Methods and Techniques of Research on Climate Change Impact Assessment

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Abstract- This paper deals with method and techniques of conducting research on climate change. It outlines the need for climate change impact assessment research areas of investigation and comparability of research outcome. This paper makes a special note on methods and tools of conducting the climate change research with reference to quantitative models, biophysical; models, economic models, integrated system model, empirical research, expert judgement and remote sensing and GIS method. This paper concludes with some interesting findings.

I. INTRODUCTION

Climate change impact assessment refers to research and investigations designed to find out what effect future changes in climate could have on human activities and the natural world. Climate change impact assessment is also frequently coupled with the identification and assessment of possible adaptive responses to a changing climate. To the extent that adaptation can reduce impacts, the assessment of adaptation measures is part of impact research. Thus impacts may be described as "gross" or unmodified impacts, and as "net" impacts after adaptation has been taken into account. Climate change impact researches are necessarily conjectural. That is to say, impacts cannot usually be experimentally confirmed or verified. Clearly it is not possible to conduct a controlled experiment by changing the global atmosphere to test the effects of climate changes on human and natural systems.

II. APPROACHES OF CLIMATE CHANGE IMPACT RESEARCH

In the absence of controlled experiments, other ways have to be developed to try to find out what the impacts of climate change may be. There are five approaches which have been applied as investigative techniques to try to cast more light on the potential impacts of future climate change:

1. Palaeological, archaeological, or historical studies of how climate changes and climate variations in the past have affected human and natural systems.
2. Studies of short term climatic events which are analogous to the kind of events that may be expected to occur with human induced climate change, such a droughts, and floods. This approach is the use of climate analogies that has been developed into a formal method called "forecasting by analogy".
3. Studies of the impact of present day climate and climate variability.
4. The creation of models, often quantitative of the relationship between climatic variables and selected impacts sectors to try to answer the "what if" kinds of question.
5. Expert judgement, which refers to a variety of methods whereby especially well informed and experienced specialists are brought together to develop a consensus view.

Models are the method used most frequently in climate change impacts assessments, and it is to the description and evaluation of such models. Inevitably these studies are predicated upon a number of assumptions many of which are themselves likely to be proved wrong with the passage of time. Forecasting, or telling the future, by whatever method used, is notoriously unreliable. The first three approaches listed belong to the historical climate impacts, analogue impacts, and contemporary climate impacts. Thay are therefore important as inputs to the assumptions made in models, and serve as the best 'reality check" available. The fundamental problem that all of these methods face is that all approaches are based on observations and experience with climate change and climate variability. Climate change may introduce new conditions that have not been seen and that are not understood. While the results of these assessments may be the best information we have on potential impacts of climate change, they should not be interpreted as reliable forecasts of the future.

III. NEED FOR CLIMATE IMPACT ASSESSMENTS

Over the past three decades, since 1970 or even earlier, the scientific evidence for human induced climate change has become steadily stronger. By 1995 the international scientific community of atmospheric and related scientists, organised in the Intergovernmental Panel on Climate Change (IPCC). It was able to conclude in a cautiously worded statement that "the balance of evidence suggests that there is a discernible human influence on the climate" (IPCC, 1996). With all the appropriate qualifiers and Climate change is a present reality.

This leads to two further questions:
1. How important or serious are the impacts of human induced climate change likely to be?
2. What can and should be done to prevent and modify these impacts, and when and how should it be done?

The answer to the second question has been construed in the UNFCCC as falling into two main dimensions, mitigation or sometimes limitation and adaptation. Methods for the study of greenhouse gas emissions and their mitigation have been fully described elsewhere. This paper focuses upon the second category of response, adaptation. Information about climate impacts is needed both to help decide upon both the urgency and the desirability of mitigative and adaptive measures, actions, and policies, and their appropriate combinations. Since climate change is a global problem, decisions with respect to both mitigation and adaptation involve actions or choices at all levels of decision-making, from the most local and community level including families and individuals to the broadest international levels, involving all national governments and many transnational bodies as well. The intended target audience or client for impact studies therefore is also very wide ranging, and this will affect the design if the study in many ways.

IV. GOALS OF THE ASSESSMENT

Often the goals of the assessment are specified by the client (sponsor) or are strongly set or implied by the circumstances of the assessment. It is important to clarify the objectives at the outset, since they determine to a large extent the problem definition, scope, and boundaries of the assessment. Many climate impact assessments have been designed to serve the policy interests of national governments. Other levels of jurisdiction, from local to regional, may also be interested in the results. Often there are multiple objectives, where, for example, a national government may wish to have impact research results to inform its own policy, and at the same time contribute to an international assessment.

V. TIME AND SPACE

The decision with respect to the spatial extent of the assessment and the length of time into the future that will be considered clearly depends on the factors previously discussed. As per the report by IPCC (1996) it is common practice to think of climate change as long-term changes in means. It could be noted that mean global temperature may rise globally by 1.0 to 3.5 C by 2100 and precipitation may vary by plus or minus 10 to 20 percent, and by equivalent regional changes in means, where these can be derived from GCMs.

VI. AREA COVERAGE

The matter of geographic boundaries of the assessment is important. Countries are often faced with the choice of studying the entire country or a region such as province, river basin, or ecological zone. For small countries, this issue is not typically relevant as the whole country can readily be studied. For large or even medium-sized countries, this issue can be challenging. Focusing on a region or a river basin allows for more indepth analysis. In these cases the compatibility and integration issues will be very important. For instance, it is of limited use to study irrigated agriculture in one region while water availability is studied in another region. Studying the entire country gives results that appeal to a broader audience and allow national policy issues to be more readily addressed, but it may be harder to fully integrate large geographic scale studies. Typically the trade-off is between depth and breadth.

VII. THE DEPTH OF THE ASSESSMENT

A difficulty that is quickly encountered is that the impacts in most sectors are connected to other impacts in other sectors, and themselves have secondary tertiary and N order effects. Where is the analysis to stop? For example, damage to mangrove forests may affect breeding of fish species, which in turn affects fish populations, which affect coastal fishing communities, which affect local and perhaps regional nutrition, which affects human health and raises demands for alternative food supplies from agriculture, which is itself under climatic stress, and so forth. To assess the importance of climate as a factor in the decline of fish populations, and the importance of fish in nutrition, it is important to know what other factors may be affecting the fish population such as overfishing, and how costly fish is compared with alternative protein supplies. Such ramifications of climate impacts can spread throughout an ecosystem, throughout a socio-economic system, and from a local impact to regional and wider geographical areas. It is tempting to think that such expanding ripple effects get progressively weaker proceeding away from the initial focus in time and in space. This is not necessarily the case. It depends in part of the condition of the systems or targets impacted. Where these are vulnerable, or their adaptive capacity is reduced for other reasons, the impacts may actually become more severe with distance. Any assessment team should therefore engage in a discussion during the "getting started" phase of the boundaries of the assessment, and how these are to be determined and then followed.

VIII. SECTORS AND AREAS

The choice of the scope of the assessment is crucial. Clearly this is dependent upon the objectives, but it is commonly found that the researchers themselves have ideas about the most appropriate sectors to include. The focus of an assessment can be as small as a single cultivar in terms of the impact of climate change on wet rice production or extend to a whole agricultural system, or to all the socio-economic and natural systems in a specific country or region. Sometimes another spatial unit of analysis may be selected, such as an island, The choice of the content of the assessment is often constrained by the availability of financial and other resources. It is in the nature of the climate impacts problem for a wider scope to be preferred, especially at this stage of development of the field where there are so many unknowns. Both the science and the policy requirements tend to lead to studies designed to gain a broad overview, rather than to providing precise answers to narrow and hypothetical questions.

IX. COMPARABILITY

It is always tempting for researchers to follow their own inclinations and hunches, and to allow the nature of the problem as they see it to determine the choice of methods, and the ways in which they are applied. Often such curiosity-driven research can be highly productive and innovative. In research that is aimed at providing understanding which will serve a policy process, this often conflicts with the need for the research results from one subject area to be comparable with those in other areas. This requirement is important if the results of individual component studies are to add up to something more than the sum of their separate parts. This tension applies both within studies and between studies. For example, in a country assessment of the impacts of climate change, the results will not be comparable or compatible if the various sector components in water, agriculture, health and biodiversity use different scenarios of climate change or different assumptions about the future state of the economy. Consistency is essential in this matter. The same applies outside the assessment, for example, if the results of an impact assessment in one region are to be comparable with those in another region, or an adjacent country, which may share the same river basin. The domain of climate impact studies is so broad that the tendency for individual component studies to be conducted in relative isolation is very strong and hard to resist. The question of integration is not the same as the question of comparability. Integration refers to a much closer examination of the ways in which sectors and regions interact.

The magnitude of climate change impacts estimated from a assessment is often very sensitive to the assumptions made about adaptation. It is difficult to predict exactly how people will respond to climate change. Will they continue their behaviour from the past because they do not understand climate change and its implications or will they know exactly what to do to efficiently adapt? Studies have made very different assumptions about adaptation, and thus have yielded very different estimates of impacts. It is therefore important to consider adaptation at the design phase of the assessment and to decide how it is to be brought into the impacts research at an early stage. Where a assessment is being organised by sectors, it can be helpful to select one person from each of the sectoral groups to serve as members of a cross-cutting group specifically devoted to the adaptation questions.

X. METHOD AND TOOLS

There is a range of different approaches or methods that can be used in the assessment of climate change impacts. These include quantitative and predictive models, empirical studies, expert judgement, and experimentation. Each of these approaches has it own advantages and weaknesses, and a good strategy may be to use a combination of approaches in different parts of the assessment or at different stages of the analysis. In addition to formal modelling approaches, consideration should also be given to methods of stakeholder involvement, and the use of expert judgement. In some cases empirical studies of current climate impacts may be useful. There are also other tools that may be used, such as geographic information systems (GIS) and remote sensing.

XI. QUANTITATIVE MODELS

Where feasible, it is desirable to use models where the variables can be expressed in quantitative terms, so that a variety of tests can be carried out and so that results can be expressed in more precise terms. However, one has to keep inmind that the results generated by these models may look very precise, but should be handled with caution since the underlying assumptions – not only climate and socioeconomic scenarios but also assumptions about processes – can be rather weak or incorrect.

A crucial test in the choice of modelling approach and specific model is data needs. Often the data needs are high and difficult to meet, and this may lead to simplification of the model or even in some cases the development of a new model or models. The choice of model is best conducted by experienced modellers, since detailed foreknowledge of the problems likely to be encountered is especially valuable. Where experience with climate impacts modelling itself is not available, experience with other types of modelling can be of great help.

There are broadly three kinds of quantitative models that can be used in climate impacts studies: biophysical models, socio-economic models, and integrated system models. The ideal that is being sought is a model or models which deal with climate and socioeconomic and natural systems in an interactive way. Many of the available models, are simple cause and effect models, in which one or more climatic variables are changed and the consequences predicted and measured. In reality we are dealing with an interactive system in which one set of cause and effect relationships leads to another. The integrated systems models represent an on-going effort to deal with this complexity.

It should be noted that models do not do everything. Models that address only one sector or aspect of a system may simulate that sector or aspect well. But they may not include interactions from important related sectors or other aspects of the system. Models that integrate across sectors or systems may capture interactions and be useful for assessing broader scale effects. But their simulations of specific sectors or aspects of systems may be less reliable than the sector or aspect-specific models. Thus, the choice of a model should depend in part on what questions are being asked, that is, whether they are broad or narrow questions. Users of this handbook should recognize the weakness of any model they choose before using the model and interpreting the results.

XII. BIOPHYSICAL MODELS

Biophysical models are used to analyse the physical interactions between climate and an exposure unit. There are basically two types of biophysical models, empirical statistical models and process based models. Empirical statistical models are based on the quantitative relationship between climate and the particular sector or system under current climate. The models can be quite useful for simulating effects of climate within the existing range of observed climate and assuming other critical factors do not change. When these models are used to simulate climate change, it is implicitly assumed that the statistical relationship between climate and the sector does not change. Thus a linear relationship based on observations is assumed to continue to be linear outside the observations.

In contrast, process based models are based on physical laws, first principles about the workings of a system, or assumedly universal regularities. In principle, these can be applied outside of the geographic area or climate zone in which they were developed. In reality, there is much uncertainty about the exact biophysical processes under climate change, especially when other factors are included. For example, we are uncertain how the CO2 fertilisation effect will work in field or natural conditions, especially if there is severe drought from climate change.

XIII. ECONOMIC MODELS

Most of the impact models of the kinds introduced above are concerned with the prediction of first-order impacts of climate change on such variables as crop yield, runoff, or the range of insect and disease vectors. To estimate second-order effects and beyond, such as those on production of cereals, on water supply, or on industrial output, can require, among other things, the use of economic models. It is important to distinguish three types of models, which depend on the scale of analysis. At the finest scale, economic models describe the behaviour of a single actor, such as a farmer or a firm. They can be used to estimate how an individual actor may respond to climate change. For example, a farm level model can be used to determine whether a farmer might add irrigation, switch crops, or abandon farming in response to yield changes. micro level models do not simulate changes in consumer demand or in prices; so a key factor for the individual actor, prices, is assumed to be unchanged.

Meso-level models simulate behaviour in a sector of the economy. Economic models of agriculture may simulate the agricultural economy of a country or the world. Such models can simulate changes of behaviour in all actors in a sector, including consumers. Agriculture models can estimate changes in production and trade patterns. These models do not simulate interactions between the sector and the rest of the economy.

Macro-level models simulate economic activity across all sectors of the economy. They can estimate changes in total production, employment, and other macro-economic variables. Like biophysical models, economic models can be divided among empirical statistical models and process based models. Empirical statistical economic models are based on observed empirical relationships between economic variables. As with biophysical models, these types of economic models may have limitations with regard to estimating conditions outside of the observed data or when there is a significant change in basic economic conditions. In contrast, general equilibrium models are based on laws of economics and can be thought of as process based models. They may be more appropriate for simulating economic activity when there is a basic change in economic conditions. The empirical statistical models tend to be static whereas the process based models can be dynamic. Economy wide models tend to have less detail about individual sectors than do sector-based models.

XIV. INTEGRATED SYSTEMS MODELS

Assessments based upon single sector studies, or even single sector studies added together, fail to address the interactive complexity of climate impact phenomena, for instance, through competitive land and water use. For this reason, research attention is being devoted to the development of integrated systems models.

XV. EMPIRICAL STUDIES

Empirical observations of the interactions of climate and society and natural systems can be of value in anticipating future impacts. This is commonly achieved through analogue methods, in which variations over space or past time can substitute for future changes. Three kinds of analogue can be identified: historical events, historical trends, and regional or spatial analogues of present climate. A particular advantage of empirical studies emerges as they are extended into the area of adaptation because it becomes possible to ask decision makers, stakeholders, and those impacted directly about how they adapt or have adapted in the past. It is also possible to confirm their responses through direct observations. Empirical studies can be combined effectively with quantitative model scenarios. Such a combination of approaches permits modelling work to be solidly grounded in experience, and permits the extension of empirical studies into the future.

XVI. EXPERT AND STAKEHOLDER JUDGMENT AND PARTICIPATION

A useful method of obtaining a rapid assessment of the state of knowledge concerning the likely impacts of climate change is to solicit the judgements and considered opinions of experts in this and related fields. The use of expert judgement may be especially appropriate in preliminary or pilot studies. Expert judgement may therefore be used in anticipation of other types of approach, and be an aid in the design of such studies. There are many ways of organising inputs to studies by expert judgement. Often this is done informally in committees and small group discussions. While the most highly regarded experts may be drawn upon in this way, such approaches tend to lack transparency, and there is always the possibility that a different group of experts would have arrived at different conclusions. The use of expert judgement can also be formalised into a quantitative assessment method, by classifying and then aggregating the responses of different experts to a range of questions. More recently, decision support systems that combine dynamic simulation with expert judgement have emerged as promising tools for policy analysis. Here subjective probability analysis is required where simulation empirical models are lacking.

XVII. REMOTE SENSING AND GIS

Remote sensing from aircraft and satellites is the science and art of collecting data about objects located at the earth's surface by using sensors mounted on observation aircraft and satellites and of interpreting the data to provide useful information. The main civil application areas of remote sensing are cartography, agriculture, food security, forestry, environment, geology, water resources, marine resources, atmospheric quality, and regional planning.

Remote sensing can very effectively be used in combination with GIS, which is a computer system capable of holding digital maps called geographical layers or spatial information represented by points, lines, and polygons and their associated statistical and descriptive data called attribute data. The development of GIS has allowed geographically referenced data to be analysed in complex ways. GIS facilitates the analysis of multiple layers of data and allows statistical analysis of multiple factors while maintaining their spatial representation. A very important advantage of the use of GIS is that such systems facilitate the future collection of relevant data as well as future, more complex analyses.

The data requirements for effective use of GIS are high. Data need to be geographically referenced using compatible systems, and it is important that the spatial resolution of the various layers be as similar as possible. Such detailed and compatible data often do not exist, and therefore the costs of developing such a database can be very high. Other specific limitations include the cost of the software.

As per the report by Carter et al., (1994), the application of a GIS in impact assessments includes (1) depicting past, present, or future climate patterns; (2) using simple indices to evaluate present-day regional potential for different activities based on climate and other environmental factors; (3) mapping changes in the patterns of potential induced by a given change in climate, thus showing the extent and rate of shifts; (4) identifying regions that may be vulnerable to changes in climate; and (5) considering impacts on different activities with the same geographical region so as to provide a basis for comparison and evaluation. GIS can also been used in conjunction with general circulation models (GCMs), biophysical simulation models, and integrated databases to conduct regional and global impact analyses. GIS can also be a valuable tool in integrated impact assessment for storing, combining, and analysing the geographic information used and developed by the different assessment teams. If country assessment teams decide to use GIS in their studies, it is essential that all assessment teams use the same or at least compatible systems.

XVIII. PROBLEM ASSESSMENT

Climate impact assessment and adaptation studies are complex, multidisciplinary enterprises. There are bound to be strong centrifugal forces operating which send assessment participants in different directions. If the assessment is to retain coherence, it is important to create at the outset a procedure for periodic review and assessment of progress and to be prepared to make "course corrections". Therefore it is suggested that meetings of the study team be held at frequent enough intervals to permit collective.

CONCLUSION

It could be seen clearly from the above discussion that conducting research on impact of climate is very essential. It is observed that the need for conducting the research on impact of climate change on society, environmental health, biodiversity and other sectors is very essential. The various tools of conducting the impact of climate change discussed in this paper is very essential for climate change researchers, planners and policy makers. Hence, the government should promote research on climate change impact through research grants and other financial assistance.

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