emphasize the role of human agency. Different groups guided by the decisions of all or key figures in the community seem to pursue different strategies in coping with a climatic crisis in their region. However, it seems that the choice is limited to a few options at any one time, and that certain options seem to be favored by the majority of the population. Further, interaction within and between regions seems to provide different groups with the choice of reconsidering their position. In some cases they may adopt or adapt certain innovations that they deem to be advantageous. However, people inevitably make decisions on the basis of subjective probabilities, biased information derived from anecdotal evidence, and prejudicial positions based on their values and worldviews. Additionally, the long-term consequences of any decision are not, in most cases, apparent within the lifetime of a person or a couple of generations. It is thanks to human ingenuity, not climate change, that in responding to environmental crises or endogenous cultural perturbations (Hassan 1993) people tend to make adjustments to sustain their modes of life. In so doing, they unwittingly set the stage for new problems that future generations have to cope with.

Endowed with the vision of a "good life" and the capacity to modify habitats, people have introduced changes that ultimately lead to the emergence of new conditions that expand their capability of modifying their environment. Today we have reached the point at which our human impact now extends to a modification of the forces that regulate the climate of our planet (Goudie 1993; Hassan 1992; Redman 2004). Our environmental impact has increased with our continued expansion and intensification of food production and industrial products, caused by adapting agriculture, developing complex managerial organizations (state societies), expanding the size of the labor force, and utilizing progressively more powerful sources of energy beginning with draft animals and ending with nuclear power. In the meantime, our numbers have soared from a few million during the Pleistocene to more than six billion today, with unprecedented rates of population increase over the last one hundred years (Lutz, Sanderson, and Scherbov 2004).

Clearly our modern crises are not caused solely by climate change. But today, as in the past, societies become vulnerable to millennial or centennial climatic changes because they do not recall or anticipate abrupt, severe climatic events that are outside the range of human reckoning and collective memory (Hassan 2000b). People and societies, as my analysis of agricultural origins in this chapter shows, are conservative. They tend to guard and cling to the paradigms, values, and institutions that have proved to be successful in their own past based on coping with decadal fluctuations in climate change or multigenerational social perturbations. As a result they are reluctant to undertake corrective actions that go against their social grain—for example, moving from a mobile subsistence economy to a settled economy (a process that took more than five thousand years in the Levant). The veneration for old habits, which may become encoded in religious precepts, is in most cases advantageous, but it is harmful if adhered to dogmatically in all cases given endogenous cultural developments and novel external conditions. Today certain interest groups in many countries are still reluctant to accept the impact of climate change on current and future human affairs. In so doing they miss not only the lessons from world history, but also the opportunity to examine the social dimensions of climate change critically.

Also, because modern industrial nations overvalue industry and science, current efforts to cope with climate change focus on reducing emissions or the use of new alternate technologies instead of considering the social dimensions of climate change. Studies of climate change are still dominated by climatologists and environmental scientists, though the last few years have witnessed some overtures for collaboration among social and environmental scientists (see Costanza, Graumlich, and Steffan 2007; Costanza et al. 2007; Dearing, Cromer, and Kiefer 2007).

The threat of climate change may divert our attention from the explosive nature of our postindustrial world, with its inequities and mass poverty, expanding population, progressive organizational complexification, and spiraling demands for critical resources. These factors compound the danger from climate change. We should recall that climate change, as in the case of the Classic Maya civilization, may be a catalyst hastening collapse.

In the following sections I discuss the problem of confusing correlation and causation and the role of human agency in recognizing and responding to climate change with reference to the limitation of the human scale. I then review the main millennial climatic events that influenced the course of human history over the last 13,000 years to illustrate the frequency of abrupt, severe events that humans have had to cope with since the emergence of humankind. I subsequently deal briefly with the role of climatic events in the peopling of the world during the last 100,000 years, followed by a summary of the role of climate change in the origins of food production, with a primary focus on Southwest Asia and North Africa. This discussion reveals the importance of regional expressions of climate change and the role of independent innovations that converge toward similar solutions following a similar sequence in historical developments. I then deal with the impact of climate change on the spread of food production to other parts of the world and the beginning of significant cultural differentiation under varying environmental conditions. The last part of this chapter considers the origins and collapse of civilizations in different parts of the world to illustrate that the impact of severe abrupt climatic events is not necessarily negative. This should serve as an antidote to sensationalist accounts of the role of climate in destroying civilizations.

Correlation, Causation, and Oversimplification

Archaeologists have for a long time debated the role of climate change in human affairs. Gordon Childe (1928, 1934) made one of the most influential contributions with his contention that desiccation by the end of the glacial period led to the emergence of agriculture, as people congregated along river courses and within the orbit of oases, where conditions were appropriate for the domestication of plants and animals. The relationship between climate change and the origins of food production was revisited in the 1960s, as Binford (1968) linked post-Pleistocene climatic events with agricultural origins in arid regions. He hypothesized that a worldwide change in sea level in post-Pleistocene times led to a greater exploitation of fish and other aquatic resources, which prompted sedentary settlements and rapid population increase where food resources were abundant. Excess population from such optimal zones was forced into less productive, marginal habitats where food production was initiated out of necessity.

More recently, Weiss highlighted the causal role of climate in cultural evolution (Weiss et al. 1993). Together with Bradley et al. (2001, 610), by making use of high-resolution paleoclimatic data they argued that climate change has been a primary agent in repeated social collapse. However, such generalizations fail to acknowledge the intricate relationship between human agency and the impact of climate change on societies. Archaeologists have been hampered in the past by crude data on climate change and poorly dated environmental and cultural events. Explanations based on climatic forcing depended upon rough correlations, which were often hastily translated to causal linkages with climate playing a determining role.

Correlations are uncertain because climatologists still do not agree on the mechanisms and details of climate change during the last 10,000 years (the Holocene) in spite of attempts since 1983 to using radiocarbon dating (Bond et al. 1997). In addition, some climatic events are global, while others are regional or local. In some cases, in the absence of well-dated climatic records in an area, correlation with global events may be erroneous when local evidence is lacking. Moreover, some global events are time transgressive and may not be of the same amplitude, duration, or even direction (e.g., wet episodes may be synchronous with dry events) in different regions.

Even when adequate records of climate change and high-resolution archaeological data exist for a given region, other appropriate information—for example, on rates of depopulation and relocation and the extent of famines, morbidities, or land use—needed to explain the causal role of climate change may be lacking. This may be due to the selective nature of the archaeological record or lack of sufficient archaeological research. There are also only a few special cases when there are high-resolution and appropriate data both for climate change and cultural developments to allow for credible assertions on the causal links between climate and culture. To establish such causal links, it is imperative to show how climate change influences human activities through its impact on surface and groundwater resources, availability and quality of food, settlements, transportation, industry, trade, or any other cultural variables influenced directly or indirectly by changes in climatic parameters. That a drought may have led to the "collapse" of a civilization or to a dramatic cultural transformation may be intuitively appealing, but that is not sufficient to validate any such claims, since droughts are common and climate is constantly changing.

Today, the realizations not only that climate changes over millennia, but also that drastic shifts in climate can and did occur within a century or less, make it possible to comprehend how abrupt climatic events could have been influential in the course of human history. People are likely to respond to climatic signals if they are within the scope of their perceptual span. Climatic events that are not perceptible or too distant in the past are not likely to be effective in the way people react to their environment (Hassan 2000b).

Human Agency, Scale, and Adaptability

An appreciation of the role of human agency is essential if we are to make any sense of the impact of climate change on human societies. Societies vary in their size, scale of organization, social differentiation, subsistence activities, productive strategies, ideologies, and worldviews. They are maintained, reproduced, and transformed as a result of the impact of day-to-day practices by individuals who are constrained by their perceptions, beliefs, norms, values, and mind-sets (cognitive schemata). They are likely to maintain or alter their practices and ideas subject to what they perceive to be positive or negative outcomes of their actions (Craik 1972). Neither the past nor the future is too far from the present when it comes to making decisions, because people consciously or routinely select from among alternatives based on their past experiences and future plans and possibilities.

Perceptions of climate change can only be assessed through tangible proxies within the purview of the culturally conditioned canons of perception and comprehension. In a hunting-gathering society, the group is small and differentiation of occupations is minimal. In addition, such groups are intimately familiar with the seasonality, condition, and changes in the location of game and wild plants. They are also familiar with different habitats over a large region. Within that context they are likely to detect environmental change that may ultimately be directly or indirectly related to climate change, but might also be due to changes in endogenous landscape responses or to overhunting or overexploitation of certain resources.

Climatic change can only be inferred from proxies. Among all potential proxies, those that will be observed are those that are pertinent and relevant to the life support system, comfort, and sense of aesthetics among other natural phenomena that an individual or a group consider of interest and value. In addition to perceptions of changes in amount of rainfall, seasonality, frost, wind, heat, and humidity, changes in climate are likely to lead to noticeable changes in surface water distribution, vegetation, animals, and geomorphological and sedimentary processes such as soil erosion, deflation, or invasion by sand dunes (Bridges 1997; Derbyshire 1997; Lawlor 1997; Mannion 1997; Stonehouse 1997; Whitehead 1997). In dealing with climate change and human responses it is crucial to employ both an ecological approach and a focus on landscape ecologies (see Burel and Baudry 2003; Cordova 2007). It is now becoming clear that ecological responses to climate change over the last fifty years were associated with major shifts in the distribution of species (Walther et al. 2002) and that abrupt climate change can have catastrophic ecological consequences (Davis and Shaw 2001; Scheffer et al. 2001).

Information gained from individual experiences is likely to be shared by members of hunting bands, as well as among other bands that habitually come in contact with each other. It is also likely that practices that ensure survival in the face of food shortage, cold nights, or lack of critical resources will be adopted and shared within and between groups. Given that climate changes on millennial, centennial, and decadal scales, people are not likely to recall millennial or centennial events, and are more likely to recall extreme events that have been experienced in their lifetime or by others in the community who often span no more than three generations, or roughly sixty years (Hassan 2000b). More distant memories are likely to fade exponentially with a selective retention of those that have caused severe hardships and loss of life. Given interannual variability in climatic conditions, people are most likely to respond to such “routine,” predictable change by regulating the size of a group, mobility, and other means of coping. They are also likely to have set responses for dealing with decadal changes, but are not likely to have a stock of actions in response to widely spaced centennial to millennial events.

Smithers and Smit (1997) provide a useful guide for interpreting the impact of climatic perturbations on social “systems” and the probable adaptive responses. The intensity of the impact depends on the magnitude, areal extent, frequency, duration, and suddenness of the climatic disturbance. The system will respond depending on its stability, resilience, vulnerability, flexibility, and scale. As a result the system will either fail (collapse) if people are incapable of overcoming the negative impact of climate change in time or undergo remedial actions if people do not or cannot act in time through effective coping mechanisms.

In the following section, I discuss briefly one of the well-recorded climatic events and its implications for cultural responses.

Global Climatic Events—the “Medieval Warming Period”

Analysis of the series of Nile floods dating back to the seventh century AD, which serves as a proxy to climate changes below the millennial scale, reveal decadal variations in the amount of Nile flood discharge in the range of

40 years (from 20 to 50 years) with four episodes lasting from 120 to 170 years and an average of 140 years. Over a period of 1,220 years, historical accounts highlight the recurrence of stressful events from the tenth to fourteenth centuries when severe famines, civil disorder, depopulation, and plagues were attributed to the vagaries of Nile flood discharge. Recent analysis of the frequency of extremely low or excessively high Nile floods revealed that these famines coincided with an increase in the frequency of extreme events, and a reduction in their spacing (Hassan 2007b). Such episodes linger and become a part of collective memory, triggering human responses that lead to new practices or ideas that may then become normative and precipitate structural changes in social organization, ideology, or productive technologies.

It is clearly not coincidental that the extreme fluctuations in Nile floods and associated famine were synchronous with dramatic climatic changes in Europe during the period that came to be known as the Medieval Warm Period, described by H. H. Lamb in his pioneering work *Climate, History and the Modern World* (1982). This period has become known as a time when Norse farmsteads were established in Greenland, vineyards flourished in sunny central England, and barley and wheat were grown in south Iceland. This was also a time that "saw a great expansion of European civilization" (Street-Perrot 1994, 518). Although the magnitude, duration, and geographical extent of this period have been debated, it is becoming clear that it was a global event with different manifestations in different regions. A study of relict tree stumps rooted in present-day lakes, marshes, and streams in California (Stine 1994) revealed that sustained droughts occurred in two clearly separable intervals in AD 892–1112 and 1209–1350. Similarly, recent analysis of Nile floods reveals that the period from the ninth to fifteenth centuries was not uniform but was characterized by critical flip-flop transitions from one climatic regime to another at AD 900, 1010, 1070, 1180, 1350, and 1400 (plus or minus twenty years).

Recent reexaminations of the Medieval Warm Period (MWP) narrow this period to AD 890–1170, when warmth is indicated across a number of temperature proxy data from the Northern Hemisphere (Osborn and Briffa 2006). Hughes and Diaz (1994) observed also that the period from the ninth to fourteenth centuries AD was warmer for some regions, particularly during the summer, than those that prevailed until the recent decades of the twentieth century. These regions included Scandinavia, China, the Sierra Nevada in California, the Canadian Rockies, and Tasmania. However, these warm episodes were not strongly synchronous. Other regions such as southwest United States, southern Europe along the Mediterranean, and parts of South America do not reveal such warming conditions. Similarly, the medieval climate was clearly unusual in some areas, but studies of large-scale climate variations reveal that some regions do not follow the global or hemispheric trend (Bradley et al. 2001). Further, the warmest medieval temperature was not synchronous around the globe, and the High Medieval period (AD 1100–1200) was not warmer than the late twentieth century (Bradley, Hughes, and Diaz 2003).

The so-called Medieval Warm Period does not in fact represent warming conditions throughout the world. It was a complex phenomenon that probably was expressed differently in different regions, with different impacts on local environmental conditions. This period may thus serve as an analogue for other case studies in which high-resolution climatic and historical data are missing.

Archaeologists should be aware of the ambiguities and uncertainties of paleoclimatic reconstructions before embarking on oversimplified generalizations. On the other hand, it is certainly possible that certain global events that were sufficiently severe and extensive have had an impact on the course of human societies. Global extreme events occur at a millennial scale and can have an indelible impact on human life support systems. The effect of such events, however, depends on the scale of societies, their ability to rebound without significant structural changes, and the potential to take timely remedial actions to sustain viable populations. In many cases, cultural developments in response to climate change in one area can influence adjacent populations. They are also likely to lead to further social changes that can, in the long run, lead to a transformation of the overall identity of society, thus marking a transition from one cultural state to another.

Climatic Events and Human Dispersal: The Peopling of the World

Before agriculture, the effect of severe climatic events led mostly to dispersal into more favorable regions, extinctions, or small incremental change in technology and land use. This was probably because early humans were on a foraging track with an emphasis on the improvement of hunting and food collection technologies, including hunting implements and strategies. The number of foragers was small; their organization was minimal to allow them to disband and regroup as needed in the face of food shortages and in order to roam over large areas. Throughout a history of numerous glaciations and warm periods, early humans spread out of Africa to populate most of the inhabited world by the end of the last glacial maximum. The option of dispersal was congruent with a mobile mode of subsistence. It was also unhindered by fixed territorial ethos or a strong affiliation to a permanent group identity. Dispersal and adaptation to new habitats led, by the end of the last glacial, to a world of foragers in very different world biomes with advanced stone technologies well tuned to their habitats (Hassan 1981).

Human dispersal out of Africa took place between 130 and 190 kyr (130,000 and 90,000 years ago) and may have coincided with the global climatic changes associated with the last major glaciation.[4] Modern humans appeared in Palestine ca. 90 kyr, and remains of early humans in Southeast Asia date to ca. 75 kyr (Burroughs 2005; Hoffecker, Powers, and Goebel 1993; Mellars 2002; Schurr 2004; Turner et al. 2001).[5] This suggests that this phase of dispersal may have been associated with warmer interstadials that cluster in the period ca. 85–75 kyr.

Evidence of a third wave of dispersal is from Nieah Cave and Wadjiak in Southwest Asia 50–40 kyr ago and in northern Europe ca. 40 kyr ago, apparently triggered by severe cold conditions ca. 50 kyr (Heinrich event 5). The distances involved were not very long by comparison with the second wave. These waves were separated by approximately 25,000 years, suggesting that the dispersal was rapid and not as gradual as what happens during warmer periods.

The next wave, which included the penetration of Australia 38–30 kyr ago, coincided with a period of frequent millennial changes in climate starting before 40 kyr until 36 kyr (Heinrich event 4). The subsequent wave is indicated by the penetration of northeastern Siberia ca. 20 kyr during the Last Glacial Maximum (LGM), perhaps in response to episodic amelioration in climate during that cold phase. The movement into North America began perhaps before ca. 16 kyr because postglacial warming conditions would have made it difficult to cross the Bering Strait (see Bryan and Gruhn 2003). However, another wave could have crossed during the Younger Dryas 13,000–11,600 years ago. The movement into hitherto uninhabited territory was rapid, reaching Patagonia in South America by 11,000 cal BP.[6]

The Transition to Agriculture: Climate, Regionality, and Innovation

The transformation from the peripatetic life of foragers into sedentary farming communities approximately ten thousand years ago was a momentous development in the history of humankind. From a sparsely populated planet exploited by loosely organized bands, the world population shot from less than ten to fifty million in a few thousand years (Hassan 1983). Novel social, religious, and political foundations attending this transformation provided the basis for the rise of complex chiefdoms and state societies. Explanation of the causes for this transformation, aptly called the *Neolithic Revolution* by Gordon Childe (1936), has become one of the most intractable puzzles in contemporary archaeology (e.g., Asouti 2006; Bar-Yosef 1998; Bellwood 2005; Cappers and Bottema 2002; Garcea 2004; Harris 1996, 1998; Hassan 2000a; Issar and Zohar 2004; Kuijit and Goring-Morris 2002; Reed 1977; Rosen 2006; Simmons 2007). At a time when it was believed that the end of the Ice Age led to desiccation in the Near East, Childe (1936) hypothesized that domestication of animals and plants began as people and animals took refuge in well-water locations on the banks of rivers and in desert oases. Our understanding of the effect of glacial conditions and the subsequent warmer conditions in Southwest Asia and North Africa provides a more informed evaluation of the role of climate change in the origins and spread of food production in southwest Asia and North Africa.

Although most archaeologists thought that they could determine whether climatic events "caused" agricultural origins by examining proxies of climate change at the time domesticates appear, it is likely that domestication and the appearance of an agricultural mode of life was an intractable, multi-stage, long-term transformation that has to be traced back to the climatic and environmental transition from the last glacial to the period of postglacial warming (Hassan 1977, 604; 1981, 219). My contention has been that "the onset of the Holocene and the retreat of glaciers marking the termination of the last major glaciation, and the possible impact of such changes on wild resources in climatically unstable areas such as semiarid and subtropical regions, seem to explain the independent emergence of food production in several places of the world beginning with the Holocene. The change in subsistence patterns that ultimately led to agriculture, however, must be sought in the impact of climatic fluctuations associated with the Terminal Pleistocene on cultural systems that were receptive for the transition in areas where domesticable plants were available." (Hassan 1981, 219)

Human dispersal during the last glacial out of Africa led to the peopling of the world; regionalization; growth of local populations; and a series of innovations in tool making, hunting gear, foraging strategies, social organization, communication, symbolism, and art. Populations built up in the midlatitude areas and, during the last glacial maximum, in well watered areas along riverbanks, grasslands and woodlands.

The impact of global climatic warming on world populations beginning ca. 16,000 cal BP, as well as subsequent severe climatic fluctuations—particularly the droughts associated with the Younger Dryas (13,000–11,600 cal BP)—varied widely depending on the local expression of the global climatic events and the local environmental settings. The origins of food production were first of all a matter of a sequence of social transformations brought about by changes in the mode of subsistence in response to climatic fluctuations involving population situated in vulnerable subarid ecotonal habitats. In North Africa and Southwest Asia (the NASWA region), these habitats included the northern Levant, the southern Levant and the Sinai, the Nile Valley, the African Sahel, the Mediterranean coastal region of North Africa, and the series of massifs in the Sahara. In these habitats, people responded to local conditions by making the most appropriate decisions given local opportunities, available resources, and their perceptions of the food potentials of specific subsistence modes. I argue that in all areas, sedentary life was resisted as highly risky under unstable climatic regimes and that similar steps were undertaken to intensively utilize cereals and probably "keep" or "manage" animals.

In Africa, the period 16–8.2 kyr witnessed the invention of pottery, the invention and spread of innovative hunting equipment such as the bow and arrow, the use of grinding stones to process cereals and tubers, the harvesting of wild sorghum and millet, increased reliance on fishing, the "management" of Barbary sheep, the domestication of cattle, and probably the preservation of fish (Garcea 2004). During this period, in some cases base camps in favored spots were repeatedly visited. A mobile strategy and an ethos of sharing and exogamy, as is the case among foragers, made it possible for some items and ideas to be passed from one end of North Africa to the other through corridors connecting one region with the other.

In the Levant a similar adaptive response was taking place, but differences included a lack of pottery (Simmons 2007), less emphasis on fish resources, and a more intensive utilization of wild wheat and barely. Here too, and in spite of a precocious attempt to restrain mobility from 14,500 to 13,000 cal BP (the Early Natufian), it was not until much later that mobility was constrained. The switch to more sedentary conditions was due to the onset of stable wet climatic conditions during the Holocene Wet Maximum from 11.6 to 8.2 kyr. It was during this period that successive generations of foragers, who took advantage of the well-watered habitats in the Levantine corridor, had enough confidence to settle down and progressively increase their dependence on homegrown cereals and legumes. This option was not open to, or welcome by, neighbors who lived in less favorable desert areas such as the Negev and the Sinai, despite other shared cultural traits. Within the span of two millennia some of the farming hamlets in the Levantine corridor developed into "mega-villages" with elaborate social organizations, ritual, and art. During 10,600–8,800 cal BP, known as the Pre-Pottery Neolithic Period (PPNB), naked six-row barley and free-threshing bread and hard wheat were cultivated, as were pulses such as peas and lentils, and sheep and goats were domesticated. In northern Levant and central Anatolia, cattle were domesticated by 8,800 cal BP (Bar-Yosef 1998), and in Greece domesticated cattle appear ca. 9,000 cal BP and pigs and goats ca. 10,000 cal BP (Halstead 1996).

The adoption of farming and herding during the PPNB was associated with the development of sedentary populations in villages of substantial size with sophisticated architectural features, including nonresidential structures with communal or ritual significance, and elaborate nonresidential sites (Simmons 2007). It is not clear if the farming villages constituted egalitarian or hierarchical societies, suggesting that social organization was not strongly hierarchical and may have consisted of communal management of village affairs. Mortuary "skull cults" and evidence of rich symbolism suggests that ritual and religion might have played a major role in group dynamics as a means of alleviating conflicts and promoting solidarity. It is noteworthy that some groups opted to pursue hunting and foraging, while others continued to lead a nomadic life with the adoption of domesticates, especially animals, eventually evolving into pastoralists (Simmons 2007, 167).

In the succeeding period 8,800–8,200 cal BP, the end of the PPNB, populations in the southern Levant shifted east, particularly to highland Jordan, where they established a series of very large settlements or mega-villages. Such sites are also recorded outside the southern Levant, including Çatalhöyük. The emergence of large settlement aggregates does not seem to be related solely to climate change, but rather to a combination of factors. It appears that sedentary farming communities overexploited their surroundings and that relocation to more favorable, previously unused habitats was one of the responses (Rollefson 1992). Aggregation of communities from neighboring villages to form compound villages was apparently facilitated by social and kinship ties.

By 8,200 cal BP, the mega-villages were suddenly depopulated. The PPNB came to a sudden end. The 8,200 cal BP event was apparently responsible, at least in part, for the collapse of the Final Pre-Pottery Neolithic (Bar-Yosef 1998). After favorable climatic conditions for close to a millennium (Kohler-Rollefson 1988, 88), these early Neolithic societies overextended (thus reducing their margin of safety) and exposed themselves to the hazard of unanticipated climatic turns. The collapse of the PPNB was not a local event; this pronounced, millennial, global, abrupt cold event (Alley et al. 1997) was a severe "environmental crisis" (Cordova 2007).

The period 8,200–6,800 cal BP was characterized by unstable climate with a shift from forest to maquis[7] in the northern Levant and more olives in the southern Levant (Rosen 2006). It was under this climatic regime that village communities were established with greater reliance on a mixed farming-herding economy that established the foundation of the Mediterranean agrosystem (Butzer 1996). Dairying apparently led to the widespread use of pottery for keeping and serving milk, butter, yogurt, cheese, and other milk products, and thus this phase is characterized as the Pottery Neolithic. The Neolithic communities in the Levant appeared to have maintained a heterarchical social organization based on aggregation of extended families within a communal organization with an emphasis on religion and ritual as a means of group solidarity (Simmons 2007).

Climatic Instability and the Spread of Farming, 8,200–6,800 Cal BP

One of the main aspects of the period postdating the 8,200 cal BP event is the spread of farming activities into coastal areas in Syria and Lebanon and eastward into Mesopotamia and Iran. This led to regional differentiation that was to become the foundation of further cultural trajectories: a transition to agrarian state societies occurred in Mesopotamia and the Nile Valley, while the southern Levant, restricted by its limited resources, remained at a stage of relatively small-scale social complexity. The onset of drier conditions detected at 8,200 cal BP and the perpetuation of unsettled climatic conditions until 7,800 cal BP, when a period of greater rainfall became evident, were in part responsible for a simultaneous dispersal of cattle from the Eastern Sahara toward the Central Sahara and the introduction of caprines from the Levant to the Red Sea coast in Egypt and the Eastern Sahara. All these developments came in the wake of the "collapse" of the Levantine PPNB farming communities ca. 8,200 cal BP.

In short, the populations taking advantage of the changes in vegetation and animals as a result of the postglacial warming commencing ca. 16,000 years ago also developed significant new subsistence and settlement strategies over a period of three thousand years. The period 14,500–13,000 cal BP was particularly wet and warm. However, the "good life" under centuries of relatively lush vegetation and abundant resources came to an abrupt end with the onset of the Younger Dryas (13,000–11,600), a cold interval of 1,400 years, which in turn led to strategic responses and innovations. This period, however, also came to an abrupt end with the return of warmer and wetter conditions. The appearance of sedentary farming communities in the Levantine corridor during the tenth millennium cal BP coincided with the practice of cattle keeping and intensive utilization of sorghum in the Eastern Sahara. Both developments were synchronous with fairly stable wet conditions that lasted, with minor interruptions, until the transition to cold climatic conditions ca. 8,200 cal BP, followed by inclement weather conditions until ca. 7,800 cal BP. The 8,200 cal BP (8.2 kyr) event hastened the collapse of PPNB communities in the Levant and led to a dispersal of populations from the Levant into North Africa, the Arabian Peninsula, and Europe. The movements were rapid. The displaced individuals and groups were not demographically viable, and it was advantageous to intermarry with the indigenous local foraging populations, fusing multiple subsistence and social traditions and adapting new farming and animal-keeping technologies to the local ecological settings.

The 8,200 cal BP event must be regarded as one of the most important climatic events of the Holocene. It led to a wave of dispersal and the transformation of many parts of the world as local populations began to adopt, adapt, and modify their ways of life in response to innovative methods and technologies of food production.

Climate Change and Saharan Populations in 7,800–6,800 cal BP

Although wet conditions recurred, the period 7,800–6,800 cal BP was characterized by frequent climatic oscillations and droughts. Climatic conditions became progressively drier and led to the onset of severe aridity by 5,500–5,300 cal BP, signaling the prevalence of desert conditions over most of North Africa. The succession of wet and dry episodes seems to have encouraged successive movements of cattle and then ovicaprids (sheep and/or goats) westward following the better-watered range and basin areas associated with Saharan highlands, such as the Ennedi, Tibesti, Tassili, and Hoggar massifs (Hassan 2000a, 2002b).

A millennium after the initial spread of cattle out of the Eastern Sahara and the introduction of sheep and goats from the Levant into the Eastern Sahara, a number of independent events occurred simultaneously ca. 6,800 cal BP, such as the first appearance of domesticated cattle in the Sudan along the banks of the Nile and at Merimde farther north in the Nile Delta ca. 6,800 cal BP, and in the Central Sahara ca. 6,900 cal BP. These events were a response to the onset of dry conditions in the Eastern Sahara, which is well documented by the disappearance of the temporary lakes that once filled the depressions where oases are located. The disappearance of those lakes and the onset of a freezing cold desert climate are attested at Farafra Oasis at that time (Hassan et al. 2001; Hassan 2003). In the Central Sahara, local conditions in the massif range areas ca. 7,800–5,200 cal BP were favorable for the emergence of varieties of livestock keeping and pastoralism, since large basins were fed by great wadis (desert water courses) that drained from the massif ranges. Seasonal variations in rainfall between north and south might have allowed transhumant pastoralism.

Meanwhile the populations that remained in the Eastern Sahara, which receives less rain, were becoming increasingly isolated. Their livelihoods were precarious and those that remained depended more on occasional springs than on rainfall. Sheep and goats were incorporated into a subsistence regime that also emphasized hunting gazelle and other desert game. However, there is no evidence that the adoption of sheep or goats originating in Southwest Asia was accompanied with the introduction of the cultivation of domesticated wheat or barley.

Climate and the Origins of the Egyptian Civilization

Desert dwellers apparently struggled during 7,800–6,800 cal BP under uncertain climatic conditions and frequent spells of aridity. By 6,800 cal BP many of the inhabitants of the Sahara adjacent to the Nile Valley apparently decided to risk settling along the banks of the Nile. Until then they probably had not regarded the area as an ideal habitat because its peculiar resources were not concordant with their preferred mode of life as desert hunters and gatherers. It is precisely at this time that we begin to see the first evidence for sheep/goats and domestic cereals, introduced earlier from the Levant into the Sahara, in the Nile Valley (Hassan 1988; Wetterstrom 1998). The early Neolithic sites of the Nile Valley contain artifacts analogous to those from the Eastern Sahara dating from 7,600 to 7,300 cal BP (Hassan 1988, 2003).

For perhaps as long as 6,800–5,800 cal BP, the Nile Valley south of the Delta and the Faiyum were inhabited by a mélange of communities with various subsistence strategies dominated by hunting, fishing, or herding. During that time, the main farming communities were located along the margins of the Delta, in contrast to Upper Egypt where farming villages become a major feature of the cultural landscape by 5,800 cal BP (Naqada I).

This suggests that the inhabitants of Merimde Beni Salama were the result of the fusion of farmers who relocated to the edge of the Delta and Delta dwellers. It took the southerners a longer time to adopt the new way of life, perhaps as a result of increasing contacts or incentives to enter in economic exchanges for goods provided by the northerners.

This transition to a predominantly agrarian mode of subsistence by 5,800 cal BP marked the emergence of the economic foundation of the Egyptian civilization. Within the relatively short span from 5,800 to 5,300 cal BP, Egyptian farming communities made a transition to a state society that was fast by comparison to Mesopotamia, where this transition is estimated to have taken two millennia (ca. 7,500–ca. 5,500 cal BP). In both regions, the cultural developments that led to the rise of state societies, altering the cultural map of North Africa and Southwest Asia, were due to the vast fertile plains of great rivers. In Egypt, however, the flood plain in Upper Egypt is narrow and linear with the Nile as a single transport artery. Political transformations may have been attempts to counteract the decadal variations in Nile flood discharge (Hassan 1988). The recognition of a global climatic cold event leading to a reduction of Nile floods is likely to have hastened the process of unification as it became advantageous to expand the size of the groups participating in a shared economy as a buffer against crop failures. The frequent depiction of boats suggests their use for food transport. There is also evidence for expansion of trade and elaboration of rituals.

Core and Periphery: A Divided World

By contrast to the agrarian civilizations of Egypt and Mesopotamia, the rest of North Africa and Southwest Asia, which lacked the fertile plains and flood discharge of great rivers, was constrained by the limited productive potential of rain-fed agriculture and pastoralism (see Barker and Gilbertson 2000). Improvement in agrarian productivity there depended on a suite of methods of water harvesting such as check-dams, terracing, cisterns, and wells (Hassan 2007a). In many areas, farming was risky if the interannual variability was high, as it is today in the Mediterranean coast of Egypt. In addition to herding and pastoralism, desert nomads exchanged food and goods with settled farmers, and on occasion benefited from raids. Subject to the vagaries of decadal droughts, the nomads had recourse to either a pattern of episodic raiding or a flexible mode of farming and herding.

The emergence of farming in the Sahel appears not to date earlier than 3,300–3,100 cal BP in northeast Nigeria and Burkina Faso (Breunig and Neumann 2002; Wetterstrom 1998) and 3,800–3,700 cal BP in Mauritania (Ambelard 1996). It came soon after the appearance of the first pastoralists in the Sahel of northeast Nigeria as the culmination of the movement westward that began from the Eastern Sahara around 7,800–6,800 cal BP. Within the Sudano-Sahelian zone of Africa, people today practice nomadic pastoralism, settled agriculture, and a variety of different agropastoral strategies.

In this zone, rainfall is unpredictable and subject to frequent oscillation of the intertropical convergence zone. Because the livestock is rain fed and the grain (sorghum) fields are not irrigated, rainfall is the determinant of the year-to-year variation a family experiences in both crop and livestock yields.

Using a stochastic modeling technique whereby a decision is made to cultivate, keep family wealth in the form of livestock or stored grain, or some mixture of the two, Mace (1993) concluded that pastoralists are likely to increase their chances of long-term survival by taking up agropastoralism if their wealth declines below a certain level. Inversely, when agropastoralists become wealthy, they will usually do better to give up cultivating and devote their effort to their herds. Her conclusions are confirmed by ethnographic observations. However, the model does not deal with the consequences of severe, prolonged droughts that are likely to lead both to the failure of crops and the decimation of herds and stored grain, which may force pastoralists to raid settled farmers, become settled farmers if possible, or emigrate. They may also buffer the stochastic variations in the yield of crops and herds through trade. This can be a source of wealth, prestige, and power, but it ultimately depends on the viability of the agrarian communities. Lees and Bates (1974) present a model for the origins of another type of specialized nomadic pastoralism within a cultural setting characterized by specialized irrigation. In this case, the origin of pastoralism is predicated upon the increased labor requirements of irrigation agriculture and the consequent conflict of interest related to land use and labor allocation in alluvial zones, as well as the hazards of irrigation agriculture through time. Being mobile, pastoralists respond to climatic events in a way that differs from that of sedentary farming communities.

Agrarian Communities and Pastoral Nomads

The rise of the agrarian state and pastoralism created a new cultural dynamic that became a major force in the history of world civilizations from Egypt to China. Invasions by pastoral nomads who may be unified under charismatic leaders, especially at times of droughts, may allow them to overrun agrarian-based states and to establish their own dynasties. In Egypt and Mesopotamia, the nomads were an integral force in the history of the two regions. It would be useful to examine the history of nomadic invasions in connection with climatic upheavals and droughts.

In Arabia, the earliest evidence of herders dates to 7,700–7,000 cal BP, even though moist conditions prevailed as in the Eastern Sahara and the Levant from 9,800 onward. The introduction of herding into the Arabian Peninsula thus seems to have been caused by the dispersal of nomadic herders or hunter-herders from the Levant after 7,800 cal BP simultaneously with their movement into North Africa. Pastoralism thrived in Arabia, supplemented by the hunting of gazelle and ostriches. Cattle herding is attested at 6,700–6,300 cal BP in Yemen and along the Tihama coastal plain

(Edens and Wilkenson 1998). By 4,400 cal BP, a millennium after the end of the Holocene wet phase (McClure 1976), early cattle pastoralism begins to disappear in favor of sheep and goat herding, which becomes dominant ca. 2,700 cal BP. Camels were apparently domesticated sometime prior to 3,000 cal BP. In Eastern Africa, goats and sheep were introduced into the Sudan from the Sahara by 6,800 cal BP, and reached southern Kenya and northern Tanzania by 4,500 cal BP (Gifford-Gonzalez 2000), where the emergence of specialized pastoralism dates to 4,000 cal BP (Gifford-Gonzalez 2000; Marshall 1994).

In sum, the initial phase of food production in the Levant was followed by a period of dispersal into Arabia and North Africa from 8,200 to 7,800 cal BP. This led to a variety of regional developments depending on local ecological settings and past cultural histories. The onset of desertification by ca. 5,300 cal BP and a series of hyperarid spells at 4,200 and 3,300 cal BP led to further dispersal from North Africa toward West and East Africa. Outside areas where extensive fertile land and water persisted, sustainable economy under repeated decadal and centennial droughts and high interannual unpredictability of rainfall led to ingenious water harvesting and management technologies. Eventually some of these societies developed into agropastoral communities who used raiding and trade to buffer their survival in climatically unstable areas.

The inherent instability of agropastoral and agrarian economies is further compounded by unpredictable centennial and millennial variations in climate (Allen et al. 2000). Such climatic variability also played a key role in the rise and collapse of some early civilizations depending on their local environmental and cultural circumstances.

Climate and the Collapse of Civilization

Perhaps in the rush to dramatize the impact of climate change in the past, as a warning or a premonition, some attention has been given to the role of climate in the breakdown of complex state societies, especially during the third millennium BC (de Menocal 2001; Weiss 2000). A climatic deterioration ca. 4,200 has been detected in many areas (Dalfes, Kukla, and Weiss 1997; Drysdale 2006) and is considered a cause for the breakdown of complex societies at that time. Although I agree that we can make a case for the role played by millennial abrupt severe climatic events on the temporary descaling of social complexity and the breakdown of centralized authority, I do not think that climate change should be blamed for what is in fact a problem in the social management of natural resources. This is abundantly clear from the thorough discussion of the topic of the collapse of complex societies by Tainter (1988). It is also invalid to restrict the role of climate change to the unmaking of civilizations.

The rise of social complexity appears in the first place as a mechanism to buffer shortages in agrarian productivity within an ecological context that has the potential to accommodate a very large population. The initial success of linking villages in a corporate society that pools its resources, and thus evens out the chance loss of crop yield by a single household or a village, leads to expanding this strategy to more and more communities. Since food security is enhanced as the number of participants increase, the temptation to expand the number of joint villages also increases. However, this process requires specialized managers and specialists to enhance solidarity and minimize conflicts through ritual among other means, and thus a complex social organization characterized by administrative and religious elites who wield power in order to execute their assigned tasks. This implies an increase in the number of non-food-producing elite and the rate of consumption by the elite, who reveal and consolidate their power through lavish displays of wealth, possession of exotic goods, and monumental palaces and temples. The elite also carry their duties with the help of an ever-expanding cast of clerks, guards, entertainers, servants, and craft specialists. Such dramatic increase in the non-food-producing sector places a premium on progressively higher crop yields. Meeting the rising demands may be accomplished through conquest, slavery, overtaxation, or encouraging population growth. Since most capital outlays are not for increasing productivity through capital investments in productive projects, the maintenance of the expanding system relies on pacifying a hard-working population living close to a level of misery, conquest, or expanding into progressively less fertile lands.

Complex agrarian societies thus evolve through time into metastable organizations that are vulnerable to internal or external perturbations. Internal perturbations may result from mismanagement, rivalries among elite groups, or revolts, while external perturbations may be due to adverse unforeseen consequences of farming (e.g., salinization, erosion, pollution, depletion of key resources), attacks by foreign enemies, or climate change undermining the life-support systems. The perturbations may not lead to a "collapse" in the sense of the breakdown of the organization, but may serve as a means to develop better tactics and strategies to increase the resilience and robustness of the organization, or to place it on a new level (of complexity) where productivity, at least in the foreseeable future, does not exceed the cost of managing and maintaining the complex organization. The effect of the perturbation may also be temporary. The system may recover due to the reimplementation of the previous level of complexity. In the case of climate change, the impact of the perturbation is also a function of the rate of environmental recovery.

In the case of Egypt (Hassan 1993, 2007c; O'Connor 1974), the sudden, unanticipated series of reduced Nile flood discharges led to a breakdown of centralized authority for a few decades. This breakdown, associated with famines, violence, and civil disorder, was primarily due to a social system that exploited farmers to support a non-food-producing elite, who siphoned labor and resources for the construction of monumental pyramids and to lead a life of luxury and leisure. Within decades, bountiful Nile floods were resumed, and a new set of "managers" emerged to reunify the country and reestablish the monarchy. Within two centuries and following internal conflicts between rivals for the throne, all of Egypt was again governed by monarchs who restructured the government and promulgated a new code of ethics and royal responsibilities.

China and Central America: Agriculture, Climate, and Collapse

Examples from Central America and China also show marked differences in the pace and timing of cultural developments in response to global climatic events. In Central and South America, wet conditions from 14,600 cal BP with a maximum from 13,000 to 8,800 cal BP led to the formation of lakes, attracting hunters and foragers (Messerli et al. 2000). In central Chile, however, Paleo-Indian occupation ended as a result of rapidly increasing aridity ca. 11,000 cal BP that caused mega faunal extinction (Núñez, Grosjean, and Cartajena 2001). As a result of the droughts Paleo-Indians retreated to ecological refuges around lakes (see also Zárate, Neme, and Gil 2004)[8]. In the Atacama Desert (and Altiplano of northern Chile), the first period of human occupation came to an end by ca. 9,000–8,800 cal BP. Hyperarid conditions from 8,800 until 4,000 cal BP made the region inhospitable (Messerli et al. 2000). Extreme events at Querbrada Puripica from 8,800 to 5,500 cal BP contributed to the transformation of Archaic hunters into the complex Late Archaic cultural tradition (Grosjean et al. 1997).

The few areas blessed with flowing water (e.g., Puripica on the western slopes of the High Andes) provide evidence of domestication by 5,500 cal BP and a shift to farming with channel irrigation and terracing after 3,300 cal BP. Since the shift from hyperarid to more humid conditions with a return of rain-fed lakes occurred ca. 4,000 cal BP, domestication would have been achieved under hyperarid conditions, and farming under more moist conditions. However, the lack of detailed, high-resolution environmental data hampers any attempt to make reliable interpretations. The shift to farming coincided, however, with a large-scale reoccupation of the Atacama area (by 3,400 cal BP). Data on climatic variability over the past 3,500 years in the Yucatan Peninsula (Mexico) (Curtis, Hodell, and Brenner 1996; Hodell, Curtis, and Brenner 1995) reveal that the period 3,500–1,800 cal BP was wet. Afterwards exceptionally arid events occurred at AD 862, 986, and 1051.

The period AD 980–1050 also correlates with the first phase of the Medieval Warm Period, which is manifest in Europe, North Africa, and North America. Curtis et al. (1996) attribute what they refer to as the Classic Maya Collapse (AD 750–830) to droughts. They also note that other cultures in South and Mesoamerica experienced declines at or near the time the Classic Maya collapse, citing the abandonment of Teotihuacán, Mexico, around AD 750–800, and the collapse of the Andean Tiwanaku at about AD 1000. Shimada et al. (1991) also suggest that the prominent pre-Hispanic culture of Mochica (also known as Moche), with its heavy dependence on large-scale irrigation, experienced an upheaval as a result of a series of severe sixth-century droughts, including one of the severest droughts of the past 1,500 years in AD 562–594.

There are, however, reasons not to single out climate change as the main cause of the collapse of the Classic Maya. For example, the Classic Maya civilization developed under arid conditions and is thus likely to have developed mechanisms to cope with droughts. Also, the collapse alternatively may be explained by a shift in organizational strategy, population movements, or the cessation of monumental carving in Mayan cities. Moreover, the facts that the hydrogeological situation is rather complex and that we lack a model of the sociodynamics of the collapse cast serious doubt on the primary role of climate as a forcing factor. Scarborough (2003) does provide a sociodynamic interpretation, arguing that the collapse was primarily caused by what may be called *cultural gigantism*. The Classic Maya depended on an elaborate system of waterworks and control by elites who continued to aggrandize their civic centers, creating a superstate in a fragile, dry subtropical environment. Their growth was unsustainable, and severe droughts would have only hastened the civilization's demise.

Some of the most salient global climatic events that have had a significant impact on the course of human civilization appear to have been connected with cold events associated with equatorward shifts of the Intertropical Convergence Zone (ITCZ). This, in turn, causes droughts in a transcontinental belt that extends from Central Mexico and the Andes to China (Hassan 2002a). In China, Cohen places the initial period of rice domestication at 14,600 cal BP in the south at Hamadong, 16,000–13,000 in the Xia Ren Phase in northern Jiangxi (Xianrendong and Diatonghuan sites) and 13,000–10,800 during the Wang Phase (Cohen 1998). A subsequent shift from garden to paddy rice agriculture occurred in the Jiangxi phase (11,000–6,800 cal BP). Liu (2004) links the emergence of sedentary villages with pottery, dogs, and pigs to 11,000–9,700 cal BP in the central plains with the advance of monsoonal rainfall northward into the present arid and semiarid regions. It appears that the transition to the intensive collection of rice was linked to the postglacial warming commencing 16,000 years ago. Additionally, the Younger Dryas (13,000–11,600 cal BP) was followed by the beginnings of full domestication, paddy farming, and the establishment of sedentary villages during the period 11,600–8,200 with warm, wetter conditions. Recently, a five-year resolution, absolute-dated oxygen isotope record from Dongge Cave, southern China, provided evidence of a warm, wet season during the summer months when the Intertropical Convergence Zone (ITCZ)[9] shifts northward and monsoonal convective rainfall reaches its maximum.

During a period of warm and wet climate from 9,800 to 4,500 cal BP, early Neolithic cultures were established in the Yellow River valley from 9,000 to 7,000 cal BP. Under more humid and warmer conditions from 7,000 to 5,000 cal BP, populations increased rapidly. According to Huang and Zhang (2000) pollen, phytoliths,[10] and carbonized grains reveal that cultivated varieties of rice occurred slowly from 7,000 to 6,300 cal BP, with maximum variation from 6,300 to 5,500 cal BP (late Neolithic) due to effective artificial selection. Millet also appears with sedentary villages at 10,000–7,000 cal BP. During the period 6,000–5,500 cal BP, the number of agrarian settlements increased dramatically.

According to Stanley and Chen (1996), Neolithic settlements in the southern Yangtze delta plain dating from 7,500 to 4,400 cal BP began within five hundred years of delta formation as a result of sea rise. However, continued sea level rise led to a rise in groundwater level and poor drainage, resulting in a shift of Neolithic settlements eastward toward higher, more restricted areas of the Yangtze delta chenier plain. The transition to fortified settlements in the middle reaches of the Yangtze in 6,400–6,100 cal BP (Yasuda et al. 2004) coincided with the onset of arid conditions as a result of decreased monsoon activity and cold climate, as in North Africa (see also Wang et al. 2005). Rapid urbanization at 5,300 cal BP also coincided with a period of drier conditions in the Eastern Sahara. A period of abandonment of settlements at 4,000 cal BP apparently was caused by the 4,200 abrupt cooling event (Yasuda et al. 2004). Liu (2004) recognizes the multiple roles of population increase, shifts in the course of the Yellow River, soil erosion from farming, and climatic fluctuations in the rise of hierarchical complex societies in China as a result of conflicts leading to political integration. He also concludes that the Longshan culture in the Yellow River valley declined around 4,000 cal BP. Wenxiang and Tungsheng (2004) similarly recognize a collapse of Neolithic cultures around Central China at the time of the 4,000 cal BP cooling event.

Conclusion

Climate changes at different scales. Societies are often "adapted" or better "tuned" to multidecadal fluctuations, but are not immune from experiencing environmental stresses caused by unanticipated multicentennial and millennial severe, abrupt climatic events. This is mostly a function of the limited temporal range of collective memory, which is often restricted to a few generations. However, even with memory aids, such as historical records, predictability of climatic events far into the future is virtually impossible and too distant to matter within the operational range and concerns of human societies. Accordingly, an abrupt climatic event consisting of a series of unanticipated severe droughts or extremely anomalous climatic events within the span of decades on the basis of the range of decadal climatic fluctuations, such as the Younger Dryas, are likely to have an impact on human societies.

Nevertheless, abrupt climatic events do not *determine* culture change, which ultimately depends on local ecological conditions, previous cultural modalities and norms, and unpredictable social dynamics. Such dynamics are shaped primarily by political organization, technological aptitude, economy, and religion/ideology, but are also subject to individual initiatives and decisions made under uncertainty.

No society can stop climate change, but efforts can be made to minimize vulnerability to the deleterious impact and enhance the resilience of the social system. Societal upheavals as a result of extreme climatic events may provide an incentive to relocate, intensify food production, or reorganize political institutions governing labor, exploitation of resources, distribution, consumption, and environmental impact. A case in point is the "collapse" of the Old Kingdom in Egypt. During the span of 200 years that began with chaos and disorder, the Egyptians reconsidered and revised the function and responsibility of centralized government, the organization of the administrative structure, and social ethics (Callender 2000; Seidlmayer 2000).

Any response to climate and environmental change has short-term and long-term consequences, and most individuals and interest groups are likely to pay more attention to their own short-term gains than those of society at large, future generations, or the planet. The current attempt at the greening of politics, which aims to remedy this shortsighted modus operandi of societies, is at least a start in remedying the potential catastrophic consequences of this approach, which cannot be sustained under current global conditions (see Barry 1999 on environment and social theory).

Climate change is only one of many variables that can lead to the collapse of a complex state society. There are more insidious internal forces that are likely to undermine the resilience of the state. What is important and potentially fruitful is to expose the structural weakness in a complex society that can hasten its breakdown and increase its vulnerability to climate change.

Responses to environmental stresses and opportunities caused by the transition from the last Ice Age to the postglacial warming have led in many areas to the invention and spread of a variety of food-producing economies. Incipient social complexity based on communal and intercommunal management of labor, storage, and sharing shortly followed, perhaps in response to the vulnerability of agrarian regimes to failures. This may be due to the nature of agrarian ecology and management, as well as decadal and centennial climatic fluctuations affecting soil moisture, seasonal distribution of rainfall, and the amount of heat available in the growing season. In certain ecological settings, where a large number of communities could be coordinated and where the agricultural potential is high, more advanced complex (state) organizations emerged providing both psychological comfort in the face of environmental adversities and a modicum of "relief" (or at least the promise of relief) in times of famine. One example is provided by one of Egypt's governers, Ankhtifi (Hassan 1997; Vandier 1950), at the time when

Egypt was suffering from the famines that led to the breakdown of the Old Kingdom. However, those beneficent lords were also top consumers who benefited from greater yields and hence from expanding the labor force (the "taxpayers"), the agrarian land, and agrarian productivity per unit area. It was thus to their benefit that societies became larger and larger, which meant greater complexity and a progressively higher cost of managing the collection of revenues, transport from the distant corners of states and empires, payment and rewards for a religious establishment to pacify the population, and payment and rewards to a police force and an army to prevent or suppress revolts and to conquer neighboring lands or defend their possessions (Hassan 2006).

The aggrandizement and maintenance of complex state societies have been sustained against climatic perturbations and repeated climatic upheavals. This was achieved through successive transformations of state organization, the adoption of technological innovations, colonization, and the reorganization of economic strategies. The latest and most remarkable shift as far as we are concerned has been the marked transition over the last two hundred years to industrial production; the use of mechanized and techno-farming; and the use of fossil fuel, electricity, and nuclear energy as main sources of energy (for the expansion and consolidation of European states from 1415 to 1980, see Abernethy 2000).

The consequences of the managerial and productive revolution that began two hundred years ago has now led to a spiraling world population, local depletion or pollution of critical resources (e.g., water), as well as concentration of population in urban hotspots, and progressively increasing consumption rates by ever-increasing segments of the world population.[11]

Today, the mesmerizing depiction of "climate change" as the culprit that will bring our civilization down should not lead us to think that climate change is the only threat to humanity. It should in fact make us realize that we have created a social system that appears to be vulnerable to climate change. There are already more than one and half billion human beings who are in a state of abject misery, with no access to clean drinking water in a world of rabid consumerism and ostentatious consumption. We already suffer from spiraling world population that with or without climate change will spell the end of human existence if continued unchecked. If the "scare" of climate change does not lead us to a deeper examination of the ills of our global, complex society with its serious mismanagement, inequities, regional and national rivalries, sectarian conflicts, and heavy toll on natural resources, then we are likely to continue to slide closer and closer to higher levels of inequities, violence, disorder, and repression.

Although it is feasible and potentially possible to redeploy existing capital, human resources, science, and technology on a global scale, we will not likely escape from the nationalist and sectarian agendas that belong to previous historical eras. The continuation of such policies within the context of the current potential for disseminating information and mobilizing masses outside the control of the nation states, as well as access to the means of armed confrontation outside the norms of the state and international conventions, make this world particularly vulnerable to cataclysmic internal disturbances and external factors, like climate change. The strategies of repression, exploitation, and conquest can no longer be entertained as a response to those who pose a threat to organized societies. Perhaps the threat of climate change with its transnational scale and the common global threat of water shortages and planetary ecological morbidity can foster a realignment of current national and international policies to provide world governance, at least in the domains of matters that threaten our collective survival (see Conca and Dabelko 2002; Orlie 1997).

As a technical note, Taylor predicted in 1999 that it would be another twenty years before the climate changes that are predicted to be associated with the greenhouse effect become large enough to be unambiguously differentiated from naturally occurring variations in climate. In less than a decade, we are already witnessing dramatic signals of a global warming. As Taylor recommended, we should act swiftly, since procrastination will prevent making timely and urgent informed decisions and will increase the social and economic costs.

Notes

1. See www.pages.unibe.ch.
2. This refers to mechanisms that "force" the climate to change. See www.ace.mmu.ac.uk/eae/Climate_Change/Older/Climate_Forcing.html, www.ncdc.noaa.gov/paleo/forcing.html.
3. Known as Dansgaard-Oeschger (D/O) events. These events started with an abrupt warming by around 5°C within a few decades or less, followed by gradual cooling over several hundred or thousand years. However, the cooling phase often ends with an abrupt final temperature drop back to cold conditions (stadial). Another major type of climatic event in glacial times is the Heinrich (H) event. This type of event consists of cold spells due to surging of the Laurentide Ice Sheet through the Hudson Strait, occurring in the cold stadial phase of some D/O cycles (Rahmstorf 2001).
4. There are several studies of global climatic changes for the last 100,000 years including data from ice cores as well as a high-resolution palaeoenvironmental records from other sites like Lago Grande di Monticchio, Italy by Allen et al. 1999.
5. A summary of the peopling of the earth from 100 kyr to 10 kyr is provided by Haywood 2001.
6. *Cal BP* refers to age determinations based on radiocarbon dating calibrated into equivalent solar years before present.
7. *Maquis* is a shrubland in Mediterranean countries, typically consisting of densely growing evergreen shrubs such as sage, juniper, and myrtle.
8. See also the work by Sandweiss and coworkers in Peru (Sandweiss 2003; Sandweiss et al. 2004).
9. The Intertropical Convergence Zone (ITCZ) is a belt of low pressure girdling Earth at the equator. It is formed by the vertical ascent of warm, moist air from above and below the equator.
10. Phytoliths are microscopic bodies, mostly of silica, that occur in many plants. They can be retrieved after the decay of the plants.

11. Compare with Messerli et al. 2000, http://www.geohive.com/showcase/atlas.html for world population and http://www.globalchange.umich.edu/globalchange2/current/lectures/human_pop/human_pop.html for world population growth in history, and Hassan 1983 on population and cultural evolution.

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