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Climatic Changes and Socio-Economic Impacts

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Abstract

Many of the physical effects of climatic changes in the Gulf of Mexico/Caribbean Sea region will have socio-economic impacts. The presumption is that, for most cases, the net effect will be costly, but this will depend on the facts of each case. For several reasons, prior work has been mostly on the potential impacts of sea-level change, but other climatic changes in the region may have impacts which equal or surpass those. A matrix that relates types of climate-change effects to qualitative impacts on economic sectors is presented. Potential impacts on fisheries, agriculture and forestry, tourism, settlements and structures, the immediate coastal zone, public health, and waste disposal and drainage are discussed. Descriptive and prescriptive issues of public response are examined, along with attention to techniques and research issues in efforts to estimate socio-economic impacts.

1 Introduction

Industrialization and combustion of fossil fuels has increased the atmospheric level of carbon dioxide (CO_2). A continuation of this increase is expected to modify the world climate and has given rise to speculation that varies from fears of impending disaster, to the belief that there are no problems (WMO/ICSU/UNEP, 1980; National Academy of Sciences, 1983; Morrisette, 1987; Ausubel, 1991).

The increased level of carbon dioxide changes the atmosphere's energy balance and may result in a temperature rise at the Earth's surface and lower atmosphere; an intensification of the so-called 'greenhouse' effect. The warming of the Earth's surface will have different implications. This warming is associated with several effects. Increased sea-surface temperature for instance, may change the global-scale oceanic circulation, with influence on weather systems, rainfall patterns, wind trends, storm activities, etc. Worldwide concern has risen regarding the effects of significant warming at the poles. Increased temperature could gradually melt the polar ice-caps, resulting in addition of water masses to the

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oceans and accelerated sea-level rise. Indeed, even without melting glaciers and ice-caps, thermal expansion of the oceans' water volume would be expected to raise sea levels.

Sea-level change is not a new phenomenon (Cartwright *et al.*, 1985; Pirazzoli, 1985). The level of the oceans also has been changing in the more recent past with great geographical differences (Aubrey and Emery, 1983; Barnett, 1984; Emery and Aubrey, 1985; Solow, 1987). However, the human-induced climatic changes are expected to accelerate the global trend of sea-level rise that is currently believed underway. This acceleration may have serious consequences.

2 Climate-Change Impacts

Significant sea-level rise and increased sea-surface temperature are two complex effects of human-induced climatic changes, the implications of which are difficult to survey. The changes are supposed to be lesser in the tropics than at the high latitudes (*q.v.* Fig. 1.6), with great local differences arising from such factors as in coastal geomorphology. In those places where coastal areas are being uplifted by tectonic forces, for example, an acceleration in global sea-level rise could work to stabilize local shorelines. Or, in areas with very steep coastlines, rather large changes in sea level might be accommodated with little geographic alteration. Because of the complex geology and poorly understood tectonic behaviour of the region, such local differences are an added significance. In any case there is, due to local effects, considerable variation in the magnitude and direction of sea-level rise within the region (Hendry, Chapter 7; Hanson and Maul, Chapter 9), that will necessitate site-specific studies.

Much of the literature on the socio-economic impacts of climatic changes has been focused on (1) the United States and (2) on the impacts of sea-level rise (Chen *et al.*, 1983; Titus, 1986a). The former reflects the availability of resources and the existence of many highly developed areas which are already exposed to the effects of a rising sea level. The concentration on sea-level rise also can be explained by the already apparent impacts of sea-level rise on some coastal communities and ecosystems.

Another reason for preoccupation with sea-level rise is that climate models are not yet of a sufficient precision to predict the extent or even direction of some of the other anticipated changes. Such changes as altered precipitation patterns or increased storm frequency, however, may have impacts that equal or surpass those from a sea-level rise (Gray, Chapter 5). A case in point is that existing climate models cannot yet forecast precipitation changes in specific regions (Titus *et al.*, 1987). In this region, with its dependency on rain-fed agriculture, changes in precipitation may drastically alter the livelihood of large segments of the population. In contrast, it is generally agreed that the rate of sea-level rise will accelerate, although estimates are still wide ranging and are subject to revision in the light of better understanding of global processes (Brooks, 1985; Maul, Chapter 1).

Many studies advocate the incorporation of the anticipated sea level rise into public planning processes (Titus, 1986b). The high level of

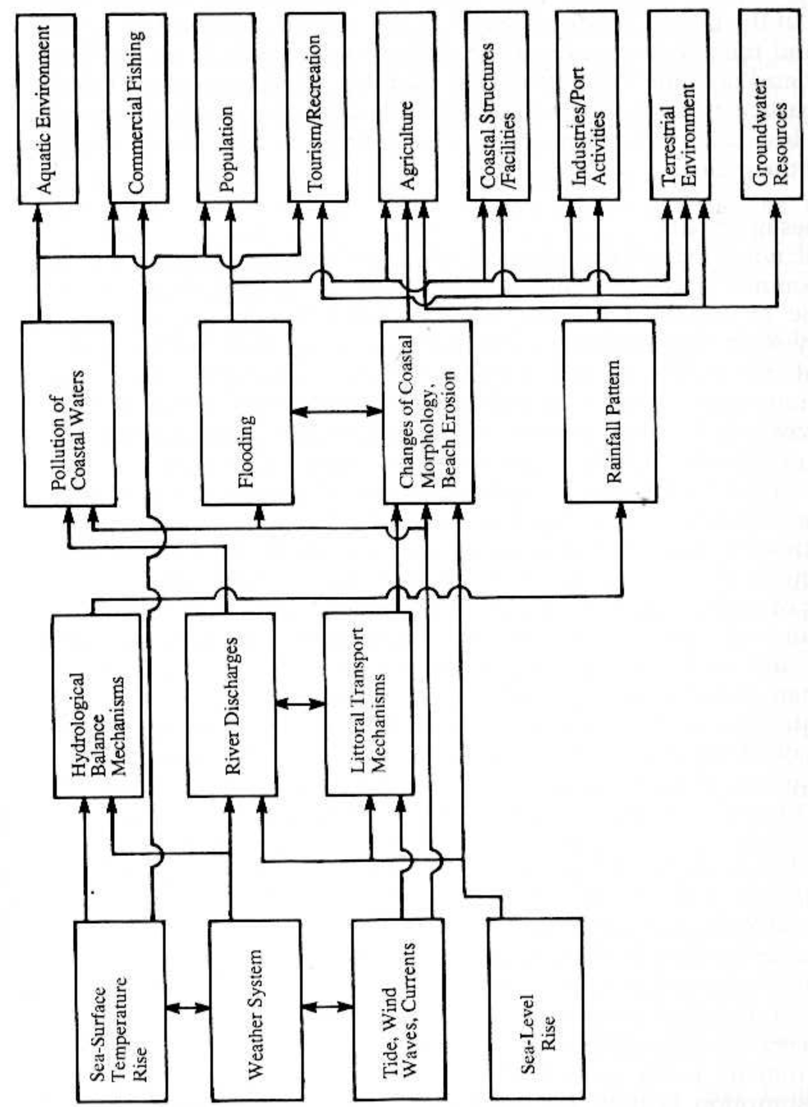

Fig. 15.1 Schema depicting implication of climatic changes on important socio-economic activities.

uncertainty about the magnitude and direction of some of the changes, however, reduces the willingness of decision-makers to initiate responses to the anticipated climatic changes. Therefore, there is a need to reduce significantly the degree of uncertainty about the likelihood, the extent and the directions of these climatic changes (*q.v.* Wigley and Santer, Chapter 2; Gallegos *et al.*, Chapter 3). Nonetheless the potential socio-economic impacts of the largest predicted changes are enormous; therefore, governments and the private sector of the region should include the evaluation of likely and possible impacts in their planning efforts and project design. This is particularly valid for the incorporation of sea-level rise, about which there is less uncertainty, and of which the impacts are already visible in much of the region.

2.1 Types of Impact

Many, if not most, of the physical effects of climatic changes will have socio-economic impacts. Such impacts may be essentially of a micro-economic or localized nature but also will have macro-economic, or economy-wide, implications. In relation to sea-level rise it will be generally true that the socio-economic impacts will have greater macro-economic implications on the smaller and the more coastal-zone-oriented economies (IPCC, 1990). In this respect the smaller islands with a high dependence on tourism or fisheries or both, seem to be particularly vulnerable.

Socio-economic impacts of climatic changes may be derived directly from the physical changes (for example, loss of property due to inundation, increased storm or hurricane damage) or indirectly through attendant changes in ecosystems (such as changing nursery grounds). The complex of underlying interactions, feedbacks and internal dependencies is still not well understood (Engelen *et al.*, Chapter 16), and many of the physical and ecological changes result also from human-induced effects other than climatic changes (sea-level rise is only one of the factors that contribute to beach erosion). Such effects will often reinforce the impacts of climatic changes, and indeed the total effect of all impacts may be greater than the sum of the individual impacts. This will make it difficult to establish clear cause-and-effect relationships, which again will not facilitate acceptance by policy-makers of advice for action.

Fig. 1.4 is a generalized presentation of the interactions between physical, ecological and socio-economic changes, while Fig. 15.1 represents some of the interactions in more detail.

The socio-economic impacts of climatic changes are typically portrayed as a sum of costs (lost or spent resources). Obviously, this can be misleading since some climatic changes will also result in benefits (say, increased agricultural productivity) in some areas. What is of interest initially is the net effect of these combined costs and benefits. The presumption is that, for most cases, the net effect will be costly. This will depend, however, on the facts of each case. In every case, it is important not to confuse *transfers* of benefits and costs within an economy with the *creation* of new benefits and costs by a climatic change. The construction sector seems a likely beneficiary of a decision to construct sea-defense works, for example, but this apparent benefit is just a transfer of resources from other uses. The cost of the defenses may be smaller than the cost of land lost to inundation, but the diversion of resources to the defense project is still a true cost to the economy that would not be incurred in the absence of climatic change.

If the above qualifications are accepted then the economic impacts could be categorized as:

1) Losses (improvements) in the existing stock of land and capital. Examples would be the loss of property caused by an increased frequency and intensity of tropical storms and hurricanes (this implies a loss in the capacity to produce future goods and services) or an improved productivity of arable land as a result of a higher concentration of CO_2 and of more rainfall, in those, as yet unknown, areas where an increase in precipitation will be one of the effects of climatic change.
2) Increase (reduction) in costs associated with maintaining the production of goods and services at the current (i.e., pre-change) level. Examples would be (a) expenditures on sea-defense works, (b) cost associated with a retreat from the seashore.

(The above categories are related to the efficiency aspects of the economy. A third category, below, would focus on the distributional or equity aspects of the economy.)

3) Which groups in a society will bear the costs of any adjustment of the economy in response to climatic changes? Or alternatively, which groups will benefit from any such changes? Eventually climatic changes may involve changes in the allocation of labour and capital among sectors. While a reallocation may be relatively insignificant for large, highly developed and diversified economies, such a process is likely to be more difficult in smaller, less diversified economies. With respect to sea-level rise, such issues will be brought into focus when governments of the region have to make decisions on the retreat or defense of low-lying areas which alternatively are being used for peasant agriculture, plantation agriculture, housing of the urban poor or that of the middle classes, industrial sites, etc. Having made a decision, the next question will then relate to who will bear the cost for relocation or for the construction of sea-defense works.

A corresponding issue to that of the distribution of national impacts is the occurrence of possible cross-boundary effects. Such effects may be relevant when impacts of climatic change have an effect in more than one country. In such cases international cooperation and possibly co-funding is likely to be cost-effective and beneficial to all parties. Examples of cross-boundary effects could be shifting nursery and fishery areas or the existence of continuous, cross-border, low-lying areas which may warrant some form of sea defense.

A related issue, but considerably more complex and likely to be subject to extensive international discussion and negotiation, pertains to the responsibility for the causes of global climatic changes and eventually to the question of the distribution of the cost adjustment to the changes in climate between the lesser developed countries and the industrial economies, both market and planned. These questions will become relevant since the lesser developed countries, as discussed below, are likely to lack the resources, technology and organization to implement the most technically efficient responses. These concerns were of major importance at UNCED (United National Conference on Environment and Development) held in Rio de Janiero in June 1992.

2.2 A Matrix of Impacts

The economic repercussions of the anticipated climatic changes may be severe, although not all sectors will be influenced to the same degree. And so the impact of some changes will be limited to one or a few sectors, while others may have an influence on many sectors. The existing literature either concentrates on a few changes and their impacts or describes a whole array of likely, possible or even remote economic impacts stemming from a large set of anticipated climate changes (Russell, 1970; Nordhaus, 1982; Heal, 1984; Kellogg, 1984; McFadden, 1984; Gibbs, 1986; Smith, 1987; Snedaker and de Sylva, 1987; Ausubel, 1991).

The assessment of the impacts of climatic changes is essentially one of close cooperation between physical and social scientists. To facilitate the translation of physical and ecological changes into socio-economic impacts, matrix methods are one of the techniques that can be usefully applied (Neuman, 1979). Matrices perform at least two functions:

1) they illustrate and help conceptualize the interrelationships between the physical, ecological and socio-economic variables;
2) for specific studies they provide a checklist in determining whether all relevant variables and implications have been included in the analysis.

Table 15.1 is a first attempt to relate the physical and ecological changes to economic impacts in a systematic manner. As a preliminary presentation it does not claim comprehensiveness in the sense that not all possible physical and ecological changes nor all economic implications have been included.

The individual cells of the matrix in Table 15.1 depict whether a particular physical or ecological change will have an anticipated impact on a certain sector (denoted by X), have no anticipated impact (denoted by –) or whether there will be an impact is unknown (denoted by ?). For example, in the first column, an increase in the concentration of CO_2 is anticipated to have a direct impact on agriculture, forestry and health. It is unknown whether there will be an impact on fisheries, while no direct impacts are anticipated for the other sectors. (The emphasis here is on direct impacts, as indirect impacts such as sea-level rise resulting from increased CO_2 are shown on a different column as having impacts on these same sectors.) The anticipation of an impact in a particular cell does not indicate whether such an impact is positive or negative, or in other words it does not signify a direction of impact.

At a later stage, the matrix can be improved by including more relevant physical and ecological changes and a broader array of relevant economic and social sectors. Further improvement also can be made by indicating the direction of the impacts and, whenever possible, by attempting to quantify the impacts ordinally.

Table 15.1 Matrix of socio-economic climate change impacts

	Agriculture	*Fisheries*	*Forestry*	*Tourism*	*Construction*	*Transportation*	*Water*	*Health*	*Settlement*
Physical changes									
Increase concentration CO_2	X	?	X	–	–	–	–	X	–
Increased concentration of other greenhouse gases	?	?	?	–	–	–	–	X	–
Increase cloud cover	X	?	X	X	–	-	X	X	–
Temperature increase	X	X	X	X	–	–	X	X	–
Precipitation	X	X	X	X	X	?	X	X	X
Wind regime	X	X	X	X	X	X	X	?	?
Increase sea temperature	–	X	–	X	–	–	?	?	–
Increased frequency of tropical storms	X	X	X	X	X	X	X	X	X
Wave/coastal current patterns	–	X	–	?	X	X	?	X	X
Sea-level rise									
Shoreline retreat/inundation	X	X	X	X	X	X	?	X	X
Beach erosion	–	–	–	X	X	–	–	–	X
Saltwater intrusion	X	X	X	–	X	–	X	X	X
Increased soil and water salinity	X	–	X	–	–	–	X	?	X
Soil moisture	X	–	X	–	–	–	X	?	X
Tides	–	X	–	–	X	X	?	?	?
Other (to be specified)	?	?	?	?	?	?	?	?	?
Ecological changes									
Coral reefs	–	X	–	X	–	–	–	–	?
Wetlands (mangroves)	–	X	X	–	–	–	–	X	?
Beaches	–	–	–	X	–	–	–	–	?
Estuaries and lagoons	–	X	–	X	X	–	–	?	X
Seagrass beds	–	X	–	–	–	–	–	–	?
Lowlands	X	–	X	–	–	–	X	X	?
Forest 1	–	–	X	–	–	–	X	X	?
Forest 2	–	–	X	–	–	–	X	X	?
Forest 3	–	–	X	–	–	–	X	X	?

3 Some Specific Impacts

3.1 Fisheries

Several major fisheries depend on upwelling of nutrient-rich waters with high biological primary production (*q.v.* Aparicio, Chapter 6). These phenomena, which are sensitive to changes in the wind regime and ocean circulation, may also affect the emigration pattern of commercially important species and the transport and distribution of eggs and larvae. Glantz (1992) edited a recent review of the issue of fisheries and climate on a global scale, which stresses the importance of this issue, one that is particularly relevant in the Intra-Americas Sea.

In estuarine and coastal lagoons the balance of fresh water and oceanic water may be altered by increased sea level. This may lead to a hypersalinity, which in combination with increased sea-surface temperature, may affect productivity. As these ecosystems serve as nursery areas for the sensitive early life stages such as fish larvae and juveniles, recruitment of commercial species may be affected. However, in some places an opposite effect of inundation of nearshore land could be to increase the total suitable reproduction area.

The impact on large-scale or artisanal fisheries of a moderate increase in sea-surface temperature and sea-level rise (1.5°C, 20 cm) is not expected to be very serious. However, displacement in traditional fishing sites may be observed to have negative effects for some local artisanal fisheries.

3.2 Immediate Coastal Zone

The most obvious effect of sea-level rise and increased sea-surface temperature in the immediate coastal zone may be the submersion and loss of low-lying land. Coastal wetlands, important sanctuaries for flora and fauna, will be lost by sea-level rise. However, every variation in sea level is accompanied not only by emergence and submersion of part of the coast but also changed littoral transport mechanisms which will initiate changes of coastal morphology. Beach erosion, which is already a serious problem in many areas in the region, may increase and various long-term shoreline stabilization and beach-defense systems might have to be constructed. The distribution pattern of river discharges, sediments and pollutants may change due to different coastal currents.

Tides, wind regime, wave and coastal current patterns may change due to increased sea-surface temperature. As sea-level rise permits tides and waves to operate from a higher base the effects of flooding will be more frequent, more serious, and threaten new areas. The economic implications due to hurricane damage may be increased, and construction of costly sea-defense systems may be necessary.

3.3 Agriculture and Forestry

Increased sea-surface temperature affects the formation, routes and frequency of storms. Sea-surface temperature is a key element controlling the evaporation process and associated heat transfer over the ocean. Changes in wind regime, levels and distribution of rainfall, and other climatic effects are of greatest importance for agriculture and forestry.

Agriculture production also may suffer from land loss in coastal areas due to permanent inundation or frequent flooding. Saline intrusion in groundwater resources may affect cultivation and living conditions in coastal areas. Changes in the hydrological balance affect river runoff (Muller-Karger, Chapter 8) and erosion processes in riverside agriculture areas.

3.4 Tourism

Tourism is a major economic activity in most of the region, and negative impacts on tourism will have severe repercussions on the prospects for economic growth and development. Changes in rainfall patterns, tropical storms and warming of the climate in temperate countries may affect the comparative advantages of tourism. However, there are still insufficient data on such implications; as an immediate policy concern, this is less pressing than beach erosion which already affects many beaches (Blommestein and Singh, 1987). Due to its nearshore character, the tourism industry will be affected by sea-level rise. Beach stabilization and other sea-defense systems may be needed to protect beach-front hotels and other tourism facilities. Important tourism beaches may have to be continuously supplied with sand and stabilized to prevent erosion. Sea-level rise is only one factor that contributes to beach erosion (Bruun, 1962; Bird, 1986) and its relative significance is not always known. Within planning efforts for recreational beaches, attempts should be made to estimate rates of erosion in the form of shoreline retreat per unit of rise through the application of Bruun's Rule or similar adjusted formula and evaluate the cost and benefits of possible beach-nourishment programmes.

3.5 Settlements and Structures

Increased beach erosion threatens buildings and other construction. Nearshore roads, bridges and other structural facilities may have to be reinforced and reconstructed. Wilcoxen (1986) concluded for San Francisco '. . . structures with long operating lives should not be built in erodible sediment adjacent to recreational beaches. Sea-level rise will make protection for such a structure expensive and preservation of the beach difficult. Sound planning for future projects must consider the erosion that will be caused by sea-level rise'.

Navigation and port facilities like wharfs and piers will be affected, and clearance under bridges will decrease. Increased maintenance dredging may be needed due to increased beach erosion, changed coastal currents and sedimentation pattern. However, as port structures normally have to be continuously reconstructed and maintained, the implications for shipping are not expected to be serious.

Saline intrusion in groundwater resources and upstream migrations of saline fronts in rivers may affect municipal fresh-water supplies to coastal communities. In low-lying cities the capacity of draining and sewage systems may be reduced. Changed coastal currents may affect the transport and dilution of urban and industrial waste waters. In nearshore poor communities these impacts may affect public health and sanitary conditions in general.

3.6 Public Health

Water is a principal agent for many diseases in tropical countries, either directly through the contamination of water or indirectly through insects which depend on water at some stage in their life cycle. In both instances it appears that water temperature is a significant factor, with higher incidences related to higher temperatures (Snedaker, Chapter 12; de Sylva, Chapter 14). The impact of the climatic changes could be both a northward shift into the area in which tropical diseases are prevalent and increased incidence in those areas already subject to some or all of these diseases. The economic impact of such a consequence on public health would be through a lower productivity of the labour force as a consequence of increased health-related absenteeism (person-days lost) and through increased expenditures on public health.

3.7 Waste Disposal and Drainage

In much of the region, solid-waste disposal sites are located in low-lying areas near the coast (such as mangroves or salt ponds) which may be at risk with increased flooding or permanent inundation during a sustained or accelerated process of sea-level rise. Sewage and drainage systems may also be affected. In many areas sewerage (raw or partially treated) is eventually discharged into the ocean. A rise in the sea level may imply a reduced efficiency of sewage and drainage systems. Sewage and drainage systems typically have a long lifespan of 30–50 years. In other words, the time is approaching when there is a risk that installed sewage and drainage systems may not satisfy design specifications well within their estimated lifespans and that retrofitting or reconstruction may become necessary. Gibbs (1986) has described cases in which near-term investment to accommodate future sea-level rise is efficient in constructing new projects.

4 Responses and Measurement

Two questions about the human responses to climatic change seem most relevant, one descriptive and one prescriptive. The descriptive question is, what will be the responses to climatic changes and how will these affect the socio-economic impact of the changes? The prescriptive question is, what should be done now and at each future point along the way? The answers for both questions will be shaped by two different views of how effective responses emerge. One view stresses that people have a strong talent for adjusting to change, and that their adjustments are most effective when crafted little by little to incremental changes spread over time (Schelling, 1983). This view often also holds that decision-makers closest to the facts of each choice are likely to devise the most appropriate incremental responses (McFadden, 1984). In a prescriptive sense, this view tends to be non-interventionist and favours letting things sort themselves out as the facts emerge. In contrast to such atomistic incrementalism, the other view of human responses stresses the value of collective actions. Whether for reasons of political ideology or the failure of free exchange to account for effects that are spread across large social groupings, this

view highlights the value of governments and other collective institutions to anticipate and help engineer effective responses. Both views share the assumption that economic decision-makers act rationally, that they act in such a way as to do the best they can with the information and other resources available.

Predicting and prescribing human responses, whether incrementalist or discrete, atomistic or centralized, require estimates of what will happen under different scenarios and how much it will cost. Thus, methods of measurement and estimation are important issues here. For estimating socio-economic effects of climatic change, however detailed or sophisticated the effort, two basic approaches are virtually unavoidable. The first depends on physical scientists and is the description of expected changes and their effects, a kind of dose-response specification often framed as a set of scenarios about what might happen. The basic economic approach is a cost-benefit analysis built on the scientific scenarios. Such an analysis seeks to compare the flow of costs and benefits over time arising from the different scenarios in order to estimate the expected net impact from each. Obviously, accurate estimation of benefits and costs will depend on the expected effects of human responses. By the same token, the choice and timing of responses will be affected by estimates of costs and benefits.

The reasonable assumption of rational decision-making leads to a fairly strong expectation about human responses. It is, that responses will be selected to reduce the expected costs and maximize the expected benefits of climatic change. Of course, mistakes may be made, but, in general, human responses can be expected to lower the net cost (or raise the net benefit) of climatic change. If they did not, they would not be undertaken. Nor is it likely that responses will be confined to the areas most affected by the physical changes. If a nation loses its low-lying coastal rice production to sea-level rise, for example, this will alter the allocation of resources in the economy in ways that extend beyond the loss of rice production. The resources formerly applied to rice (including materials, mobile capital and labour) will tend to be redirected into other activities that eventually will help replace at least part of the economic benefits lost with the rice fields. How quickly and how completely this economic adaptation will occur clearly depends on the suddenness of the initial loss, on the organization of the economy and on the availability of other opportunities for productive employment of the displaced resources.

Because the timing, magnitude and physical effects of climatic changes are still highly uncertain, potential near-term responses are more in the nature of risk management. Scientific predictions of sea-level rise reveal an increased riskiness of certain coastal activities that, as it becomes more widely known, should automatically tend to curtail those activities. For example, as developers become more concerned about the risk of sea-level rise, a likely reaction is to increase the rate of return required to justify an investment. This will tend to reduce the number of projects deemed profitable and will eventually result in reduced investment. This market behaviour would be in line with and reinforce any policy of abandonment or retreat since it will gradually reduce development activities in the exposed area. At the same time, this increased risk will lend greater value to research efforts that increase information and to arrangements that permit diversification and pooling of risks.

One important class of the near-term responses presents special problems. These are responses that, if invested in now, will reduce the cost of future climatic changes that turn out to be severe. If the future climatic changes turn out to be less severe, however, then the near-term investment will have been wasted. The point is that the investment decision must be made before the severity of climatic change has been revealed. This is the so-called 'retrofit' problem, and Gibbs (1986) and Wilcoxen (1986) have analysed sea-level-rise scenarios under which certain costly near-term public works investments are economically superior to the alternative of waiting to observe future sea level and retrofitting to meet it. Because the probability of sufficiently severe change is unknown, however, the prescriptive value of these results is still subject to question.

As a near-term aid to governments of the region attempting to manage the risk of climate change, preparation of a region-wide first-order assessment of the magnitude, timing, and distribution of economic impacts would be valuable. At the same time, for sharper focus on the details involved, a small number of case-study areas should be selected for more intensive study. These more detailed studies would be most useful if they took account of possible responses and adjustments. The studies will require interactive inputs from natural scientists.

As already mentioned, the starting point for any assessment of the socio-economic impact of climatic change is a scientific prediction or scenario describing the expected change and associating it with natural, physical impacts. For example, virtually all economic analyses of future sea-level change have begun with a statement of the hypothetical rate of sea-level rise and a topographical portrayal of the resulting area of inundation in the absence of defensive measures (Schneider and Chen, 1980; Barth and Titus, 1984; Broadus *et al.*, 1986; Broadus, 1988). Where property-value data are available, they can be projected into the future and provide a reasonable estimate of the value of land lost to inundation (Barth and Titus, 1984). In poor data cases, or where institutional arrangements render market values irrelevant, other methods of estimating the lost land's productivity must be sought (Broadus *et al.*, 1986; Broadus, 1988). (Generally, more work is required to develop practical and appropriate techniques to evaluate socio-economic impacts in cases of limited financial and data resources.) The value of lost fixed capital (such as buildings, highways, bridges, etc.), and of losses associated with salt-water intrusion, increased exposure to storm damage, etc., can also be estimated from the base provided by the scientific scenarios. The sum of such costs, and any identifiable benefits, provides a starting point against which to compare estimates based on hypothetical projected responses (though, in fact, little work has been reported that extends the estimates to include alternative-response scenarios).

Aside from the technical judgements involved in choice of growth rates and interpretation of other economic data, several controversial issues must be encountered in this basic cost-benefit approach. The most noteworthy of these include:

1) *Discounting future values:* Most people or nations tend to display a preference for a given sum of income now over that same amount in the future, if for no other reason than that the income can be put to beneficial use in the meantime. This 'time preference for income' implies that values observed in the future should be reduced by some 'discount rate' for a meaningful comparison with present values. The choice of discount rate can seriously affect estimates of the present value of future costs and benefits. While there is growing agreement among economists on the proper choice of discount rate (Lind *et al.*, 1982), this remains a difficult issue and especially where intergenerational choices are involved (D'Arge *et al.*, 1982).
2) *Welfare measures:* Different forms of cost-benefit analysis use different measures of human welfare, but most assume unrealistically that the marginal value of income is the same for all people. Also, all such analyses have difficulty with economic values not recorded in market prices, and even the use of market prices is potentially misleading. For example, transactions prices for property and other assets do not account for the so-called 'consumers' surplus' received by purchasers, and so may underestimate the benefits generated by those assets.
3) *Comparative systems:* Although all economic systems attempt the same functions of organizing production, providing employment and delivering services, there are cultural, ideological, political, organizational and distributional differences among systems that can affect the performance of different estimation methodologies These change, but cooperative international efforts should provide ideal forums for progress on this topic.

Beyond the fundamental, scenario-linked cost-benefit approach to climatic impact estimation, a number of further approaches have been attempted or show promise. One class of such approaches is the 'holistic systems models,' which may be contrasted with a diverse array of more analytical economic models. The holistic systems models (Warrick and Riebsame, 1983; Riebsame, 1985) are extremely ambitious in their attempt to capture all effects of climatic change comprehensively by describing the full range of linkages and feedbacks between causal inputs and affected activities. A major drawback of such models is that their complexity can make their results opaque. That is, difficulty often arises in discerning exactly which relationships within the model are most important in generating the model results. Perhaps most damaging, however, is the predictive failure of such models in empirical applications. Eventual perfection of holistic systems models, on the other hand, would strengthen the prospects for coupling socio-economic impact models directly with physical process models (*q.v.* Engelen *et al.*, Chapter 16).

The more analytical economic models are less comprehensive in intent, but they may also be more manageable and more instructive about the precise nature of certain key relationships. Although the cost-benefit estimations based on scientific scenarios are straightforward and natural first cuts at the impact problem, several other approaches from the arsenal of modern economics should be fruitful. For example, general equilibrium analysis may help to predict and account for indirect or secondary effects occurring outside the economy's immediately affected sectors (Smith, 1987). Smith has shown, however, that excellent approximations of the general equilibrium welfare loss arising from a shock like sea-level rise can be achieved in principle with partial equilibrium valuation estimates, especially when there are only small indirect effects outside the coastal sector. Other promising approaches include: search theory, to help model and guide responses under uncertainty; portfolio analysis, to help balance risks and returns among a variety of risky activities and responses; and identification of potential winners as well as losers and of possible institutional mechanisms (such as new markets or opportunities for exchange) through which their risks can be shared and traded.

5 Conclusion

It would be a considerable error of omission in these deliberations not to focus momentarily on a socio-economic issue that may eclipse climate change by an overwhelming amount. The human population of the earth is growing at an astounding rate, and the region with which this report is concerned is no exception. Fig. 15.2 shows a comparison between the

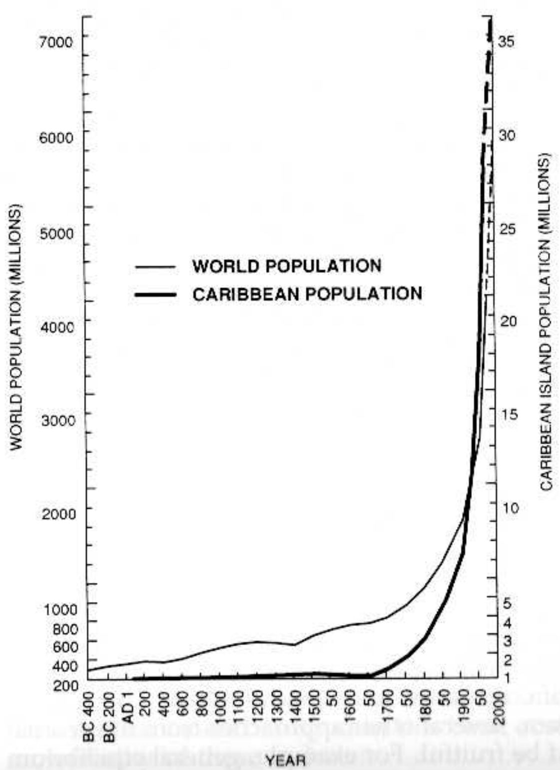

Fig. 15.2 Human population as a function of time, based on data to 1975 and projected (dashed) to 2000, showing the global curve and that of the Greater and Lesser Antilles, Bahamas and Bermuda (redrawn from McEvedy and Jones, 1978).

global human population trend for the last few thousand years, and the trend on the islands of the Antilles (Lesser and Greater), the Bahamas, and Bermuda. Although the two curves are similar, a striking difference is seen after about 1700, when the rate of population change in the 'Caribbean Islands' (McEvedy and Jones, 1978) is increasing faster than the global population change. Not shown are curves for other subregions, all of which share the characteristics presented in Fig. 15.2.

In a very thoughtful editorial entitled, *People and Global Warming: A Critical Link*, Fisher (1992) notes that 'While population has been considered in the context of environmental problems such as soil degradation and deforestation, policy-makers have neglected its relevance to global warming.' Thus, it is argued, that population growth between 1950 and 1985, 2.5 to almost 5 billion people, was responsible for about two-thirds of the global CO_2 increase and methane increase in this time period is even more closely linked with population growth. So while industrialized nations have been primarily responsible for greenhouse-gas production in the past, it is developing nations that will contribute most in the future. Fisher, reflecting on a joint statement of the Royal Society of London and the US National Academy of Sciences (Atiyah and Press, 1992), argues for a global solution in which all nations cooperate in this aspect of climate change.

Institutional responses and institutional differences will play a critical role in shaping the socio-economic impacts of climatic changes globally as well as in the Gulf/Caribbean/Bahamas/Guyanas region. The region is an area with differing institutions and levels of economic development, and the response to such climatic changes as accelerated sea-level rise will vary with political and economic factors. The more highly developed countries will have access to a larger and more expensive array of mitigation opportunities. Less developed countries may be constrained by their resource endowments to a narrower selection that may not include the technically optimal responses. Capital scarcity, in other words, may force abandonment of areas whose defense would otherwise be economically justified. Even within the poorest countries, however, there may be low-lying areas with dense concentrations of human settlement and economic activity where, for social and economic reasons, efforts may be undertaken to maintain the existing shoreline (Bird, 1987). These situations will call for difficult tradeoffs in the allocation of scarce public resources and, where foreign capital is proportionately important, in the management of international financial relationships.

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