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# CHAPTER 1

# *The Interaction of Climate and Society*

ROBERT W. KATES

*Center for Technology, Environment, and Development*
*Clark University*
*Worcester, Massachusetts 01610 USA*

## 1.1 INTRODUCTION

Climate impact assessment is one of a family of interdisciplinary studies that focus on the interaction between nature and society or the study of the human environment. As such it must draw upon theory, methods and research findings from all the great domains of science: physical, biological and social–behavioral. While hyphenated science (such as bio-physical, socio-biological) is common along the research frontier, integration of the three domains is rare. Although integration is necessary for nature–society problems, it poses a special challenge to science and scientific workers: to integrate their theory and methods with those of neighboring domains in ways that maintain the common ethos of scientific method.

Achieving that integration is a major objective of this volume. This introductory overview explores the underlying assumptions as to the relationship between climate and society common to most disciplinary or methodological approaches. The individual authors have addressed their colleagues in neighboring scientific domains, attempting to share with them the opportunities, limits, and problems of specific disciplines or methods. Nonetheless, there are at least two inherent problems with such scientific integration.

### 1.1.1 'Hard' and 'Soft' Science

The first and larger question relates to the apparent differences between the great domains. Most scientific workers would agree that as one moves from the physical to the biological to the behavioral–social sciences, one moves from older to younger sciences with less experience, consensual theory, and ability to experiment and replicate results. Thus there may be less predictability, more speculation and greater uncertainty.

These differences may be amplified further. First, it can be argued that as one progresses across the domains, complexity increases, reaching its height in the human sciences. If this is so, then it is not clear whether it is the youth and experimental limits of the human sciences or the complexity of the phenomena that they study that leads to the lack of consensual theory and predictability.

Second, a common sequence in climate impact assessment is for the ordering of impacts to parallel the ordering of scientific domains. A range of possibilities, outcomes and human choices is attached to each link in a chain of impacts, and uncertainty accumulates along the chain. Thus as one moves, for example, from an increase in global $CO_2$, to a shift in global heat balances, to regionally differentiated changes in climate, to impacts on primary production in agriculture or fisheries, to impacts on nutrition, trade and economic growth and development, the second- and third-order impacts become more diffuse, the possible outcomes multiply, and the level of precision diminishes. This ordering of impacts—from the physical ($CO_2$, heat balance, regional climate) to the biological (biomass, agriculture, fisheries yield) to the human (nutrition, trade, economic development)—parallels the major domains of science. Thus larger uncertainties are inevitably associated with the human sciences, although specific relationships (such as seasonal consumption *vs* seasonal weather) may actually be better understood.

These broad differences between the domains of science—whether attributable to the science, to the complexity of the phenomena studied, or to the ordering of impacts—all contribute to the pejorative distinction between 'hard' and 'soft' sciences. This distinction, however, should not dominate the practice of climate impact assessment. Volcanic eruptions and revolutions, jet stream tracks and business trends, may be equally difficult to predict. The coupling of the ocean of air to the ocean of water may be as poorly understood as the coupling of the biosphere to human society. Indeed, in each of the domains necessary for integrated impact assessment, a mixture of well- and poorly-understood phenomena will be found.

### 1.1.2 Linking Methodologies

A second problem of integration is the problem of linkage between very differing methodologies. For example, consider one important causal chain of impacts, the effect of some chlorine compounds on the stratosphere. For this chain, production data for chlorofluorocarbons are linked to models of chemical transformation, stratospheric diffusion and ozone depletion, informed by laboratory studies of chemical rate constants, and checked by rocket and satellite observations. These, in turn, are linked to varied epidemiological correlations with both melanoma and non-melanoma cancers, laboratory experiments with plants and animals, and economic extrapolation of the losses in productivity and costs of treatment and mitigation. Each of these methods of study and analysis has its own scientific style and language and differing standards of performance, replicability, uncertainty, and significance. Linking these diverse methodologies and estimating their cumulative error is a major task for the emerging quasi-discipline of risk assessment. As yet, there has been no comprehensive study of the problems of integrating such scientific apples and oranges.

### 1.1.3 Models of Relationships

This paper serves as an overview of impact methodology and it is organized by the assumed relationship between climate and society. All assessments of climatic impact assume, explicitly or implicitly, certain underlying relationships among climatic events and impacted people and places, often grouped together as populations of humans, plants or animals; social or economic activities; or regions defined by size or national boundaries. These relation-

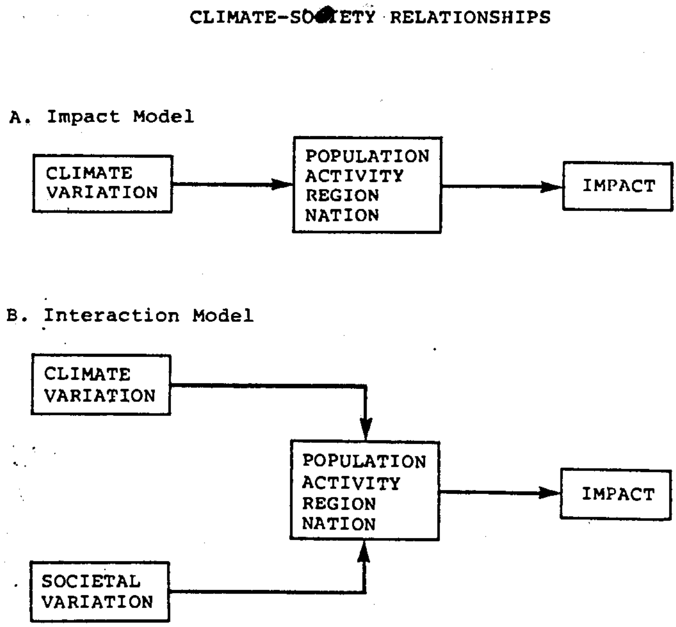


Figure 1.1 Schematics of impact and interactive models are highly simplified graphic depictions of types of study methodologies. They illustrate differences in assumed relationships and are not an attempt to 'model' or necessarily depict the 'real world' relationship. The boxes describe possible study elements and the arrows the direction of assumed relationships. Both models attempt to identify 'cause and effect' relationships, with climate the 'cause' in the impact model 1.1A and climate and society the joint 'causes' in the interaction model 1.1B

ships fall into two sets of nested models: impact models and interaction models. In their basic form they are shown in Figure 1.1.

In the simplest of assumed relationships, the impact model (Figure 1.1A), variation in one or more aspects of climate affects a defined population, activity, sector, region or nation and 'causes' impacts—changes in state that would not have occurred in the absence of the variation in climate state. Methodologies utilizing this model (and its elaborations) are overviewed in Section 1.2. Following that is Section 1.3, on studying interactions. The interaction model (Figure 1.1B) recognizes that impacts are joint products of the interaction between climate and society and that similar climatic variations will yield different impacts under different sets of social conditions. These social conditions determine whether a society is more or less vulnerable to an undesirable variation in climate or more or less able to utilize the opportunity provided by a favorable variant.

## 1.2 STUDYING IMPACTS

### 1.2.1 Impact Models

The basic impact model is part of a family of relationships (Figure 1.2) based on the assumption of direct cause and effect. Climate events impinge upon populations, activities, regions or nations and 'cause' impacts. An example from the literature can help describe that sequence.

Warrick (1980) and his colleagues set out to study the impacts of repeated droughts (five times since 1890) on the Great Plains of the midcontinental United States. His five-step study method is shown in Figure 1.3. In this model the sequence is as follows: drought (defined by specific space–time measures)

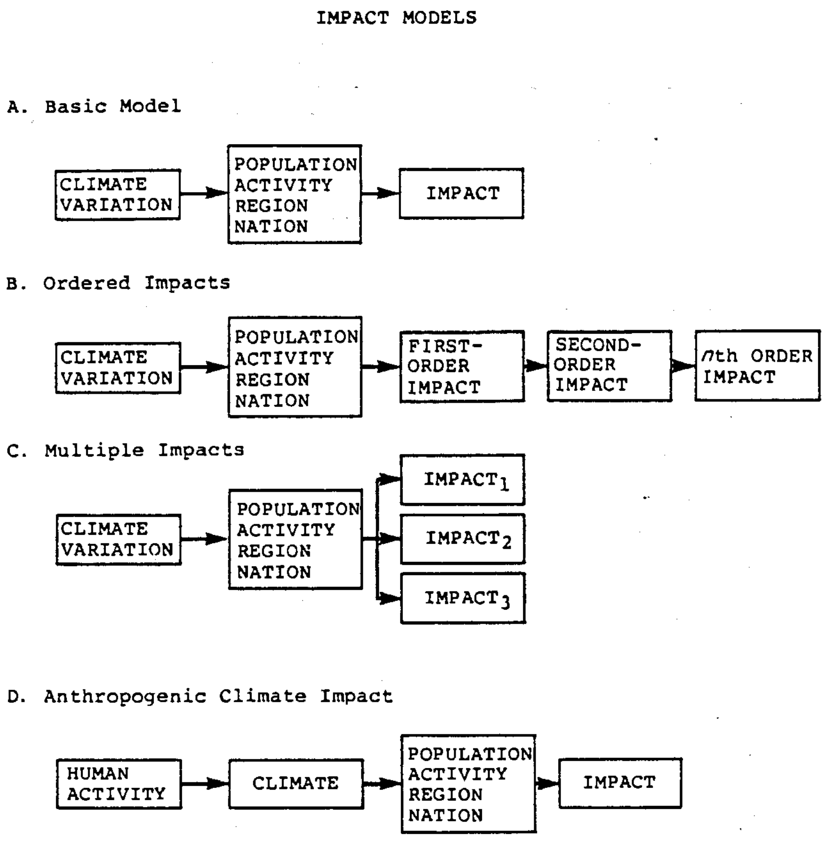


Figure 1.2 Four types of impact models: (A) the basic simplified model; (B) ordered impacts assessed as they cascade through physical and social systems; (C) multiple impacts in different sectors or within a given area; and (D) the impacts of human-induced climatic change

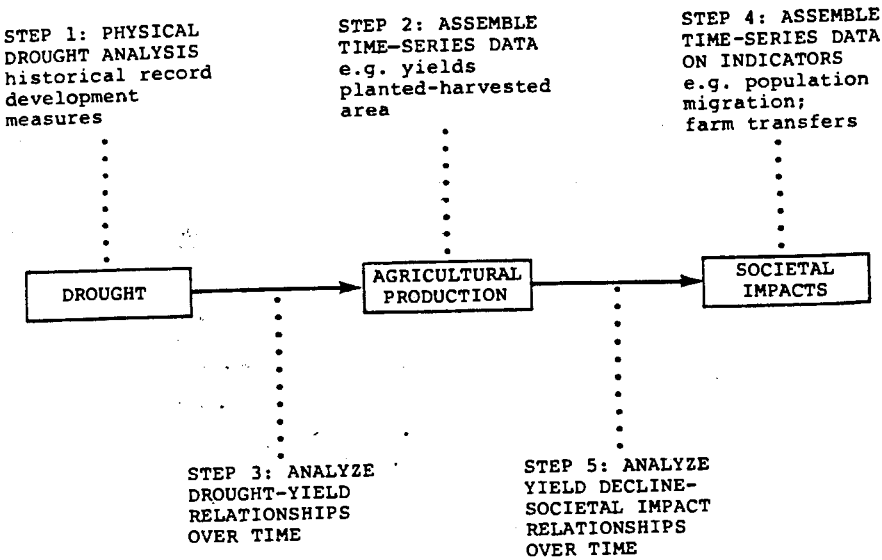


Figure 1.3 Methods used in a comparative study of a century of drought on the Great Plains of the United States. An example of an ordered impact study, with the first-order impacts of agricultural production leading to a variety of social and economic impacts impinging upon society. (After Warrick, 1980)

'causes' decreases in yield (production per unit area). In turn, this primary biophysical impact (yields) 'causes' societal impacts in the form of population movement, changes in farm ownership, and the like. The causation is implied; in actual practice drought–yield relationships combine biological theory with data from experimental plots, simulation models, and historical weather–yield correlations.

In this example, there are both first- and second-order impacts. The first-order impacts are direct measures of biological production (yield, differences between area planted and area harvested, etc.). The second-order impacts (population migration, farm transfers) ostensibly arise from the effects of yield decreases propagating through the network of social and economic relationships. This, then, is the expanded variant of the impact model with ordered impacts (Figure 1.2B). Other first-order impacts, such as yields of other crops, of grass, of insects and the like, could also be studied. This type of assessment is shown in Figure 1.2C as the multiple impacts model.

A final variant of the basic climate–society impact model describes climate changes and subsequent impacts due to human activity. For changes such as those due to fossil fuel consumption, chlorofluorocarbon production, or the use of the supersonic transport, there is an added step (Figure 1.2D) in the basic model. This is the model that underlies the Climate Impact Assessment Program (CIAP) study of the use of supersonic transport aircraft (Grobecker *et* *al.*, 1974) described in Chapter 22, and many studies on assessing fossil fuel burning (National Research Council, 1983).

### 1.2.2 Study Elements

Even with only three elements, as in the basic impact model (Figure 1.2A), the analyst must make many choices. In the Great Plains study, for example, drought had to be defined, the Great Plains areally bounded, agricultural production expressed as specific crops, impacts categorized, and indicators of these chosen. These study elements can be generalized as

1. climate events,
2. exposure units, and
3. impacts or consequences.

#### *1.2.2.1 Climate Events*

The nomenclature of climate is in dispute, depending in part on two somewhat different conceptualizations focusing on state and process (see Chapter 2). In one, climate is a statistical distribution of a set of atmospheric states, some of which are called weather. Climate variability is a measure of the dispersion of the distribution of such states. Climate change is a change in the parameters of the distribution. In the other concept, climate is a set of interacting geophysical processes that generate atmospheric states. Variation in atmospheric states arises from different interactions within the boundaries of those processes; climate change involves new and different boundary conditions.

As a statistical distribution, climate is continuous, yet it is helpful in describing impact methodologies to think of such distributions as being composed of three different scales of events: between-year weather extremes; persistent periods or decade-long episodes; and century- or multi-century-long climate trends.

For the *extreme weather events*—flood-producing rainfall, frost, fog, seasonal drought, storm, snowfall, and tropical cyclone—climate impact studies focus on the effects of their recurrent variation. When these between-year events recur consecutively, they appear as a *persistent period*. Intense precipitation events that cause floods, for example, are conveniently studied as annually-occurring events generally assumed not to be persistent, whereas droughts are studied primarily as persistent and cumulative multi-year events. Flohn (1979) and Kukla *et al.* (1977) have argued for a recent period of multi-year persistence of cooler weather. When century-long periods of above-or below-normal temperature and precipitation tend to recur in the period between glaciations, paleo- and historical climatologists delineate 'little ages', or epochs. The most notable of such recent ages are the 'little ice age' of the fifteenth to nineteenth centuries and the medieval warm epoch, or 'little climatic optimum', of the tenth to thirteenth centuries (Lamb, 1978).

In Chapter 2, our current understanding of each type of event and its controlling geophysical processes is reviewed. It is likely that each is generated by a different set of geophysical processes and boundary conditions—a different climate, in effect. They overlap, however; a 'little ice age' is composed of several persistent periods which in turn will be marked by cool and wet years, perhaps with early frosts or major floods. Understanding these relationships is very much a part of the research effort of the World Climate Programme. For the purpose of most impact study, however, this threefold distinction may be sufficient. The analyst needs to choose the appropriate scale of event to be considered and then describe its expected (normal or changed) variation.

### *1.2.2.2 Exposure Units*

Whatever the choice of events for which impacts are to be studied, an impacted group, activity or area exposed to those events must be selected. In general the focus is on individuals, populations (human or non-human) or species; activities in the form of livelihoods; specific sectors (in more differentiated economies); or on both the groups and activities found within a specific society, region, or nation-state. Some impact studies use a nested approach, building, for example, on models of a regional economy based on economic sectors, which in turn are based on the activity of individual people, households, or economic units participating in that sector. As with the choice of climate events, it is not easy to decide how to select the exposed groups, which activities to include or exclude, or how extensive the area of impact should be.

One strategy for selecting units is to focus on the climate event and to enclose the group, area or activity within a climatic boundary (such as semi-arid regions, hurricane-prone coasts, coastal upwelling zones, or floodplains). Conversely, one may use society as a starting point (as described in Section 1.3.1) and encompass especially sensitive societal groups or activities (see Chapters 10, 14 and 17) or areas engaged in certain activities (Chapters 5, 6, 7, 8 and 9). A third strategy is to select a unit relevant to some exogenous purpose, for example a national boundary, which might be neither climatically nor societally homogenous. Finally there is selection by opportunity, such as determining the unit to be studied by an existing model (Chapter 18) or data source, or by a particular extreme event (Chapter 15). The latter approach is particularly prominent in historic studies, where the availability of data seems to dictate the unit to be studied (Chapters 11, 21).

### *1.2.2.3 Impacts and Consequences*

The most difficult choices of study elements are the choices of impacts and consequences. Here it is helpful to assign an order of propagation (first, second, ... *n*th order) to events, although these may be arbitrary in the sense that the real time process actually takes place simultaneously or that the sequence, if any, is unknown. Nonetheless, it is useful to distinguish first-order impacts, usually of a biophysical nature, from higher-order impacts consisting of socioeconomic valuation, adjustment responses, and long-term 'change'. It is also important to recognize the dual nature of impacts: gains as well as losses are experienced, and growth as well as decline takes place. One version of such ordering to describe historic analyses is given in Figure 1.4 from Ingram *et al.* (1981).

First-order or primary impact studies are the most common form of impact study and have the best developed methodology. In several activity sectors—food and fiber, water, heating and cooling energy—quantitative functional relationships in the form of weather–yield models (Chapters 5, 8), rainfall–runnoff models (Chapter 8) and energy demand models (Chapter 9) have been constructed for many parts of the world. Midlatitude tree growth is carefully calibrated with climate indices because it serves as proxy data for inferring climates, and can be used for forest growth studies. In other primary production areas, such as fisheries (Chapter 6) and pastoralism (Chapter 7), relationships are often qualitative, both species- and locale-specific, or in need of study.

The most common secondary impacts studied are hunger and malnutrition (Chapter 10), economic disruption (Chapter 12) and other social impacts (Chapter 13). Detailed historic examples of the depopulation of marginal lands during the fourteenth to seventeenth centuries in Scotland (Parry, 1978), widespread hunger in Europe in 1816–17 (Post, 1977) and other historical case studies are given in Chapter 21. Studies of contemporary problems (Chapter 22) include hunger, starvation and death, and economic loss in the Sahel (Seifert and Kamrany, 1974; García, 1981); or the socioeconomic effect of diminished crop yields (National Defense University, 1980).

The chain of impacts can be extended to the wider economic and social impacts, as shown in Figure 1.4. One set of such impacts involves adjustment responses, activities designed to alter potential impacts by modifying climatic processes or altering biospheric vulnerability. For convenience these impacts are discussed within the framework of interaction studies (see Section 1.3), but they should also be viewed as direct consequences of climatic variability and change. Indeed, in many areas (such as urban water supply) the major impacts of climate variation are the very large efforts and expenditures made to prevent adverse effects.

The use of the basic impact model is criticized in this volume and elsewhere for its literal determinist implications, and for its use of climate as a major determinant of human events (Chapters 3, 11, 14 and 21). While there are many examples of such usage, most analysts use it not for simplistic thinking but as a simplifying assumption. Through a variety of research designs and

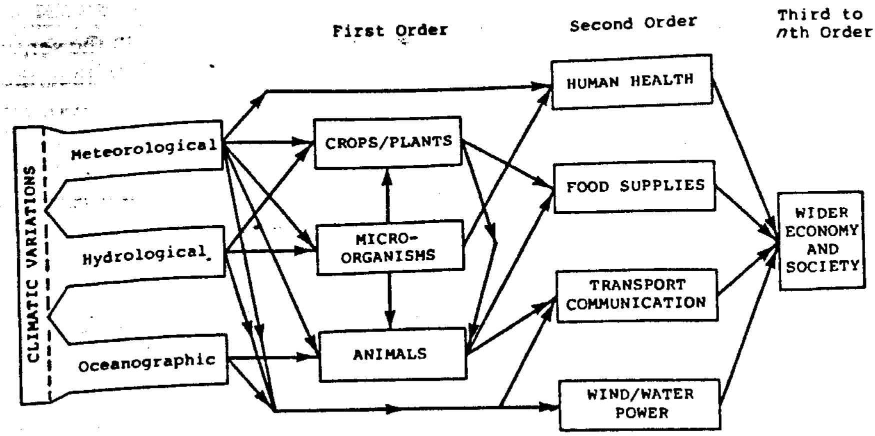


Figure 1.4 First- to *n*th-order effects of climate on the environment and society. As the specific impact becomes more removed from the 'cause', progressively more interactions intervene to disguise and modify the link. (Reproduced by permission of Cambridge University Press from Ingram *et al.*, 1981)

statistical devices they seek not to ignore societal interaction, but to hold it constant in order to examine the climatic contribution to impacts in isolation from societal influence. Alternatively, other analysts seek to include societal variation as a specific element in interactive studies.

## 1.3 STUDYING INTERACTIONS

The specific inclusion of some aspects of human activity and social organization along with climatic variation is the essence of interactive models. Such an approach is explained in the observation made by the SCOPE *Workshop on Climate/Society Interface* in 1978:

> ... that a change in *either* climate *or* society affects impact. Since both climate and society are constantly changing, the magnitude and character of impacts is also not constant. Impact studies must, therefore, involve investigations of climatic variability *and* of social change. The question to be addressed to any society at any time is: 'Is the society becoming more or less vulnerable to climatic variability?' Or to put the matter differently, 'Will any specific proposed social change or development have the effect of increasing or decreasing vulnerability?' (SCOPE, 1978, 17).

### 1.3.1 Interaction Models

The basic interactive model is sketched in Figure 1.5A. Such an interactive model forms the basis of the historical work of Rosenof (1973) on Ellis County, Kansas (USA) and to a lesser degree that of Parry (1978) on Scotland, as well as a number of case studies in the International Federation of Institutes for

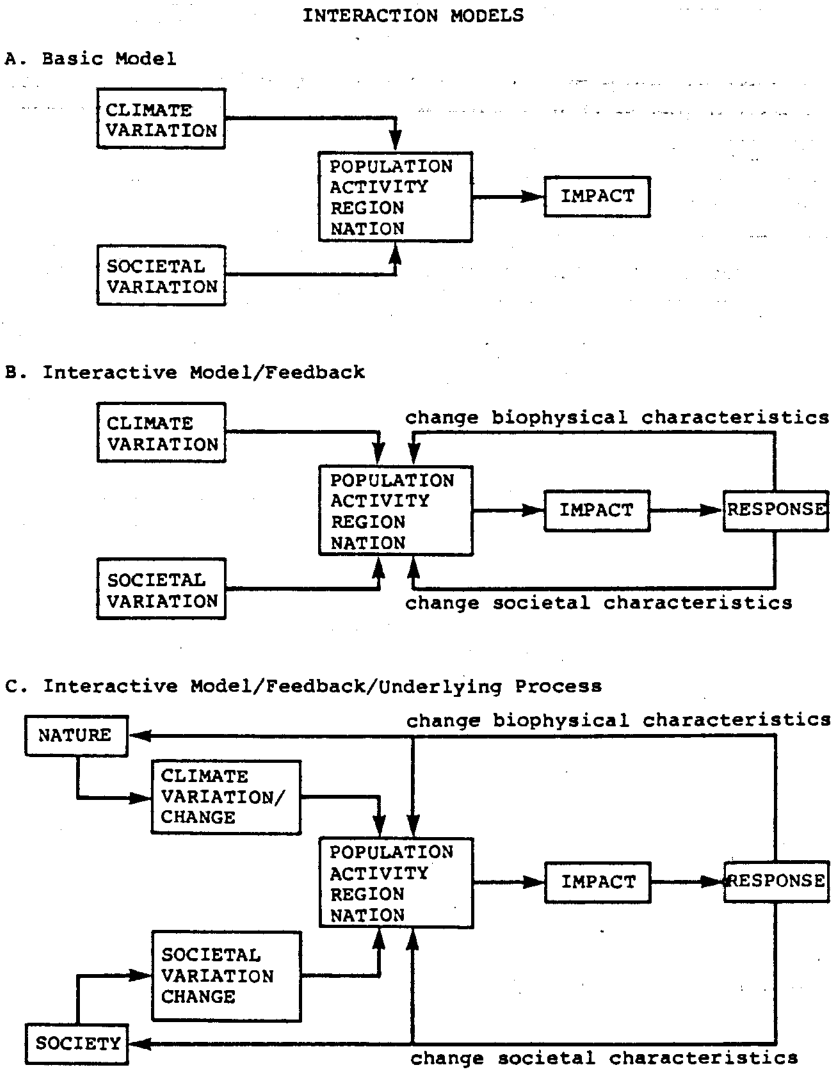


Figure 1.5 Three types of interaction models stressing: (A) simple interaction, (B) feedback to the social activity, and (C) feedback to underlying physical and social processes and structures

Advanced Study (IFIAS) project, *Drought and Man, 1972* (García, 1981). But studies that limit themselves to considering only a single sequence of climate–society interactions are actually few in number. Combinations of human activity or social organization invariably lead to the consideration of human responses. Such responses, in the form of adaptations or adjustments, act functionally to change either the biophysical characteristics or the societal characteristics of the interaction (Figure 1.5B).

It is easier to draw schematics than to describe what actually occurs. Variables described as 'climatic variation' or 'societal variation' are themselves products of the underlying processes of nature and society. Thus one can move further upstream to consider the 'nature' system from which climate variation is derived and the 'society' system that provides social variation (Figure 1.5C).

In the natural system there are basic variations in process (solar fluctuation, orbital variation) that may underlie climate variation. Or there may be anthropogenic activity, such as the burning of fossil fuels or deforestation, with a resultant increase in the $CO_2$ content in the atmosphere. In the recent IFIAS study of the impact of drought worldwide in 1972 (García, 1981), it is suggested that several societal processes, wholly independent of the climate event, actually created the basis for some of the observed impacts of food shortages, high prices and resulting famine. These processes included major changes in US and USSR national food policies as well as the historical effects of colonialism in increasing the vulnerability of Third World people to external forces.

In moving from an idealized sketch of interactive relationships with feedback—acknowledging the distinct processes of society and nature—to a concrete design for an assessment, a process of oversimplification inevitably seems to take place. When societal interaction and human response are added to the basic impact model the analyst has to grapple with three new problems:

1. How to characterize society, social organization, and societal change and variation?
2. How to study and describe human response, adjustment and adaptation? and
3. How to examine the interaction between society and nature, social change, and climatic change?

### 1.3.2 Characterizing Society

The term 'society' is commonly used for small social groups, as a generic term for human organization, and as a reference to particular ethnic, livelihood, geographic or political entities that range from groups greater than families to archetypes of socioeconomic organizations which include many nations. Thus while conveniently ambiguous, it requires specific characterization in assessment studies.

#### *1.3.2.1 Between Societies*

On a global basis, the division of societies focuses on issues of development. This is done in two ways, by dividing societies into 'developed' and 'developing' nations, either as individual nations or regional clusters, or by generalized archetypes of development that do not necessarily coincide with political boundaries. Both developed and developing nations are frequently differentiated by whether they are market- or centrally-planned economies. Developing nations may be classified by income (per capita, gross national product) and/or other measures (such as percentage of literacy, percentage of employment in manufacturing), yielding such classes of nations as 'least developed' or 'most seriously affected'. The World Bank (1980) groups nations into a sixfold hybrid classification (low income, middle income, industrialized, capital surplus, oil exporters, and centrally planned) and the Organization for Economic Cooperation and Development employs a similar sevenfold classification. Beyond the simplicities of North–South and East–West regional groupings, Mesarovic and Pestel (1974) employed 10 regions in their World Model and Leontiev (1977) employed 15 regions in his.

In lieu of dividing the world, matched samples have been a convenient device. For example, studies of the national impact of three major atmospheric hazards have used matched country samples: drought (Australia, Tanzania); flood (Sri Lanka, United States); and tropical cyclone (Bangladesh, United States) (Burton *et al.*, 1978). Although these studies are in many ways an odd assortment (arranged for the most part by the availability of cooperative investigators), summary results as shown in Table 1.1 reveal a general and consistent set of differences. Deaths are found primarily in the three developing countries studied, and although the absolute amounts of economic costs and losses are greater in the cases of Australia and the United States, the relative impact of the events is still felt most heavily in the developing countries. In terms of the percent of per capita GNP, these three atmospheric hazards extort an economic impact ten times greater in the developing countries than in the two industrialized countries.

### *1.3.2.2 Within Societies*

Within a particular nation or region several different approaches have been used to characterize society, including

1. modeling the overall society, economy or particular activity;
2. identifying perturbations—extreme or unusual social events that are the equivalent of extreme natural events or climate anomalies;
3. differentiating groups, livelihoods, subregions or activities by their potential vulnerability to climate change and variability; and
4. examining social factors, mechanisms, and trends that lead to greater or lesser vulnerability.

### *1.3.2.3 Society, Economy, Activity*

For most societies, economies, or livelihood activities, there already exists a

Table 1.1 Selected estimates of natural hazard losses

| | | | | | Losses and costs *per capita* at risk | | | |
|---|---|---|---|---|---|---|---|---|
| Hazard | Country | Total population (millions) | Population at risk (millions) | Annual death rate/million at risk | Damages losses ($) | Costs of loss reduction ($) | Total costs ($) | Total costs as percent of GNP |
| Drought | Tanzania | 13 | 12 | 40 | 0.70 | 0.80 | 1.50 | 1.84 |
| | Australia | 13 | 1 | 0 | 24.00 | 19.00 | 43.00 | 0.10 |
| Floods | Sri Lanka | 13 | 3 | 5 | 13.40 | 1.60 | 15.00 | 2.13 |
| | United States | 207 | 25 | 2 | 40.00 | 8.00 | 48.00 | 0.11 |
| Tropical cyclones | Bangladesh | 72 | 10 | 3000 | 3.00 | 0.40 | 3.40 | 0.73 |
| | United States | 207 | 30 | 2 | 13.30 | 1.20 | 14.50 | 0.04 |

(After Burton *et al.* 1978)

body of scientific description of structure and function. In some cases, primarily economic activities, quantitative models have been built. Some type of national economic model exists for most countries. Thus, one starting point for an interactive study is to draw on existing societal theories, descriptions or models and attempt to relate these to climate variations. In practice, there is only limited experience with the use of existing economic models (Chapter 12), biophysical models (Chapter 18), and social theory (Chapter 13).

The *Global 2000 Report* by the US Council on Environmental Quality (1980) attempted to link climate data to available government models with little success. The Computing Center of the USSR Academy of Sciences is currently constructing a global biosphere model that would link the global atmosphere and oceans, economy and ecology (see Chapter 19). Some success in using existing models has been obtained with agricultural and food models, such as the Model of International Relations in Agriculture (MOIRA) (Linneman *et al.*, 1979); the US Department of Agriculture grain, oilseed and livestock (GOL) model (USDA, 1978); the University of Southern California interactive model (Enzer *et al.*, 1978); and the International Futures Simulation (IFS) model (Liverman, 1983).

Johnson and Gould (1984) have used the extensive archeological/anthropological theory and description of Mesopotamian floodplain irrigated agriculture to construct a model of the society along the Tigris and Euphrates Rivers during the last 5000 years. This working model (abstracted in Figure 1.6) was then used to examine the impact of climate variability on the size of population. In their simulation, a variable climate as opposed to a constant climate was found to limit the 'carrying' capacity of the system, but actually extreme periods of drought lead to an increase in population carrying capacity by stimulating the extension of the irrigation system.

### *1.3.2.4 Vulnerability Concepts*

An alternative to trying to describe or model an entire society, economy or region is to focus on particular aspects of social structure that the analyst thinks are related to the issue of increased vulnerability to or utility of climate. Several related methods have been used to approach the issue; underlying each is a common conceptual basis somewhat akin to the engineering concepts of stress and strain.

In this view, societies experience *perturbations* that stress the system(s) under consideration. How the society responds to the perturbation is determined by its *vulnerability*, literally meaning its capacity to be wounded. In the sense of societies impacted by climatic or social perturbation, vulnerability is the capacity to suffer harm or to react adversely (Timmerman, 1981).

Societies have as well a capacity to resist such harm in quite different ways, which may be suggested by the contrast in western and eastern metaphors of

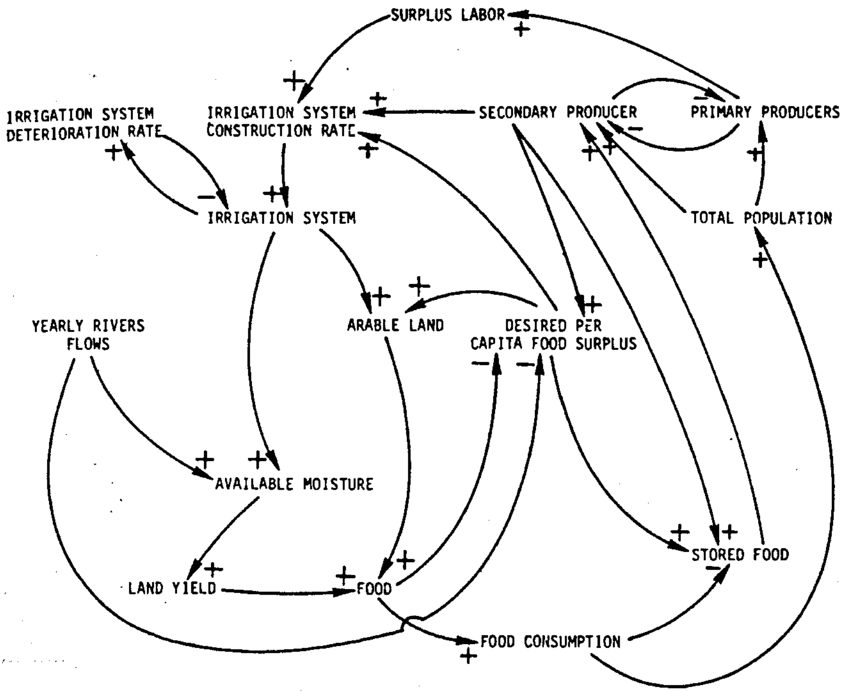


Figure 1.6 Major feedback loops of a model construction of an irrigation-based village or tribal society on the floodplain of the Tigris–Euphrates rivers *c.* 5000 years ago. The model is used to test the impact of climate variability and change on human population numbers. (Source: Johnson and Gould, 1984)

martial arts—the strength of the oak tree versus the resilience of the bamboo. Thus some societies respond to perturbation with properties that resist displacement from an equilibrium variously characterized as *stability* (Holling, 1973); *absorptive capacity* (Burton *et al.*, 1978); and *endurance* (García, 1981); or by such terms as *inelasticity* or *resistance*. Other societies respond by being *elastic* or highly *resilient* (Holling, 1973; García, 1981); they may be displaced easily from an equilibrium but they eventually rebound to that equilibrium position without *structural change* (García, 1981); *extinction* (Holling, 1973); or *societal collapse* (Timmerman, 1981).

An extension of these basic concepts finds differing emphases by various authors. García (1981) notes that these modes of response are not mutually exclusive and societies might possess properties of both high or low resilience and endurance. Alternatively, Holling (1973) contrasts resilience and stability, suggesting an implied tradeoff. This tradeoff is carried a step further by Bowden *et al.* (1981), who hypothesize that various technological and social responses that lessen the impacts of minor climatic stresses may serve to increase the catastrophic vulnerability of the society to a major perturbation.

The value of this conceptual framework beyond the heuristic level of metaphor or illustration is not yet clear and is not helped by the profusion of somewhat different definitions accorded to the same concept (resilience, for example, is variously interpreted by Holling [1973], García [1981], and Timmerman [1981]). But as a guide towards characterizing society, these concepts lead naturally to three methodological emphases: on perturbation; on vulnerable people, regions and activities; and on societal actions that increase or decrease vulnerability.

### *1.3.2.5 Perturbations and Extreme Events*

The first approach attempts to deal with a major criticism of the basic impact model; namely, that it assumes that the observable impact results from a climatic variation or change, whereas in reality it may have been produced by another cause or by the joint action of climate with another event.

For example, in the Great Plains case study (Warrick, 1980), the social impacts in the form of population migration and farm transfer were surely affected by the great worldwide economic depression during the 1930s that preceded and coexisted with the drought conditions. The 'year without summer' in North America and Europe, 1816–17, which was linked to the eruption of Mt Tambora in Indonesia, similarly saw widespread agricultural failure coupled with a post-Napoleonic-war economic slump (Post, 1977).

Identifying such events, then, is one form of societal description. The analyst, particularly in historical studies, abstracts from the massive social experience those events that would seem to reinforce or buffer the impacts of climatic variation or that serve as alternative explanations for observed impacts. Parry (1981) has labeled such events 'proximate factors'. Such events can be thought of as perturbations in the system's environment.

In this view of climate–society interaction, adverse perturbations may arise from either climate or society, and in rare cases they may be functionally the same even if their origin differs. The clay tablets of the Kingdom of Larsa, which existed 4000 years ago on the floodplain of the Euphrates River, tell of the dependence of the city–state on its major irrigation canals and the efforts of invading forces to throw dikes across the canal in order to sever the water network (Walters, 1970). In terms of perturbations, such warlike activity is functionally indistinguishable from a major flood that severed the network by washing out the canal. Similarly, the loss of water from a sustained drought could be functionally equivalent to the loss of water from failure to organize the cleansing of the irrigation channels of silt and vegetation.

### *1.3.2.6 Vulnerable People, Regions and Activities*

A second method of characterizing society's relationship to vulnerability is to focus on vulnerable people, groups, places or livelihood systems. Climate variation may be expected to impact especially those groups, activities or regions that under 'normal' climate conditions are already stressed (Chapter 14). Thus peoples whose social or economic position is already marginal are especially vulnerable. Similarly, places that during 'normal' climate conditions are already on the margin of cultivation or pastoralism are most susceptible to adverse impacts from unfavorable climate anomalies or changes. And within economies, activities that at best are hardly remunerative cannot withstand further stress from climatic variation.

To give but one example, two great droughts have occurred in the Sahelian-Sudanic region of West Africa in this century (Kates, 1981). In brief, there are two major livelihood groups in this area whose activities overlap—nomadic pastoralists and sedentary agriculturalists. Between 1910–15 when the first drought occurred, and 1968–74, the period of the most recent drought studied, a major change in the social status of the two groups took place. During the first drought, the nomadic pastoralists, especially the camel-herding Tuareg, were still reasonably independent of colonial rule and had a complex set of vassal relationships with agriculturalists, who tilled in their behalf. By the time of the most recent drought, the numbers of nomads had diminished, former slaves and vassals had been freed, raiding for food was no longer an option, and the Tuareg role in trans-desert transport had almost disappeared. Independent governments administered by agriculturalists existed in each Sahelian country. This shifting fortune was strongly mirrored in the impacts of hunger, starvation, malnutrition and economic loss suffered during the recent great drought. And in the region as a whole the same pattern held. The Sahelian countries—arid, poor, mostly landlocked—suffered more than their neighbours in Nigeria or Senegal.

### *1.3.2.7 Cumulative Changes*

The shifts in vulnerability among Sahelian peoples exemplify a third analytic approach, one which focuses on trends that may consist of small, cumulative changes in either lessening or increasing vulnerability. For example, let us return to the Great Plains case study. Commercial agriculture on the Plains is about 125 years old, and during this period five major droughts have been experienced. Warrick (1980) and colleagues hypothesized that if one could equalize or normalize the physical extent of these droughts, their negative impacts would appear diminished over time because of long-term societal trends that tend to lessen the impact.

Analysts frequently assume these trends in an unspecific way. For example, technology in agricultural studies is often represented simply by a linear time trend (see Chapter 5). The assumption is that technological changes account for yield increases and can be simulated by the passage of time. Comprising 'technology' are many small changes in plants, cultivation techniques, farming machinery, and farm organization that increase yields over time. Thus yields during a drought occurring late in a time-series undergoing such a trend will surely be larger than yields during an earlier drought. To that extent, the impact of drought is lessened.

Conversely, the analysis might argue for increased vulnerability. The shifts in vulnerability observed in the Sahel over time, for example, were part of a larger trend in which colonialism increased the commercialization of agriculture in many parts of the world. The result was decreasing proportions of crops grown for local consumption and increasing amounts of export crops, thereby reducing the stores of food crops and of labor available to buffer drought (Kates, 1981).

Thus societal trends related to vulnerability can be described in such unspecific terms (technological change, commercial development, or even 'colonialism'), or in very specific terms. In a major US review of natural hazards (including nine atmospheric hazards), a number of major and minor societal trends were examined for their impact on hazard vulnerability and included: population size and distribution; the establishment of second homes; the use of mobile homes; corporate organization; health, safety, consumer protection and environmental impacts leglislation; the legal system; tax policy; and communication patterns (White and Haas, 1975).

### 1.3.3 Describing Human Response

Purposive action is the distinctive characteristic of human behavior. Almost all climate events, if they recur or persist, evoke some individual and collective human activity intended to prevent, reduce or mitigate undesired impacts or to enhanced desired outcomes. The World Climate Programme and this volume are part of that process, but so are nomadic movements, granaries, futures markets, and collecting firewood.

The ways in which such activities are described are quite numerous. For example Ingram *et al.* (1981) describe four classes of adjustments: the adjustments of climate, of the biosphere, of society, and inadvertent, unplanned or uncontrolled effects (see Figure 1.7). In dealing with anthropogenic change, Kellogg and Schware (1981) distinguish between measures designed to avert change and those designed to mitigate the effects of change. Meyer-Abich (1980) distinguished between prevention of, compensation for, and adaptation to $CO_2$-induced climate change. Schelling (1983) suggests four categories of response to $CO_2$-induced climate change—options involving

1. the production of $CO_2$,
2. its removal from the atmosphere,
3. the modification of climate and weather, and
4. adaptation to anticipated and experienced change.

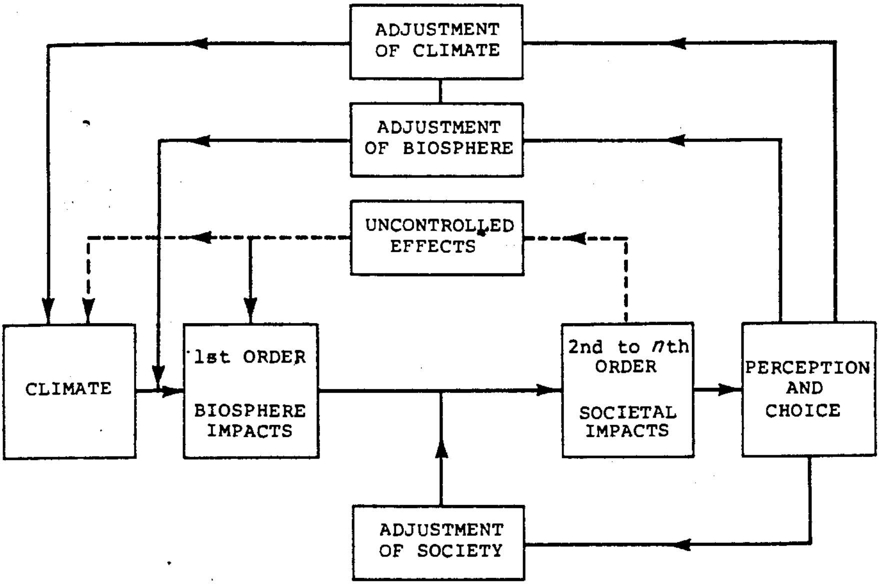


Figure 1.7 Conceptual model of the impact of climate on man and society, showing possible feedbacks via adaptive strategies. Uncontrolled effects refer to inadvertent or unplanned modifications of the biosphere and/or the climate as a result of climatic stress or otherwise. (Reproduced by permission of Cambridge University Press from Ingram *et al.*, 1981)

These logical distinctions have been elaborated on in a typology of human responses developed by geographers in their collaborative work on natural hazards (Burton *et al.*, 1978).

### *1.3.3.1 Adaptation and Adjustment*

This typology distinguishes between cumulative long-term responses to natural hazards, called *adaptations*, and short-term responses, described as *adjustments*. Adaptation can be biological or cultural. There are a few well understood biological adaptations to climate (for example, body heat and evaporation control). But it is primarily through culture that human societies adapt to the many different climates that humans inhabit.

The distinction between adaptation and adjustment is not very clear. Burton *et al.* (1978) give the following examples:

> Building a dam to store additional water for irrigation during a drought period would be classed an adjustment. A system of cut-and-slash farming in the Laotian highlands, with all its requirements for appropriate social organization in timing the cutting, burning, cultivation, and revegetation of forest lands, would be counted an adaptation. Designing a house to resist a storm surge would be an

> adjustment; locating and organizing a community over a long period of time so that its houses are beyond the reach of storm surge would be an adaptation. An individual or group may, however, choose to apply as an adjustment a practice that long has been an adaptation elsewhere, as when a home owner builds a house flood-proofed with a design imported from a distant place. (p. 37)

Adjustments are both incidental and purposeful. *Incidental adjustments* are those actions that functionally serve to reduce vulnerability, although their origin is for a non-hazard-related purpose. Thus a community that restricts mobile home usage for taxation, social class or amenity purposes also lowers its vulnerability to tornadoes and windstorms. *Purposeful adjustments* take three general forms: accepting losses and distributing their impacts in various ways; reducing losses by trying to modify events or prevent their effects; and basic changes in location or livelihood systems. The range of theoretical adjustments for an individual or small group is shown in Figure 1.8. In actual practice, this range may not be available, especially to marginal social groups or areas.

In all these classifications, their authors acknowledge the somewhat arbitrary typology and the overlapping categories involved, but in practice there seem to be few problems of interdisciplinary understanding. The problems of studying adaptation and adjustment are not those arising from

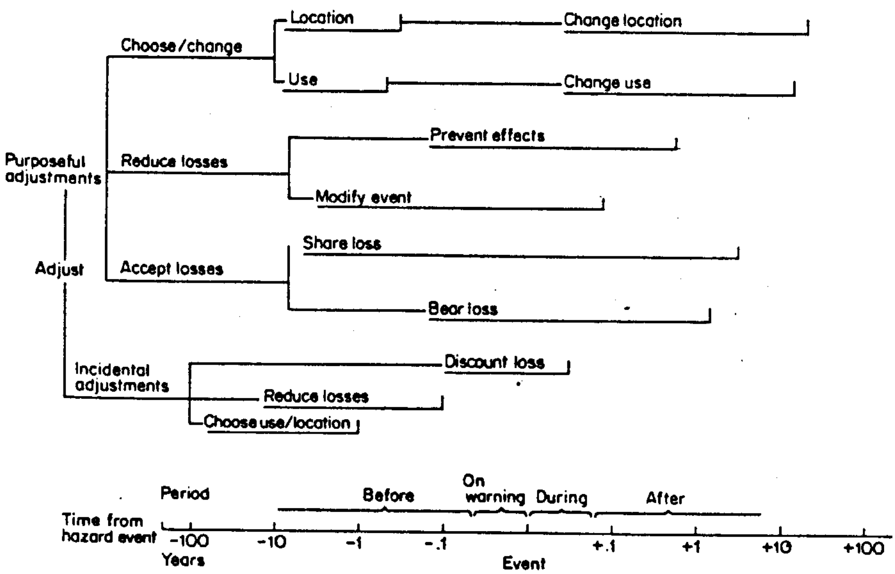


Figure 1.8 A Choice Tree of Adjustment. Adjustment begins with an initial choice of a resource use, livelihood system, and location. For that choice various incidental and purposeful adjustments are available, at somewhat different time scales for initiation. The most radical choice is to change the original use or location. (Reproduced by permission of Oxford University Press from Burton *et al.*, 1978)

different terminology or categories. Rather they involve basic problems of perception, function analysis, and social theory.

### *1.3.3.2 Understanding Perception*

To understand retrospectively the utilization of adjustments, one needs to reconstruct the perceived climate, its variability and changes (Chapter 16). Such historical reconstruction (Wigley *et al.*, 1981) requires documentation, which limits such work to literate societies and the literate classes within societies. Ideally, such perception data (from reports, letters and journals, for example) should be calibrated with a climatological record. When such calibration can be done, surprising results may follow. For example, Lawson and Stockton (1981) demonstrate that the widely denigrated fictional 'myth of the Great American Desert' was actually supported by the experience of the Long expedition, whose report identified an area of the Great Plains of the United States midcontinent as desert. By happenstance the expedition took place in the core region of a severe drought, providing in a relative sense a drought greater than that of the 1930s. In general, however, there is a considerable circular involvement in the reconstruction of past climates (Chapters 11, 21), with the perceptions of climate used to reconstruct a climate record which in turn might be used to calibrate the perception. An example would be the use and interpretation of personal diary observations.

In modern studies, there is a large body of theory and method that can be used in eliciting current perceptions of climate variability and change, but except for extreme events there has been little study of perceived climate variation. One recent study in Toronto, Canada finds a very widespread popular belief that climate is changing (Chapter 16).

Perceptions are not limited to those who live and work in an area under study. The line between scientific judgments and perceptions is a narrow one. Studies such as the one conducted by the National Defense University (1980) formally elicit professional judgments of trends in climate change in a probabilistic format, then utilize such judgments as input to impact studies. The link between perception and adjustment has been explored only in limited ways. Warrick and Bowden (1981) have shown, in the case of the Great Plains, that recurrent droughts seem to have created a scientific and public perception that leads to relief measures in anticipation of actual drought, to the point of providing relief to local areas in which drought does not actually materialize.

### *1.3.3.3 Attributing Function*

A second major problem in adjustment–response analysis is the attribution of function to discrete actions which are part of a cultural whole. Porter (1976) has posed this question in his description of Kamba farming practice in Kilungu, Kenya. To the external observer the fields of the Kamba are jumbled and disordered—maize, beans, cow peas, sorghum, groundnuts, bullrush millet, red millet, cassava, pumpkins, callabashes and pidgeon-peas planted together in a single field. Porter describes the functional adjustments:

> The crops come up all together in a riotous profusion of vines, leaves and stems. Weeds have no chance. The phosphorus flush in the soil that comes with the first rains is taken advantage of by these crops. Crops, such as maize, which might be indolent about putting down roots and strong tillers in a soil well supplied with moisture, have to compete with the other plants, and thus they put down roots to a depth of several feet. These deeper roots come into play later on in the season. Although the rate of moisture use of all these crops planted together is high, it occurs at the one time of the season when there is likely to be enough moisture available. Further, the interplanting provides a good continuous canopy within which photosynthesis can proceed. Since tropical areas have a relatively uniform radiation income all year around, a continuous leaf canopy, one with a moderate to high leaf-area index, is the most efficient user of radiant energy for photosynthesis....
>
> After about seven or eight weeks some of the crops are harvested. Beans may be harvested as green vegetables. As the season progresses the millet is harvested; beans harvested for seed are taken and the vines pulled up. The number of plants per square meter of soil begins to decline and only crops requiring a longer time to mature are left. The bare weedless soil between the plants is dry, which forms a barrier to the movement of moisture to the surface. Evapotranspiration thus is reduced. The sparse plant population remaining is able to tap moisture from a larger volume of soil without competition from adjacent plants. This moisture, combined with the lesser amounts of rain which come at the end of the 'grass rains', many times is sufficient to bring the maize and the longer growing millets to harvest. The plants also provide some shade for crops set out to get a start on the main rains. The thick mat of plant cover in the first weeks of the 'grass rains' and the second rains also serve to hold the soil. There is also the adaptive fact that if the rains do give out, some crops will have been harvested and the agricultural effort will not have been a total loss. Another fact is that interplanting reduces the amount of work considerably by eliminating the need to weed, which often is the most serious impediment to agriculture and the management of larger acreages. (Porter, 1976, 134–135)

This agricultural system has considerable built-in capacity to absorb the effects of drought. The complex of practices may be described as a cultural adaptation or a mix of incidental adjustments. In either case they are largely unconscious on the part of the farmer; in a sense he farms better than he knows. This presents two problems to the analyst: how to characterize the complex of practices made up of so many distinctive and interwoven plants, activities, cultural practices and timing, and how to attribute individual or aggregate purpose to the cumulative successful function. These problems are exacerbated in historical case studies (Chapters 11, 21), where the complex is preserved only sketchily by archeological and historical reports and the farmers are beyond inquiry.

Such perplexities are not limited to societies where formal agricultural science is absent. In industrialized countries similar analytic problems exist. Riebsame (1981), as part of the Great Plains Case Study, sought to examine the mechanisms of adaptation and adjustment that have diminished the adverse impacts of drought in spring wheat production in the state of North Dakota, USA. From 32 technical and 30 social adjustments employed to some extent in North Dakota between 1890 and 1980, five had a major effect on reducing vulnerability: summer fallowing, stubble mulching, crop insurance, disaster payments, and farm diversification; for several other widely promulgated adjustments, like marginal land retirement, shelterbelts and maintaining reserves, it was difficult to demonstrate whether their employment had any effect at all.

#### *1.3.3.4 Using Theory*

Finally, there are competing theoretical models of the major social processes in adjustment and adaptation. For example, neoclassical economics emphasizes market processes in which the 'invisible hand' will encourage or discourage various adjustments (Lave, 1981). Neo-Marxist analysis emphasizes the differential access to adjustments by social class or marginal group and the interrelationship between decreased vulnerability for one group and increased vulnerability for others (Spitz, 1980). Social–psychological or policy-oriented decision-making studies emphasize processes of conscious choice by rational or 'boundedly' rational decision-making individuals or groups (Slovic *et al.*, 1974). In practice, all of these activities—markets, class conflict, rational choice and many more—can be found in societal structures. But the selection of emphasis has strong implications for what might be learned from past experience or which public policies to suggest for future action.

### 1.3.4 Examining Interaction

The characterization of climate and society and the identification of feedback mechanisms is but a first step towards exploring the interaction between climate and society. At least three methods of investigating such interaction are in common use:

1. causal and correlational explanations,
2. experiments, and
3. modeling and simulation.

#### *1.3.4.1 Causal and Correlational Explanations*

In causal explanation, the chain of causality with the varying contributions of climate and society would be carefully detailed and verified. There are no ready examples of interactions for which the physical, biological and social principles are so well understood that a causal analysis is explicable. Perhaps closest to such an ideal are experimental agricultural studies of the interaction of moisture (climate) and fertilizer (society), but even these principles are derived more from experiments and correlational data than from causal theory. Correlational explanation lacks the assurance of causal explanation; its convincing quality must rest on associations so strong as to dominate chance or alternative explanations. As with all correlational analysis the description of relations can take various forms: descriptive, mathematical, or graphic.

A good example of descriptive correlational analyses is Post's (1977) study of the widespread food shortages that developed in Europe following the eruption of Mt Tambora in 1816 and the associated poor weather. Within the general theme of the impact of this event, Post tries in qualitative fashion to estimate the impacts on the European population of the extreme climate event, the post-Napoleonic-war crisis, and the imperialist attitudes of the British and Austro–Hungarian empires.

In mathematical form, correlational analysis centers around multiple regression, in which impacts are functions of various climate indicators and societal indicators. For example, Johnson and McQuigg (1974) try to examine the joint impact of temperature, precipitation, soils, population density, property taxes and government subsidy on US Great Plains land prices. They use principal components analysis to characterize the climate and combine these climate components with the societal variables in multiple regression equations that account for 60 percent of the variation in prices.

In graphic form, Parry (1981) sketches in Figure 1.9 the relationship between cultivation limit, a measure of farm abandonment (his impact variable), the areal level of resource availability (the amount of cultivable land determined by climate variation), and proximate factors (disruptive societal events).

### *1.3.4.2 Quasi-experiments*

Correlational studies could be enhanced if the factors to be compared were placed within an experimental design. Although it is possible to study experimentally the response of plants to the doubling of $CO_2$ in the greenhouse (Lemon, 1983), it is not possible to study the response of society. However, it is possible to use matched 'before and after' or 'with and without' situations as controls in natural quasi-experiments. Such methodologies have been used in studies of long-term local impact following natural hazards (Friesema *et al.*, 1979; Wright *et al.*, 1979; see also Chapter 15). In another example, as discussed in Section 1.3.2.6, the two great droughts in the Sahel were compared for impacts, although population size, societal organization and activity differed considerably. With drought held constant, the variability in impact was ascribed to changing social organization and trends.

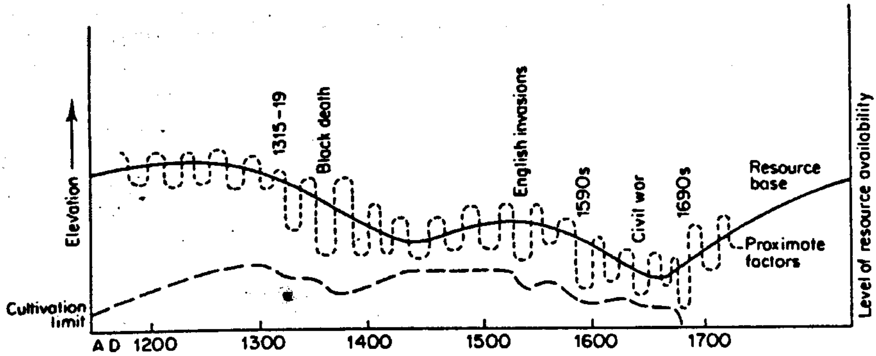


Figure 1.9 Proximate and indirect factors behind farmland abandonment in upland Scotland. Between 1200 and 1700 AD there was a long-term downward trend in the level of potential resource availability, i.e. the available amount of cultivable land determined by adverse climate experienced at lower and lower elevations in the upland regions. Concurrent with this trend are various societal fluctuations in fortunes called 'proximate factors'. These perturbations combine to depress agricultural activity as shown in the dips in the cultivation limit, which measures the level of actual cultivation use and its inverse, farm abandonment. The recurrent shocks of the seventeenth century combined with the adverse climate lead to total abandonment of the area under study. (Reproduced by permission of IIASA from Parry, 1981)

Inadvertent climate modification has provided yet another quasi-experimental format. Urbanization changed the climate downwind of St Louis, Missouri in the United States, providing an opportunity to trace the 'before and after' primary impacts on soil, streamflow, agriculture and buildings, and secondary impacts on the economy, institutions, and public health and welfare (Changnon *et al.*, 1977).

Recently it has also been shown that sharp discontinuities in regional climate, sustained for one or two decades, take place (Karl and Riebsame, 1984). Such changes arise from normal variation in the climate system and do not require fundamental climate change as explanation. Yet the populace affected experiences a real change in its climate, on the order of 1 °C in mean temperature and 25 percent in mean precipitation between periods. Such changes provide an opportunity to investigate impacts perception and adjustments, and quasi-experimental designs are being developed for this in several countries (Kates *et al.*, 1984).

Finally, the World Climate Applications Programme provides still another experimental format. This program, designed to provide new or newly disseminated climate data tailored to specific applications, can change people's understanding of their climate, with subsequent changes in perception and adjustment. Baseline studies of perceptions and adjustment can be made prior to introducing the new data and the effect of the data and their presentation in varying formats can be carefully monitored.

### *1.3.4.3 Simulation and Modeling*

Finally, computer experiments employing mathematical modeling and simulation can be designed. Using the model of irrigated agriculture in the Tigris–Euphrates floodplain, Johnson and Gould (1984) examined the impact on population size of a constant climate, a variable climate, and extreme drought events. These results are shown in Figure 1.10.

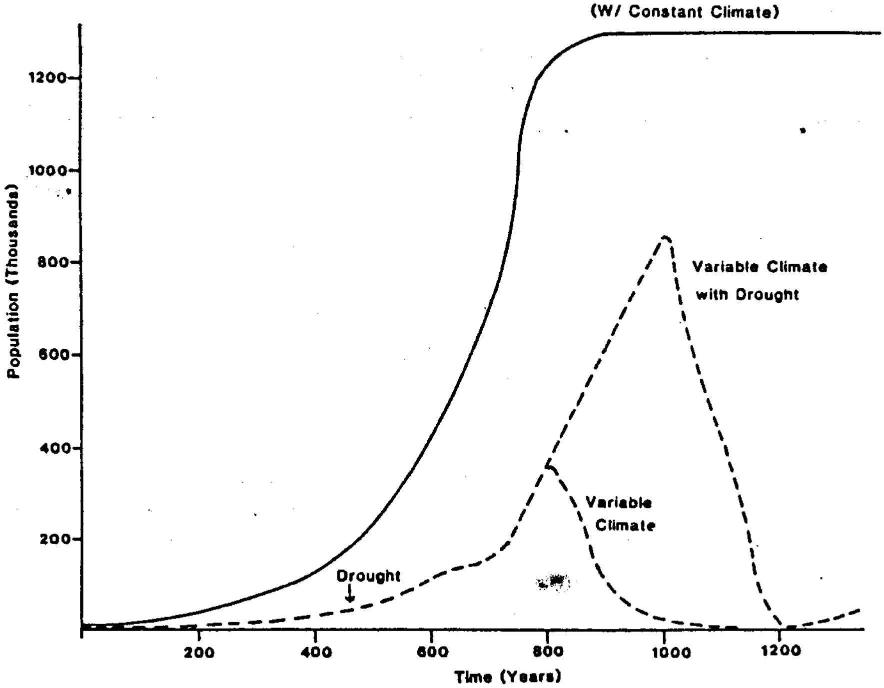


Figure 1.10 Three simulation traces of an irrigation-based village/tribal society model of the Tigris–Euphrates floodplain. Under *constant climate* (mean annual streamflow available each year in irrigation system), population grows, then stabilizes in classic form of the demographic transition. Under *variable climate* (by normal distribution of streamflow) population rises to 25% of constant climate and collapses (as in historical record). If a major persistent drought period is inserted into the variable climate (*variable climate with drought*), this leads to an adaptive response (extension of irrigation system) and an expanding population which, nonetheless, eventually collapses. (Source: Johnson and Gould, 1984)

A recent unpublished effort by Warrick, simulating a recurrence of 1930s drought with current technology in the United States, utilized the University of Southern California food model (Enzer *et al.*, 1978). Warrick found only minor global impacts if the recurrence were limited to the wheat-growing regions, but major impacts if the drought simultaneously affected both corn-and wheat-growing areas. Liverman (1983) has carefully investigated the use of a basic global model, the International Futures Simulation version of the Mesarovic and Pestel (1974) world model for climate impact experiments. She found that models of this type have little predictive value, limited policy application, but considerable promise as research tools.

## 1.4 CLIMATE IMPACT ASSESSMENT

Returning to the basic impact model (Section 1.2.1), we can attempt to bring together this overview, linking the model to a typology of impact assessments or modes and techniques of analysis. We begin with an expanded impact model containing four sets of study elements:

1. climate events,
2. exposure units,
3. impacts and consequences, and
4. adjustment responses (Figure 1.11).

Each set has a number of elements. *Climate events* (Chapter 2) are distinguished on a temporal scale: extreme weather events, persistent periods, and 'little ages'. *Exposure units* are socially grouped (individual, populations, species), sectorally divided (livelihoods, activities, economic sectors), or areally defined (societies, regions or nations). *Impacts and consequences* are ordered, with primary impacts on biological systems, productivity, and activity. Secondary impacts (gains or losses) propagate through economy, society and ecosystem, resulting in *n*th-order changes. For *adjustment responses*, there exists a broad array of adaptive-adjustive mechanisms to prevent, reduce or mitigate these impacts and it is possible to describe their perception and choice or to encourage their use through specific policy prescriptions.

Each set of elements is linked by an analytic mode, a way of studying the connections between sets. These modes serve as the framework for this volume.

Sensitivity studies (Chapter 4) attempt to identify climate-sensitive groups, activities and areas, linking them to the varied levels of climate events (Chapter 2). The direct impacts experienced by such exposed groups, activities or areas are identified through *biophysical impact studies* and include studies of climate impact on biological or physical productivity: in agriculture (Chapter 5), fisheries (Chapter 6), pastoralism (Chapter 7), water resources (Chapter 8) and energy resources (Chapter 9). Examining how biophysical impacts are propagated into human socioeconomic and political systems is the task of *social impact assessment*. The focus for such studies can be human populations (Chapter 10), past societies (Chapters 11 and 21), the economy (Chapters 12 and 20), current societies (Chapter 13), marginal locations or groups (Chapter

14), or the area impacted by an extreme event (Chapter 15). *Adjustment response studies* link impacts with responsive behavior, and analytic methods may focus on the perception and choice of adjustments (Chapter 16) or on their availability and efficiency (Chapter 17).

*Integrated assessments* include at least three links—sensitivity studies, biophysical impact studies, and social impact studies—and may correspond to the simple input–output model. Because of the scale and linkages of integrated assessments, some form of modeling is frequently used, including global modeling and simulation (Chapter 18), biosphere modeling (Chapter 19) and scenarios (Chapter 20). When such studies include feedback in the form of adjustment response, they are designated as *assessment-adjustment* studies, coresponding to the interactive model with feedback. Examples of both types of integrated studies are found in the reviews of historical and recent integrated studies, (Chapters 21 and 22, respectively). Missing, both from the diagram (Figure 1.11) and from experience, is a mode of analysis labeled *comprehensive impact assessment*, envisioned as corresponding to the interactive model with feedback and studies of underlying historical natural and social process.

In practice many attempts at assessment do not follow this carefully linked causal system; rather, they attempt to 'jump' study elements, going directly from climate events to inferences of higher-order consequences. These are probably less reliable than the more carefully specified and linked analyses (see further Chapters 11, 14, 20 and 21). In general, reliability seems greatest at the beginning of the causal chain—more is known about biophysical impacts, less about long-term social or ecological change.

This volume, the product of over 100 authors and reviewers, is an authoritative up-to-date statement of what-we-know about climate impact assessment. Viewing the 22 chapters as a whole leads to four major conclusions:

- More and better methods exist to assess the impacts of climate variability and change than are currently being employed. This is partly due to disciplinary isolation and partly to the limited effort expended to date on the study of the interaction of climate and society as compared to the study of the dynamics of climate itself. Recent, ongoing or planned second-generation studies, however, evidence levels of conceptual sophistication, scientific clarity and methodological integration not previously found (see, for example, Nordhaus and Yohe, 1983; Parry and Carter, 1983; Waggoner, 1983; Kates *et al.*, 1984; Santer, 1984). Moreover, there is evidence in these studies of an emerging consensus as to the use of key concepts and terminology.
- While it is convenient to consider climate impact assessment methods as ordered by classes of impact or interaction models, even the simplest of impact models use some underlying concept of climate–society interaction. The best-defined climate impact relationships are relative, rather than

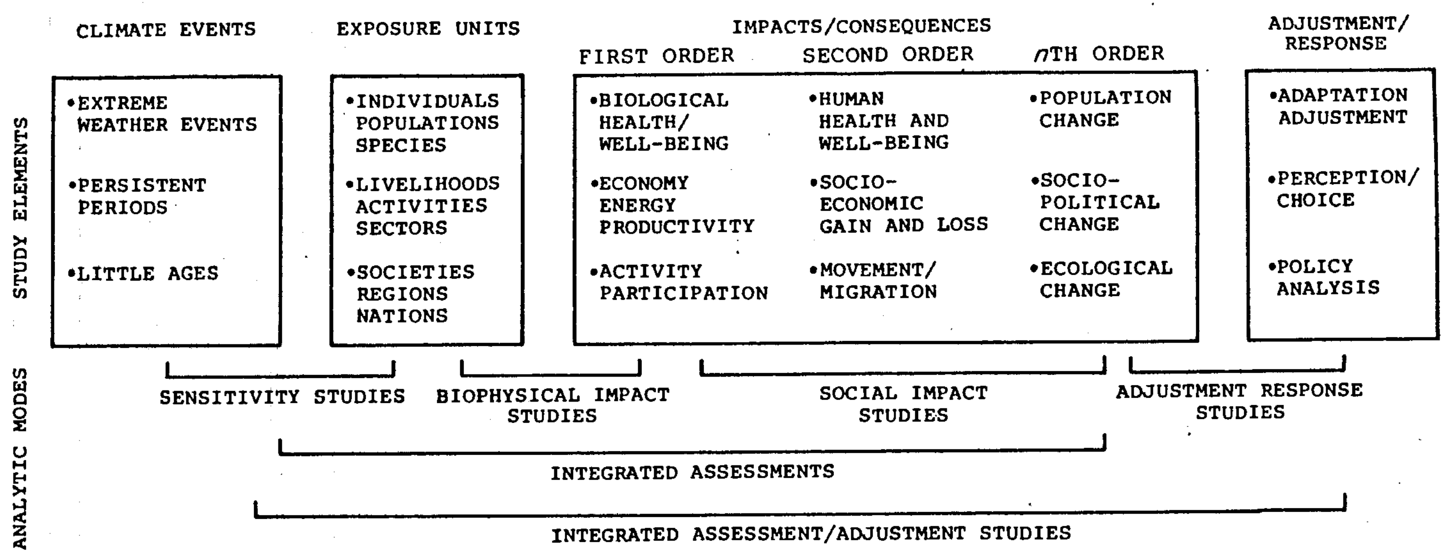


Figure 1.11 Climate impact study

absolute, appropriate to a given technology, social organization, group vulnerability, and the like. Invoking climate as a sole determinant of human events is rarely if ever justified. Scientific studies of climate impacts always need to consider alternative, joint and multiple hypotheses for postulated impacts.

- The largest single impact of climate is the human effort expended to adjust or adapt to the seasonality, variability and change of climate. Most case studies are negatively biased, excessively preoccupied with the residual damages and losses experienced by society, and ignore the significant costs of human adjustment. In practice, low residual losses or damages may be a sign of relative insensitivity to climate, or conversely, of very great sensitivity accompanied by effective, successful, albeit costly, human adaptation. Concepts and methods to elicit loss or damage are better developed than concepts and methods that assess the social cost of adaptation. Least developed are concepts to assess and utilize the opportunities presented by climate as a resource.
- There is a great disparity in both methods and effort of climate impact assessment between the industrialized and the developing nations. Developing nations are clearly more vulnerable to climatic perturbations and suffer greater damages and extraordinarily greater losses of life, yet the scientific effort in identifying and mitigating climate impacts is not centered where it is needed most. Methods do exist, however, to identify the major climate sensitivities of all societies, and current knowledge of climate variability and potential human adjustment can serve to diminish the vulnerability of developing nations.

If there is a single conclusion to this volume, it is that more is known about the interaction of climate and society than is utilized and much of what remains to be known is discernible. Scientists in all parts of the world who recognize the practical necessity of informed adjustment to climate are invited to take up the challenge of integrated assessment, and to share in the intellectual adventure of developing theories and methods on the borders of current thought.

## REFERENCES

Bowden, M. J., Kates, R. W., Kay, P. A., Riebsame, W. E., Warrick, R. A., Johnson, D. L., Gould, H. A., and Weiner, D. (1981). The effect of climate fluctuations on human populations: Two hypotheses. In Wigley, T. M. L., Ingram, M. J., and Farmer, G. (Eds.) *Climate and History*, pp. 497–513. Cambridge University Press, Cambridge, UK.

Burton, I., Kates, R. W., and White, G. F. (1978). *The Environment as Hazard*. Oxford University Press, New York.

Changnon, S. A., Jr., Huff, F. A., Schickedanz, P. T., and Vogel, J. L. (1977). *Summary of Metromex. Vol. 1: Anomalies and Impacts*. Illinois State Water Survey Bulletin 62, Urbana, Illinois.

Enzer, S., Drobnick, R., and Alter, S. (1978). *Neither Feast Nor Famine*. Lexington Books, Lexington, Massachusetts.
Flohn, H. (1979). Short-term climate fluctuations and their impact. Introduction at *International Conference on Climate and History, 8–14 July, 1979, University of East Anglia, Norwich, UK*.
Friesema, H. P., Caporaso, J., Goldstein, J., Lineberry, R., and McCleary, R. (1979). *Aftermath: Communities after Natural Disaster*. Sage Publications, Beverly Hills, California.
García, R. (1981). *Drought and Man: The 1972 Case History. Vol. 1: Nature Pleads Not Guilty*. Pergamon, New York.
García, R., and Escudero, J. C. (1982). *Drought and Man: The 1972 Case History. Vol. 2: The Constant Catastrophe: Malnutrition, Famines, and Drought*. Pergamon, New York.
Grobecker, A. V., Coroniti, S. C., and Cannon, R. H., Jr. (1974). *The Effects of Stratospheric Pollution by Aircraft*. CIAP Report of Findings, DOT-TST-75-50. US Department of Transportation, Washington, DC.
Holling, C. S. (1973). Resilience and stability in ecological systems. *Annual Review of Ecology and Systematics*, **4**, 1–22.
Ingram, M. J., Farmer, G., and Wigley, T. M. L. (1981). Past climates and their impact on man: A review. In Wigley, T. M. L., Ingram, M. J., and Farmer, G. (Eds.) *Climate and History*, 3–50. Cambridge University Press, Cambridge, UK.
International Meteorological Institute (1984). Progress report for Problem Area IV: Impacts on managed and unmanaged terrestrial ecosystems. *Project on International Assessment of the Impact of an Increased Atmospheric Concentration of Carbon Dioxide on the Environment*. Draft, 11 April 1984. IMI, Stockholm.
Johnson, D., and Gould, H. (1984). Effects of climate fluctuation on human populations: Study of Mesopotamian society. In Biswas, A. K. (Ed.) *Climate and Development*. Tycooly International Publishing, Dublin.
Johnson, S. R., and McQuigg, S. (1974). Some useful approaches to the measurement of economic relationships which include climatic variables. In Taylor, A. S. (Ed.) *Climatic Resources and Economic Activity*. John Wiley & Sons, New York.
Karl, T. R., and Riebsame, W. E. (1984). The identification of 10- to 20-year temperature and precipitation fluctuations in the contiguous United States. *Journal of Climate and Applied Meteorology*, 23 (6 June), 950–966.
Kates, R. W. (1981). Drought in the Sahel: Competing views as to what really happened in 1910–14 and 1968–74. *Mazingira*, **5**, 72–83.
Kates, R. W., Changnon, S. A., Jr., Karl, T. R., Riebsame, W., and Easterling, W. E. (1984). *The Climate Impact, Perception, and Adjustment Experiment (CLIMPAX): A Proposal for Collaborative Research*. Climate and Society Research Group, Center for Technology, Environment, and Development, Clark University, Worcester, Massachusetts.
Kellogg, W. W., and Schware, R. (1981). *Climate Change and Society: Consequences of Increasing Atmospheric Carbon Dioxide*. Westview Press, Boulder, Colorado.
Kukla, G. L., Angell, J. K., Korshover, J., Dronia, H., Hoshiai, M., Namias, J., Rodewald, M., Yamamoto, R., and Iwashima, T. (1977). New data on climatic trends. *Nature*, **270**, 573–580.
Lamb, H. H. (1978). *Climate: Present, Past, and Future. Vol. 2: Climatic History and the Future*. Methuen, London.
Lave, L. B. (1981). *Mitigating Strategies for $CO_2$ Problems*. CP-81-14. International Institute for Applied Systems Analysis, Laxenburg, Austria.
Lawson, M. P., and Stockton, C. (1981) The desert myth evaluated in the context of

climatic change. In Smith, C. D., and Parry, M. L. (Eds.) *Consequences of Climatic Change*, pp. 106–118. Department of Geography, University of Nottingham, UK.

Lemon, E. R. (Ed.) (1983). *$CO_2$ and Plants: The Response of Plants to Changing Levels of Carbon Dioxide*. AAAS Selected Symposium No. 84. Westview Press, Boulder, Colorado.

Leontiev, W. (1977). *The Future of the World Economy: A United Nations Study*. Oxford University Press, New York.

Linnemann, H., Deltooge, J., Kayser, M., and Van Heemst, H. (1979). *MOIRA: Model of International Relations in Agriculture*. North Holland Publishing Co., Amsterdam.

Liverman, Diana M. (1983). *The Use of a Simulation Model in Assessing the Impacts of Climate on the World Food System*. University of California, Los Angeles-National Center for Atmospheric Research Cooperative Thesis No. 77. NCAR, Boulder, Colorado.

Mesarovic, M. D., and Pestel, E. (1974). *Mankind at the Turning Point*. E. P. Dutton, New York.

Meyer-Abich, Klaus M. (1980). Chalk on the white wall? On the transformation of climatological facts into political facts. In Ausubel, J., and Biswas, A. K. (Eds.) *Climatic Constraints and Human Activities*, pp. 61–92. Pergamon, New York.

National Defense University (1980). *Crop Yields and Climate Change to the Year 2000*. NDU, Fort Lesley J. McNair, Washington, DC.

National Defense University (1983). *World Grain Economy and Climate Change to the Year 2000: Implications for Policy*. NDU, Fort Lesley J. McNair, Washington, DC.

National Research Council (1983). Board on Atmospheric Sciences and Climate. *Changing Climate* (Report of the Carbon Dioxide Assessment Committee). National Academy Press, Washington, DC.

Nordhaus, W. D., and Yohe, G. W. (1983). Future paths of energy and carbon dioxide transmissions. In National Research Council, *Changing Climate* (Report of the Carbon Dioxide Assessment Committee), pp. 87–153. National Academy Press, Washington, DC.

Parry, M. L. (1978). *Climatic Change, Agriculture and Settlement*. Archon Books, Hamden, Connecticut.

Parry, M. L. (1981). Evaluating the impact of climatic change. In Smith, C. D., and Parry, M. L. (Eds.) *Consequences of Climatic Change*, pp. 3–16. Department of Geography, University of Nottingham, UK.

Parry, M. L., and Carter, T. (1983). *Assessing Impacts of Climatic Change in Marginal Areas: The Search for Appropriate Methodology*. IIASA Working Paper WP-83-77. International Institute for Applied Systems Analysis, Laxenburg, Austria.

Porter, P. W. (1976). Climate and agriculture in East Africa. In Knight, C. G., and Newman, J. L. (Eds.) *Contemporary Africa: Geography and Change*, pp. 112–139. Prentice-Hall, Englewood Cliffs, New Jersey.

Post, John D. (1977). *The Last Great Subsistence Crisis in the Western World*. The Johns Hopkins University Press, Baltimore, Maryland.

Riebsame, W. E. (1981). *Adjustments to Drought in the Spring Wheat Area of North Dakota: A Case Study of Climate Impacts on Agriculture*. PhD Dissertation, Department of Geography, Clark University, Worcester, Massachusetts.

Rosenof, T. (1973). *Cultural Sensitivity to Environmental Change: The Case of Ellis County, Kansas, 1870s–1900*. Institute for Environmental Studies, Institute for Humanities (Report 5), University of Wisconsin, Madison, Wisconsin.

Santer, B. (1984). Impacts on the agricultural sector. In Meinl, H., and Bach, W., Socioeconomic Impacts of Climatic Changes Due to a Doubling of Atmospheric $CO_2$

Content. Contract No. CL1-063-D, Commission of the European Communities, Brussels.

Schelling, T. C. (1983). Climatic change: Implications for welfare and policy. In National Research Council, *Changing Climate* (Report of the Carbon Dioxide Assessment Committee), pp. 449–482. National Academy Press, Washington, DC.

SCOPE (1978). *Report of the Workshop on Climate/Society Interface*, held 10–14 December, 1978 in Toronto. SCOPE Secretariat, Paris.

Seifert, W. W., and Kamrany, N. M. (1974). *A Framework for Evaluating Long-term Strategies for the Development of the Sahel-Sudan Region. Vol. 1: Summary Report: Project Objectives, Methodologies, and Major Findings*. MIT Center for Policy Alternatives, Cambridge, Massachusetts.

Slovic, P., Kunreuther, H., and White, G. F. (1974). Decision processes, rationality, and adjustment to natural hazards. In White, G. F. (Ed.) *Natural Hazards: Local, National and Global*, pp. 187–205. Oxford University Press, New York.

Spitz, P. (1980) Drought and self-provisioning. In Ausubel, J., and Biswas, A. K. (Eds.) *Climatic Constraints and Human Activities*, pp. 125–147. Pergamon, New York.

Timmerman, P. (1981). *Vulnerability, Resilience and the Collapse of Society*. Environmental Monograph No. 1. Institute for Environmental Studies, University of Toronto, Canada.

US Council on Environmental Quality (1980). *The Global 2000 Report to the President*. US Government Printing Office, Washington, DC.

US Department of Agriculture (1978). *World GOL Model Analytic Report*. Foreign Agriculture Economic Report No. 146. USDA, Washington, DC.

Waggoner, P. E. (1983). Agriculture and a climate changed by more carbon dioxide. In National Research Council, *Changing Climate* (Report of the Carbon Dioxide Assessment Committee), pp. 383–418. National Academy Press, Washington, DC.

Walters, S. D. (1970). *Water for Larsa: An Old Babylonian Archive Dealing with Irrigation*. Yale University Press, New Haven, Connecticut.

Warrick, R. A. (1980). Drought in the Great Plains: A case study of research on climate and society in the USA. In Ausubel, J., and Biswas, A. K. (Eds.) *Climatic Constraints and Human Activities*, pp. 93–123. Pergamon, New York.

Warrick, R. A., and Bowden, M. J. (1981). The changing impacts of drought in the Great Plains. In Lawson, M. P., and Baker, M. E. (Eds.) *The Great Plains: Perspectives and Prospects*. Center for Great Plains Studies, University of Nebraska, Lincoln, Nebraska.

White, G. F., and Haas, J. E. (1975). *Assessment of Research on Natural Hazards*. MIT Press, Cambridge, Massachusetts.

Wigley, T. M. L., Ingram, M. J., and Farmer, G. (Eds.) (1981). *Climate and History*. Cambridge University Press, Cambridge, UK.

Wright, J. D., Rossi, P. H., Wright, S. R., and Weber-Burslin, E. (1979). *After the Clean-up: Long Range Effects of Natural Disasters*. Sage Publications, Beverly Hills, California.