PAPER 1

INTRODUCTION: BUILDING DECISION SUPPORT SYSTEMS IN STAGES

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ABSTRACT: The origins of this book emerge from five papers originally presented at the "Bridging Scales and Linking to Policy" conference held at the University of Maryland, in Adelphi, USA from 9-11 May 2007. The unifying theme of the session in which these papers were presented was: "Linking Impacts and Adaptation Modeling of Climate Change to the Policy Process" from which this book takes its title. This paper outlines the threads that stitch the papers together, and provides brief introductions to each of the ten papers. Part I of the book consists of two papers that describe the underlying elements of climate change adaptation including a feedforward decision framework, and a bibliometric analysis of the climate change adaptation literature. Part II of the book presents the evolution of a planning methodology (or suite of methodologies) referred to collectively as RACe (Rapid Assessment to Climate) which is discussed within the context of the Regional Municipality of Halton. Papers in this section include descriptions of the rapid assessment of the impacts of climate change; how to select a global climate model for projections of future climate change; environmental prediction indicators; rapid adaptation assessment; and adaptation through learning. Part III of the book focuses on 'adaptation extensions' – specifically the concept of climate change adaptation, mitigation and sustainable development (AMSD); the application of geographic information systems (GIS) in climate change impact and adaptation analysis; and upscaling approaches to inform policy at the global level. The only certainty that would appear to have emerged from the work within this book is the necessity of becoming involved in actual planning exercises. The rest it seems will evolve.

Keywords: climate change, impacts, adaptation, planning, Halton Region

1. Introduction

The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) has established the existence of climate change (i.e. as determined from global observational evidence) and its origins as "very likely" human (i.e. consistent with modeling projections). Impacts will include changes of increasing magnitude to all components of the earth's biosphere, and by extension to all aspects of human well being (Millennium-Ecosystem-Assessment, 2005). The major issue for researchers and government officials is no longer the possibility of climate change therefore, but in identifying appropriate human responses to climate change (IPCC, 2007).

The literature suggests that there are three fundamental perspectives regarding the appropriate form of human response (Schipper 2006). The first holds that society is inherently adaptive. It is based upon a *laissez faire* understanding of human behaviour and represents a lingering debate in economics (Hirshleifer 1977) and the evolutionary sciences (Sober 1994). Its associated prescriptive interpretation holds that society need do nothing in the face of climate change (Ausubel 1991); the invisible hand of either natural selection or market forces will ensure that societies adjust to changes. Kates (1997) calls this the *adaptionist* view.

At the other extreme is the *limitationist* view which holds that the only action required for dealing with climate change is a reduction of green house gas emissions (Schipper 2006). Thus climate change response is constrained to a single strategy, traditionally designated as mitigation. This perspective is partially legalistic, the product of interpreting climate change as 'human induced' (i.e. GHG emissions) as done in the Framework Convention on Climate Change (FCCC) (Pielke 2005). Though the UNFCCC and the Kyoto Protocol contain adaptation provisions, the main emphasis of national and international climate policy has historically been mitigation (i.e. stopping the cause of environmental change).

This bias against climate change adaptation (implicit or explicit) is considered by many (Burton *et al.* 2002; Cohen *et al.* 1998; Pielke 1998, 2005; Pielke *et al.* 2007) to be unfounded despite the defeatist connotations initially associated with it[1]. These authors contend that adaptation is necessarily an integral response to climate change for the following reasons: 1) even if mitigation is successful, climate change will still be experienced due to past emissions: 2) vulnerability to climatic variability and extreme events has increased for reasons other than the magnitude of the changes; and 3) those who suffer the most due to climate change will be the least able to cope with the change (Pielke *et al.,* 2007).

In contrast to *adaptationists* and *limitationists,* a third perspective contends that the appropriate climate change response considers a balanced portfolio of adaptation and mitigation (AM) strategies. This realist, or middle ground position (Schipper 2006) assumes that climate change is a fact, uncertainty of impacts exist, and adaptation is considered a *'crucial and realistic response option along with mitigation'* (Klein 2003). Yet while this approach may be the most intuitively

1 It is noted by Pielke Jr.(2007) that Al Gore (1992) referred to CCA as a "kind of laziness, an arrogant faith in our ability to react in time to save our skins." Conversely, .. states "Mitigate we will, adapt we must (get)"

appealing, the task of managing such a position is typically reported in vague terms and assertions. The relationship of climate change adaptation to mitigation is in fact, far from evident.

The easiest way to comprehend this balance is by first considering its most idealized form: an optimised portfolio of mitigation and adaptation actions[2]. Optimization was initially considered by Schelling (1992), and later elaborated by Kane and Shogren (2000). In their model, Kane and Shogren (2000) formalise the AM issue in a simplistic model, grounded in the economic theory of endogenous risk. They assume a nation faces a monetary net damage from a bad event (i.e. sea level rise) and can reduce its risk through mitigation, or adapt to realised damages (i.e. shifting resources from good to bad states of nature). The optimal decision provides the best AM choice or pathway, taking into account the fact that mitigation-adaptation can complement or substitute each other[3].

From this simple model, general insights emerge. For instance, a nation would strictly rely upon adaptation if the international community cannot design a collective contract for global mitigation. The expected net benefits of any mitigation would be negative given that they are the sole mitigator and would have no effect on reducing the odds of climate change. Alternatively, an international regime that gets each nation to mitigate to a globally desired level will reduce the expected benefits of adaptation. Thus there is no incentive to adapt or adjust production practises if there is no climate change. In sum, the likelihood of witnessing an all mitigation/no-adaptation scenario depends upon the effectiveness of international environmental treaties (Kane and Shogren, 2000).

Beyond these somewhat obvious, meta-scale generalities, the optimality model and its assumptions of rationality, become problematic. Optimality presumes that a set of comparable AM strategies can be developed, evaluated, compared, and an optimal solution identified. Yet it is difficult even to compare a small set of AM options due to uncertainty, the dynamic nature of the problem space, and incompatibility between options (i.e. the problem of comparing apples and oranges) (Klein *et al.,* 2005). Tol (2005) states that: 1) most adaptation is local while mitigation is global; 2) adaptation is undertaken by different people, at a different spatial and temporal scale than mitigation; and 3) mitigation can

2 As Ackoff (1979) quibbled, such methods are "mathematically sophisticated but contextually naive".

3 The nation must balance the marginal costs of emission reduction with the marginal benefits of reducing climate change; the marginal benefits would result from balancing the marginal costs of adaptation to climate change with the marginal residual damages. So, a global CBA, or a national CBA for that matter, yields insights into the trade-offs between adaptation and mitigation, at least in principle (Tol, 2005)

remove resources from adaptation, causing non-linearities in the set. For Wilbanks *et al.* (2007) adaptation is simply more complex than mitigation. Adaptation and mitigation differ in their nature, their timing, their geographical impacts, their sectoral focus, their co-benefits, their limits, as well as who decides and who pays versus who benefits.

The AM dichotomy is one manifestation of what various authors have termed *complexity, hyper complexity, wickedness,* or *confounding effects.* Wicked describes a class of problems typified as having: 1) no correct formulations; 2) numerous stakeholders, with different perspectives; 3) no stopping rules to determine when a problem is solved; 4) no criteria to judge the 'goodness' of decisions; 5) the inability to test decisions except by their execution; and 6) no enumerable or exhaustible describable set of possible solutions (Rittel and Webber 1973).

> "No person, committee or research team, even with all the resources of modern computation can complete the analysis of a complex problem. Too many interacting values are at stake, too many possible alternatives, too many consequences to be traced through an uncertain future – the best we can do is to achieve partial analysis, or in Herbert Simon's term, a "bounded rationality." (Lindblom, 1979)

In the late 1950s, at the height of the management science revolution Charles Lindblow (1959) argued that the rational, comprehensive or synoptic (i.e. complete) method was grossly inadequate for informing actual decision or policy making. Along with Churchman (1967), he went as far as to suggest that those researchers\analysts whom defend and seek to apply synoptic rationality were guilty of fraud. The ideal, rational decision method suggests that you can: 1) specify all ends or values to be pursued (as distinct from means); 2) weigh them; 3) examine all possible sets of means to reach those ends; 4) evaluate each set of means against ends; then 5) for each set of means, calculate its overall measure based on the weighted average of its scores on achieving the different ends; and finally 6) choose the set of means with the highest weighted score. For complex problems, all this is simply not possible.

We do not formulate ends or values, in this manner; we cannot even list them, let alone compare them. Means are intimately linked to ends, and can neither be exhaustively listed. And the ability to search through a feasible set of means, if such a set were possible to define, is fundamentally limited epistemologically, methodologically, and computationally. In other words, any attempt at a complete rational methodology is nonsense. And using rationality as regulative ideal, according to Lindblom (1979), is equally suspect. In place of synoptic rationality, Lindblom suggested that policy makers approach problems incrementally. In this method: 1) ends and means are intimately intertwined; 2) only a few means are considered; 3) only strategies which do not stray far from the status quo are considered; 4) an analysis of means is kept as simple as possible; and 5) the choice among the means is determined by agreement, which is the only true measure of success of a strategy.

As a result, single, isolated decisions that are intended to initiate dramatic, sweeping changes are atypical[4]; decision makers rather 'muddle through' in small steps (Lindblom 1959). Far from seeking a synoptic rationality, Lindblom suggests that analysts support this more accurate, incremental description of decision making. Yet Lindblom does not make it entirely clear how this can be accomplished. Part of the problem in qualifying rationality in this manner (as with Herbert Simon's *satisficing* (Simon 1957) is that innumerable interpretations are possible[5]. Examples from the CAA literature (Beg *et al.,* 2002; Hughes *et al.*, 2003; Mills 2007; Pyke and Andelman 2007; Walsh *et al.,* 1993) illustrate the complex relationships that exist between humanity and the environment, as well as the factors that must be taken into consideration to formulate an effective adaptation strategy. The dilemma for researchers/analysts is that there can be no definitive adaptation strategy, or decision support system to identify strategies. Many formulations, which incorporate many different combinations of knowledge, technology, and institutions, are possible.

While some authors have attempted to get underneath this complexity by proposing fundamental laws or rules that all complex systems follow (ecological, social, and even institutional) (Gunderson and Holling 2001; Holling 2001; Holling 2004), the majority or researchers\analysts, adopt\apply a plurality of approaches (Roe 1998)[6]. Not only is there a general recognition that decision makers *'muddle through'*[7], but researchers\analysts themselves *'muddle through'* in their development of support systems for these decision makers[8]. *Muddling* would therefore be an apt description for the content as well as the structure of this book.

4 Although see Glantz' argument for this form of decision and policy making with respect to climate change (Glantz, 1979.

5 See Lindblom's gradient of rationality Lindblom, C.E. 1979. Still Muddling, not yet through. Public Administration Review 39(6): 517-526..

6 Roe's book "Taking Complexity Seriously" generated a strong debate by authors such as Holling, as can be seen in the journal Ecology and Society Vol. 4, Iss. 2 (2000).

7 This is quite evident in the concept of 'mainstreaming' (Huq and Reid, 2004). In essence, this concept is an acknowledgement by researchers that the best approach for increasing local adaptive capacity is to embed information about climate change into local decision frameworks and protocols.

8 Muddling through for muddlers.

Taken as a whole, the articles in this edited volume represent a piecemeal, incremental approach to building and supporting adaptive capacity for climate change in Canada. In this sense, 'muddling through' is interpreted as an opportunistic, evolving, locally contingent, process that is never entirely complete.

This book reflects the idea of open-ended incrementalism, in the way it informs the planning imperative of climate change adaptation. Though the articles can stand on their own, when read in this larger context they offer something more. For instance, a number of common threads run through the articles presented in this edited volume. The five articles that make up the warp of this volume were originally presented at the "Bridging Scales and Linking to Policy" conference, which was sponsored by The Global Water System Project, and held at the University of Maryland, in Adelphi, USA from 9-11 May 2007. The unifying theme of the session in which these papers were presented was: "Linking Impacts and Adaptation Modeling of Climate Change to the Policy Process" from which this book takes its title. Despite this common framework, these papers nevertheless represent a wide array of research topics.

The second thread that runs through these articles is the Adaptation Impacts, Research Division (AIRD) of Environment Canada; the common institutional denominator where most of the authors work, or have worked. As a result, the authors share a common institutional environment, mandate and history which are undoubtedly reflected in their research. In a sense, the tools, methods and information developed by researchers at AIRD forms the foundation of the articles presented in this book. As a group of researchers, AIRD has a long history of undertaking research on climatic modeling, scenarios development; impact assessment; and decision support system development. Attempts are currently being made to produce more generic, aggregate, and integrated knowledge that can be applied across a range of scales and feed into national and global systems. Part of this mandate is reflected in this volume.

A third common thread is the utilization of case studies. Not only does this unify the papers in a methodological sense, but many of the authors have collaborated on specific cases over the course of their careers. Case studies have been employed to verify findings, integrate system components, disseminate research results, to garner information and ideas, and to maintain the relevance of the research. Initially, much of this work was undertaken on large, ecosystem level research projects such as the Mackezie River Basin Project (Cohen 1997) and Great Lakes Basins Project (Mortsch *et al.,* 1997). More recently this work is being extended to scales that are more familiar to the majority of Canadians as in the work of Livia Bizikova and Ian Burton in the Richmond, BC study, and of Adam Fenech and James MacLellan in the Regional Municipality of Halton, which forms the context of a number of papers in Part II of this book.

The final thread is a focus on urban\suburban case studies in climate change adaptation. Both the Richmond study and the Halton study were initiated during the development of this book. The Richmond study will soon be complete and the Halton study is in its final phase. This focus on urban and suburban areas will be critical in the future if we are to deal with climate change. Cities represent a crucial element in any effort to mitigate and adapt to the effects of climate change due to their direct effect upon the environment through growth and development, the shear numbers of consumers they represent (88 percent of net increases in human population, 2000 to 2030, will occur in urban environments (Worldwatch Institute, 2007) and the global effect of their ecological footprint (Dietz, 2007).

What a climate change adaptation, decision support system should look like is clearly open to debate. The point here is that the development process itself is also necessarily incomplete, and should be treated as such. The only certainty that would appear to have emerged from the work within this book is the necessity of becoming involved in actual planning exercises. The rest it seems will evolve.

2. The Collection of Peer-reviewed Papers in this Volume

The papers hold three related sections of this book: the first section (Part I) deals with a general overview and understanding of climate change adaptation. The second section (Part II) describes the design considerations of a climate change adaptation, decision support system (CCA-DSS), as it relates to a specific region in Canada (i.e. the Regional Municipality of Halton). The final section (Part III) serves to identify gaps, not only with reference to the specific example in Part II, but in terms of climate change adaptation research in general.

Part I consists of two papers that describe the underlying elements of climate change adaptation. Paper 2 offers a simplistic, agent-oriented perspective that highlights basic differences between feedback and feedforward systems (i.e. the adaptationist versus the limitationist or realist perspectives). In their description of the fundamental elements of planning (i.e. data, predictive models, vetting systems), MacLellan and Fenech do not pretend to completeness nor do they offer an ideal (i.e. as with Lindblom's notion of synoptic rationality). They simply present a vantage point from which the artificial nature of planning systems becomes self-evident (i.e. a human construct used to mediate our relationship with the environment). Taken as such, their framework can be interpreted heuristically as providing scaffolding for the relationships between apparently discordant planning components (i.e. data, knowledge, models, consultative systems, etc.). This framework is used to organise the various models developed by AIRD.

Paper 3 - 'Climate Change Adaptation for Neophytes' - is meant to introduce the fundamental elements of climate change adaptation as they are interpreted in the literature. The way a topic is perceived in the literature and the way it is interpreted locally is an important distinction which is addressed later in Paper 8 on the local/global dialectic. The more general purpose of Paper 3 is twofold: in the first case, the article is a straightforward guide to the climate change adaptation literature for researchers who have not had that much exposure to the field (i.e. neophytes). Paper 3 is intended to provide the language and content of the CCA field to a wider audience so they can partake in, and add to, the discussion. The second purpose of Paper 3 is to provide a foundation for planning itself. The problem with the concept of adaptation is that it is promiscuous: it appears to be all things to all people. Where then, does a local planning exercise begin? As a starting point, because of the formal structure of scientific literature, we can easily determine what is important to scientists by simply measuring what they have published through bibliometrics. What is discovered, for instance, is that scientists talk a lot about agriculture and water. Clearly it would be wise to take these two sectors into consideration when devising a climate change adaptation plan. But MacLellan's framework is just as informative for identifying what is missing. The field does not have that much to say about biodiversity conservation or ecosystem services for instance. Clearly these are critical issues, but they may be under-represented in the literature and may therefore be potential areas of future research.

In Part II, the evolution of a planning methodology is discussed within the context of the Regional Municipality of Halton. The approach is actually composed of a suite of methodologies that are collectively referred to as RACe (**R**apid **A**ssessment to **C**limat**e**). The starting point for this approach is RAICC (Rapid Assessment of the Impacts for Climate Change). The objective of the exercise was to develop a planning process that integrates the various resources of the AIRD research community (which also includes various university, government and private enterprise partners) into a framework that can be used in CCA planning exercises. The authors take as their starting point the output of climate models. Halton is used as the context for the development and application of this RACe methodology. Halton is appropriate precisely because it will not be overwhelmed by sea level rise or desertification, yet it is subject to numerous influences that a majority of Canadians will experience.

The Municipality of Halton is a regional Ontario government within southern Canada, representing approximately 400,000 constituents, spread over 967.17 km^2. In the north, the landscape is predominantly rural (agricultural and forested) despite recent dramatic growth in the towns of Milton and Halton Hills. The major environmental feature is the Niagara Escarpment, a prominent topographical feature of Southern Ontario[9]. In the south, Halton is dominated by the presence of Lake Ontario which is the 14th largest freshwater lake in the world. In addition to its important economic services such as supplying fresh water, transportation and recreational opportunities, the lake also provides many important environmental services, such as climate amelioration and biodiversity maintenance.

Within this ecologically diverse and complex environment exists an equally diverse and complex, social, economic, and cultural environment. Halton is part of the Greater Toronto Area (GTA) as well as the Greater Golden Horseshoe, which together represent the most industrialized region in Canada. This area had the largest population and industrialization growth rates of any region in Canada between 2001 and 2006 (Statistics Canada, 2007). And within it, the town of Milton grew the most, by an astonishing 71.4 percent. As described, Halton represents a very interesting mix of factors which climate change will affect in numerous and interrelated ways. How does one approach the issue of climate change adaptation within such a complex urban environment system?

Fenech and MacLellan's solution in Paper 4 represents an incremental approach that starts with climate. In the simplest of decision frameworks, a proactive response to climate change involves three successive steps: 1) determining future climate; 2) determining the impacts of future climate change; 3) formulating and implementing that response. This requires the integration of data, predictive models and a possibility/scenario vetting process. A fourth overarching step 4) includes intentional learning (i.e. adaptive management techniques, or reflexive methodologies) which can be applied to all of the previous stages. According to Fussel (2007) this basic linear framework is

9 The Niagara Escarpment is an UNESCO Biosphere Reserve.

complicated by factors such as current climate variability, future climate change, non-climate factors and their development; policy and management context; current and future climate risks; sustainable development goals; mainstreaming of adaptation; and other policy criteria. The actual ecological and social environment can make this linear framework exceeding complex.

Paper 4 applies RAICC - a rapid, low-cost, scoping exercise set within a larger CCA planning platform that provides institutional support, tools, methodologies, data, expertise, and national and international linkages. It is intended to be simple, transferable, built on existing tools, linked to the global academic community and to present the decision maker with a relative risk assessment. The approach connects climate models to policy and decision-making by identifying the risks of climate change to various social and economic sectors as well as the natural environment within a given locality, or municipality. It is premised on the idea that municipalities require an initial overview of the potential impacts of climate change and an initial means of prioritizing those impacts for further consideration. The choice and prioritization of sectors should reflect local circumstances, yet also inform regional, national and international programs through an upscaling procedure currently under development.

Paper 5 presents some direction on *muddling through* the wide selection of climate models available to provide projections of future climate change. All are mathematical models that simulate the functioning of the global climate system varying in size, scope, scale and complexity. The fourth, and most recent, assessment of the Intergovernmental Panel on Climate Change (IPCC) provides projections of future climate change using twenty-four global climate models under three major greenhouse gas emission scenarios. These provide for a wide range of possible outcomes when trying to inform managers about possible future climate changes. In order to narrow the projections to a handful of models that could be used in a climate change impact study, three approaches are taken – extremes (max/min) approach; ensemble approach; and validation approach. The extremes (max/min) approach suggests that it is best to plan within the full range of possibilities that the ~72 GCM scenarios present. The approach takes the projection for the maximum change, as well as the projection for the minimum change, and uses both as the range of consideration when planning. The ensemble approach suggests that it is best to plan for the average change of all the models. The approach uses a mean or median of all the models (or many models) to reduce the uncertainty associated with any individual model. The validation approach suggests that those models that compare well to historical climate observations should be the ones used for planning. The approach takes the historical climate observations over a thirty-year period from a global gridded dataset (for example, the National Centres for Environmental Prediction (NCEP)) and compares this against all models to see which ones reproduce the values best. Subsequently, only the four or five best-agreement models are used to produce the validated projections for planning. Using all three approaches, the future projections of climate for Halton Region are presented.

Paper 6 considers the impact of climate change on indicators in ten economic and ecological sectors of Halton Region including forestry, fisheries, agriculture, built environment, human health, tourism, transportation, water quality, energy, and biodiversity. A literature review on the impacts of climate change was conducted for each of the 10 eco-sectors, and one climate-sensitive indicator (factors sensitive to temperature and precipitation were selected) per eco-sector was examined for illustrative purposes. These sensitivities are triggered at certain climate thresholds, above or below which result in significant changes that may require some form of human intervention, so-called "adaptation thresholds". These thresholds were examined using data from Halton Region's past observations and future modelling. A relative risk ranking of eco-sectors sensitive to climate change was conducted by modifying Ontario's Hazard Identification and Risk Assessment (HIRA) approach, and applying it to the Halton Region.

A complete view of the climate change impacts picture for Halton is not sought. Instead an attempt is made to create a system that proactively emerges from its shortcomings, *muddling* iteratively towards a fuller view of the possible. Changes can be positive (opportunities) or negative (vulnerabilities) and exist over a gradient of outcomes. The intent is to identify those points where a specific sector is sensitive to extremes of temperature and precipitation. But finding a common measure between sectors is problematic. The author offers a simple yet elegant solution, which affords for their comparison. In this stage, the previous analysis is condensed into a single matrix which describes the relative regional risks associated with the indices that represent a given sector. The Relative Risk Ranking (RRR) uses data from Halton Region observations and models, to project past and future impacts, which are then placed within a framework that allows for their easy comparison.

Paper 7 examines the relationship central to the challenge of responding to climate change between the experts who produce counterfactual knowledge, and the individuals who apply it. Awareness of the possibility of human-induced climate change is foremost a product of modern science, yet local access to this highly abstract knowledge is necessarily limited. Alternatively, access by experts to the particularities of local circumstances, typically presumed by various methodologies of rational analysis, is also inherently limited. MacLellan adopts the position that a local\global dialectic exists in the context of climate change adaption; the challenge is to broker this relationship towards actions beneficial to local stakeholders. A heuristic is developed that is intended to aid in the exchange of knowledge between highly abstract, synoptic planning systems versus experientially and procedurally rich, local systems that are oriented to the particular. This method is intended to identify and complement the competencies of both systems within the context of climate change adaptation action. A specific case study that partners a high level of local planning acumen, (i.e. the planning community within the Regional Municipality of Halton) with expertise in climatic modeling and impacts (i.e. the Adaptation Impacts Research Division of Environment Canada) is used to demonstrate the utility of the method.

Paper 8 visits an approach applied earlier to link climate data analysis to assist communities in planning for climate change adaptation. Communities have long been clear on their need for information on extremes of climate so that they can determine how they have adapted in the past to these extremes, and how to best plan for these in the future. By showing biosphere reserve communities how the climate has changed in the past, the question can be asked as to how they have adapted to these changes. Years of climate extremes may have required intervention from the community to save agricultural crops, preserve endangered species habitat, or ensure the quality of groundwater. This knowledge, taken together with scenarios of future climate change showing similar extreme hot or dry years in the future (i.e. changed return periods), can identify some adaptation measures that might be taken to ensure that an adaptation infrastructure is in place, or that alternative management of the biosphere reserve occurs. In other words, what lessons did the community learn from the last event that can be drawn on with advanced knowledge about the future to minimize the negative impacts and maximize the benefits from climate change? The authors title this approach Adaptation Through Learning (ATL), and the paper provides an example from Canada.

Part III of this volume focuses on 'adaptation extensions' – specifically the concept of climate change adaptation, mitigation and sustainable development (AMSD); the application of geographic information systems (GIS) in climate change impact and adaptation analysis; and upscaling approaches to inform policy at the global level.

Paper 9 addresses the concept of climate change adaptation, mitigation and sustainable development (AMSD). Exploring linkages between climate change and sustainable development to propose 'win – win' solutions is currently one of the priorities of the Intergovernmental Panel on Climate Change (IPCC). Although current approaches tend to view adaptation and mitigation as two separated fields, it is becoming increasingly recognized that climate change mitigation could have adaptation benefits and vice-versa. In addition, adaptation and mitigation responses to climate change, taking into account principles of sustainable development, could improve long-term development planning initiatives. However, linking sustainable development with responses to climate change may pose significant demands on both researchers and policy-makers. Bizikova demonstrates that there is a considerable interests both from the researchers' and practitioners' community to explore synergies between adaptation and mitigation when the focus is on addressing local sustainable development challenges that frames responses to climate change and creates opportunities to involve local-specific value-based participatory approaches.

Paper 10 presents geographic information systems (GIS) as a tool to allow for interdisciplinary efforts to foster collaborative science, spatial data interoperability, and knowledge sharing in climate change impacts and adaptation studies. The use of GIS has made data sets compatible, and created a bridge between the atmospheric sciences, geography, ecology, other more spatially-based sciences, and the natural resource management and planning communities. There is a need for better integration of datasets/models with GIS to address climate change issues, particularly for adaptation, mitigation and sustainable development at the practitioner level. Rong and Fenech present a framework in the form of a Web-GIS based Climate Change Impact and Adaptation Integrated Assessment Tool (CCIAT). This three-tier system framework is based on the J2EE technologies, and includes different web services linking climate model outputs to feed into impact models. A database server was setup to support various applications and online access to decision-support tools was provided. Overall, WEBGIS is the "great integrating technology" when used for climate change impacts and adaptation research.

The final paper in the volume – Paper 11 – considers upscaling as an approach to inform adaptation policy at the global level. Adaptation is recognised as an important part of climate change policy agenda, but it has received less attention and support than mitigation for a variety of reasons having to do with the social construction of climate change as an environmental pollution issue. Burton *et al.* identify and briefly explore four approaches that might help to transform the way in which climate change is socially constructed including i) the qualitative accumulation of case study evidence, ii) meta-analysis, iii) adaptation modelling, and iv) the integration of adaptation with mitigation in case studies and in models. The authors argue that reliance upon the qualitative accumulation of case study evidence is not sufficient by itself to bring about the required redress. This does not mean that such studies should be abandoned; rather it is argued that detailed local studies involving stakeholders and those at risk are an essential component of adaptation. However, in addition to the strengthening of place-based adaptation research, it is proposed that the three other options considered suggest that case studies should be designed with sufficiently similar topics, focuses, and methods to investigate and develop the possibilities of meta-analysis.

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