SCOPE 27 - Climate Impact Assessment

3 Research in Climate–Society Interaction

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3.1 INTRODUCTION

Research on the ways climate, biomes, and society interact is framed by abiding views of the relationship between humans and their environment. Extreme episodes in the early 1970s fostered a resurgence of expressions of human vulnerability to climate, reminiscent of the `climatic determinism' voiced in the early decades of this century. Simultaneously, recognition of the potential for intentional and unintentional human-induced climate change heightened our awareness of climate as a natural resource that can be managed or mismanaged. This chapter reviews the development of these and other ideas about climate subsumed in four broad categories: climate as setting, climate as determinant, climate as hazard, and climate as natural resource. The discussion considers the basic perspectives and research emphases that tend to be associated with each view.

The classification used here derives from a survey of the literature of climate impacts and appears to embrace and to order that literature reasonably neatly. Clearly, the classification is subjective and alternatives with more or less detail might be developed. Also, theoretical bases for various abiding myths of nature, of which climate is an element, can be proposed. For example, the anthropologists Douglas (1972) and Thompson (1982) explored how nature is characterized by different authors and societal groups. Holling *et al.* (1983) and Kates (1983) have derived taxonomies of natural systems and man–environment interactions based on ecological and geographical perspectives, respectively.

3.2 FOUR VIEWS OF CLIMATE

3.2.1Climate as Setting

One sense of climate is as the setting for the processes of biophysical and socioeconomic systems. Nature provides the climate, and climate provides the setting. In this view, expressed in the thorough and extensive calculations of climate means and normals, climate is a given and stable element of the terrestrial environment. Much of early scientific climatology, reviewed in detail by Leighly (1949), was an effort to measure, describe, and establish climate as a static, or very slowly varying, element of the environment (see also Chapter 2, this volume).

The view of climate as a stable backdrop to life on earth is strongly evident in the first scientific climate classification schemes. These were based on vegetation assemblages implicitly assumed to have established themselves in equilibrium with the fixed climate (see, for example, Köppen and Geiger, 1930). While a view of climate as strongly repetitive, only gradually changing, with few surprises, has endured to the present, some climatologists (see, for example, Thornthwaite, 1961) have argued for a more 'dynamical' climatology, based on an accounting of flows of energy, mass, and momentum in the climate system. Studies of paleo-climates, polar climates, and climates of other planets also take a broad view of climate as evolutionary setting.

Typical expressions of the present climate as setting are the many regional climatologies produced in the 1940s and 1950s, what Terjung (1976) called studies of 'climate-for-its-own-sake'. Contemporary climatologists, attempting to relate climate more closely to aspects of biophysical and socioeconomic systems, have developed more specifically adapted ways to express climate characteristics. For example, the Growing Degree Day, based on the `heat unit' idea (see Mather, 1974, 158), relates temperature to a critical base value above which plant growth occurs. Similarly, the Heating Degree Day expresses temperature with regard to a base below which interior space heating is assumed necessary. Such indices are then related to variables like crop yield and energy consumption. Other indices used to describe the climate background in meaningful terms include Palmer's (1965) drought index and various comfort and heat stress indices (see, for example, Belding and Hatch, 1955).

3.2.1.1 Research Implications

A view of climate as setting encourages work aimed at better observation and description of climate variables seen as rigid characteristics of the environment. Regional climatologies continue to appear (see, for example, Nieuwolt, 1977), and these now regularly include discussions of radiation and water balances and synoptic conditions, but they hesitate to draw connections between climate and biological and social systems. The underlying assumption of descriptive climatology is that good description can provide the basis for the finer adjustment of human activities like agriculture, as well as the design and construction of transportation systems and human settlements. The field of applied climatology, as codified in texts such as Griffiths (1976) and Oliver (1973), has developed around the notion that better knowledge of the statistics of climate can inform the design of systems to minimize adverse effects and to maximize positive opportunities of climate. Thus, mapping, sorting and classification are the characteristic activities associated with the view of climate as setting.

3.2.2 Climate as Determinant

The sense of climate as a pervasive, powerful element of the environment forms a basis for climate determinism, the view that climate is a dominating influence in the molding of natural and social systems. The first recorded, concise statements of this view are attributed to Greek and Roman scholars. For example, Hippocrates, in his *Airs, Waters, Places* (see Jones, 1962), cast climate as the determinant of health and disease, and claimed that the microclimates of cities affect the civility and personality of their inhabitants.

Early historians and geographers, blending natural and human scientific exploration and description, lent a scholarly basis to determinist views. They described vegetation, animal, and even human populations as adapted to climatic constraints. This perspective is exemplified by Alexander von Humboldt's *Kosmos* (see Otte,1849). Although recognizing that humankind's mental powers provide some independence from environmental factors, von Humboldt argued that culture is essentially a product of adaptation to the physical world, a key element of which is climate. In the first decades of the twentieth century, Ellsworth Huntington (1915) extended this view, claiming that climate is all-pervasive in molding social structure, settlement patterns, and human behavior.

Although the contention that climate molds human behavior and development and may actually determine great events fell into disfavor among social scientists after Huntington's time, it occasionally re-emerges in contemporary thought. For example, Carpenter (1968) and Bryson *et al.* (1974) argued that drought caused the decline of Mycenaean Greek civilization during the late Bronze Age. Writing about contemporary disparities in the development of nations, Lambert (1975) and Harrison (1979) attribute to global climate patterns a range of sociotechnical characteristics, from labor productivity to agricultural efficiency. Some modern analysts continue to invoke climate to explain the slow economic development of particular regions, especially the tropics (see, for example, Oury, 1969; Myrdal, 1972). A contemporary natural science approach that has a determinist flavor is found in Chang (1970). Chang explored the temperature dependence of net photosynthesis and concluded tentatively that in warmer climates yields are smaller. A certain fatalism seems to underly the determinist view, a sense that deliberate societal strategies will make little difference in modifying the impacts on society. Instead, it focuses on the importance of how societies are initially endowed with climatic resources, which is largely a matter of chance occasioned by the unequal distribution of energy, water and land mass across the earth's surface.

3.2.2.1 Research Implications

The view of climate as a determinant is evidenced in contemporary research by the search for causal chains that link climate to specific elements or behaviors of biophysical and socioeconomic systems (see Maunder, 1970). This work has concentrated on outcomes, such as crop yields or industrial output, that can be quantified and numerically modeled. A statistical relationship between climate and some element of interest is termed a transfer function. Transfer functions have now been developed for most crops (see Nix, Chapter 5, this volume; Baier, 1977), for water supply (Nováky *et al.*, Chapter 8, this volume; World Meteorological Organization, 1974) and for energy use (Jäger, Chapter 9, this volume; McQuigg, 1975).

The major thrust of research associated with the climate-as-determinant view involves the detailing of climate-crop production linkages. Baier (1977) cites a long history of attempts to correlate crop yields with such elements as precipitation, temperature, soil moisture, and insolation. He argues that much of the work prior to about 1960 was based on shaky methods, but that in recent years several groups, for example, de Wit and colleagues at the Agricultural University of Wageningen, The Netherlands, have advanced the science by applying careful validation techniques. While such approaches are not strictly `determinist' in the language of statistics, both correlation-based and more physically oriented models, such as the deterministic crop growth approaches reviewed by Baier (1983), are founded on concepts of inescapable cause and effect between climate and crop yields.

Less formal relationships, sometimes simply verbal statements of the result expected in a biophysical or socioeconomic system given some initial climate state, have been described for several other areas. These include fisheries (Kawasaki, Chapter 6, this volume), forestry (Baumgartner, 1979), transportation (Wintle, 1960; Bollay, 1962; Beckwith, 1966; Evans, 1968), recreation (Hentschel, 1964; Clawson, 1966; Paul, 1972; Perry, 1972; Taylor, 1979), and construction (McQuigg and Decker, 1962; Russo, 1966; Musgrave, 1968; Martin, 1970; Maunder *et al.*, 1971). These studies are limited by their exclusive focus on one industry or one economic sector, and they are dated by technological change, but they nevertheless represent qualitative and quantitative attempts to describe causal linkages between climate and human activity.

Several obstacles have hindered the development of reliably applicable causal formulas for climate and impacted activities. Lack of understanding of the specific processes involved limits explicit, deterministic modeling, as does the absence of reliable, long time-series of quantitative data for both selected climate variables and the activities to which they would be linked. Crop yield data are of good quality in some parts of the world, encouraging the development of climate-crop transfer functions. Alternatively, fish populations are difficult to observe and available data series are short, hindering the estimation of quantitative relations between fisheries and climate.

Perhaps the greatest problem for determinist approaches is coping with complexity. Quantitative functions tend to be unidirectional, linear and limited in their ability to represent accurately the effects of simultaneously or abruptly changing factors. Difficulties in quantifying certain kinds of variables and in specifying nonlinear relationships have especially limited the development of reliable formal models of climate and socioeconomic factors such as health, population change, and economic activity. Some recent work, for example, Palutikof's (1983) study of the impact of climate on industrial production in Britain (see Table 4.5, this volume), by virtue of good care in accounting for factors exogenous to the climate ─society link, indicates promise for building better climate-society transfer functions in the future.

Often expressed in the scientific vernacular of dependent and independent variables, the contemporary development of climate─society transfer functions maintains the central core of determinist ideas and mostly represents a unidirectional view of cause and effect. While this paradigm is logical with regard to immediate climate─biophysical connections, it is more controversial when applied to connections between climate and human behavior, given the capacity for adjustment and adaptation. As Kates (Chapter 1, this volume) points out, deterministic models are useful simplifying tools that have allowed the explication of several important climate─society linkages, while, of course, not capturing the full complexity of climate-society interaction.

3.2.3 Climate as Hazard

Like the two previously described concepts of climate, the view of climate as a hazard to be suffered, accommodated, or mitigated is long-standing. Climate historians find ample records of extreme climate conditions (see Lamb, 1983), suggesting that the harmful and threatening aspects of climate attract the greatest human attention. For example, after overcoming their early expectations about climate (Kupperman, 1982), the early European inhabitants of North America were impressed by the severe and changeable aspects of that continent's very `un-European' climate (Ludlum, 1966, 1968). The modern view of climate as natural hazard owes its strength chiefly to droughts that occurred during the first half of this centry. Sub-Saharan Africa experienced extreme climate variability in 1910─15 (perhaps comparable to the 1968─74 `Sahelian' drought), and the North American Great Plains experienced multiyear droughts in the mid-1930s, described in detail by Worster (1979). In the southern hemisphere, parts of Africa south of the equator experienced major drought in 1919 (Tannehill, 1947) and Australia experienced severe droughts in 1902 and 1944─45 (Campbell, 1968).

While such widely reported climate extremes set the stage for the climate-as-hazard view, the accounts of droughts, cold waves, heat waves, and other climate variations were largely anecdotal until the 1930s, when researchers began to investigate systematically the role of natural hazards in human affairs, focusing first on riverine flooding in the United States (White, 1945). During the 1970s this interest evolved into an international research effort involving anthropologists, economists, psychologists, geographers, and sociologists along with geographical scientists. Case studies of a wide range of natural hazards were undertaken, including several atmospheric hazards in both developed and developing countries (White, 1974; see also Heathcote, Chapter 15, this volume).

Extreme climatic episodes during the late 1960s and early 1970s were assessed by some as a switch to a more variable and dangerous climate epoch. This view has been argued recently by Lamb (1983), who provides statistical evidence for a global increase in variability in the 1960s and an impressive list of climate extremes during the two decades 1960─80. Whether or not the global climate system has recently shifted to a more variable state (see Hare, Chapter 2, this volume), this perception has spurred studies of the impacts of extreme events and has been used to amplify the messages of those concerned that society's sensitivity to climate disruption might also be increasing, another of Lamb's arguments.

Several works on climate─society interaction addressed to a broad audience dwell on extremes and emphasize the increasing actual or perceived vulnerability of societies to climate. Roberts and Lansford (1979) present a roster of severe seasons and individual weather events to illustrate climate impacts, especially on global food supply. Case studies of particular climate extremes have ranged from García's (1981) eclectic review of the events of 1972 to assessments of the impacts of recent droughts, heat waves, cold waves, and wet seasons (see, for example, Posey, 1980; Assessment and Information Services Center, 1981).

While the studies of natural hazards have the merit of readily discernible climate─society linkages, the studies of extreme events do not often utilize common assessment methodologies or validation techniques and thus do not provide the comparable information needed to make broader generalizations about climate─society links in *extremis.* Moreover, it is questionable whether one can extrapolate from them to more common, moderate circumstances. The approach also tends to focus on a limited realm of adverse extremes. For example, although studies of extreme failures of grain harvests are common, little or no attention is given to surplus agricultural production situations, which may be equally climate-related and, in some respects, also carry important impacts. The view of climate as hazard is *a priori* rather negative, introducing a bias into the research that may be contrasted with the characteristics of the climate as resource view discussed below.

3.2.3.1 Research Implications

Research in the climate-as-hazard tradition is organized around the approach of `reasoning from extremes'. By focusing on extreme cases, which initially become known through firsthand reports of the event and its associated impacts, the researcher is virtually assured of relevant new source material and the discovery of climate linkages. While, as mentioned above, one might argue that the climate-as-hazard approach is by its nature limited to exceptional cases, it is also possible that the linkages easily observed in extreme cases also function in some more common `day-to-day' situations. For example, studies of how Great Plains wheat farmers cope with drought (Warrick, 1980) have illuminated a wide range of strategies inherent in that agricultural system for absorbing many types of climate variations, not only extreme ones.

Using `reasoning from extremes', natural hazards researchers have exposed issues important to climate impact assessment (see Heathcote, Chapter 15, this volume). First, hazards researchers have attempted to relate the level and distribution of hazard impacts to societal vulnerability across different levels of social integration and technological development (Burton *et al.,* 1978). For example, variations in vulnerability across societies in the developing world were scrutinized by Susman *et al.* (1983), who argued that vulnerability to disruption by natural events is closely tied to the problem of unequal international development and the marginalization of populations forced, by economic and political pressures, to rely on unsuitable lands for subsistence (see also Waddell,1975; Regan,1980; Spitz, 1980).

A second contribution of hazard research to climate impacts is focused on the particular mechanisms by which societies adjust to natural events. One collaborative research effort sought to identify adjustments in an international context (White, 1974) by studying 24 hazards, 21 of which were atmospheric in origin. Collective and individual adjustments adopted at local, national, and global levels were described first by a listing of theoretically possible adjustments, which were then compared to adjustments documented in actual field observation. The pattern of differences between theory and actuality led to the development of adjustment models that incorporate limitations in individual and group perception and decision-making (Slovic *et al.,* 1974).

Most generally, natural hazards workers have attempted to develop a perspective that visualizes impacts as the joint product of both geophysical states and levels of social vulnerability, a form of the interactive model described by Kates (Chapter 1, this volume). The underlying bias of hazards research is to see climate and nature as rather capricious and, thus, also to see a need for widespread defensive actions on the part of individuals and social groups. These actions often involve a reduction in the demands placed on climate, for example, through nonstructural increases in the efficiency of water use.

3.2.4 Climate as Natural Resource

Although the notion of climate as resource has a decidedly contemporary tone, especially with regard to wind and solar energy, the view predates the recent burgeoning of climate concern. For example, Landsberg (1946) discussed `climate as a natural resource' and `climate as national income', arguing that climate, once properly assessed, could be exploited to enhance human productivity, health, and comfort. During the 1940s and 1950s the notion of climate as resource was used to argue for better record-keeping and analysis. The international weather observation network, oriented toward daily forecasting and aviation safety, was not functioning well as a climate network. By arguing that climate was an important national resource, Landsberg and others urged better climate data management. Thus, an initial focus of the climate as resource theme was on measuring and assessing the climate resource base, similar to efforts in the minerals, energy, water, and forestry resource areas. In this respect, the resource view overlaps with the view of climate as setting.

Where the resource view differs from other perspectives is in its incorporation of attempts to value, allocate, manage, and manipulate climate. These approaches have been apparent in discussions about weather modification, and they are also evident in the development of the discussion of climate as an economic resource.

Resource economists, thinking about climate, have not settled on a single definition. Most resource analysts agree, however, that climate is a nonmarket resource, that is, a resource that is not valued and allocated by price mechanism in private trade. Thus, climate is initially best viewed as a public good. It is essentially a `free resource' (see Freeman, 1980), available to all economic actors at a given location. It is also a factor in production, and in some respects a common property resource (a resource to which access is open to all and whose utilization might affect all other users).

Although Samuelson, in 1954, provided a definition of public goods that can apply to climate—a good which provides benefits to all users with individual consumption leading to no decrease in any other user's benefits (see also Lovell and Smith, Chapter 12, this volume)— the analytical tools necessary to value and manage climate without recourse to conventional market criteria (which would obviate climate's inherent 'publicness') have been slow to develop. Some momentum was provided by the growth of environmental awareness in the late 1960s, when trends in population, living standards and environmental pollution exposed a wide rift between private and public goals with regard to the environment. Economists began using normative management models to calculate values for selected common property resources like oceanic fisheries (Gordon, 1954) and clean water; public property resources like wilderness; and intangible resources like quiet and scenic views. (See Kneese,1977, for a broad review of the development and nature of environmental economics.)

During this period, and by virtue of its visibility and the economic questions involved, the issue of air pollution further fostered a view of the atmosphere as an exhaustible natural resource to be valued and managed—and even bought and sold as a receptacle and disperser of industrial wastes (see Ausubel, 1980).

Of course, the resource view of climate does not rest solely on the many definitions emanating from the discipline of economics. Farmers, water resource managers, and even foresters might well consider climate simply as an extension of the commodity resources they manage. Most farmers would reckon climate as a basic resource when it is not being regarded as a hazard. As Ausubel (1980) argued:

> ... climate is matter and energy organized in a certain way. If a climatologist were to say to a farmer that the climate is going to change, the farmer could interpret this to mean that deliveries of matter and energy may be going to change in quantity, time and place, in ways similar to how supplies of fertilizer or gasoline might change. (Ausubel, 1980, 23)

The development of scientific cloud seeding by Langmuir and Schaefer in the mid-1940s (see Schaefer, 1946) also encouraged a natural resource view of weather. A key attribute of natural resources is that they are malleable in some way; that they can be managed for optimum characteristics and yield. Following Langmuir and Schaefer's pioneering work, weather modification was quickly developed and adopted as a resource management tool, although with little or no success. During the 1960s and 1970s, several countries attempted to manage rainfall resources via cloud seeding; operational projects were initiated in Australia, Honduras, the USSR, Israel and the United States, for example (see Hess, 1974, for a review of early weather and climate modification projects). Simultaneously, scientists began to search for economic and decision-making analyses that would determine how best to allocate weather and climate management efforts (see, for example, Sewell, 1966). They turned chiefly to cost-benefit analysis, which had been widely used to assess water development projects (see Prest and Turvey, 1965), thus putting climate (as measured, for example, by average rainfall, frequency of hailstorms, or number of foggy days) on a par with the traditional natural resource of surface water.

The growing recognition that human activity might, unintentionally, change global climate strengthened further its aspect as a natural resource. During the early 1970s, questions about the way an increase in high-altitude, supersonic air transport might affect the climate caught the attention of economists and other social scientists (see Climate Impact Assessment Project, 1975 and Glantz *et al.*, Chapter 22, this volume), who then sought to place social and economic value on climate elements in order to compare the costs of climate change to the benefits of supersonic transportation. Questions surrounding possible socioeconomic impacts of a CO_2-induced climate change also began, in the mid-1970s, to elicit reviews, programs, and analyses aimed at assessing the value of climate, and various scenarios of altered climate, to economic systems (see Clark, 1982). The notion of climate as a fixed constraint weakens in light of the potential consequences of human activities. Although the dominant focus in studies of the impacts of human-induced climatic change has been on negative aspects, the resource view also has led some scientists to consider the potential positive benefits of changed climate (Hare, 1983), and to propose altering human activities in order to manage the climate resource for maximum positive benefit (Kellogg and Schneider, 1974).

3.2.4.1 Research Implications

As noted earlier, research and analysis associated with the natural resource view of climate has evolved slowly, groping for an appropriate theory and perhaps hindered in some circles by the view remaining from the first half of the twentieth century that the background, unmanaged environment has no economic value (Krutilla and Fisher, 1975, 9). The resource of climate is essentially external to traditional economic markets and thus does not lend itself to standard neoclassical economic analysis. The development of welfare economics and the study of public goods has encouraged analysts to account for the effects of economic activity by calculating benefits and costs associated with natural resource utilization outside of the traditional market framework.

When climate is seen as a tangible good, it can theoretically be measured, valued, and managed in optimal ways that increase the derived net public benefit. Questions of climate change and weather modification have been the focus of such research approaches. For example, d'Arge (1979), attempting to assess the costs or benefits associated with anthropogenic climate changes, suggested three approaches for valuing climate:

1. assess the *alternative costs* associated with maintaining current production levels despite the climate change;
2. assess the costs of all production *opportunities* deleted or provided by the climate change; and
3. assess the *willingness to pay* of `users' of a given climate to maintain or change that climate.

Similar approaches have been applied to traditional natural resources like forests, and other newly recognized ones like wilderness and clean air.

Other approaches used to put a value on climate include calculating the differences it causes in wages and prices at different locations, the value it adds or subtracts from land, the impacts on crop prices, water supply costs and energy demand, and even the health maintenance costs associated with different climates (see, for example, Climate Impact Assessment Project, 1975; Freeman, 1980; Haurin,1980; and Lovell and Smith, Chapter 12, this volume).

Research under the climate as natural resource theme also focuses on ways that it might be managed and allocated. Curry (1962, 1963) studied how farmers are already managing the climate resource through land valuation, seasonal programming of activities, and support of weather modification projects. Because weather modification represents (in theory) direct management of climate resources, it has elicited research aimed at assessing the value it adds to climate-sensitive production (see Sewell, 1966).

Despite calls for better recognition of the natural resource attributes of climate (see, for example, Taylor, 1974, and White, 1979), this theme remains rather ill-defined and ambiguous. It awaits both further development of natural resources theory and the application of that theory to climate. However, the view of climate as partly influencable by human action is obviously an abiding one, recognizable in early as well as modern culture. What may be changing is that that view is being matched by a capacity to effect the transformations envisioned.

3.3 CONCLUSION

The four views of climate presented are not mutually exclusive. All appear in contemporary thought about climate and its impact on society, and climate certainly partakes of all four attributes. It acts as background, occasionally determines critical outcomes, often presents hazards or triggers disasters, and is a basic resource to human activity. Indeed, the difficulty in seeing the multifaceted role of climate in human affairs may be a key hindrance to progress in our thinking on the climate─society equation. The questions involved demand multiple cultural and disciplinary perspectives, and, as Hare (1982) noted: `In attempting to grapple with climate impact we (are) shaking the crystal lattices of politics and intellectual clan structure'. While climate research will benefit from the attention of several scientific schools, both physical and social, practitioners may be hesitant to leave their specialized realms and join one other in an integrated effort (Chen, 1981).

One might also argue that it is partly the nature of climate, allowing us so readily to project into it the character of determinant or hazard or resource or setting, that has also hindered our ability to focus research on climate problems. If climate is neither narrowly defined nor the particular specialty of any `intellectual clan', then who will take responsibility for pushing forward our understanding? This volume illustrates one way: by encouraging broadminded specialists to explore the application of their research tools to climate problems, by looking on climate fairly from many points of view, and by assembling those points of view.

Finally, what does the existence of multiple, enduring perspectives on climate and its impact tell us? Is there an implicit succession or cycle of the kind of themes discussed here? Can we achieve a more profound synthesis or will we largely reaffirm a set of basic biases with more refined arguments? Readers of this book are invited to form their own judgments.

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