SCOPE 27 - Climate Impact Assessment

15 Extreme Event Analysis

Kates, R. W., J. H. Ausubel, and M. Berberian (eds.), 1985. Climate Impact Assessment: Studies of the Interaction of Climate and Society, ICSU/ SCOPE Report No. 27, John Wiley.

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15.1 INTRODUCTION

Most societies, in developing the physical resources of the environment in which they are located, have evolved strategies to cope with climatic events which have a limited range of magnitudes. Such a limited range, experienced over time, becomes accepted as the `normal' spectrum of climatic events for that society. Extreme climatic events, that is, those events with magnitudes outside the normal spectrum, may pose severe and unexpected stresses upon the society.

It is the aim of this chapter to provide an overview of the methods used in the analysis of such stresses and to raise some questions to be considered in such future analyses. To do this we shall examine first the nature of the extreme events; second the nature of their impacts; and third, the methods used in the analysis of those impacts and societal adjustments and adaptation.

It is hoped that this review will show that the methods of extreme event analysis have a wider relevance, indeed may be pertinent to the analysis of the societal impacts of fluctuations within the normal spectrum of climatic events and to the analysis of the impact of climatic change itself.

15.2 THE NATURE OF EXTREME CLIMATIC EVENTS

As energy flows in the global ecosystem, variations in winds, temperatures and precipitation can be measured for specific locations and conventional periods of time (Chapter 2). The extreme climatic events, as defined in this chapter, are those short-term perturbations of the energy flows which provide magnitudes outside the normal spectrum or range of the typical averaging period. Such events at any one location, as we shall see, may be measured in minutes or in years' duration. Their frequency, however, is likely to be limited to return periods of at least 10 years.

15.2.1 Definitions

The general definition above glosses over the considerable difficulties facing any attempt at broad definitions of extreme climatic events. To define such events purely in terms of their physical parameters, for example, ignores the question of their impact upon the society. To society the significance of the events is not only that they are of a certain magnitude, but that this magnitude creates an unexpected impact upon society. Whether such an impact occurs depends as much upon the vulnerability of the society to stress as the magnitude of the event itself. Thus on Figure 15.1 the variations in the physical variables of climatic events are considered `normal' as long as they do not exceed the range of values within which they provide the basis for effective resource management. Magnitudes in excess of that range become stressful to the society because they cannot be accommodated in the normal resource management system.

The practical difficulties of providing a specific global definition of extreme climatic events, given this changing interface between physical parameters and societal vulnerability based in part upon expectations of future events, is obvious. Even if it were possible to forecast the 50- or 100-year return periods for certain magnitudes, and the most recent research suggests that this is as yet impossible within any acceptable levels of accuracy (see Kishihara and Gregory, 1982), the future vulnerability of the society to stress would itself probably have changed.

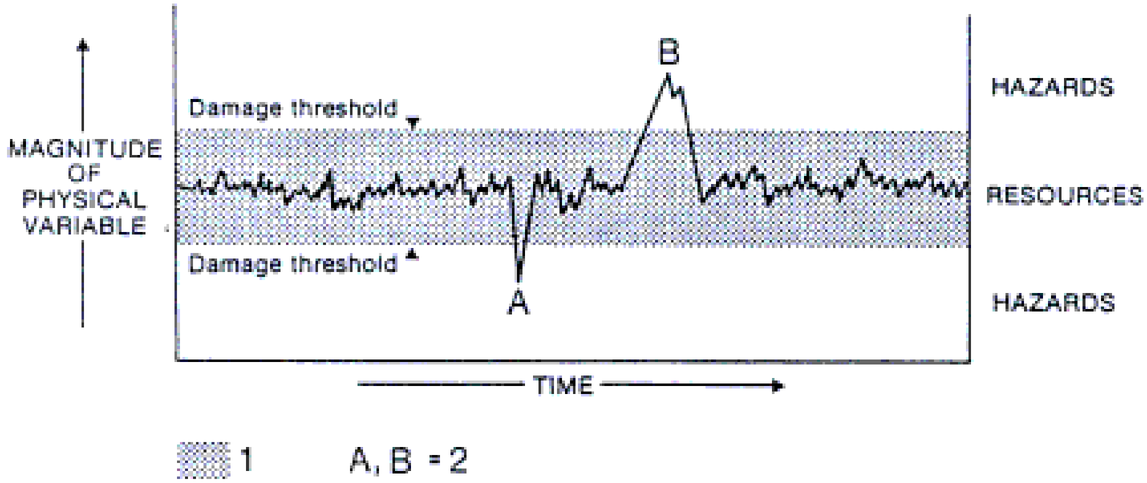

Figure 15.1 Identifying the extreme events. 1, zone of insignificant damage from variations in magnitude of the physical variable with upper and lower limits. Within this zone human activity regards the variations as resources. 2, lower (A) and upper (B) magnitudes of the physical variable which constitute hazards for human activity and which form the extreme events beyond the lower or upper damage thresholds of the resources zone. (Adapted from Burton and Hewitt, 1974)

In practice we are faced by multiple definitions of extreme events resulting from the analysis of specific combinations of certain physical magnitudes of phenomena and the associated societal reactions. Thus, for drought in Australia the official physical indicator is rainfall in the first decile of records, but this is justified by evidence of the coincidence of such occurrences over time with widespread reporting of drought impacts from other sources (Gibbs and Maher, 1967).

Using such composite definitions in the same spirit as the definitions of natural hazards in White (1974) and Burton *et al.* (1978), we can identify a variety of extreme events in the past which have been the subject of specific analysis. Such events would include the cyclone and storm surge in Bangladesh in 1970, the Sahel drought of 1968–73, the blizzard in the United States of February 1978, and the tropical cyclone `Isaac' which hit Tonga 2–3 March 1982. Listings of some of these events will be found in Dworkin (n.d.) and Thompson (1982), and a recent spatial overview of `natural hazards' is provided in MRG (1978).

15.2.2 Classification

A useful classification of extreme climatic events, using energy concentration, duration and spatial extent and in which particular events may reflect physical characteristics along a scale from `pervasive' to `intensive', has been suggested by Kates (1979, Table 15.1). The contrasts in spatial and temporal contexts implied by this scale for such events require that monitoring systems and societal responses be able to cope with a variety of phenomena. On the one hand such phenomena might occur over a track of some few meters wide, but perhaps several kilometers in length, occurring over minutes or at the most hours (as with tornadoes and windstorms). On the other hand they may occur over half a continent for 2

–3 years or more (as with some droughts). Such variations have obvious relevance also in any assessment of the impacts of such events—a variation simplistically stated as between the potential for rapid total local destruction or the slow but steady attrition of regional resources.

Table 15.1 Characteristics of extreme climatic events

Criteria		Spectrum of characteristics: Pervasive events	Spectrum of characteristics: Intensive events
Spatial	Area affected	Extensive	Localized
	Energy release per unit area	Low	High
Temporal	Frequency	Frequent (?)	Rare (?)
	Onset	Slow	Rapid
	Duration	Long	Short
Event Type		Drought	Tornado
		Windstorm	Hailstorm
			Avalanche
		←Cyclone→	←Cyclone→
		←Flood→	←Flood→

Source: Modified after Kates, 1979, 517.

15.2.3 Monitoring the Events

The varying spatial and temporal characteristics of extreme events pose specific monitoring problems. The basic technical problems are of equipment failing under extreme conditions. The anemometer at Darwin airport, Australia, for example, failed after recording a wind gust of 217 km/h during Cyclone Tracy's impact in 1974, when maximum gusts were *estimated* to be up to 250 km/h. In addition, however, the network of weather stations may be too sparse to enable adequate regional monitoring of even basic data such as precipitation and temperatures—this is a particular problem in developing countries where data have to be interpolated over large rural areas from a few, often urban, weather stations (Rijks, 1968). Further, it is generally easier to monitor the intensive extreme events because of their energy magnitudes and their relatively short duration, both of which show up easily in time-series analysis and enable the onset and retreat of the event to be fairly easily identified. In contrast, the onset of events such as drought and sea level fluctuations (associated with climatic changes) may be very difficult to recognize because of the long lead time and gradual, almost imperceptible, transformation of the environment.

The cross-cultural natural hazards research studies show that most societies are aware of critical thresholds of climatic stresses and have identified them in terms, for example, of the required timings of the `opening rains' for crop plantings (White, 1974). Independent studies have confirmed this kind of predictive awareness. In northeastern Brazil's semi-arid *sertão:*

> tradition holds that if it does not rain by 19 March, St. Joseph's Day, a *sêca* [drought] is bound to follow (Hall, 1978, 18).

In Nigeria there is a considerable body of peasant farmer knowledge of both `normal' and abnormal climatic stresses upon crop potentials, which is encapsulated in folklore, oral histories and local vocabularies for climatic events (Oguntoyinbo and Richards, 1978). Analysis of such sources reveals those events which the society had, from past experience, identified as crucial to its future well-being.

15.3 THE NATURE OF EXTREME CLIMATIC EVENTS IMPACTS

The occurrence of an extreme event does not automatically imply an impact upon a society. Apart from the obvious situation where an event occurs in an uninhabited area, impacts will vary depending not only on place of occurrence but also with spatial and temporal dimensions and the population and material wealth at risk. The relationship between the magnitude of the event and the nature of its impact can be very complex, as in the qualitative descriptions measuring the height and significance of Nile floods (Figure 15.2). A reduction of annual flood volumes resulting from low rainfalls in Ethiopia could lead to increasing societal distress as the flood levels decrease and fewer areas can be irrigated. However, heavier than normal rainfalls in the river catchment could produce an extremely high level of flooding which could destroy the society so precariously perched on the river banks.

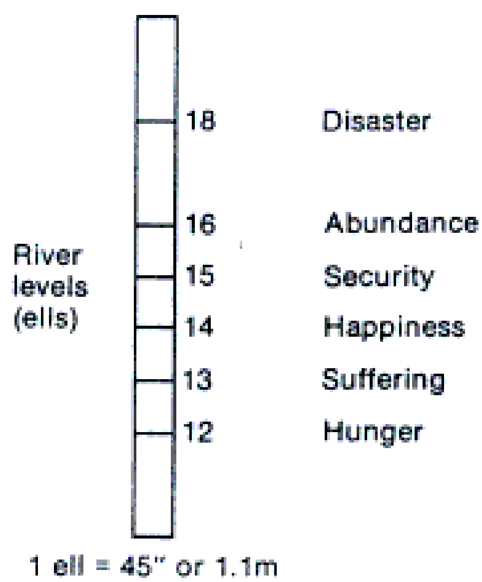

Figure 15.2 The Nilometer. (Reproduced by permission of Oxford University Press from Drower, 1956 (after Pliny), in Suiger *et al.*, *A History of Technology*, Vol. 1)

15.3.1 Monitoring the Impacts

Given the variety of physical characteristics of extreme events and the variety of global societies, the monitoring of impacts is fraught with difficulties. Their reporting may be distorted and the analyses themselves may be distorted by biases in the researchers and their monitoring systems.

Because extreme events have impacts upon societies, and because societies have a long history of regarding these impacts as resulting from external forces and therefore of considering the victims as deserving of the support of the entire society, there can be situations where both some underestimation and some exaggeration of impacts occur.

On the one hand, there may be attempts by government officials to play down the significance of the extreme event because the impact is seen to affect a minority group or segment of society currently in disfavor politically (Swift, 1977), or because the distress is seen to have resulted from unwise resource management or even reckless exposure to climatic risks from practices such as `compensation farming' (Amiran and Ben Arieh, 1963). On the other hand, the `victims' may be tempted to exaggerate their losses in order to gain public sympathy and official relief (Heathcote, 1969a), or politicians may exaggerate impacts in order to obtain external financial aid for their own regions in the nation (Glantz, 1976). In the former cases the full impact may be hidden and the plight of the victims worsened by being denied relief, while in the latter cases relief donors might recognize a `cry wolf' syndrome and regard future disaster reporting with undue suspicion.

Whether the impacts are monitored at all seems to reflect the operations of the 'Issue-Attention Cycle' elaborated in Foster and Sewell (1980, 2). A sequence of popular concern is suggested for particular environmental issues in the developed countries. From the situation prior to recognition of any problem to alarm at recognition of a problem, opinions change. Enthusiasm for measures to mitigate the problem is followed by the realization that the problem may be a necessary consequence of `progress', and public interest fades until the stage is set for the next cycle of public attention to a specific issue. This rapid discounting of past events (by planners as well as by the general public) has been noted by Linstone (1973) and is a serious constraint upon the effectiveness of monitoring systems.

Table 15.2 `The many perspectives of hunger'—researchers' biases in famine studies

Research discipline or ideology	Diagnosis of causes of famine	Recommended solution for famine problem
Medicine	Nutritional disorders; environmental stress;	Vaccination; breastfeeding/ weaning food; environmental

	disease	sanitation
Agriculture	Low food supply	Food production; food aid; post-harvest technology; marketing
Education	Ignorance; food habits	Nutrition education; mass communications
Population sciences	High population density and high growth rate	Population control; resettlement
Neoclassical economists	Maldistribution of food	Fiscal policies; income generating projects; employment programs
Marxists	Capitalism	Revolution
Planners	Lack of planning and coordination	Food and nutrition councils; training

Source: Jonsson, 1981, 1.

Individual researchers bring a variety of biases, which affect the data collated, to their studies. A recent review of studies of the causes of, and remedies suggested for, famine provided a salutary comment on the distortions of such potential biases, not least on what is monitored (Table 15.2, see also Chapter 10, this volume). Only an overview which recognizes all such possible viewpoints could hope to have the basis for a balanced assessment of the impacts of famine, and the same is true for the analysis of extreme events.

Where and when attention is focused, however, various monitoring systems have been adopted. Different types of extreme events may need different impact assessment periods. The recently inaugurated climate impact assessments of the Center for Environmental Assessment Services (CEAS) in the United States distinguish two time periods for reporting upon climate impacts:

1. monthly, for events over land, and
2. quarterly, for events over the marine environment.

The first appears to be an arbitrary but convenient time period, but the second is dictated by `the extended intervals that frequently exist between the climate-induced event and the observed impact' and the details relate to dominant seasonal characteristics of the marine environment (Center for Environmental Assessment Services, 1982a, i).

Monitoring systems may use maps of areas affected, tables of the sequences of events, time-series graphs or trend lines, or even computer-simulated sequences of actual past events. Specific indices calculated to show relative intensities of losses by area may be attempted. Thus the United States climate impact assessment monitoring system provides national maps of areas affected by `major weather events' together with maps showing, for example, areas of above- or below-normal demand for energy (using calculations of daily temperature departures from means weighted by the population within the weather station area), as well as maps of transport disruptions (Center for Environmental Assessment Services, 1982a, 12–13). Australia's `Drought Watch System' uses monthly rainfalls to predict the likelihood of a drought (defined as rainfall in the first decile) and provides national maps of rainfall deficiencies by deciles. These maps are used as one component in federal government drought relief policies. It has been proposed to adapt them for drought surveillance in Botswana (Lee, 1979).

A standard method of monitoring impacts has been to use time-series correlations of climatic and socioeconomic phenomena. Graphs of a 'Business Index' (weekly coal, raw steel, motor vehicle and lumber production against temperatures*) were used to suggest the socioeconomic impacts of the 1976–77 winter freeze conditions in the United States, for example (Center for Environmental Assessment Services, 1982b). Studies of the impacts of climatic change also make extensive use of time-series correlations.

The method, despite its plausibility, can be criticized on two grounds. First, although the correlation may be shown to exist, no causal relationship is usually established; and second, often a mechanistic relationship between climate and the state of the societal economy through agricultural yields is assumed, and again without necessary proof (Anderson and Jones, 1983).

*The `Business Index' was derived from a weekly index combining production of raw steel, automobiles, trucks, electric power, crude oil refinery runs, bituminous coal, paperboard, paper, lumber, machinery, defense and space equipment and rail and truck traffic. The temperature data were departures from the normal number of days during the month in which the temperature dropped to 0°F or lower at seven industrial cities.

15.3.2 Identifying the Victims

In terms of the spatial relationship between extreme events and their impacts, most evidence suggests that the area over which the event occurs tends to be smaller than the area over which the impact of that event is felt. In part this may result from the type of event. The blocking of a vital road or rail route by an avalanche or flood will result in societal costs far beyond the area of the avalanche or flood itself through delays in transport and rerouting of materials or passengers.

Research has suggested that most extreme events produce a `cascade' of impacts—in bureaucratic societies by sharing some of the economic costs among all taxpayers (Figure 15.3), and in less bureaucratic societies by sharing losses among relatives and kinfolk (Cochrane, 1975; Waddell, 1983). In simplistic terms, therefore, in addition to the directly affected population devastated by storm, flood or drought, we must recognize those indirectly affected through increased voluntary charitable donations, involuntary taxation, or social responsibilities for kinsfolk.

In terms of time-scale a similar relationship between the duration of the event and its impact can be suggested. The destruction during an event, whether of life or property, usually occurs over a shorter period than the post-event impact. Injured victims die long after the tornado has struck, flood-damaged structures take time to be repaired, grazing herds may take up to ten years to reach predrought levels and, for some victims, the psychological traumas of the event may remain throughout their lifetimes.

15.3.3 Identifying the Impacts

Accepting the definition of first-, second-, and *n*th-order impacts as noted in Chapter 1, a wide spectrum of sources for analysis may be identified—from the personal testimony of eyewitnesses to satellite imagery. To accommodate this spectrum and some of the problems of biases in reporting, it may be convenient to identify at least three distinctive groups among the `observers' of the impacts. For each group there are implicit constraints upon the accessible sources of information and the methods by which the data are analyzed.

For immediate victims who have survived the disaster, the impact is clear enough—deaths and injuries, property damaged and food shortages. Their experiences provide sources for three different types of interpretation of the disaster. First, the experience becomes part of the collective societal experience of the environment, expressed perhaps as folklore, poetry, aphorisms or preferred sequences of activities such as the timing of crop plantings. Second, the experience becomes the source for research by academics or government officials enquiring into the disaster, and finally the experience, as translated through the media, becomes the basis for the general public's view of the event.

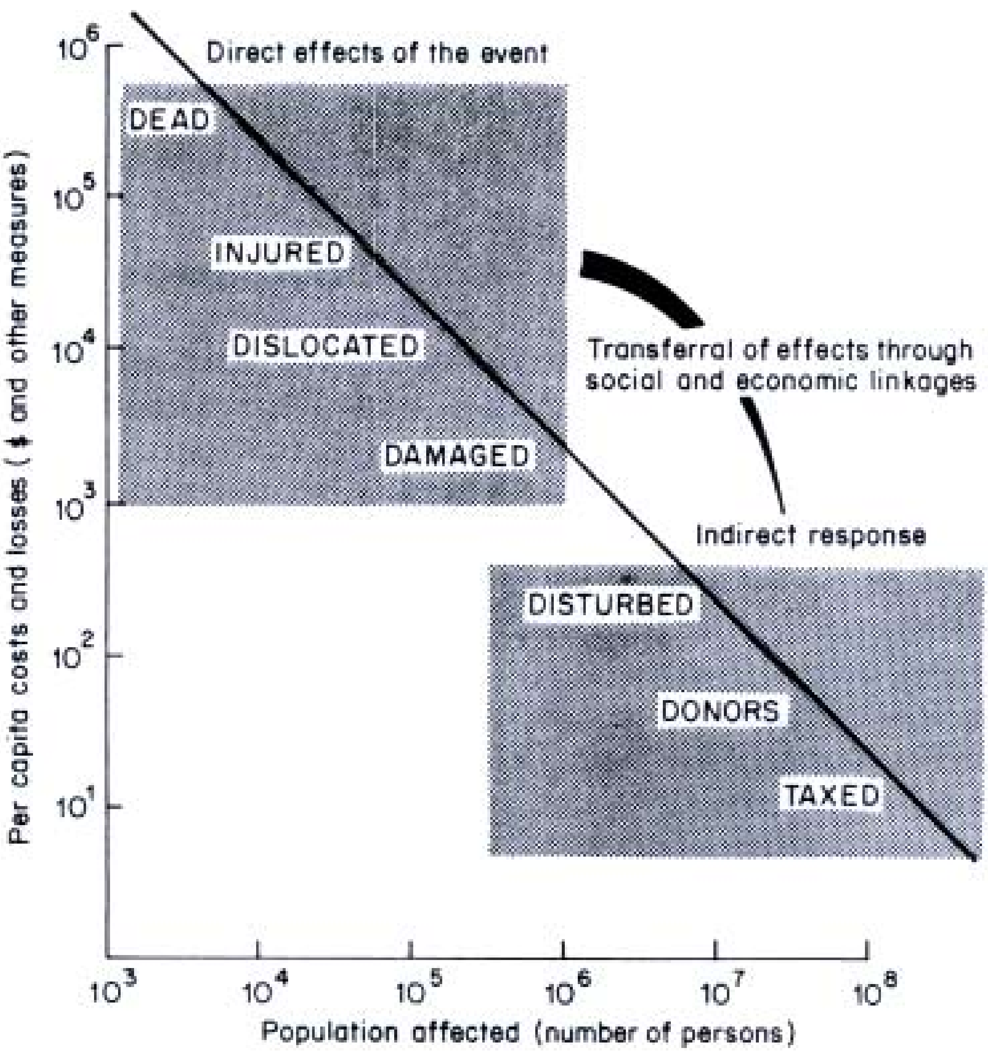

Figure 15.3 The cascade of disaster impacts. (Source: White and Haas, 1975, 76)

The technical specialists—the academics, the insurance loss assessors, the disaster relief agencies, the government officials—form the second group of observers attempting to identify the impacts. They use a combination of field observation of areal impacts after specific events; historical study of chronological associations of climatic events and other data on human activities through time-series analysis; historical study of media reporting of events and impacts; and simulation of actual or hypothetical interactions of the climatic events and human responses through modeling (for example, of ecological relationships) or developing scenarios of future alternative response strategies. (For a discussion of these methods, see Chapters 11, 18, 20 and 21.)

Such assessors face considerable problems in trying to identify the disaster impacts. There may be differences in the assessment of the significance of the impacts between the victims and the researchers, stemming perhaps from a fatalistic acceptance of the disasters by the impacted society (Burton *et al.*, 1978, 103), lack of awareness of the long-term effects of the extreme events (such as the effects of droughts upon *future* crop yields through accelerated soil erosion—see Tennakoon, 1980), or a failure to link climatic events and human activities with environmental impacts (such as Navajo attitudes to soil conservation—see Fonaroff, 1963). Indeed the requisite data for impact assessment may not be available; for example, a recent study noted that although a useful model for estimating the `net severity of a disaster' existed, namely

$$\text{Impact Ratio} = \frac{\text{Losses from National Disaster}}{\text{Total Community Resources}} \qquad (15.1)$$

the ratio could not always be used because `information was not readily available' even in a developed society such as the United States (Rubin, 1981, 7). Apart from the lack of data, any attempt to quantify the concept of `total community resources' would be difficult in itself.

A further general problem facing any attempt at assessment of the significance of the impacts relates to the distinction between what natural hazards research has identified as human `adjustments' and `adaptations' to stress situations (White, 1974; see also Chapter 1, this volume). The difference lies partly in the duration of the impact and partly in the characteristics of the human reactions. Adaptations imply long-term responses (over 100–100,000 years) to environmental stresses, responses which may be biological or cultural. Adjustments are those more immediate and short-term responses, both incidental and purposeful, which may last only one or up to 100 years after the stressful event (Figure 15.4). Such distinctions may be too fine to be recognized either by victims or technical specialists. Adaptations may not be recognized to be responses to particular extreme events because of their distance in time from the event, for example, and as a result no significant impact would be perceived (see Chapter 16).

This dilemma faces historians attempting to assess the significance of climatic change upon societies. In the short term the coincidental chronology of climatic variabilities with socioeconomic fluctuations (such as crop failure and human starvation) may exaggerate the climate impact assessments, whereas longer-term societal adaptations to climatic variations (such as changing agricultural practices or life styles) may be overlooked and the climate impacts underestimated (de Vries, 1980; Post, 1980). The impact may indeed relate less to the absolute fluctuations of the climate and more to whether those fluctuations came after a period of relatively stable or unstable socioeconomic conditions (Parry, 1975). In any event, impacts should be viewed not merely as the direct consequences of climatic events but analysis should attempt to include the effort and cost involved to adjust and to adapt to both past and future events.

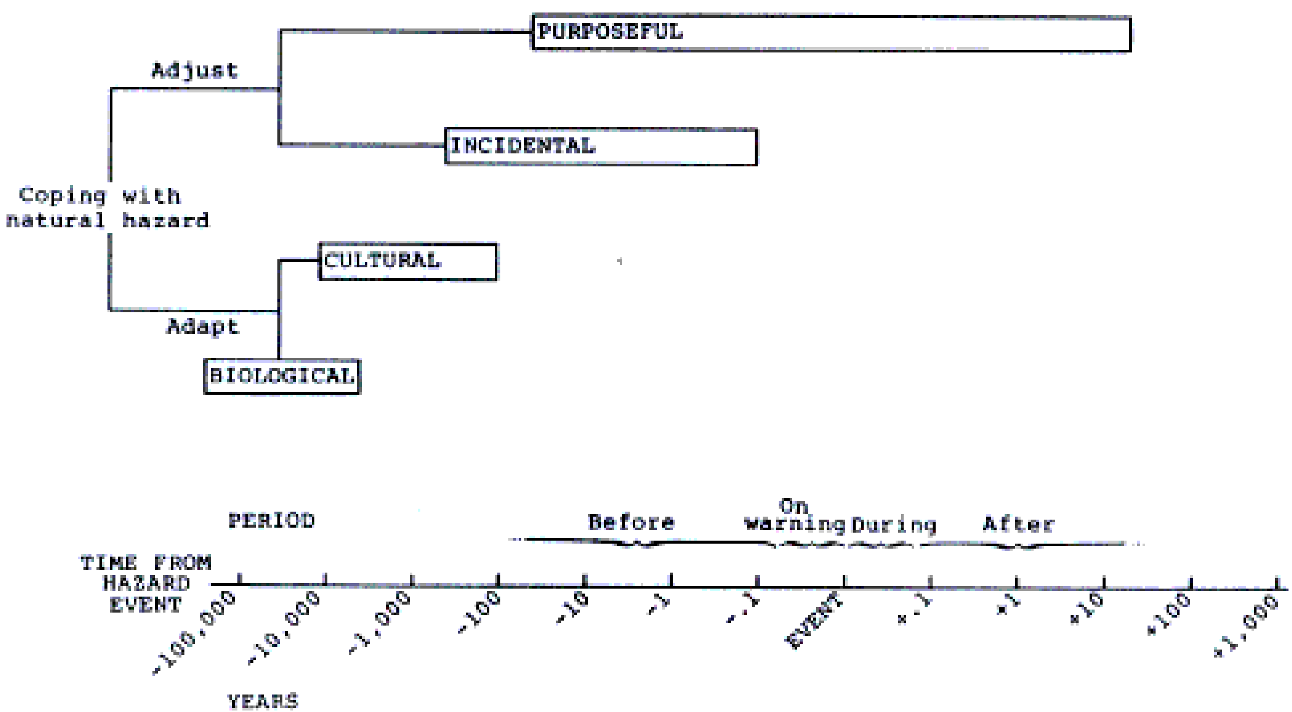

Figure 15.4 Adjustments and adaptations to natural hazards. From *The Environment as Hazard* by Ian Burton, Robert W. Kates and Gilbert F White. Copyright © 1978 by Oxford University Press Inc. Reprinted by permission

For the general public, its view of the disaster impact is constrained by the media coverage of the event and to some extent by the official response to the potential `cascade' of effects from the disaster (Figure 15.3). Apart from their varied ability to cover the disaster, the news media (newspapers, radio and television news services) have their own biased policies on the reporting and presentation of news items, stemming from their ownership and capacity to search out and relay information. Thus the immediate, short-term, spectacular impacts may be reported, but the longer-term post-event impacts may be overlooked.

15.3.4 Displaying the Impacts

For the technical specialist, the nature, location and duration of the impacts need to be displayed so that the significance can be assessed and, if necessary, a relief response coordinated. For the victim there is no need for display, he or she is fully occupied during and immediately after the event in trying to assess the losses and staying alive. For the general public the newspaper headlines and graphic reports on radio and television provide the brief display.

For the technical specialist concerned with disaster relief or mitigation, the impact of the disaster must be displayed within a relevant time period if an effective response is to be mounted. Since communication networks and power lines are often the first casualties in a disaster, obtaining relevant information promptly is difficult. Some success in locating lightning-induced forest fires, by means of strategically located sensors coupled to a computerized reporting network, has been claimed in Canada (Ellis, 1982) and presumably similar techniques could be adopted for river flood levels in remote locations. For the developed countries at least, microcomputer technology does offer the chance of impact displays within relevant time periods.

In cases where the specialist concern is to display the environmental effects of disasters, techniques developed to monitor land degradation and environmental pollution have been found useful. Perhaps the most useful are those for pervasive events such as droughts. Changes of vegetation patterns along climatic transition zones have been studied, using literary and field sources, in North America, Africa and Australia. In all cases a combination of human activities with stressful climatic conditions (that is, droughts) seems to have produced significant changes in vegetation patterns, leading to claims of desertification or deterioration in the resource potential of the vegetation (Kokot, 1955; Harris, 1966; Mabbutt, 1978). The difficulty with all such studies is, first, to distinguish the role of the extreme climatic events. The often unresolved question is: were the extreme climatic events the trigger or merely the final link in a long sequence of environmental stresses? The second difficulty is to convince the decision-makers that such long-term trends are relevant to short-term decision-making and that they should not be ignored as they have been in the past.

Some specialists have attempted to predict and display future disaster impacts, using computer-based simulations and scenarios. In nearly all cases, however, it is the intensive events, such as floods, which have been studied. Reviewing the United States experience, White and Haas commented that simulation allowed factors such as variations in the event, land use in the areas at risk, building codes affecting vulnerability, and the role of insurance to be incorporated in the models. Against these advantages were set the crudity of the assumptions which had to be made, the lack of information on some relevant variables, the complexity of the data required, and the geographical uniqueness of some of the characteristics of each event which could not be covered in the model (White and Haas, 1975, 134–135). Ericksen (1975) considered scenarios more effective in the sense that they can be used for analyses of interrelationships of events and impacts at one time or over a sequence of time, while a combination of scenarios and computer simulation offers an even better tool (see also Lave and Epple, Chapter 20 of this volume).

15.4 ANALYZING FIRST-ORDER IMPACTS

Extreme climatic events initially affect local and regional ecosystems, both natural and managed, in ways that may modify the character of those ecosystems as resource bases for human activity. Documentation of those impacts may involve methods ranging from those requiring complex technology, such as satellite imagery analysis for drought impacts in vegetation and crop patterns (Chakraborthy and Roy, 1979), to those drawing upon field surveys of the condition of the ecosystems and analysis of local peasant environmental monitoring systems (Oguntoyinbo and Richards, 1978).

The techniques for the documentation of these initial impacts have generally been successful, although they have required considerable technical ingenuity and there are some limitations. For example, there can be no doubt of the general value of satellite imagery in global environmental monitoring of both climatic events in the making (particularly the intensive types such as hurricanes and windstorms) and their impacts (such as flooding). However, local weather conditions, particularly cloud cover in the tropics, can considerably reduce the value of such imagery (Currey *et al.*, in press).

Human deaths and injuries are usually the most obvious evidence of first-order impacts from intensive events, although the accurate documentation of deaths may be difficult. Indeed, in the greatest disasters bodies may not be recovered—for example in the Bangladesh cyclone of 1970 total fatalities will never be known, as whole communities were wiped out and prior census data were probably wrong to begin with. The exact cause of death or injury also may not be clear in all cases. Sorting out `abnormal' from `normal' death rates may itself be difficult, particularly when the `normal' is unknown (Caldwell, 1975; Kates, 1981) or there are regional variations in death rates which may themselves reflect regional climatic differences, as is suggested for southern versus northern United States city death rates in the eighteenth century (Fischer, 1980, 829).

Field evidence of past impacts can provide useful clues to potentially risky sites for human activity. Thus vegetation scars from avalanche tracks (Prowse *et al.*, 1981) and past flood levels (Figure 15.5) can furnish evidence of the physical dimensions of the event. Research in geomorphology, pedology and hydraulics can provide estimates of the likelihood of soil erosion from rainfalls of different intensities (Ormerod, 1978, 359) and of actual losses by `soil loss equations' such as those developed for the United States (Beasley, 1972). The role of extreme events in landform modification, particularly the importance of the rapid erosion/deposition associated with events of 15- to 25-year return periods, has also been demonstrated (Wolman and Miller, 1960).

In terms of relevance to the society, however, such analysis of these first-order impacts must be followed up by examination of the ramifications of the second- to *n*th-order impacts.

15.5 ANALYZING SECOND-ORDER IMPACTS

Second-order disaster impacts are defined as those short-term effects upon a society of the ecosystem disruptions which form the first-order impacts. The complexity of these second-order impacts is impressive: the resulting negative impacts or disasters have several components (post-event fatalities and injuries, financial losses and societal disruption), the precise documentation of which may be very difficult, while the positive impacts may be even more difficult to recognize.

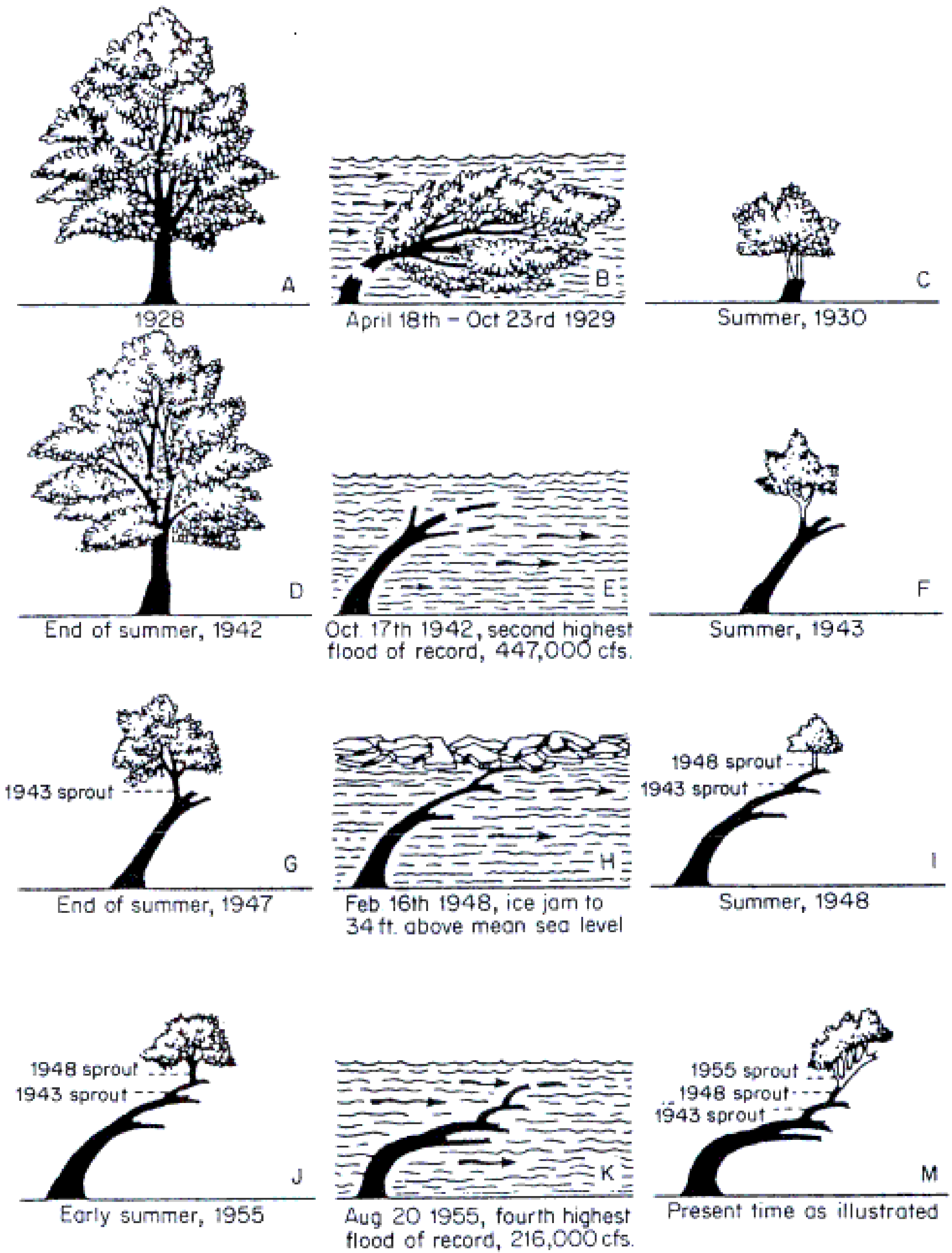

Figure 15.5 Vegetation indicators of flood levels. (Reproduced with permission from Foster, 1980, 57)

Table 15.3 Definitions of disasters

Descriptive term	Definition	Source
Major disaster	> $1 million property damage	Sheehan and
	> 100 people killed or injured	Hewitt (1969)
Accidents	1–999 people killed	Michaelis (1973)
Disasters	1000–1 million people killed	
Catastrophes	> 1 million people killed	

Definitions of `disasters' as the extreme form of general environmental stresses affecting a society have ranged from arbitrary thresholds based upon deaths and property damage (Table 15.3) to attempts to index community stress. Examples of the latter are Foster (1976, 1980), who provided a general formula:

$$CS = a + b + cd \qquad (15.2)$$

where

CS = the community stress experienced in the time period under review

a = number of deaths [multiplied by factors scored differently between developed and developing countries]

b = number of injuries or illnesses [multiplied by factors scored differently between developed and developing countries]

c = stress resulting from damage to the infrastructure ...

d = population affected by the event (Foster, 1980, 38).

The details of this formula will be discussed below and the table of infrastructural stress values which he suggested for item `c' in the formula is reproduced here as one attempt to scale the significance of the impact (Table 15.4).

15.5.1 Human Health and Well-being

Deaths and injuries as first-order impacts are only part of the stressful societal impacts of extreme climatic events. In their turn they, together with financial and material losses, generate further mental anguish on a wider section of the society, and may even generate population movements leading to the collapse of the entire society.

Foster (1976, 1980) has provided an attempt both to assess such mental anguish and to assess what he suggests are possible differences in the magnitude of those stresses between the developed and developing world. Adapting the `Social Readjustment Scale' of Homes and Rahe (1967) and using deaths as a surrogate for stress, he makes assumptions about the size of families

Table 15.4 Infrastructural stress values

Event intensity	Designation	Characteristics	Stress value
I	Very minor	Instrumental.	0
II	Minor	Noticed only by sensitive people.	2
III	Significant	Noticed by most people including those indoors.	5
IV	Moderate	Everyone fully aware of event. Some inconvenience experienced, including transportation delays.	10
V	Rather pronounced	Widespread sorrow. Everyone greatly inconvenienced, normal routines disrupted. Minor damage to fittings and unstable objects. Some crop damage.	17
VI	Pronounced	Many people disturbed and some frightened. Minor damage to old or poorly constructed buildings. Transportation halted completely. Extensive crop damage.	25
VII	Very pronounced	Everyone disturbed, many frightened. Event remembered clearly for many years. Considerable damage to poorly built structures. Crops destroyed. High livestock losses. Most people suffer financial losses.	65
VIII	Destructive	Many injured. Some panic. Numerous normal buildings severely damaged. Heavy loss of livestock.	80
IX	Very	Widespread initial disorganization. Area	100

	destructive	evacuated or left by refugees. Fatalities common. Routeways blocked. Agriculture adversely affected for many years.	
X	Disastrous	Many fatalities. Masonry and frame structures collapse. Hazard-proofed buildings suffer considerable damage. Massive rebuilding necessary.	145
XI	Very disastrous	Major international media coverage. World-wide appeals for aid. Majority of population killed or injured. Wide range of buildings destroyed. Agriculture may *never* be reestablished.	180
XII	Catastrophic	Future textbook example. All facilities completely destroyed, often little sign of wreckage, surface elevation may be altered. Site often abandoned. Rare survivors become lifelong curiosities.	200

Source: Foster, 1980, 38–39.

and circles of close friends and combines these with estimates of infrastructural stress values (Table 15.4) to offer two versions of his basic community stress formula (equation 15.2 above):

$$TS_{DD} = 445a + 280b + cd \tag{15.3}$$

or

$$TS_{DG} = 630a + 410b + cd \tag{15.4}$$

where a, b, c and d are as for equation 15.2 above, and TS_{DD} and TS_{DG} = total stress caused by a calamity occurring in the developed world (TS_{DD}) or developing world (TS_{DG}). On the basis of these formulae he assessed a variety of 'calamities' (from a motorist's parking ticket, through the Cyclone Tracy [1974] impact in Australia, to the stress generated by the Second World War) on a Calamity Magnitude Scale (Foster, 1976, 246). As a means of comparison between different types of disasters the formulae provide extremely crude, but nonetheless useful, preliminary measures.

Societal stress may further be shown in attempts to modify events by prayer. This seems to be a standard component of responses to drought-induced crop and livestock losses in both the developed and developing world (Burton *et al.*, 1978). One study even attempted to use the incidence of prayers conversely to indicate the severity of the event! namely drought (Fischer 1980, 821). Sociologists and psychologists have indicated that post-disaster stresses can be considerable and have demonstrated the extent to which stress can be buffered by social groups (Young, 1954; Barton, 1969) and can vary among the victims (Raphael, 1979). Such studies have identified the morbidity effects of disasters and the high-risk groups within societies, using interviews of survivors and control (unaffected) groups immediately after the impact and longitudinal follow-up of the survivors' success or failure in adjusting to their changed personal and family circumstances.

In terms of the demographic impact of the disasters, the scale may range from the proven loss of a generation and whole communities, as with the Bangladesh cyclone of 1970, to dubious overestimates of deaths, as with the `100,000' deaths attributed to the Sahel drought (Caldwell, 1975, 23–24). In the latter case Caldwell found little evidence of an increased death rate but convincing evidence of an increase in the traditional stress reaction, namely migration of the people affected. Kates (1981), assessing the evidence 5 years later, agrees with Caldwell's claims regarding the specific estimate of Sahelian deaths yet concludes that overall, deaths were probably underestimated by the `100,000 claim'. A basic problem for the Sahel is the absence of detailed longitudinal mortality data for so-called normal conditions.

15.5.2 Socioeconomic Gains and Losses

Probably because of the immediacy of the impacts and the possibility of reducing them relatively quickly to a common denominator—namely, money—research has been most prolific in this sector of the extreme event impacts. The bibliographies of natural hazards research (for example Cochran, 1972; Torres and Cochran, 1977; Morton, 1979) contain many references relating to the socioeconomic impacts of intensive events such as windstorms (tornadoes to hurricanes) and floods, and to a lesser extent of pervasive events such as droughts.

The immediate question facing any analysis of these impacts is `what to measure?' The recent ongoing climate impact assessment in the United States identifies eight categories of societal activities which are to be monitored—from human resources to food and energy production and government spending (Center for Environmental Assessment Services, 1982a; see also Chapter 4, this volume). At the national level this would be an example of the technical specialist's view of the impacts in the same way that the checklist of items to be investigated in the `Field Report Outline' used for comparative analysis of six United States disasters (Rubin, 1981, 26–28) would provide a local scale for the same view. In the latter case the checklist has four components: first, description of the event's magnitude and estimates of deaths, injuries and property damage set in the context of similar prior events and impacts; second, the recovery activities, differentiated by participants; third, the mitigation measures, divided according to their short- or long-term character; and fourth, the assessor's perception of the impacted community's commitment and capacity to carry out these mitigation strategies.

In the developing world, one of the few studies to address the question of what to measure proposed an evaluation of six major adjustments in terms of four disaster relief objectives for Bangladesh. The six adjustments (improvement of disaster warning systems, evacuation procedures, emergency relief, land use controls, coast protection measures and improvement of economic conditions) were to be evaluated according to whether they met the four objectives: reducing loss of life; reducing property and crop damage; generating employment; and generating higher income (Islam and Kunreuther, 1973). The study recognized, however, that not all objectives could be equally met and that compromise in disaster mitigation planning was inevitable.

15.5.3 Economic Losses

What are the economic costs of the disaster? Most disaster reports list the number of human dead and injured separately from the value of property damage. However, a human life can be given an economic value, usually by estimating the loss of expected earning capacity over a normal life span based upon actuarial tables. On this basis and on figures from insurance payouts and civil court actions, human life has been variously valued at from $US 9 thousand to $US 9 million (Foster 1980, 37) and from $A 12 thousand to $A 35 million (Cordery and Pilgrim, 1979, 222–223). However, what would the premature death of Albert Einstein have cost the world?

Although there are formidable problems of data collection and interpretation, the assessment of property damage by insurance companies, government agencies and relief organizations is based upon standard procedures, even though there may be no standardization among the assessing agencies! For the intensive impacts—the crops flattened by hail, the vehicles swept away by floods and the buildings demolished —the job of assessment is relatively easy. For the pervasive impacts the task is more difficult.

One of the most difficult impacts to cost has been that from drought. This is partly because of its slow onset and broad spatial extent, which makes the impacts difficult to recognize; partly also because of the ramifications of the long-term effects upon other components of the ecosystem (for example, soils and vegetation composition); and partly because some members of the impacted society might actually benefit from the drought (Heathcote, 1969a). Estimates of economic losses based upon crop production shortfalls, price fluctuations and government and private drought relief payments do exist, however, as well as estimates of drought-related research costs (Heathcote, 1967, 1979; Warrick, 1975), although their crudity as technical specialists' views is acknowledged.

The problem of assessing drought impacts raises a further question, namely `What is the long-term economic cost of the impacts?' This question impinges in part upon the problem of distinguishing adjustments from adaptations as mentioned in Section 15.3.3 above, but if the time-scale is reduced to less than a century to concentrate upon the impact responses as adjustments there are some longitudinal studies available.

Using local area statistics and interviews with local officials, an investigation of the impact of Hurricane Audrey upon a Louisiana parish found that, in comparison with the conditions before the event, 4 years later more people were in debt but the quality of the housing had improved, social institutions had become more formalized, and prior social trends had been accelerated (Bates *et al.*, 1963). Expanding the social survey techniques used in that study, Friesema *et al.* (1979) tried to establish trends of both economic and social measures of `community performances' for four impacted communities in the United

States for 10 years before and after an extreme event. Time-series analysis of over 200 sets of data suggested that because in each case the basic economic resource of the community was not seriously affected, serious economic impacts did not last more than a year.

This assessment of the long-term, community-level effects of natural disasters has been further confirmed by Wright *et al*. (1979) who claimed that the `Impact Ratio' (Section 15.3.3, equation 15.1 above) could be calculated using time-series data for census tracts in the United States and concluded that ›natural disasters do not cause long-term, community-level effects'.

What of the spread of the economic costs of disasters through the impacted society? Cochrane (1975) analyzed the disaster losses, official disaster relief strategies, insurance and bankruptcy data and urban renewal programs for the United States. Apart from establishing the validity of the `cascade' effect of disaster impacts noted in Section 15.3.3 above, he concluded that different sectors of the society suffered differently:

> the lower income groups consistently bear a disproportionate share of the losses: they receive, in most instances, the smallest proportion of disaster relief; they are the least likely to be insured (for either health, life or property); and they live in dwellings which are of the poorest construction and most subject to damage.
>
> (Cochrane, 1975, 110)

The middle- and upper-income groups offered the safest security for relief loans; with the greatest value of property at risk they generated the greatest flow of insurance claims, and were most aware of the possibilities of external disaster relief.

Such conclusions on the economic impacts of disasters relate mainly to the developed world. What, however of the situation in the developing world?

15.5.4 Social Losses

Natural hazards research, which has provided many of the studies of human adjustments to environmental stresses (White, 1974), has been criticized for its apparent bias towards developed world case studies and concentration upon monetary economic cost assessments. In the developing or Third World nations, so the argument runs, not only are the economic reserves of the society lower, but intrusive, often foreign-derived, policies of resource development—particularly associated with pressures for expanded cash cropping to develop a monetary economy—push the rural communities into resource management strategies and locations which are more vulnerable to extreme impacts. This process, which is claimed to illustrate a `theory of marginalization' (Susman *et al*., 1983), is exacerbated as reliance upon traditional socioeconomic adjustments to climatic stresses is reduced (Wisner *et al*., 1976; Oguntoyinbo and Richards, 1978; Watts, 1983). The Third World studies, relying much more upon anthropological and sociological observations of village activies and on folklore, are more aware of the views of the potential victims. This is an important attribute because the studies are of societies where the members can expect much less disaster relief from outside the impacted community than similar victims in the developed world.

In fact, there seems to be some evidence that social impacts magnitude per event tend to be less in the developed than the developing world. Thus, the United States longitudinal studies noted above suggested that long-term social impacts were relatively small and `the basic social structure survived their natural disasters virtually unscathed' (Friesema *et al.*, 1979, 107). In the developing world, however, severe social disruption may result, either because the traditional emergency management strategies are no longer feasible, as where the traditional emergency food stores have not been maintained because of the conversion to cash crops or a cash economy (Apeldoorn, 1981), or because official relief measures have temporarily reduced the need for these strategies without adequately encouraging local future self-reliance (Waddell, 1983). The resulting disruptions may take the form of family disintegration as well as community breakdown and increased levels of prostitution, banditry and other crimes of violence (Hall, 1978, 12).

15.5.5 Socioeconomic Gains

The disastrous impacts of extreme events bring benefits to some members of the impacted society and even to other nations. For example, drought-induced crop failures benefit farmers in grain-producing regions in Australia, Argentina, Canada and the United States, since massive purchases of grain on the world market force up grain prices. Given the global trade in plant and animal products, shortfalls in production from disasters in one nation are likely to prove beneficial to competing producers.

Within the nation also, there may be benefits from disasters. Reconstruction following extensive property damage creates employment and larger profits for the construction industry; emergency evacuation of people or livestock generates increased business for the transport industry; government relief brings money into local and regional economies which would otherwise not benefit; and changes in the regional infrastructure (for example), modernization of buildings and land-use zoning controls) may be easier after total destruction of the urban fabric than before. The methods for analyzing such gains incorporate all those used for estimates of losses plus, for example, estimates of the proportion of regional income from government relief payments as opposed to normal commercial activities. Borchert (1971) demonstrated the role of relief in maintaining the Great Plains economy in the United States through the droughts of the 1930s and 1950s. Another method used noncompliance with relief legislation requirements as an indicator of local beliefs that relief was in fact not needed, because the benefits from recapitalization following the disaster outweighed the losses (Friesema *et al.*, 1979, 13).

Although most of the studies that show gains from the impacts refer to the monetary economies of the developed world, there is some evidence of similar benefits in the developing world. Studies of the drought impacts in the Sahel in the early 1970s suggest that commercial cash cropping was still profitable at times when other subsistence sectors of the various national agricultures were showing considerable stress that was merging into famine (Meillassoux, 1974; Kates, 1981). Hall's study (1978) of land tenure, crop production, population trends and rural incomes in drought-prone northeastern Brazil suggested that the drought stresses brought considerable losses for small holders and landless laborers, whereas for larger landholders the stresses brought opportunities to buy up bankrupt small holders and provided the government with surplus labor for relief works. Such benefactions were in addition to:

> the *industrias da sêca* [drought industrialists], a term used to describe anyone who exploited the drought situation for his own profit. These included simple thieves of relief shipments, corrupt officials in charge of public works and those in search of quick profits caused by food shortages. (Hall, 1978, 8)

There may be political benefits from extreme climate impacts. Regional political representatives will press for official relief from the national treasury for their own districts and the exaggeration of impacts may be part of their strategy. Victims may exaggerate losses to increase their share of the national budget or international relief, as we saw in Section 15.3.1. Resource mismanagement leading to increased loss from climatic events may be concealed by putting the sole blame on the climatic event, rather than on the socioeconomic system which has proved inadequate to cope with the vagaries of the regional ecosystem (Hall, 1978, 125).

15.5.6 Human Movements and Migrations

There is evidence of both the impact of climatic change and of extreme climatic events upon human population movements. A historian commented recently.:

> There is abundant evidence of the importance of climate as a determinant of population movements in Scandanavian history ... . The beginning and end of Iberian expansion may have been influenced in part by ... the desiccation of the Spanish peninsula. (Fischer, 1980, 827–828)

Flight is a standard human response to extreme events, and over time it might result in the permanent relocation of population. This seems to have been the case with the nomad population shifts associated with the Sahel droughts (Caldwell, 1977) and with rural labor migrations from northeastern Brazil (Hall, 1978). In both cases the researchers were able to distinguish abnormal from normal movements by comparing pre-event with post-event patterns or comparing movements from stressed as opposed to non-stressed areas. In the case of Brazil, for example, rural/urban migration (1960–70) in the worst drought-affected state involved 36 percent of the population compared with neighboring state figures of 14 and 22 percent (Hall, 1978, 124). As such figures suggest, however, the impact of the event is to accelerate an existing process, not necessarily to initiate a new one.

15.6 ANALYZING SUBSEQUENT IMPACTS: THE ADJUSTMENT/ ADAPTATION RESPONSES

> In the short or relatively short term (on an intradecennary, decennary, and in certain cases interdecennary scale), agricultural history is vulnerable to the caprices of meteorology which produce bad harvests and used to produce food crises. But in the long term the human consequences of climate seem to be slight, perhaps negligible, and certainly difficult to detect.
>
> (Le Roy Ladurie, 1971, 119).

The difficulties of identifying these long-term consequences— the ramifications of the first- and second-order impacts—require that studies look for relevant data far and wide. On a time-scale of centuries, evidence of a climatic change in the northern hemisphere *c*. 1150–1200 AD (drawn from tundra advances in North America, expansion of the Greenland–Iceland sea ice areas, decrease of summer temperatures from pollen analysis in Michigan, and desiccation of vegetation in western Iowa from palynological and paleozoological data) tempted Baerries and Bryson to reconstruct the hypothetical pattern of rainfall which would have resulted in the formation of the central plains of the United States and to compare it with actual human activity during the period. They found that a sporadic reduction of 30–50 percent in July rainfall from 1150 to 1200 AD over the northern plains was accompanied by *wetter* Julys on the southern plains. Coincidentally, archaeological evidence suggested that:

> On the northern high plains ... thousands of small villages characterized by rainfed maize agriculture before 1100 AD had completely disappeared by 1200 AD and many became covered with wind-drifted soil ... Farther east, in western Iowa ... maize farmers ... had occupied valley floors with forested terraces in a region of generally tall-grass prairie. After 1200 AD the forests were gone and short-grass prairie dominated ... After a little less than two centuries the culture succumbed ... About 1200 AD a number of villages practicing the rain-fed maize agriculture were established in the Panhandle regions of Texas and Oklahoma, in a region where that had not been possible before and is not at present.
>
> (Bryson and Padoch, 1980, 596–597)

Over similar time-scales in Europe, the relevant indicators of stress and human response may be the changes in the types of crops grown, as suggested for the spread of buckwheat (a hardy crop) in the Netherlands during the cooler, wetter, Little Ice Age of the seventeenth century and its decline in the milder winters of the eighteenth century (de Vries, 1980, 625).

If we reduce the time-scale to less than a century, other indicators may be relevant. Trends in attitudes to, and policies of, resource management may be identifiable from the analysis of changing legislation on land management—particularly that relating to the principles and administration of public disaster relief or subsidies for settlement in what are designated as stressful environments (Gates, 1968, especially Chapters 18 and 22). In this context the transformation of societal controls from Toennies' *Gemeinschaft* to *Gesellschaft* systems indicates the codification of customs, possibly in response to extreme environmental stresses over time (Heathcote, 1969b).

At the other end of the time spectrum, individual extreme events may give rise to weather manipulators —individuals who claim to be able to influence weather events and whose activities, plotted over time, provide further evidence of a society's reaction to unfavorable weather conditions. Significantly, the most recent and comprehensive study for the United States, although restricted to the period up to the Second World War, identified and concentrated upon the `age of "pluviculture", from roughly 1890 to 1930' when the advance of agriculture onto the subhumid to semi-arid western plains made the activities of rainmakers a relevant strategy to resource managers beset by droughts (Spence, 1980, 2).

Indeed, one of the most successful studies of the scope of regional adjustments to extreme events has been the study of drought impacts on the Great Plains of the United States (Warrick, 1975). Reviewing responses since the droughts of the 1930s a variety of adjustments were identified and trends over time suggested (see Chapter 1, this volume and Figure 15.6).

A further study used the same basic methodology—a careful time-series analysis of detailed population data, farm transfer rates, and regional production data alongside the meteorological sequences for the study area—to compare drought impacts in the Great Plains (1880–1979), the Tigris-Euphrates Lowland (6000 BP to the present) and the Sahel (1910–74) (Bowden *et al.*, 1981). The findings were that in the Tigris-Euphrates area lack of sufficiently detailed information prevented any firm conclusions on the significance of the role of extreme climatic events on the societal collapse in the area, but for the Sahel and the Great Plains the impact of the extreme events had lessened over time. In the latter two cases, however, catastrophic potential remained, but rested less upon climatic extremes than on socioeconomic and demographic factors which would increase their vulnerability should disaster strike.

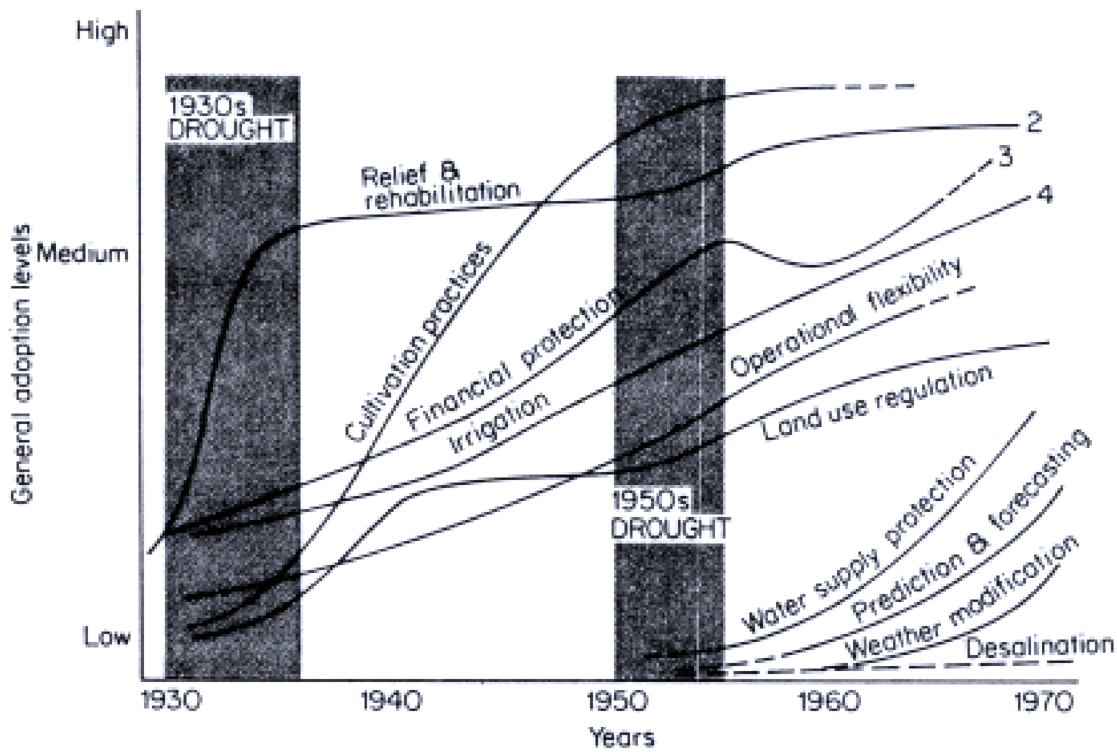

Figure 15.6 Generalized historical trends of drought adjustment on the Great Plains of the USA (1, Very rough approximation of relative levels of adoption). 2, institutional arrangements for R & R (not payments); 3, shape of curve generalized from number of acres insured and amounts of loans in the United States (dip in 1950s reflects lower adoption of insurance at that time); 4, based on total irrigated acres in the United States. (Reproduced with permission from Warrick, 1975, 102)

There is little doubt that many of the responses to extreme climatic events both reflect the sociopolitical character of the impacted society and, in turn, modify that character. Governments supported by a centralized bureaucracy can, in theory, coordinate responses at a regional or a national level. Where a special problem appears, perhaps in response to the issue–attention cycle noted in Section 15.3.1, a standard response is to create a special branch of the administration to cope with it. Indeed, one method by which the seriousness of the impact on a society is assessed uses the chronology of the growth of departmental responsibilities as indicators, the creation of a separate government department being seen as evidence of the official recognition of the seriousness of the problem. Hall's study of responses to drought in northeastern Brazil used changing government responsibilities both to indicate changing strategies and to demonstrate the lack of success of most of them (Table 15.5). The lack of success of such institutionalized strategies may result from a variety of causes such as incompetence, corruption or irrelevant policies, but may also reflect the departmentalization or sectoral approaches of governments to extreme event impacts—what Baker (1976) identified as the ›administrative trap' for the Sahel.

The failure of a government's responses to offset the impacts may result in its removal from office by national elections or revolution. The specific role of the extreme event in the political changes may be difficult to identify—was it the sole cause or the final straw after a sequence of other societal stresses inadequately met? The drought and associated famines in the Sahel in the early 1970s have been assumed to be partly responsible for the Ethiopian revolution in 1974 and the revolutions in Niger in 1974 and Chad in 1975.

Successful official disaster relief may solve the immediate problem but create many more. Greater vulnerability of the society to future disasters may result from an inreasing dependence on external sources of relief. In a colonial or politically dependent situation, the reinforcement of institutional controls which official relief programs provide may also increase vulnerability (Waddell, 1983).

Table 15.5 Government drought relief institutions in Brazil, 1877–1970s

Droughts	Institutions		
	Established	Title	Policy
1877–79	1877	National Commission of Inquiry [into drought]	
	1906	'Superintendencia dos Etudos e Obras Contra os Efectos da Seca' (SEOCES) [Superintendency for study and mitigation of drought effects]	
	1908	This became 'Inspectoria de Obras Contra as Sêcas' (IOCS) [Inspectorate for the mitigation of drought effects]	Water storage in man-made reservoirs
	1918	This became 'Inspectoria Federal de Obras Contra as Sêcas' (IFOCS) [Federal Inspectorate for mitigation of drought]	
1930–32 1945	1945	This became 'Departmento Nacional de Obras Contra as Sêcas' (DNOCS) [National department for the mitigation of drought]	
1951			
	1952	'Banco do Nordeste do Brasil' (BNB) [Bank of Northeastern Brazil] set up as commercial bank	
1958	1956	'Grupo de Trabalho para o Desenvolvimento do Nordeste' [Working group on development of the northeast—as part of BNB]	Irrigation works
	1959	'Superintendencia do Desenvolvimento do Nordeste' (SUDENE) [Superintendency for development of the northeast]	
1970			
	1974	'Programa de Desenvolvimento de Areas Integrados do Nordeste' (POLONORDESTE) [Integrated development program for the northeast]	

Source: Hall, 1978, 6–14.

One method by which such official strategies to mitigate extreme societal stresses may be assessed has been put forward by Foster (1980). A series of criteria for evaluating the strategies together with 'strategy-related questions' were suggested and may be grouped in terms of the context for their assessment (Table 15.6). He further suggests a matrix for the planning of general disaster mitigation activities spread over at least 4 years (Foster 1980, 36). Such activities include `risk mapping' through `disaster simulation and prediction' to `planning for reconstruction'. The aim is to design a `forgiving environment' where planners `assume a relatively high incidence of destruction or misuse' and plan their defenses on the assumption that disasters *will* occur (Foster, 1980, 107 and 113). Whether such an analysis would identify the range of positive and negative aspects of the official relief measures remains to be seen.

Table 15.6 Evaluating mitigation strategies

Context of assessment	Foster's criteria for evaluating mitigation strategies		
	'Criteria'*		'Strategy-related questions'
Time	2.	Timing	Will the beneficial results of this strategy be quickly realized?
	6.	Continuity of effects	Will the effects of the application of this strategy be continuous or merely short term?
	7.	Compatibility	How compatible is this strategy with others that may be developed?
	11.	Hazard creation	Will this strategy itself introduce new risks?
	12.	Hazard reduction	What proportion of the losses due to this hazard will this strategy prevent?
		potential	Will it allow the safety goal to be reached?
Environment	10.	Effects on the environment	What will be the environmental impacts of this strategy?
Economy	4.	Cost to government	Is this strategy the most cost-effective or could the same results be achieved more cheaply by other means?
	9.	Effects on the economy	What will be the economic impacts of this strategy?
Society	1.	Equity	Do those responsible for creating the hazard pay for its reduction? Where there is no man-made cause, is the cost of response fairly distributed?
	3.	Leverage	Will the application of this strategy lead to further risk-reducing actions by others?
	13.	Public and pressure group reaction	Are there likely to be adverse reactions to implementation?

	14.	Individual freedom	Does the strategy deny basic rights?
Institutions	5.	Administrative efficiency	Can it be easily administered or will its application be neglected because of difficulty of administration or lack of expertise?
	8.	Jurisdictional authority	Does this level of government have the legislated authority to apply this strategy? If not, can higher levels be encouraged to do so?

* Numbers refer to Foster's list.

After Foster, 1980, 28.

15.7 CONCLUSION

Such a brief review cannot hope to do more than hint at the wealth of studies relevant to the assessment of extreme climatic event impacts. At the risk of some generalization we may conclude that a considerable number of methods exist for the study of disasters (natural or man-made) and many are relevant sources for the assessment of climatic impacts. Most studies have assessed such impacts in the developed world and in economic terms. Studies of social and psychological impacts are fewer and less well-documented (see Chapter 13). Studies of climatic event impacts for the developing world are sparse and stress more the social than the economic impacts. The most successful methods—successful in the sense of appearing to present a logical description of the complexities of human response to environmental stress—seem to be those which combine the detached viewpoint of the technical specialist with the intimate knowledge of the potential and actual victims. Such methods, in fact, draw upon a wide range of disciplinary expertise, are truly interdisciplinary in their approach, and promise the greatest future insights.

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The electronic version of this publication has been prepared at the *M S Swaminathan Research Foundation, Chennai, India.*