

## METHODS OF SENSITIVITY ANALYSIS FOR ASSESSING IMPACTS OF CLIMATE CHANGE ON TOURISM AT THE REGIONAL SCALE

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### ABSTRACT

Assessment of the impact of climate change on tourism requires knowledge of future climate as well as methods capable of transforming this knowledge into likely societal effects. There are two ways of approaching these challenges: from the top down or the bottom up. In the top down or single scenario approach, a future climate state is identified and its impacts evaluated. Unfortunately, this method is hampered by the unreliability of global climate models on which future climate scenario development relies. As output from climate models is particularly unreliable at the regional level, the likelihood climate models being ‘wrong’ is high. Clearly, this has serious planning implications. In the bottom up approach, many of these problems are circumnavigated by using sensitivity assessments. Sensitivity of a tourism activity to climate is assessed, and then the question is asked: What is the net effect of change on the tourism activity? By identifying the sensitivity to climate and evaluating it in terms of the adaptive capacity of the tourism-related exposure unit, vulnerability of tourism to change may be determined and evaluated. With this information, planning decisions would be possible without knowing precisely the magnitude of climate change that will occur. Details of the sensitivity approach are presented and specific examples discussed.

**KEYWORDS:** *Sensitivity to climate change, Response surface, Tourism climate, Regional climate*

### INTRODUCTION

There are two ways of assessing the impact of climate change on tourism. These are the so called top down or bottom up approach. The top down method is by far the most common. In this approach, a future climate state is identified using global climate models and impacts evaluated. But this method is hampered by the unreliability of climate models. The truth is that there are no dependable predictions of future climate, especially at the regional scale. Present understanding of

global atmospheric processes is barely sufficient to predict the weather a week ahead let alone climate many decades into the future.

Another problem is that there is often an implicit assumption that a specific changed climate condition is predicted. This is reinforced by the fact that global climate models are limited to calculating a single equilibrium response condition. Clearly, the consequences of models being 'wrong' could have serious planning implications. To make matters worse, there are large discrepancies between predictions from different global climate models, especially when model output is transformed into impacts at the regional scale, the very scale at which planners and policy-makers typically operate.

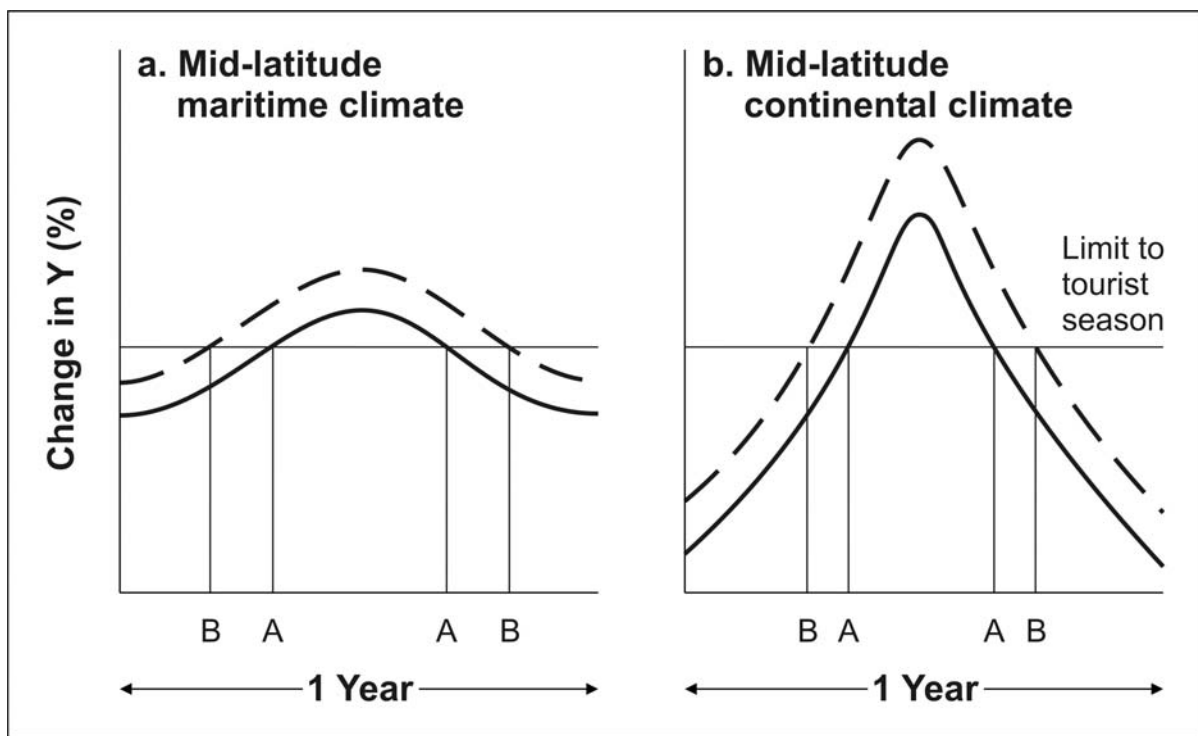
The alternative bottom up approach, circumnavigates many of these problems. First the sensitivity of a tourism activity to climate is assessed, and then the question is asked: What is the net effect of change on the tourism activity or tourism-related socioeconomic exposure unit? By identifying the sensitivity to climate and evaluating it in terms of the adaptive capacity of the exposure unit, vulnerability of tourism to change may be determined and assessed. With this information, planning decisions would be possible without knowing precisely what future climate will be like.

The purpose of this paper is to examine concepts and methods that address some of the above issues. Concepts of impact sensitivity based on climate type at the regional scale are described which provide a broad framework that may be useful in climate change impact analysis. A generalised approach is taken that is climatic-zone or climate-type specific rather than activity specific. This enables regional rather than point-specific assessment to be made. Scenarios of future changed climate are used to show the relative effects on tourism, to provide information for use in local scale impact assessments for operational planning purposes.

### **SIMPLE APPROACHES**

The aim of climate change impact assessment is to determine how the availability of tourism climate resources will change and which regions will lose or gain from these changes. The impact potential of a given change in climate is related to the overall sensitivity of a particular tourism activity to those aspects of climate that do change. Alternatively, it may be related to the particular climate type or climate regimes in which change occurs. For example, an average 2 °C temperature rise and 10 % increase in the number of rain days may be of little consequence in an equatorial climate region where high air temperatures are commonplace and where there are already extended periods of rainfall throughout the year. On the other hand, a sub-temperate environment already marginal for tourism may be highly sensitive and thus respond dramatically to even the smallest decrease in temperature or increase in precipitation in an already short summer beach recreation season.

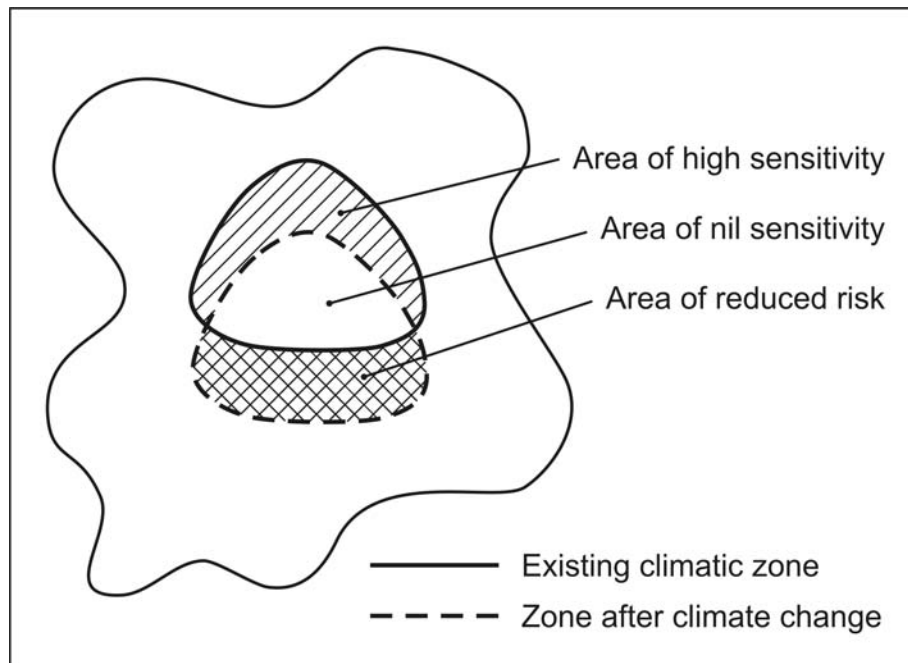
There are a variety of ways of identifying sensitivity. In theory, sensitivity of a region or activity to changes in climate does vary depending on climate type or regime. Climatic types can be characterised and assessed on the basis of this sensitivity since a given change will perturb some climatic regimes more than others (1). But the net effect is not always intuitive. For example, in coastal and maritime climates, the occurrence of higher average annual air temperatures due to greenhouse gas induced warming could be moderated by the local moderating influence of the nearby ocean on air temperatures. However, this could be deceptive since, for any given increase in annual average air temperature, the sensitivity to that change could be quite different. An example of the relationship is shown in Figure 1, where a given increase in mean monthly air temperature results in a greater increase in the length of the tourist season (A-A increased to B-B) at a site with a maritime climate (Figure 1a) than at a site with a continental climate (Figure 1b).



**Figure 1: The effect of a small change in mean monthly air temperature on the length of the tourist season for a mid-latitude maritime climate (a) and a mid-latitude continental climate (b). Counter intuitively, the effect (period B-A) will be greater in the mid-latitude maritime climate. Adapted from Ford (2)**

The observation that, in some areas, tourism conforms to climate regions that are preferred or are optimal for a particular type of tourist activity has given rise to labels and climate connotations; for example, the ‘Sun Belt’ in the United States, the ‘Costa del Sol’ and ‘the Riviera’ in Europe and the ‘Gold Coast’ and ‘Sunshine Coast’ in Queensland, Australia. Building on this conceptually, imagine how these ‘zones’ may evolve spatially. In theory, neglecting non-climatic constraints, if

there is a significant change in climate, the size and appeal of the zone will not necessarily change. Rather, the geographical location of the zone will shift. As climate changes, there is a shift of the margins or transition zones at the boundaries. This change in location of the zone is a spatial manifestation of response to changed climatic conditions. Figure 2 shows how the boundaries are affected. Taking a southern hemisphere example and using a very simple case of air temperature as an index of climate, an increase in temperature will result in a southerly shift of a hypothetical vacation-climate ‘zone’. Figure 2 shows that the north is most vulnerable to change since the new climatic conditions are no longer optimal or as appealing for tourism. The central region is unaffected, in that there is no change in appeal or suitability. It is therefore labelled a zone largely ‘insensitive’ to the specified change in climate. To the south, there is a zone in which conditions for tourism improve, assuming that tourists and the tourist industry respond accordingly and exploit the changed opportunities.



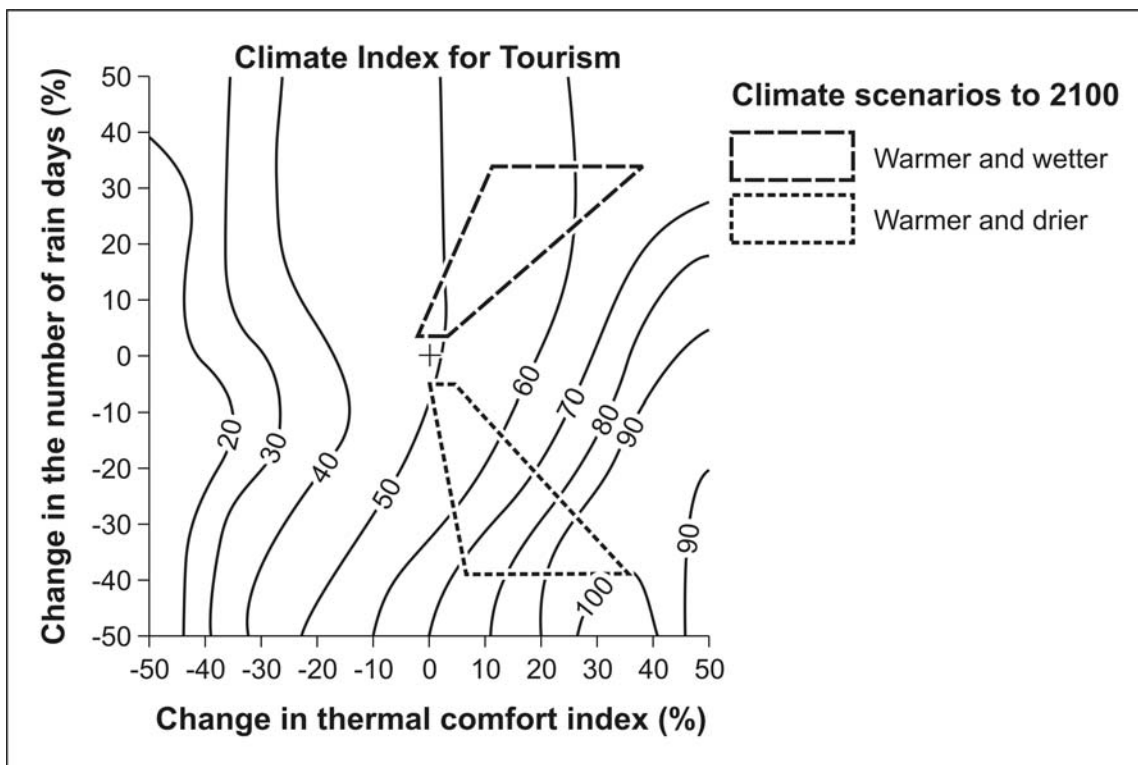
**Figure 2: Simulated spatial shift in a climatically determined vacation region (e.g. ‘Sun Belts’) in the southern hemisphere resulting from climatic warming showing zones of sensitivity to change**

Thermal time indices such as degree days, or other indices such as a rain free days or ‘sunshine days’, can be used as measures of the changing appeal of tourism climate. These indices may be employed along with climate-change scenarios to approximate possible spatial shifts in boundaries to identify zones of high risk or vulnerability to change. In analogous examples from agricultural climatology, Newman (3) and Blasing and Solomon (4) found that climatic warming would displace the United States Corn Belt approximately 170 km per degree of warming in a roughly northerly

direction. Williams and Oakes (5) describe a similar northward expansion of the Canadian Small Grain Belt, neglecting all environmental barriers other than climate.

## RESPONSE SURFACES

Climate change impact assessment of the type described above relies on a greatly simplified picture of the role of climate, mainly because it deals with change in terms of single, secondary climatic variables that allow for only elementary statistical connections to be made with impacts. This approach is of limited use since the significance of the impact will depend on the net combined effect of several changed climatic variables. For example, thermal state of the climatic environment in terms human comfort is a function of the combined effect of air temperature, humidity, solar radiation and wind (6). Impact will also depend on the timing as well as the magnitude of change. For example, increases in the number of raindays in winter may have no consequences for mid latitude locations geared to summer beach recreation while increases in summer may destroy the tourism climate amenity value of a place with an already a marginal beach recreational climate. A response surface analysis allows the decision maker to take these issues into account all at once. An example of this is shown in Figure 3.



**Figure 3: Response surface showing the sensitivity of the tourism climate of a region, expressed as change in the Climate Index for Tourism (7), to climate change expressed as change in number of rain days (%), and change in thermal conditions expressed as an integrated thermal comfort index. Climate change envelopes show incremental change based on hypothetical scenarios**

A response surface is a two-dimensional representation of the sensitivity of a specific response variable (for example, the Climate Index for Tourism in Figure 3) to change in the two controlling features of climate (for example, change in rain days and change in thermal comfort index in Figure 3). The relationship between the response variable and climate is determined from a pre-tested set of relationships, usually in the form of an empirical model, called a transfer function (such as is in the case for the Climate Index for Tourism presented by de Freitas et al (7)). The output from the groups of determinants can be plotted using values relative to a baseline representing no climate change (Figure 3). The latter representation is a step removed from absolute input and output but does have the advantage of providing a direct measure of sensitivity. For example, a 20 % response to a 10 % change in a controlling climate variable is clearly an example of impact amplification. Response surface isolines are a summary of a matrix of response points associated with various combinations of changes to the two groups of driving climate variables (Figure 3). The required data are derived from repeated runs of the transfer function with the prescribed changes to the input. The slope and closeness of the isolines are an indicator of sensitivity, and discontinuities an indicator of change in response (Figure 3). Plotting climate change scenarios on the response surface enables it to be used for impact analysis. A scenario of, say, a 10 % increase in rain days and a 20 % increase in the thermal comfort index, for example, can be plotted on the response surface to assess the anticipated impact on the response variable, say, a change in the Climate Index for Tourism (Figure 3).

## **CONCLUSION**

Given that, for many regions, climate is the main impetus for attracting visitors, it forms an important part of the natural resource base for tourism. Any change in climate will affect not only the resource but also demand for the resource. The capacity of society to respond will depend on tourism's sensitivity to changing climate. This will vary from region to region. An advantage of the response surface method is that it is less likely to obscure inherent sensitivities to change that can occur in top down approach. Another advantage of this method is its flexibility. A wide range of new or changed scenarios can be easily handled by plotting them on the response surface. This avoids the need to rerun the transfer function, thus facilitating use by non-climate specialists such as planners and policy makers wanting to reassess impacts. In the top down approach the impression is given that a future climate state will occur at a particular time. This may not be particularly useful since a variety of planning time frames may be required. In contrast, the response surface method has an additional advantage of allowing, through interpolation, both longer and shorter term impacts to be assessed by way of response envelopes.

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