GETTING ADDITIONAL INFORMATION

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Some important questions for climate impact assessment are: How does current climate affect human and natural activities? How will climate change impact human and natural systems? What are the linkages between climate and a particular activity, or climate and an area? What are the sensitivities? What are the vulnerabilities? Are there significant thresholds? How do we adapt to the current climate – its variability and extremes and how we might adapt or respond to future climate change?

The climate change issue is exceedingly complex. There are many information needs. In our group (Adaptation and Impacts Research Group formerly Environmental Adaptation Research Group), we focus on *direct impact*s of climate change but there is also value in considering *indirect impact*s. The challenges are identifying the problems/impacts and developing solutions-adaptation. In terms of adapting and assessing our vulnerability to climate, we need to consider impacts of climate change, extreme events, and the cost of the "normal" climate (e.g., water resources management and planning is a cost of adapting to our current climate). Adaptation can become a maladaptation; one of our researchers described how crop insurance may impede adapting to climate variability in agriculture. By studying the impact of a 2 x CO_2 scenario, we identify the costs of the future climate, and how we could adapt. Since countries are having difficulties reducing their emissions and concentrations of greenhouse gases continue to increase, we should assess the impacts of 3 x and 4 x CO_2 .

In the remainder of my presentation, I will outline information needs on themes relevant to the discussion at this workshop. I will draw upon my experiences from the *Great Lakes – St. Lawrence Basin Project* and the *Canada County Study*.

Scenarios. Consider temperature and precipitation changes in the Great Lakes basin. The current climate change scenarios from GCMs (General Circulation Models) do not incorporate the aerosol influence. Some people think that global warming is not occurring in the Great Lakes area because there has been little measured temperature change (approximately 0.5 ºC). But the warming within our region in the short term may be masked due to cooling by sulfate aerosols.

We use climate change scenarios as plausible futures or "what if " conditions. We provide this information on the Great Lakes basin to give some boundaries for planning and to illustrate the seriousness of the issue. Scenarios are not predictions. But consider: "what if" temperature within this region increased 4-9 ºC in the winter? "What if" in the summer, it went up 4-6 ºC? "What if" precipitation went down by 10% or up by 20%? For the Great Lakes-St. Lawrence basin, the scenarios indicate an increase in temperature but precipitation change is variable.

Assessment Design

In the *Great Lakes-St. Lawrence Basin* (GLSLB) *Project,* we used a matrix (Figure 1) as a framework to guide the content of studies and their integration. We chose four *climate sensitive theme* areas – water use and management, ecosystem health, human health, and land use and management. The studies were also to address key *cross-cutting research topics*: climate and biophysical systems or impacts, socioeconomic impacts, adaptation, and also

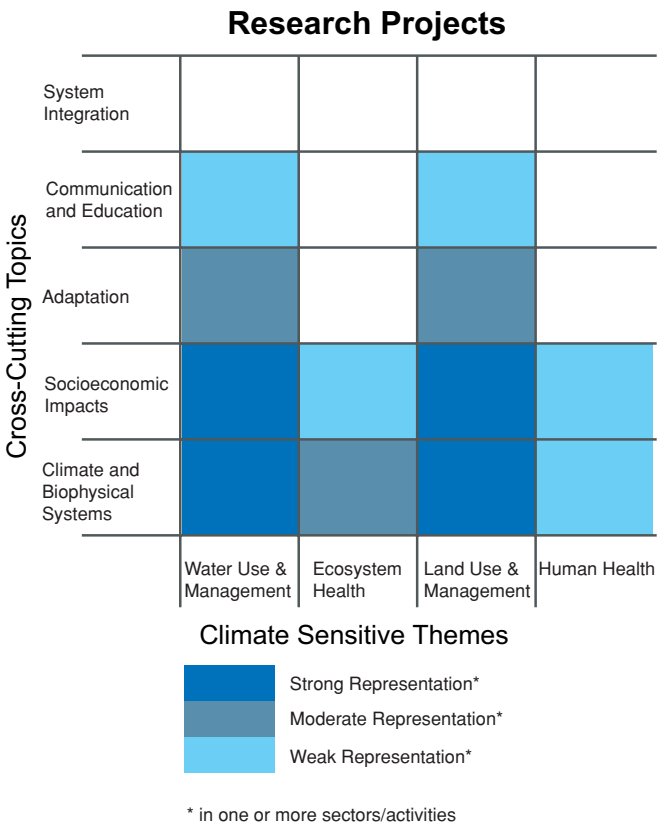

Figure 1: Great Lakes-St. Lawrence Basin Project research matrix. The cross-cutting research topics are identified by rows (e.g., System Integration, Communication & Education, Socioeconomic impacts, etc.)

communication and education. The color graph (Figure 1) shows that in some theme areas these topics were better integrated than in others. Water use and management and land use and management have a long history of being sensitive and vulnerable to climate, and the assessments are more advanced. Ecosystem health is next, and human health is an assessment area that is in its infancy (we had two studies). One key gap was that we do not have a good understanding of urban impacts of climate change. We did not address that particularly well in our Project.

What were some of the objectives of our assessment? We wanted to identify "no regrets" strategies. I guess, in a sense, it is hedging the uncertainty with respect to the scenarios for future climate. What adaptation strategies make sense now, in terms of addressing climate variability and climate change and other known environmental problems and make sense irrespective of how much the climate changes? We wanted to express the impacts in simple terms, so that we could work with decision makers and policy makers. We wanted to highlight social, economic, and political impacts, develop some vulnerability indices (we did not do that very well), and also provide some guidance on the divergence of information. For example, Great Lakes lake levels were recently at an all-time high, and our scenarios suggest water levels might drop 20 cm-2.5 m. One question that emerged frequently in our impact discussions was "what are the impacts of extreme events?" We need methods for developing scenarios to address that particular problem.

Water Resources. In the *Canada Country Study* and in the *Great Lakes – St. Lawrence Basin Projec*t one of the water resources issues that was considered critical was groundwater – the bottom line is we do not know very much about it. First, we do not have an inventory of how much groundwater is in the Great Lakes basin (at least, I am sure that is true for the Ontario side). Therefore, it is extremely difficult to assess the impacts. I know of one study in the Great Lakes region on ground water impacts of climate change scenarios (Grand River Basin in Ontario). There is a new study characterizing the regional ground water hydrology for southwestern Ontario to assess climate change impacts – the results will be extremely interesting.

Some of the information requirements that emerged from the 1997 Symposium on "Adapting to climate change and variability in the Great Lakes – St. Lawrence Basin" were integrating water quantity studies with water quality studies, and integrating these results into policies such as the Great Lakes Water Quality Agreement. Other questions relate to adaptation – how do we respond to climate change? How do we

better conserve water? How do we value water more appropriately?

Land and Water Ecology. Ecosystem characteristics and functioning – how might they be affected by climate change? Consider climate change interacting with other air issues such as acidification. A study reported that pH levels in small lakes in the Dorset area, north of Toronto, were recovering because of reductions in sulfur dioxide and then pH remained constant – this is [likely] tied to drought effects.

Exotics and Their Effects on Native Species are an Important Issue

In the Great Lakes basin protection, remediation, and restoration of habitat is important. The case that I am familiar with is wetlands. We want to protect, remediate, and restore existing wetlands and to secure more wetlands. But what are the impacts of climate change on hydrology, water level changes, and precipitation and how will these changes affect wetlands and our success at remediation?

Boreal forests [may] decline in certain areas. Why? How? What are the impacts of droughts and fires? [These are] Extremely important [questions].

Agriculture. Mike Brklacich (who was a lead author for the Agricultural Chapter in the *Canada Country Study*) reviewed climate change and agriculture research in Canada. He found that we have done a fair amount of assessment on agro-climatic properties, (e.g., the number of freeze-free days, growing-degree days, etc.) and what climate change means to those agro-climatic properties in the Great Lakes region. We have looked at productivity changes for individual crops and land, in certain regions of Canada, such as Ontario. Also, grain crops such as corn and wheat, are better understood than specialty crops, like potatoes. Brklacich recommends studying the indirect impacts of climate change on international agriculture on Canadian agriculture e.g., Russia's production of grain potentially increasing and changing patterns of migration affecting demand for food. How does climate change affect international agricultural economics and the competitive advantage or disadvantage of a particular region? He also talks about mitigation and adaptation, preventing climate change by using cropping and tillage practices to enhance CO_2 uptake, and coping mechanisms to deal with the impacts of climate change. There is the issue of what climate change means to agricultural economics at the farm level, individual farm-level decision making, and the farmers' bottom line, and how this translates to the economy within a region, and also within a country.

Human Health. The topic of human health within our Project was addressed in a limited fashion. We looked at the incidence of heat stress and the potential for malaria in Toronto. I think human health is an extremely important theme because it can make climate change "personal." Important policy changes may be made, if it means protecting human health. Research on human health effects should explore the relationship between warmer air temperatures and potential increase in air pollution such as smog in Windsor and other areas, and trends in extreme events (e.g., storm tracks, heat waves, storms, and floods). Another area that should receive attention is [evaluating] what are the risks of infectious diseases for a particular region? For example, the risk of malaria increases for the Toronto region, because of favourable temperature conditions for certain mosquitoes. This is a potential stress on the health care system and we need to examine ways to respond to that risk. We need case studies on the health and well being of people – the physical and psychological health – in response to extreme events such as heat waves, floods, etc.

Economy & Commerce. Some of the questions that emerged from discussions in the

GLSLB Project were: What are the costs of impacts? What are the costs of adaptation? For example, in agriculture, farmers can adapt, but we need to assess the "costs" of adaptation in terms of money, technology, new research efforts as well as the best timing for adaptive measures. How do the costs of adaptation compare from one region to another? What are the costs to take advantage of opportunities? What activities might we lose because of climate change? Historical analogues, such as the 1988 drought, provide information on past extreme events, the economic impacts, and how people responded.

One study for the GLSLB Project, assessed the economic impact of two climate change scenarios. Impacts were represented by productivity changes in agriculture, forestry, fishery, hydro-electricity generation and commercial navigation (about 10% of the Ontario economy by employment) in an Input-Output Model, called LINK. The "net" impact on the Ontario economy was assessed. One scenario showed a very small positive gain, and the other showed a small negative impact on the economy. "Net" economic impact fails to represent the distributive effects; one number does not present which regions have gains, which regions will be affected, and how that will play out in the policy and the decision making for Ontario. This method has to be used carefully.

Another area that needs serious consideration is economic tools that we can use to promote adapting to impacts of climate change, such as conservation of water or energy.

Governance. There are significant governance issues in the Great Lakes – St. Lawrence Basin on water apportionment, for example. The Niagara River Treaty involves apportioning water between Canada and the US for hydroelectric generation and tourism to maintain sufficient flow over Niagara Falls. This treaty may be re-negotiated soon.

Lakes Superior and Ontario are regulated. For example, Lake Ontario is regulated to maintain water levels for navigation, recreation, hydroelectric generation and to prevent shoreline erosion. We have the potential for upstream and downstream conflicts. If you have significantly lower water levels in Lake Ontario because of climate change, studies indicate that the regulation plan fails. The issue becomes how to effectively regulate to maintain lake levels within Lake Ontario and to meet minimum flow targets for hydroelectric generating needs and levels for Port of Montreal navigation. What are the economic impacts to the Port of Montreal if flow in the St. Lawrence River decreases 20-40%?

Through the Great Lakes Water Quality Agreement, 43 areas of concern (AOCs) have been identified within the Great Lakes. These areas need remediation to enhance and bring back beneficial uses. The Remedial Action Plans (RAPs) for the 43 AOCs have not considered climate variability or potential climate change. We are assessing the impact of climate change in one RAP by studying the Bay of Quinte watershed. Lakewide Management Plans (LAMPs) are being developed for the Great Lakes – they are starting to consider climate change, which is of great interest to me.

One of the questions that came out of the 1997 symposium was "Are there any adaptations that could be harmonized on a bilateral basis … or a strategy for integrated adaptation?"

Communication. Communication has repeatedly emerged as an important need. In the early 1980s, communication and climate change were not issues – and now they are very important. We realize that we need to build stakeholder participation and public awareness, understand-

ing, and (hopefully) action into climate impact assessment.

We need to communicate our probabilistic data more effectively. The general public and many stakeholders do not understand our science in terms of probabilities and uncertainties. People want information on what is known and what is certain about climate change. Scientists always talk about uncertainties. Barry Smit illustrated a communication problem. "We scientists talk in terms of mean climate change such as temperature …." Perhaps some of the problem in communication is that we are not using the right words to talk to our stakeholders. For instance, when talking to people in the wine industry in southern Ontario, we might refer to "the mean temperature in winter." What we really should say to them is, "your ice wine industry – the one you rely on for freezing temperatures … Actually, no other conditions in the world are quite as good for ice wines …The conditions may no longer occur because of climate change." You would have their attention because you are talking about something to which they can relate.

I think that it is encouraging to have the climate change research agenda driven in partnership with stakeholders. A successful strategy is local stakeholder forums within, for example, watersheds. One of the studies in the GLSLB Project approached farmers' groups in Quebec and held forums and outreach sessions with the farmers, to get feedback and help answer their questions on climate change impacts and adaptation.

Adaptation. Once some of the impacts have been identified – we have to think about how we are going to cope with climate change. We need to define operationally what we mean by adaptation and maladaptation. What is the process of adaptation? What do you have to do to adapt? What are the costs? A schematic (Figure 2) by Burton et al., 1993 identifies potential adaptation strategies. *Share the loss*. Use insurance. *Bear the loss*. If you build in a flood plain and it floods, you are on your own. *Modify the events*. *Prevent the effects*. Use structural, technological innovation, and legislative, regulatory, financial, institutional, administrative changes, market-based incentives, and changes in on-site operations. *Research.* Consider *education* and promoting *behavioral change*. *Avoid the impacts*. Some adaptations to consider are changing your use or your location.

Why adapt? Climate is not constant. It has a range of conditions and it creates uncertainty. So, adaptation is a way of responding to the uncertainty in our information. We have both opportunities and risks that we should consider. Think about how you might respond – do not necessarily respond –

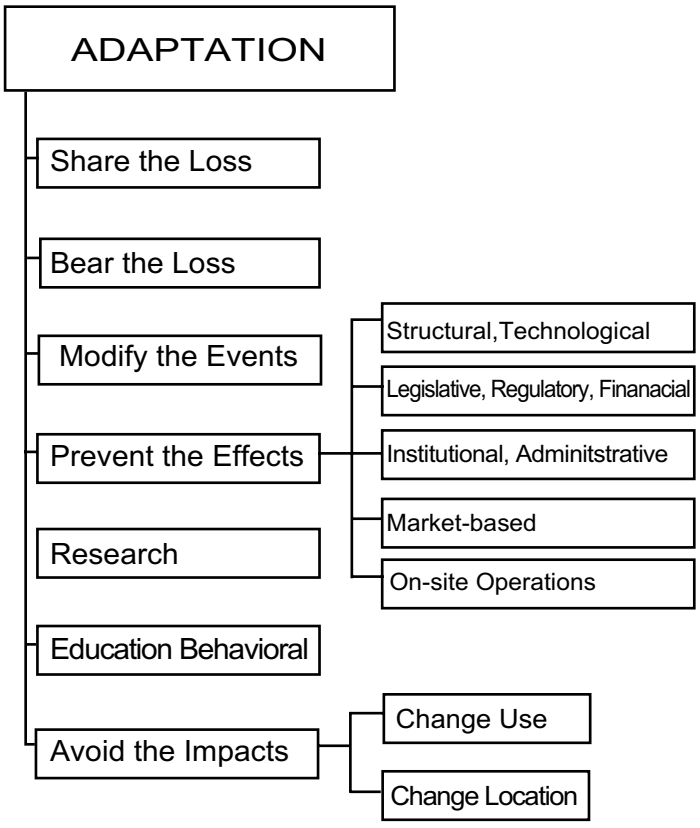

Figure 2: A conceptual framework of adaptation. Source: adapted from Burton et al., 1993.

but at least think about climate change impacts and adaptation in a proactive manner. Also, our experiences are based on past climate, and it may not be a reliable guide in the future.

Advances in Methodology. What do you need to do? Some ideas for innovation are listed in Figure 3. The current studies portion lists what we tried to accomplish in the Great Lakes-St. Lawrence Basin Project as well as other studies in Canada. Impacts in sectors need to be integrated. For example, agriculture researchers should talk to the water resources people. We are starting to make those linkages and beginning to integrate on a cross-sectoral basis.

In most cases, we have always used 2 x CO_2 equilibrium scenarios which is an artifact of the modelling exercise. We need to address current climate variability and what it means. We also need to get a better picture of 2 x CO_2 and beyond to 3 x CO_2 and 4 x CO_2. This is necessary, because people will get the impression that the changing climate is going to stop at 2 x CO_2 and it will not. The Intergovernmental Panel on Climate Change (IPCC) has identified a number of GCM scenarios that will be available to impacts researchers around the world for the next assessment (on a web site). There will be three or four model results available, which will lead to some continuity in scenario use.

[In past climate impact assessments, we have assumed that] Everything-else-remains-equal (EERE) – society, economy, technology – and that climate change is imposed in the future on a region, a sector, an activity that has remained the same. We need social and economic scenarios that [do not] simply acknowledge an increase in population in a region, but include an increase in a demand for water, a change in technology and perhaps chart a different development paradigm. In the past we have focused on the biophysical impacts. We still do. That is the closest link, the most obvious and the easiest link to climate – but we have to develop methods to analyze the economic, social and policy implications as well.

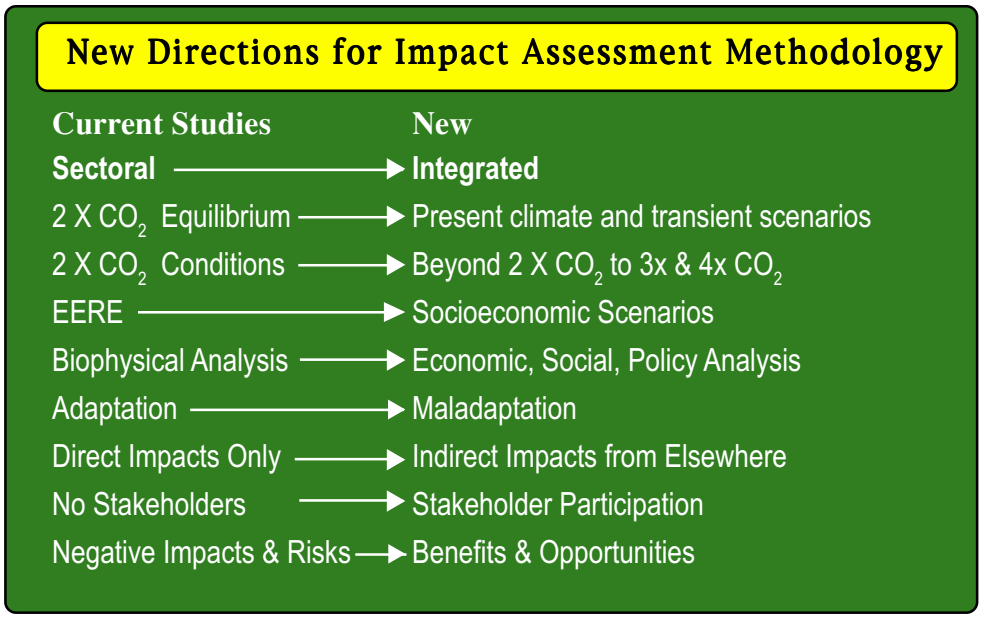

Figure 3: New directions for climate change impact assessment methodology.

In the GLSLB Project, we initiated research on adaptation. We also have to think about maladaptation. A recent research proposal for the Prairies of Canada described adaptation to drought only in terms of technology and finding new supplies of groundwater to augment irrigation for agriculture. We need to think more broadly than that and consider institutional and behavioural changes.

In the past we have looked only at direct impacts – an impact on a region, an activity – we need to consider indirect impacts from outside our region.

We need to include stakeholders (e.g., Sierra Club). They make valid contributions on identifying research needs and communicating impacts and adaptation.

We have always focused on negative impacts and only the risks. In some instances, like a study in the Arctic for the oil industry on decreasing in ice cover and potential increase in storm surge, the stakeholder only wanted information on the negative impacts so they could respond. But I think we have to acknowledge that there may be some benefits and opportunities to climate change and position ourselves to take advantage of those conditions.

In conclusion, part of the role of our impacts work is to help decision makers, policy makers, and the public to pay attention to the climate change issue and help them plan for the future. Use this goal to help guide future research.