SCOPE 27 - Climate Impact Assessment

4 Identifying Climate Sensitivity

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4.1 INTRODUCTION

Where does one begin in undertaking specific climate impact studies? Often, such selection is already dictated by circumstances or events; that is, there is a previous commitment or preference to examine the relationship between climate and a particular crop, region or population. However, the questions of what activities to study, in which places, affecting whom also are frequently not predetermined. This paper attempts to assist the impact assessor by surveying which activities, places and populations analysts have found important to study in the past and the methods they have used to identify climate sensitivity.

4.2 SUBJECTS OF EARLIER STUDIES

There are two overlapping sets of studies that constitute implicit, if not explicit, surveys of activities or places that are highly sensitive to climate. The first set consists of studies of the users and value of the information that national weather services generate. The second includes studies connected with integrated assessments; scientific symposia, or governmental and intergovernmental conferences.

Typical of the impact studies related to national weather services are those of Mason (1966) for the United Kingdom and Tolstikov (1968) for the Soviet Union. Maunder (1970) surveyed the value of the weather with examples from many areas. Such studies emphasize the importance of meteorological conditions and information for agriculture and point out their role in a variety of other activities, such as aviation. To illustrate further, the value of meteorological services was discussed at a New Zealand symposium (New Zealand Meteorological Service, 1979). At this event topics examined included the relation of weather and climate to:

- forest fires and forest management,
- agriculture (wool, wheat, potatoes),
- ship operations,
- electricity supply,
- design and siting of power stations, and
- boating and sport.

Although the national meteorological service studies generally focus on weather, rather than climate, they still may be viewed as a first-order approximation of the climate sensitivity of human activities. Clearly, the range of activities impacted by short-term climate variation will be close to that impacted by weather. Table 4.1 presents a summary of annual dollar and percentage losses due to adverse weather in the United States as estimated by Thompson (1977). According to Thompson, agriculture is an order of magnitude more sensitive to weather than any other activity in both relative and absolute terms.

The Assessment and Information Services Center (AISC) (formerly the Center for Environmental Assessment Services, CEAS) of the US Department of Commerce routinely makes climate impact assessments on a weekly and monthly basis for the United States and several other countries and regions of the world. The monthly impact assessments for the United States cover the following eight broad categories of societal activity (Center for Environmental Assessment Services, 1980):

1. *Construction*—including housing starts, commercial and industrial construction, property damage, soil erosion and land use.

2. *Economics and Commerce*—including employment, banking, business, trade, manufacturing and industry.

3. Energy—including utilities, supply and consumption of the different energy types and alternative energy sources.

4. *Food and Agriculture*—including food, fiber and orchard crops, forestry and fisheries.

5. *Government and Taxes*—including executive, legislative and judicial branches; federal, regional, state and local.

6. *Recreation and Services*—including travel, vacation activities and sport.

7. *Society*—including fatalities, injuries, health, air pollution, education, crime, and population movements.

8. *Transportation and Communications*—including highway, railroad, air, and mail delivery.

Table 4.1 Losses due to adverse weather in the United States

Activity	Overall losses (US$ x 10^6)	(% of annual gross revenue)
Agriculture	8240.4	(15.5)
Construction	998.0	(1.0)
Manufacturing	597.7	(0.2)
Transportation (rail, highway, and water)	96.3	(0.3)
Aviation (commercial)	92.4	(1.1)
Communications	77.4	(0.3)
Electric power	45.7	(0.2)
Energy (e.g., fossil) fuels	5.1	(0.1)
Other (general public, government, etc.)	2531.8	(2.0)
Totals	12,684.8	

(After Thompson, 1977, 71)

In AISC's estimates of climate sensitivity, agriculture is again dominant, but other sectors, such as energy and transportation, increase their relative position as seasonal factors come into play.

Besides central government groups concerned with the operation and provision of climate-related services, the second major source of information on climate impacts is a rather miscellaneous research literature, much of it stemming from conferences. The agendas of such conferences and the contents of the reports provide a *de facto* judgment about what is sensitive to climate. Table 4.2 compares these individual agendas with one of the weather studies to suggest both the convergence of opinion on climate sensitivity and the idiosyncratic judgments as well. The list includes Maunder's survey (1970), the Climate Impact Assessment Program (CIAP, 1975), the Aspen Institute Conference of 1977 on effects of climatic change (Aspen Institute, 1977), the 1979 Australian Conference on Climate and the Economy (Commonwealth Scientific and Industrial Research Organization [CSIRO], 1979), the 1979 World Climate Conference (World Meteorological Organization [WMO], 1979), the American Association for the Advancement of Science research agenda on effects of CO_2-induced climate change prepared for the US Department of Energy (DOE) (1980), the Assessment and Information Services Center ongoing assessments (CEAS, 1980), and this volume.

Table 4.2 Topics covered in 8 major climate impact studies[a]

Sensitive area [b]	Maunder 1970	CIAP 1975	Aspen Institute 1977	CSIRO 1979	WMO 1979	DOE/AAAS 1980	CEAS 1980	SCOPE 1984
1. Agriculture	X	X		X	X	X	X	X
2. Forests and forestry	X	X		X	X	X	X	
3. Pastoral activities				X		X	X	X
4. Fish and fisheries	X	X			X	X	X	X
5. Ecosystems						X		
6. Environmental conservation								
7. Water supply, demand		X	X	X	X			X
8. Energy supply, demand	X	X	X	X	X		X	X

9. Manufacturing operations, location of plants	X	X		X			X	
10. Offshore operations					X			
11. Mining (extractive industries)				X				
12. Transportation—water, air, rail, highway	X		X	X			X	
13. Construction	X		X	X			X	
14. Materials weathering		X						
15. Esthetic costs		X						
16. Trade	X						X	
17. Public expenditures		X					X	
18. Communications							X	
19. Insurance	X			X				
20. Financial planning and institutions			X				X	
21. Recreation and tourism	X			X			X	
22. Sea level rise, coastal zones						X		
23. Health–mortality, morbidity	X	X			X	X	X	X
24. Migration							X	
25. Social concerns, crime	X	X				X	X	X
26. Military planning and operations								
27. Political systems and institutions	X	X				X		
28. Legal systems and institutions	X					X		

[a] To be checked here, topic must be treated explicitly or extensively.

[b] List includes 2 topics (6 and 26) not covered in studies listed, but covered in other studies.

This overview suggests a broad consensus on the sensitivity to climate variation of agriculture, water resources, building construction, transportation, and energy activities. In addition, there is repeated concern about impacts on insurance, governmental expenditures, and recreation. The table may suggest more orderliness and conscious selection than exists. Any agenda represents to a certain extent networks of available researchers and not systematically identified topics. Moreover, impact studies and conferences have often focused on geographic regions, especially drought-prone ones (the Sahel, South Asia, northeast Brazil, North American Great Plains) and high latitudes (Parry, 1983), where life is obviously sensitive to climate.

An alternative to the identifying of large sectoral or regional sensitivity is to focus sharply on specific topics where climate impact analysis appears most useful for applications. Topics from a Massachusetts Institute of Technology (1980) conference on `Climate and Risk' illustrate sensitivities more specifically, for example:

– extreme wind speeds and structural failure risks;
– weather hazard probabilities and the design of nuclear facilities;
– application of climatology to air force and army operational planning;
– impacts and use of climatological information in the hail insurance industry;
– importance of climate and climate forecasting to offshore drilling and production operations in the petroleum industry;
– seasonal climate forecasts and energy management;
– evaluating farming system feasibility and impact using crop growth models and climate data;
– the utilization and impacts of climate information on the development and operations of the Colorado River system; and
– snow management and its economic potential in the Great Plains.

While it is clear from this survey that there have been some attempts to be reasonably comprehensive from a sectoral point of view, few of the efforts have been internally consistent in assessing sectoral impacts. Differing methods and definitions of climate variation have often been employed within a conference or study. Also, the sectoral studies vary in their attention to receptors or exposure units. The largest portion of studies examines impacts at the national or regional level. Other levels may be important, however. For example, municipalities may have their expenditures for education, welfare, police, fire, sanitation, and sewage services affected by climate variation (Sassone, 1975). Households may be sensitive in terms of income and expenditures for food, housing, transportation, clothing and medical care (Crocker *et al.*, 1975) and at the individual level, nutrition (Escudero, Chapter 10, this volume) and migration (Warrick, 1980) may be major indicators of climate sensitivity. Regrettably, few studies have been systematic in their selection of indicators of sensitivity and units of exposure for comparative examination; it could therefore be fruitful to undertake studies of relative sensitivity to a given climate variation stratified in a variety of ways, for example, by urban, suburban and rural families, or by different firms in a particular region, or similar firms in different regions. Table 4.3 suggests a framework for defining sensitivity to climate and illustrates it using several available studies.

An important deficiency in making sensitivity judgments based on studies of the value of weather services or agendas is their dominant relationship to industrialized societies. While individual papers from the World Climate Conference, for example, relate to developing country situations (see Burgos, 1979; Fukui, 1979; Oguntoyinbo and Odingo, 1979), the balance of analysis and methods development has been restricted to industrialized nations. Although there is considerable evidence that primary activities (agriculture, pastoralism, water resources) may be even more sensitive to climate in developing countries than in industrialized countries, careful surveys of sensitivity remain to be done.

4.3 METHODS

There is not likely to be any single best method for making an initial assessment of a society's climate sensitivities. Several early, related steps might be considered. As implied by Section 4.2, these might include:

1. Analysis of uses and users of weather and climatic information in the proposed study area; this would provide an idea of which groups value climate knowledge and, thus, may be exhibiting sensitivity.

2. Review of scientific literature, especially local sources, related to climate impacts; this would lead to an implicit ranking of activities as to their sensitivity to climatic influences.

This section suggests and gives illustrations of several additional analytical methods. These are analyses of communications media and information content, reviews of national income and product accounts, examinations of seasonality, and correlation analysis. These methods all enable one to take readily available data and perform tentative analyses aimed at identifying the climate signal in social and economic activities.

Table 4.3 Sample of impact studies in framework for defining sensitivity to climate

	CLIMATE VARIATION				IMPACT LEVELS						INDICATORS USED		
						social system unit of exposure							
	change	variability	season	extreme	biophysical						quantitative		qualitative
Study						globe	nation/ region	locality	firm	house hold	mone- tary	non- mone- tary	

CIAP (1975)	X				X	X	X	X	X	X	X		
WMO (1979)		X			X		X	X				X	
DOE/AAAS (1980)	X				X		X						X
Seifert and Kamrany (1974)				X	X			X				X	X
National Defense University (1980)	X				X	X	X				X	X	
García (1981)				X	X	X	X	X			X	X	X
Chambers *et al.* (1981)			X		X			X		X	X	X	X

Studies are placed in framework according to their emphases.

4.3.1 Media Analysis

In many regions perhaps the best guide to weather/climate sensitivity is obtained by a critical analysis of agricultural, economic and business journals, and by a careful appraisal of the area's newspapers. Indeed in many nations—both developed and developing—the media (newspapers, journals, radio and television) often provide the only indication of the importance in a real-time sense of weather and climate.

A media analysis is particularly important in two kinds of situations: first, in data-poor nations or areas, where what little data do exist are available for analysis only several months (and in some cases several years) after the event; and second, in those data-rich nations or regions where decisions are made on a day-to-day (sometimes even hour-to-hour) basis and where the prices of commodities are important. In both cases the financial, economic and agricultural sections of the daily press (or, if available, the more specialized newspapers such as *The Wall Street Journal* or *The Financial Times)* publish valuable information, provided the reports are read with a critical eye.

Probably the most developed use of media-type information (such as that described above) for climate impact assessment is that published by AISC. As a guide, AISC uses the sensitivity of the gross national product (GNP) to widespread anomalous weather as given in Table 4.4. This table was compiled from an analysis of the weather/climate sensitivity of various economic and social sectors in the United States as reported in the *New York Times* during a 10-year period. The AISC survey shows that a major increase in the GNP can result from an unusually hot summer (specifically in GNP elements of personal consumption expenditures on electricity and food at home), and an unusually cold winter (GNP elements of personal consumption expenditures on natural gas, fuel oil and coal; also in net imports), whereas a major decrease in the GNP can be expected as a result of unusually mild conditions (specifically in the GNP elements of personal consumption expenditures on food at home, changes in business inventories and net imports). While the sensitivities shown in Table 4.4 should be regarded as tentative, they do give an indication of how the GNP of an industrialized nation may be affected by widespread anomalous weather conditions.

Specific weather/climate events have also been studied by AISC. For example, during the 1980 summer heat wave and drought, there was a series of reports (see Center for Environmental Assessment Services, 1981) updating mounting economic losses in the United States that were finally estimated at more than $20,000 million. Six months after the last special report on the summer heat wave and drought was issued, official statistics were released confirming these estimates. To compare this impact of weather/climate with previous events, a report was prepared (Center for Environmental Assessment Services, 1982) on the 1976-77 winter in the United States which indicated that the economic losses during that winter were almost twice those of the 1980 summer heat wave and drought. These media-based studies of a national economy are a useful method of placing specific weather/climate events in perspective. The AISC studies further point out that although last month's climate is history, the measurement of its economic impact is not; short-term losses (for example, suppressed consumption) may be compensated for or magnified by subsequent economic developments, and early indicators may be replaced by more reliable data and information. Further, since weather information is available in real-time, whereas weekly national economic indicators—even in the United States—have a time publication delay of 2 or 3 weeks (or months, depending on the economic parameter), weather-based forecasts of economic activity can be made available 1, 2 or 3 weeks (or months, depending on the economic parameter) *before* the actual production/consumption information is available.

Table 4.4 Sensitivity* of Gross National Product elements to widespread anomalous weather

GNP elements		Hot summer	Cold winter	Dry summer	Storm/rain	Snow	Mild
1. Personal consumption expenditures							
(a)	Gasoline and oil	–	–	–	–	–	++
(b)	Electricity	++	+	?	++	?	–
	Natural gas, fuel oil, coal	?	++	?	++	+	–
(c)	Furniture and appliances	–	–	–	?	–	++

(d)	Food at home	++	+	++	+	++	– –
	Food away	– –	– –	?	?	– –	++
(e)	Apparel	–	+	?	?	–	+
(f)	New and used cars	–	–	–	–	–	++
(g)	Housing	–	– –	?	?	–	++
(h)	Transportation	–	–	?	–	–	++
(i)	Other	?	?	?	?	?	?
2. Non-residential fixed investment		?	?	?	?	?	?
3. Residential		–	–	–	?	–	++
4. Change in business inventories		+	+	+	+	+	–
5. Net imports		+	++	+	+	+	–
6. Government purchases							
(a)	Federal	+	+	+	+	+	–
(b)	State and local	+	+	+	+	+	–

*Weather-related changes in consumption: + = increase; ++ = major increase; – = decrease; – – = major decrease

(Adapted from Center for Environmental Assessment Services, 1980)

4.3.2 National Income and Product Accounts

A more thorough and orderly process can be a critical reading of national income and product accounts from a climatic point of view. Although when looking at an economy the trained eye may be able to differentiate quickly between sectors of an economy that are weather/climate sensitive and those that are not, systematic approaches can be helpful. As an example, let us consider the climate sensitivity of New Zealand by examining the various components of the economy as they appear in the *New Zealand Official Year Book.* The approach involves an overview of the economy and then a more detailed look at key elements. A few examples will indicate a typical step-by-step process to make an initial assessment of national climate sensitivity.

In calling the roll of activities, let us focus first on transport. Transport, an important component of the economy, should be considered specifically by its various sectors and the climate-sensitive aspects of these sectors. For example, in New Zealand the gross expenditure on railways (using data from the 1981 *Year Book*) was $404 million; this included $26 million (or 6 percent) spent on fuel. On the basis that any change in fuel used—as a result of better weather and climate or information about them for rail transportation—will affect the economy, the fuel expenditure can be said to be weather/climate sensitive. Other aspects of railway expenditures may also be weather/climate sensitive in other countries, but analysis shows that few other sectors of the railway operations in New Zealand are weather/climate sensitive. In the case of shipping, the key weather/climate factors that can be identified are the loading and unloading of containers. In New Zealand, the number of containers moved exceeds 200,000 in a year, and many contain climate-sensitive commodities such as dairy products, wool, meat and fruit. Optimal movement of these perishable commodities is crucial to New Zealand's export competitiveness, and thus it is logical to include container movements in a list of activities that are climate sensitive.

When we look at the energy sector, the key factor is the heavy reliance of New Zealand on imported oil, 50 percent of New Zealand's total energy being supplied by imported oil. In contrast, of the 22 percent of the total energy supplied from primary electricity, a very high 86 percent comes from hydroelectric generation. The energy situation in New Zealand is therefore related mainly to two factors—the need to use imported oil and the natural availability of relatively cheap hydroelectricity. Both factors are sensitive to an adequate supply of water at hydroelectric stations during the critical summer and autumn periods, and the severity of the winter. The latter is a critical determinant of the proportion of electricity to be generated by more expensive oil and gas.

A third area to consider is government expenditure, especially subsidies from public funds. The *New Zealand Official Year Book* lists two relevant subsidies—the first concerning adverse events (such as drought conditions), the second, a fertilizer subsidy. This latter subsidy is in several ways weather/climate sensitive. It reflects concern of the New Zealand Government about farm income variations, in that a subsidy on fertilizers is often given following a relatively poor income (climatic) season, in order to encourage farmers to fertilize their pastures during the following season. A natural response of farmers following a poor season is to spend fewer dollars on fertilizer; the government fertilizer subsidy is in effect a means of smoothing not only the irregularities in the application of fertilizer to New Zealand pastures, but also the climate-induced variations in farmers' incomes.

A second step in a systematic survey of national economic data is to consider both absolute and relative climatic sensitivity through dollar value of production. For example, in New Zealand, wool accounts for 19 percent of the gross value of agricultural production, compared with 3 percent for vegetables. Thus, irrespective of the fact that some aspects of the vegetable sector (such as transport of vegetables to markets) are more weather sensitive than some aspects of the wool industry (such as effects of severe frost on quality of wool), in terms of monetary value the wool sector of New Zealand agriculture is six times more important than the vegetable sector. Similarly, since 62 percent of New Zealand's agricultural income is from pastoral products (that is, wool, dairy products and meat), it is evident that the climatic sensitivities will be strongly related to the state of the nation's pastures. Naturally, in other countries this could be quite different, especially where field crops or horticultural-type crops are the principal agricultural earners.

Finally, in this climatic view of the *New Zealand Official Year Book*, consider overall the components of gross domestic product. Eleven percent of New Zealand's gross domestic product comes from the agricultural sector, and 6 percent from food manufacturing. Other important weather/climate-related market production groups include transport/storage (6 percent), construction (5 percent), energy (3 percent) and wood products/forestry (3 percent). These components, clearly climate sensitive, comprise one-third of New Zealand's gross domestic product. The climate-sensitive sectors of other nations could be—and in many cases are—quite different from those of New Zealand. An analysis similar to that described for New Zealand, using appropriate scans of national `Year Books' or income and product accounts, should point to those sectors of an economy that are most climate sensitive.

4.3.3 Seasonal Variations

A development of the kind of survey described above is to look for seasonal variations in production and consumption data. It is well recognized that some economic activities follow a recurring seasonal pattern during the year; for example, the retailer is aware that there will be increased business around Christmas or other major holidays, for which to plan purchasing and personnel changes. Similarly, the contractor buys materials and hires additional workers for the increased construction activity that inevitably comes in many countries during the summer months, and the farmer's expenditure rises in the spring and autumn because of planting and harvesting costs. Bankers also recognize these and other patterns of seasonal activity and they plan for an uneven deposit inflow and demand for loans during the year. In the same manner wage earners in industries with high degrees of dependence on seasonal activity realize that their income may not flow evenly during the year. The strongly seasonal character of social welfare in developing countries has also been assessed (Chambers *et al.,* 1981).

Seasonal patterns usually follow a relatively similar pattern from year to year. Procedures have been developed to measure the fluctuations; in many cases a climatic explanation is offered for the variations. For example, economists often use statistical smoothing on weekly, monthly and quarterly data and refer to the results as `seasonally adjusted', suggesting that the revised figures account for variations in `seasonal' activities such as Christmas trade, end-of-quarter activities, winter/summer differences, and the weather. Of course, such seasonally adjusted data may have little relationship to weather events as such, but the extent of seasonal adjustments may provide another initial quantitative view of climatic sensitivities over a broad spectrum of activities.

4.3.4 Correlation Analysis

A correlation approach may also suggest sensitivities in the comparison of climate and economic data. For example, in a study of weather and the retail trade, Linden (1962) related—in a simple but telling way–sales of women's winter coats in New York department stores to the average monthly temperature in September and October. Correlations are often pointed out between the behavior of futures markets and the arrival of information about weather and climate.

More detailed correlation analyses can also be made. For example, Maunder (1979) examined climatic data in relation to sheep numbers and wool production. The analysis identified statistically the most important weather/ climatic factors and the significant months or combination of months. Palutikof (1983) used multiple regression analysis to evaluate the impact of a severe winter and a hot, dry summer on British industry (Table 4.5), revealing interesting contrasts. For example, severe winters favor utilities (+17.5) and reduce clothing and footwear production (−9.6), while a dry, droughty summer reduces utility performance (−6.4) and increases clothing and footwear performance (+3.0).

In some correlation-type analyses, however, the impact signals are weak, or hidden by larger, non-climatic fluctuations. In such cases it is useful to focus on particularly anomalous climate episodes (for example, major droughts, floods, cold spells and the like) and search for concomitant variations in social and economic activities. If no apparent variation is found, it is safe to assume that the subject under study exhibits little sensitivity to that particular type of climate variation. Such a `reasoning from extremes' is particularly useful in data-poor areas, and in some cases may be the only reasonable way of quantitatively analyzing climatic sensitivity.

Table 4.5 Performance of United Kingdom industries

Industry	Average deviation per month from mean of preceding season	
	1962–63 winter	1975–76 drought
Bricks, cement, etc.	−14.4	−0.9
Timber, furniture	−14.3	−1.8
Clothing and footwear	−9.6	+3.0
Paper, printing and publishing	−5.6	−2.2
Mining and quarrying	−4.7	−2.3
Shipbuilding	−4.3	−0.9
Engineering and electrical goods	−3.7	−2.1
Nonferrous metals	−2.7	−4.3
Drinks and tobacco	−2.4	+4.4
Ferrous metals	−2.3	−10.0
Food	−2.0	+0.7
Metal goods (not elsewhere specified)	−2.0	−4.6
Chemicals	−1.6	+2.1
Leather goods	−0.6	+0.6
Pottery and glass	−0.3	−3.9
Textiles	0.0	−0.6
Vehicles	0.0	−1.3
Coke ovens, oil refining, etc.	+3.3	−0.3
Utilities	+17.5	−6.4

(After Palutikof, 1983)

While measures of sensitivity to climate are often economic, other indices are also available. For example, measures can be offered of the numbers of people affected by a climate variation (see Burton *et al.*, 1978; Warrick, 1980) or in terms of dietary levels or patterns of land ownership (see Jodha and Mascarenhas, Chapter 17). The primary appeal of economic indicators, especially monetary ones, is ease of intercomparison. The most extensive effort to assess relative economic sensitivities of different sectors and impacts to climate variation was that of CIAP (1975). CIAP sought to formulate mathematical relationships between long-term climatic change and many of the economic activities mentioned above. The results of one calculation are presented in Table 4.6. While the accuracy of these estimates is questionable (see Ausubel, 1980), the results are surprising and, as such, worth noting. In particular, wage and health effects far surpass others, including agriculture and water resources, in importance. Other studies include those of Eddy *et al.* (1980), who have employed input/output and other economic models to assess the effects of contemporary climate variability on a range of sectors and spatial scales.

4.4 CONCLUSION

The difficulty of identifying climate sensitivities may vary with the scale of activities involved. In many industries, straightforward analysis of firm behavior may reveal climate-sensitive points. Assessment can be more difficult at the national and international levels, where numerous compounding factors play roles in determining resource use and productivity. Extracting the impact of climate variations from the signals of economic growth and decline, business cycles and so forth, is a challenge. Assessing national vulnerability may be especially difficult in developing countries where baseline data are poor and rapid social and economic changes are occurring.

Nonetheless, some general comments about sensitivity may be offered. Most studies focus on agriculture and water, which are clearly directly sensitive. In developing countries a large proportion of the population is engaged in agriculture, and agriculture could well be the most sensitive sector by several measures. In contrast, in developed countries, agriculture typically occupies a small proportion of the population and GNP, so the absolute sensitivity may appear small, although the relative sensitivity may remain high. It is harder to draw conclusions about water. Some studies (for example, Revelle and Waggoner, 1983) suggest this sector is one where impacts are amplified. Beyond agriculture and water, studies typically pick their subjects from about 20 other areas of potential impact. No clear order of importance emerges.

Table 4.6 Estimates of economic impacts of a hypothetical global climatic change (−1 °C change in mean annual temperature, no change in precipitation)

Impact studied	Annualized cost—1974 (millions of US dollars)
Corn production (60% of world)+21	

Cotton production (65% of world)	-11	
Wheat production (55% of world)	-92	
Rice production (85% of world)	-956	
Forest production		
(a) US	-661	
(b) Canada	-268	
(c) USSR (softwood only)	-1383	
Douglas fir production (US Pacific Northwest)	-475	
Marine resources (world)	-1431	
Water resources (2 US river basins)	+2	
Health impacts (excluding skin cancer) (world)	-2386	
Urban resources (US)		
wages	-3667	
residential, commercial	-176	lower bound
and industrial fossil fuel demand	-232	upper bound
residential and commercial		
electricity demand	+748	
housing, clothing expenditures	-507	
public expenditures	-24	
esthetic costs	+219	

(Source: CIAP, 1975, 1-15 and 1-25)

For an initial indication of the sensitivity of activities to climate variation, content analysis of newspapers and other media is usually a helpful beginning. Such analysis can be supplemented with more elaborate surveys (for example, Center for Environmental Assessment Services, 1980) and construction of various indices (for example, Maunder, 1972). Efforts to arrive at more reliable quantitative measures through application of more sophisticated economic models (for example, CIAP, 1975; Eddy *et al.*, 1980) are suggestive but remain subject to criticism (see Glantz *et al.*, Chapter 22; Lovell and Smith, Chapter 12; and Robinson, Chapter 18, in this volume).

Overall, it remains difficult to draw strong conclusions about the importance of various sectors when considered for different units of exposure, levels of development, and categories of climate variation. The Advisory Committee for this volume placed special emphasis on agriculture, pastoralism, fisheries, water resources and energy. Subsequent chapters take these sectors and explore the usefulness of specific methods and perspectives. Despite the reservations expressed in this paper, development of more systematic frameworks for defining sensitivity to climate is certainly possible, and their application will clearly yield useful benefits to research efforts and the operating agencies of governments.

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Back to Table of Contents

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