

# Exploratory Modelling of Socio-Economic Impacts of Climatic Change

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## ABSTRACT

Socio-economic systems may be influenced by climatic change in ways ranging from minor or very local to drastic and nation-wide. Any such changes will be superimposed on trends already present in these evolving systems. Therefore, it is vital to anticipate dangers, as well as new opportunities, as soon as possible. To allow governments and policy-makers to play an active role in managing these socio-economic systems effectively, they should be provided with tools that will permit them to explore impacts in their full holistic, spatial and temporal contexts. Decision-support systems are designed to assist in such tasks. The most essential part of such systems is a set of tools, mostly quantitative models and methods, which at relatively low cost, allow the user to analyse and evaluate a range of possible futures resulting from different scenarios and hypotheses.

In this chapter we propose, as part of a larger decision environment, a two-level mathematical modelling framework, geared to study the effects of climatic change on the level of the individual island or mainland state. The long-range mechanisms of change are modelled in a classic, non-equilibrium spatial interaction model. This model then feeds regional growth coefficients into a low-level cellular model that deals with the short-range location and interaction mechanisms. This technique of linked models is necessary in order to capture successfully the effects resulting from climatic change on the appropriate scales. The prototype presented is a first, mostly conceptual, step towards a system for use in real-world applications.

## 1 INTRODUCTION

This closing chapter of the book is an indication of the increased interest by UNEP and the IOC in climatic change: with the understanding gained from the multi-disciplinary study of the physical and biological impact of climatic change, emphasis will be put on studying the impact on human societies and their responses to the challenges raised. The ultimate aim is to provide the threatened peoples, their policy analysts and governments,

with the necessary tools to anticipate the obstacles well in advance in order to minimize the effects on their well-being and to secure their future.

This chapter is a first (and mostly conceptual) step towards the design of a model-based decision-support system, capable of integrating the knowledge gathered by different specialists. It describes the development of a modelling framework, integrating physical, ecological, economic and social characteristics of nations in the region, within which the complex multiple consequences of public policies and actions can be examined as completely as possible. The development of such a system is the subject of a long term and possibly ambitious project. However, the rapid evolution of the information technology in the past few years, together with evolving scientific paradigms and derived modelling frameworks, offer new perspectives for the management of socio-economic systems, which make us confident that such projects can lead to successful outcomes.

Practically, the chapter will propose, as part of a decision-support system for public-policy exploration, a simple version of a complex dynamic model of a purely hypothetical island with characteristics typical of those in the region. This model ultimately will evolve into a more generic tool to study important effects of climatic change on individual islands and mainland nations. As such it may serve as a discussion piece to concert further research by the task team.

## 2 POSING THE PROBLEM: CLIMATIC CHANGE IN THE REGION.

If the link between greenhouse-gases emission and climate change continues to be confirmed, then the 'consensus view' on the future of the planet could come at great cost (Davis, 1990). This cost might be tolerable for the rich industrial countries, having the technology and financial resources to cope with the immediate effects of a changing climate (Ausubel, 1991). For the developing world, however, the cost might lie beyond the bearable (Ominde and Juma, 1991). The 'sustainable growth' world view, which emphasizes adaptability and voluntarily reduced exploitation of resources and strives to match the need for economic growth with a viable, environmentally sound planet for the generations to come, is certainly more adequate in this respect. Technology will propel society toward sustainability most quickly if policy-makers can agree on the appropriate global and local guide-lines (Reddy and Goldemberg, 1990). In order to attain such agreement, a good understanding of the mechanisms linking human activity and greenhouse-gases production, and of the subsequent effect of greenhouse gases on the ecological and socio-economic systems, is an essential first step.

### 2.1 An Evolutionary Context

Tourism and agriculture, both major sources of income in the region, rely on natural systems. Any effects of climatic change on these sectors may have a long term, large scale and irreversible impact on the physical and socio-economic environment, thereby undermining the sustainability of the economic development. Thus, climatic changes will alter the evolutionary path of the socio-economic systems. Socio-economic systems

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are highly dynamic, but at the same time laden with inertia. *Dynamic*, because no such system has been found to be in equilibrium; rather it is perpetually in a transition phase between an old and a new form of organization. *Inertia*, because of the long time it takes for all effects of actions and disturbances to propagate through the system and to run out in a fully reorganized system. Hence, the dynamics driving the system today may have been set in motion, deliberately or not, a long time ago, and may continue to do so for many years to come.

## 2.2 A Global Context: Changing World Markets

Much along the lines of the approach of meteorologists, exemplified by Wigley and Santer (Chapter 2), effects of climatic change on the social and economic system need to be studied in their full spatial extent. Meteorologists are not able to separate the Intra-Americas Sea from the global weather and climatic system. The region fits like a single piece in a world-wide jigsaw and is only one of the many interacting points in the General Circulation Models. Likewise, the region is firmly embedded in the world's demographic, social and economic systems. If we really are interested in the effects of global warming in the region, some of our attention will need to be on the way the region interacts with the rest of the world. Indeed, the worst socio-economic problems in the region could well find their origin far outside the area, because a substantial part of its income is generated externally. Tourists are being attracted for reasons strongly related to its climate: year-round sunny weather, warm seas, coral reefs, exotic fruits, beaches; they typically come from regions lacking such properties: the northern USA, Canada, northern and western Europe. If climatic change affects more drastically higher latitude regions (Vicente *et al.*, Chapter 11), possibly with temperature increases as high as 4.5°C by 2025, the drive of the traditional tourist to leave his home could weaken considerably, thus depriving the region of substantial income. Other places could acquire advantages similar to the ones now unique to the area and could start acting as intervening opportunities, thus diverting important streams of tourists. Although slightly out of the scope of this book, we imagine that further depletion of stratospheric ozone with its attendant effects on human health, may completely alter peoples' attitude to sunny beaches, causing even further stress on the economic system.

In the course of history the region has become an important, specialized exporter of agricultural staple products (coffee, fruits, sugar cane). If climatic bands start shifting, bringing more precipitation to dry areas and higher temperatures to cold ones, this specialization might become questionable. Transport costs make products sold at distant markets very sensitive to competition because the distance between origin and destination allows for intervening opportunities to pop-up. By making reasonable assumptions about the likely competition for agricultural or other products, however, early detection of vanishing comparative advantages as well as the appearance of new openings on local or world markets might give the system sufficient time to transmute smoothly from the old production base to a new one. Hence, important questions regarding investments in the region need to be addressed to prevent capital from leaving and actions will have to be taken accordingly.

## 2.3 A Local Context: Areas and Activities at Risk

Countries whose economic activity is strongly concentrated in the coastal areas, on lowlands, deltas, etc., doubtlessly will be strongly affected by climatic change (Alm *et al.*, Chapter 15; and Vicente *et al.*, Chapter 11). Without adequate policy interventions, activities with low value added per unit area, such as subsistence agriculture, will suffer most from changing climate or rising sea level. Firstly, on a cost-benefit basis, it will be considered non-economical to build sea-defence structures to protect this land against intrusion. Secondly, if land used by activities with higher value added, such as commerce or industry, is endangered, these activities will preferentially relocate in the immediate neighbourhood, in order to enjoy similar location advantages irrespective of the land's value for its initial use. This has to be viewed in its historical context. If, for example, commercial activities would invade subsistence agricultural land, it has to be assumed that farmers have cultivated the land they work today because of its high productivity value within the constraints of the technology at hand. Losing it to any other usage will automatically force them to farm less adequate fields, with a reduction of productivity per unit area and labour as a consequence. To the immediate clearing and building costs resulting from such relocation will be added the cost of reduced productivity. Furthermore, social tensions are likely to be amplified as the socially weak are pushed out and often have to settle for second best. They also will face the inconvenience of travelling longer distances to services and to work. Hence, deteriorating working and living conditions will worsen an already difficult financial situation. Therefore, timely anticipation and active intervention on behalf of governments will be necessary in order to keep social peace in the system.

The above points are certainly not an exhaustive enumeration of conceivable effects of global warming on the socio-economic structure of the region. They are merely meant to widen the discussion of the possible impacts on the intensity and resilience of the socio-economic linkages between the region and the external world. Even if we are only interested in what happens in the region itself, narrowing down the study to the region as a self-contained unit, thus pretending that climatic change does not exist beyond its frontiers, in a system culturally as diverse and with an economy as export oriented, runs the risk of missing the problem at hand and excluding the driving forces of the system from the study. As explained later, successfully exploring future challenges in the area calls for modelling it as an open system.

## 3 TOWARDS AN INTEGRATED FRAMEWORK FOR POLICY EVALUATION

The Intra-Americas Sea has a unique variety of peoples, cultures and political systems, representing countries with different types and stages of economic development. Its physical, geomorphological and ecological diversity is remarkable as well (*cf.* Chapters 5–12). Hence, defining the effects of climatic change on the socio-economic systems should take into account both the diversity among countries and the reliance of their economies on more or less distant and intercontinental markets. We

