Measuring the Impacts of Climate Change

Are Central Statistical Offices Prepared to Track the Impacts of Climate Change?

Conference on Climate Change and Official Statistics

Oslo, Norway

14-16 April 2008

Michael Bordt and Robert Smith

Environment Accounts and Statistics Division

Statistics Canada

Table of contents

1 Introduction – Scope and purpose

Central statistical agencies and agencies that produce official statistics have been essential to tracking economic and social phenomena for the past 90 years. Over the past 30 years, they have developed some capacity for analysing environmental phenomena and linking them to the social and economic trends. Recently, statistical agencies have been improving their understanding and measurement of the linkages and consolidating these relationships in sets of environmental accounts.

Climate change has the potential to create a wide range of biophysical, social and economic impacts. The paper will highlight (a) the range of expected biophysical, social and economic impacts due to climate change (b) and examine environmental accounts and other statistical and data frameworks to evaluate their ability to track these impacts. Statistics Canada's experience will be used as an example of what can be done in practical terms. The paper will conclude with a discussion of what is missing and suggest priorities for filling perceived gaps.

The paper focuses on direct biophysical, social and economic impacts from a Canadian perspective. It is recognized that other countries are subject to impacts different from Canada and that secondary impacts are also necessary to consider. However, these are not treated exhaustively in this paper.

2 Expected impacts of climate change

Climate change is predicted to affect all Canadians to a greater or lesser extent as a result of its impact on their environment, society and economy. Climate changes are expected to vary regionally. While it is not possible to predict changes with certainty, there is a very high degree of agreement among scientists that changes are already occurring and that further changes will occur. Expected changes in Canada include warmer winters, more frequent summer heat waves, changes in precipitation, changes in wind patterns, and an increased frequency of severe storms. Warming is expected to be most pronounced in arctic regions, causing permafrost to melt and glaciers to retreat more quickly (Field et al. 2007).

Canadians will face challenges in managing the effects of climate change. Regional droughts may result in water shortages. Rising sea levels and heavy precipitation events may lead to greater flood damage. Warmer temperatures will favour more frequent thunderstorms and tornadoes.

This section provides a brief overview of the climate change impacts that are predicted to affect Canada. It is important to keep in mind that these impacts will vary greatly, due to the diversity of climates, landscapes, communities and economies occurring within the country.

2.1 Biophysical Impacts

2.1.1 Changes in climate patterns

Canada has, on average, warmed by more than 1.3 degrees Celsius since 1948 (Natural Resources Canada 2007). All of Canada is projected to continue warming during the next 80 years, although warming will not be uniform across the country. Temperature increases

this century are projected to be greatest in the high Arctic and in the central portions of the country.

Changes in national precipitation trends are difficult to track and even more difficult to predict. Some regions, like the high Arctic, are predicted to become significantly wetter (Natural Resources Canada 2007). Other areas are expected to receive lower amounts of summer rainfall. These changes will affect the hydrologic patterns in regions throughout Canada.

Also affecting hydrologic patterns is the possibility of glaciers melting. Glaciers play an important role in the provision of fresh water in some parts of Canada. However, some glaciers in the Rocky Mountains are receding and thinning, resulting in decreases in glacial streamflow during the critical driest months of the year. For example, the total glacial area in the North Saskatchewan River Basin decreased 23% from 1975 to 1998 (Dumuth 2007).

While single storm events cannot be attributed to climate change, scientists predict that climate change will affect storm patterns and result in increased storm activity (Solomon *et al.* 2007). Extreme weather events such as storms, floods, hurricanes and tornadoes can have devastating consequences. Economic losses from extreme events and natural disturbances can be very high, and are difficult to predict. As was the case with the 1998 ice storm in Ontario and Quebec, employment, retail trade, land cover and the viability of specific economic sectors can all be affected by extreme weather events (Statistics Canada 1998).

2.1.2 Shifting of land use cover and impacts on species and habitat distribution

The influence of climate change on Canada's habitats and ecosystems will depend greatly on factors such as species composition, site conditions and local microclimate (Natural Resources Canada 2004). Climate instability may lead to habitat change and species migrations. However, migrations may not always be successful either due to rapid change in weather patterns or to habitat fragmentation.

Rising sea levels due to climate change may also affect land cover by altering the extent and nature of coastal habitat.

2.2 Social Impacts

2.2.1 Health

Climate change has the potential to have a significant impact the health of Canadians. These impacts may be direct, occasioning increases in weather-related conditions such as heat stroke, heat exhaustion and cardio-respiratory diseases (Environment Canada 2007). Other impacts may be less direct, such as changing disease vectors, pollutant levels and risks of natural disasters.

Higher air temperatures may lead to greater levels of ground-level ozone. Observed health effects of human exposure to ozone and particulate matter include respiratory symptoms such as coughing, triggering of asthma attacks and episodes of chronic bronchitis, emphysema, angina and other heart conditions (Statistics Canada, Environment Canada and Health Canada 2007).

Climate change may also increase the incidence and distribution of vector-borne diseases. Warmer conditions could encourage the northern migration of mosquitoes, ticks and fleas

that could then increase the incidence of diseases such as West Nile virus, malaria and Lyme disease (Natural Resources Canada 2004).

2.2.2 Loss of cultural resources and values (particularly in the North)

Subsistence hunting and other uses of natural resources are central to the culture of many Aboriginal communities. The subsistence economy may constitute one-half to one-quarter of the total economy of these communities and be worth about $15,000 per household in the Arctic (Berkes and Fast 1996 in Natural Resources Canada 2007), although the full range of values allocated to the use of resources are broad and go beyond economic issues.

2.2.3 Changes in population distribution

Climate change could impact the viability of some economic activities. Such changes could lead to population redistribution.

Although agriculture, forestry, fishing and hunting account for only about 2% of Canada's GDP, many communities depend on the viability of these economic sectors for survival. For instance, more than 1,600 Canadian communities are more than 30% reliant on one or more climate-dependant industries (i.e., agriculture, forestry, fishing and hunting) for their economic well-being (Natural Resources Canada 2007).

2.3 Economic Impacts

2.3.1 Effects on agriculture and forestry

Both agriculture and forestry are very sensitive to climate patterns, including temperature and moisture availability. Climate change is expected to have both a positive and negative impact on agriculture in the short term. Warmer climate patterns may increase the growing season, but may also occasion heat stress as well as water and pest problems (Natural Resources Canada 2004). Specific impacts will vary by crop and by region.

Changes in the frequency and intensity of extreme weather events (such as droughts, extreme heat and storms) are some of the main climate change impacts faced by the agricultural sector.

In a similar way, changes in climate patterns can significantly affect Canada's forest cover. Future climate change is expected to affect species distribution and forest productivity (Natural Resources Canada 2004).

Patterns of disturbance, such as pests and forest fires, are also affected by climate. Changes in these patterns, in fact, threaten to overwhelm more gradual species and land cover changes described above. Disturbances present a particularly important concern for the forestry sector (Natural Resources Canada 2004). The severity of fire seasons is generally expected to worsen and the risk of forest fires to increase across most of the country (Natural Resources Canada 2004).

2.3.2 Effects on fisheries and aquaculture

Shifting climate conditions could lead to changes in water temperature, water levels, number of extreme weather events, ice cover, diseases and shifts in predator-prey

dynamics (Natural Resources Canada 2004). All of these impacts could have a significant impact on the extent and distribution of fish populations.

Toxic algal blooms, which may increase due to warmer weather patterns, will also have a negative impact on aquatic life.

2.3.3 Changes in energy demand patterns

Changes in climate patterns will almost certainly have an impact on energy use. For instance, warmer summers could continue to increase peak summer electrical loads due to demands for cooling. However, heating demands may decline with the advent of warmer winters.

2.3.4 Impact on transportation and access to resources

Transportation may be impacted by climate change through shifts in temperature and precipitation, increased numbers of extreme weather events, and changes in water levels (Natural Resources Canada 2004).

Milder winter weather is expected to inflict less damage to the transportation infrastructure and to occasion fewer weather-related accidents. However, the possibility of a greater number of extreme weather events could have a significant impact on traveler safety and on road infrastructure maintenance.

With regard to commercial transport in the south of Canada, Great Lakes shipping and coastal infrastructure are particularly vulnerable to climate change impacts.

Perhaps the most vulnerable transportation infrastructure in Canada is associated with the many winter-only roads that occur in Canada's North. These roads sometimes form the only road transportation link to northern communities.

Several winter roads are of critical importance to resource extraction. For instance, the longest winter road in Canada, 600 km in length, is the main supply road for the Ekati and Diavik diamond mines, the Snap Lake and Jericho mine developments and several other mineral exploration projects (Natural Resources Canada 2007).

2.3.5 Impact on infrastructure and utilities

The three most vulnerable areas of Canada's infrastructure are winter roads (mentioned above), coastal erosion and permafrost degradation (Natural Resources Canada 2007). Many types of infrastructure are currently dependant on permafrost, including buildings and other facilities such as retention ponds for hazardous materials.

Changes in hydrological regimes can also lead to infrastructure impacts. Hydro-electric facilities, for instance, can be affected due to changes in water flow. Water treatment plants may also have to content with increased levels of bacterial, nutrient and other contaminants.

2.3.6 Changes in prices

The cost of resources and services may change, both within Canada and internationally. These changes will be both positive and negative for Canada (Natural Resources Canada 2007). Although a comprehensive review of changes is not within the scope of this

paper, climate change could impact the costs of energy. Food prices may increase due to changes in crop viability. Many of the impacts mentioned above may result in more general price increases, though these are difficult to predict.

3 The role of statistical infrastructure in measuring climate change impacts

The section discusses the infrastructure – frameworks and knowledge – required by statistical offices if they are to respond ideally to measuring the impacts of climate change.

3.1 Frameworks

By frameworks, we mean the tools we use to give structure to statistics. These include conceptual frameworks; measurement frameworks, like the System of National Accounts; and standard classifications of, for example, industries and regions. Without these, information is collection and dissemination is *ad hoc*, unstructured and of limited value for decision making.

Over many years, statistical offices have built frameworks that have come to serve them very well in the domains of economic and social statistics. The question now is whether these frameworks are sufficient also for measuring the impacts of climate change and, if not, what more is needed.

Looking first at conceptual frameworks, there are several that figure prominently in official statistics, but perhaps none more so that the framework underlying macroeconomic statistics.[1] This framework has allowed statistical offices to build large and successful systems of macroeconomic accounts that are routinely used in developed nations for economic policy making. Given that climate change and its impacts are also "macro" issues, can this same framework be brought to bear to measure the missing link in climate change statistics, the environment? We think yes.

Our view is that the conceptual framework underlying the national accounts – suitably broadened – could be effectively used in measuring climate change impacts. Over the last two decades a robust literature has developed around "natural capital" as an extension of the traditional concept of capital. Natural capital broadens the traditional concept to cover those elements of the environment that provide goods and services from which humans benefit. Since it is these same elements of the environment (natural resources, land and ecosystems) that we worry about when it comes to climate change, the concept of natural capital provides a firm footing for building statistics on climate change impacts.

Conceptual frameworks are abstract and, as such, cannot be used directly to organize statistics. For that, they must first be turned into measurement frameworks. In the case of macroeconomic statistics, the measurement framework is the well-known *System of National Accounts*. In the case of environment statistics, a similar measurement framework has evolved over the last 15 years. Known as the *System of Environment and Economic Accounts* (United Nations *et al.* 2003), it provides for the organization of

[1] Another would be the conceptual framework that underpins demographic statistics.

environmental statistics into structured accounts that are compatible with the concepts of natural capital.

The final framework element required is a set of classifications that can be used to organize raw data into basic statistics that can, in turn, serve as the basis for filling the measurement frameworks needed to measure climate change impacts. For this, many of the traditional classifications used in official statistics are relevant: classifications of industries, products and geography to name some. The traditional classifications alone are not sufficient however. In addition, we require classifications that allow us to look at the economy and society through an environmental "lens." Climate change is an environmental phenomenon, so studying its impacts means first putting economic and social data in an environmental context. This means adding to existing geographic classifications new classifications that divide the national territory not according to political or census boundaries, but into biophysical units like watershed basins and ecological zones.

These are needed because the impacts of climate change will not observe political boundaries but will be differentiated by the biophysical features of the land. The ability to cast social, economic and environmental data according to these biophysical boundaries is essential to measuring impacts. It is worth noting that along with these new classifications must also come the ability to compile and analyse data using various spatial units. In practical terms, this means developing the capacity to use geographic information systems.

3.1.1 Frameworks – Statistics Canada's experience

Statistics Canada has had an environment statistics program since the 1970s. Our initial environmental publications were compendia of socio-economic statistics re-cast in environmental frameworks (Statistics Canada 1979): population by drainage area and agricultural intensity by ecozone. Existing spatial frameworks were assessed for fitness for use and improved in collaboration with the science departments that created the spatial frameworks for their own purposes.

Statistics Canada has contributed to the development of a national geospatial infrastructure framework, which ensures that geospatial data are interoperable between applications and federal departments. This is essential to the rapid response to emerging issues that require the combination of several spatial datasets (Natural Resources Canada, ND).

A program of environmental accounting was started in the early 1990s out of a need to measure the environmental influences of socio-economic activities. The *Canadian System of Environmental and Resource Accounts* today includes:

- Natural resource stocks: conventional oil and gas, offshore oil and gas, oil sands, coal, major commercial minerals, timber and water (under development)
- Land: urban, cropland, forested, grassland, tundra, snow and ice
- Material and energy flow: energy use, water use, greenhouse gas emissions
- Environmental protection expenditure: government and business expenditures

The accounts represent a good start at incorporating the contribution that natural capital makes to Canada's economy. They are largely compatible with the UN *System of Environmental and Economic Accounts*. However, they do not at this stage track all important natural resource and pollutant flows. A comprehensive set of indicators based on these accounts was last published in 2000 (Statistics Canada 2000).

Adherence to standard classifications ensures that Statistics Canada's environmental accounts and statistics are coherent vertically (*i.e.*, aggregates can be derived from details), horizontally (*i.e.*, datasets from different sources can be compared) and temporally (*i.e.*, a dataset from one year is compatible with that from another year). The following classifications are important:

- the North American Industry Classification System
- the Standard Geographic Classification
- the North American Product Classification System
- the Canadian Digital Drainage Area Framework
- the Canadian Ecological Land Classification.

Applying these in the environment accounts assures the interoperability of important datasets. It also enhances the utility of existing socio-economic data.

3.2 Knowledge development

In this section we address the knowledge required in statistical offices if they are to measure the impacts of climate change.

It was noted in Section 2 that climate change will have economic, social and environmental consequences. It seems safe to say that statistical offices routinely have the knowledge required to address the first two but not always the third. And even if a given office does have some environmental knowledge in its workforce, it is almost certain to be a fraction of that which it can bring to bear on economic and social issues. So, at least some building up of this knowledge is probably required in every office; for some, it is a matter of starting from zero.

In acquiring the knowledge to address environmental concerns, statistical offices face several challenges. Most obviously, there is the challenge of recruiting staff with the appropriate professional training and experience. Since statistical offices are not always widely known for their environmental work, potential employees might not think of them when looking for a job or might not be willing to join a statistical office if they perceive it to be on the margins of their profession.

A second challenge is development for environmental professionals. While high-quality training opportunities are routinely available for economic and social statisticians, this is less the case for environmental statisticians. The latter are more likely to have to make do training on the job.

A third challenge is subject-matter thinning. Environment statistics cover a large and complex range of issues that must be followed by a relatively small number of statisticians. This can mean that 1) that some issues go untreated; 2) that particular

individuals must cover many issues superficially rather than a few issues in depth; and 3) that progress in expanding statistical coverage is slow.

The final challenge with respect to knowledge is credibility with science-based departments. Because statistical offices are relative newcomers to environmental issues and because they mainly do not have large teams of professionals dedicated to them, there can be a perception by core environmental departments that statistical offices lack the qualifications necessary to do good work in this area.

3.2.1 Knowledge development – Statistics Canada's experience

Statistics Canada's environment statistics program has developed its knowledge base by (a) hiring generalists with some science or engineering background and (b) establishing alliances with working groups in other departments with access to specialized scientific knowledge.

One example is the Canadian Environmental Sustainability Indicators project (Statistics Canada, Environment Canada and Health Canada 2007). To assess the quality of water and air monitoring data, we found statisticians with engineering, hydrology and water quality backgrounds. The individuals had extensive experience in the scientific fields but were already working as statisticians. The project also made extensive use of interdepartmental working groups in which the statistical principles were appropriately considered along with the scientific principles.

Environmental accounting requires a combination of knowledge areas:

- science and engineering to treat the physical, process and chemical aspects;
- national accounting treat the macro-economic principles (e.g., which value to use as a denominator to calculate greenhouse gas intensities),
- statistics to apply appropriate methods to analyse trends and significance, and
- survey knowledge to develop and conduct new surveys.

The ability to properly incorporate geography into the analysis requires not only the spatial frameworks but also specialized skills to translate information between environmental and other geographic frameworks using GIS software.

4 Data needs

In this section we consider the data needed to address each of the main categories of climate change impact. As above, Statistics Canada's experience is used in illustration.

4.1 Biophysical impacts

Shifts and changes to the state of biophysical elements such as weather and seasons, land cover, natural resources and ecosystems undoubtedly have parallel socio-economic impacts. For example, declining fish stocks, occurrence of severe droughts, extensive forest fires, would have corresponding impacts on specific resource industries and the related resource-dependent communities. Unlike the data requirements for socio-economic analysis, however, any meaningful analysis of the shifts in these biophysical elements and how much of these changes could be attributed to climate change requires

data that are collected primarily from scientific activities (scientific surveys, laboratory testing, remote sensing, etc.).

In Canada, the majority of these data collection activities fall outside the mandate or realm of activities of the central statistical agency. Instead, they are carried out by other federal policy departments, scientific research institutions, and provincial/local governments that are mandated to report on the status/state of these biophysical elements.

For instance, Environment Canada collects most of the data on climate and weather. Natural Resources Canada and provincial governments collect some data on Canada's forests and on other types of land cover.

A considerable portion of these data are not collected for statistical purposes, but rather, for scientific reporting or for specific case studies and research. It is, therefore, not surprising that data fragmentation or the presence of 'silos' is quite prevalent. The overall completeness and data quality also vary quite widely among the different data sources. These conclusions became quite evident in the evaluation of the ability of the statistical infrastructure to track biophysical impacts of climate change.

Is there a role for central statistical agency? Statistics Canada believes that a statistical agency can play a lead role in the development of a conceptual framework for tracking and measuring these biophysical elements. The framework provides a coherent basis with which to integrate various pieces of the 'biophysical puzzle.'

At Statistics Canada, the *Canadian System of Environment and Resource Accounts* provides the starting point for such a framework. One of the strengths of the system is its ability to bring together scientific data collected by various organizations and put them in order to produce coherent indicators. The accounts operate at the national and broad sub-national level, however, which could be construed as one their weaknesses, since most climate change impacts will be felt locally.

4.2 Social impacts

The anticipated direct social impacts of climate change are on health, cultural resources and population distribution. Information on health (morbidity and mortality) needs to be sufficiently detailed by cause and location to distinguish causes that can be linked to climate change. Similarly, to track the impact on cultural resources, such as subsistence or ceremonial fisheries, surveys need to be in place to collect sufficient detail. To track population distribution, detailed information is required on the location of residence and workplace.

4.2.1 Health

Causes and rates of deaths, morbidity and social and mental stress could result from general increases in temperature and the type, severity and frequency of weather events. For example, increases in ground level ozone as temperatures rise may lead to respiratory problems in people in the affected areas.

Statistics Canada's *Canadian Community Health Survey* collects a variety of self reported information on incidences of illnesses and diseases. Household spending data, if detailed enough, could provide information on spending to adapt to changing environmental

conditions; for example, on the purchase of air filters. Information on other adaptive behaviours could be derived through modifications to household environmental behaviour surveys, such as Statistics Canada's *Households and the Environment Survey*.

Longer growing seasons will lengthen the period in which plant pollens are in the air and this will lengthen the exposure period for people suffering from allergies to these pollens. Statistics Canada currently publishes detailed geographic data on self reported allergies and asthma rates collected through the *Canadian Community Health Survey*. These data will serve in monitoring changing impacts of pollen levels to some degree.

Increases in incidences of diseases carried by insects and pests could be impacted by warming temperatures. In the absence of extreme cold weather to kill off insects like ticks and mosquitoes, the incidence of the diseases they transmit could increase. It should be possible to track the increasing incidence of vector-borne diseases using morbidity data sets, though it will be difficult to link incidence rates back to environmental factors.

Climate change could also lead to heat-related health impacts such as heat stroke and sunburn. Increases in these conditions where hospitalization is required should be possible to track. In most cases however these conditions are not treated by physicians and therefore will go unreported.

Changes in climate could also increase the numbers of injuries and deaths related to severe storms and flooding. Morbidity and mortality data sets provide some information in regard to injuries, especially where these lead to death. However, details that would allow linkages to climate change related causes will be limited.

Climate change could lead to changes in mental health, stress, depression, satisfaction and happiness levels related to changes in economic and other conditions resulting from climate changes. In Canada, such data are collected through the *Canadian Community Health Survey* and the *Aboriginal Peoples Survey*.

4.2.2 Population distribution, income and economic well-being

Changes in economic conditions brought on by the availability of water resources, changing temperatures of air and water and extreme weather events will have an impact on how some sectors of the population earn a living. This may stimulate population movements resulting in population increases in some parts of Canada and decreases elsewhere.

Parts of the country that currently depend heavily on biomass based resources for employment may suffer economic downturns and depopulation if those resources are negatively affected by the impacts of climate change. For example, water shortages in agricultural areas may change farming practices that reduce the income potential per hectare of farmed land. This would force some farmers out of business and others to consolidate existing properties. Areas economically dependent on forestry may suffer depopulation as forests are damaged by pests that able to survive milder winters, such as the mountain pine beetle in the interior of British Columbia. Water shortages may also have an impact on forest resources and new insect pests, fungi and diseases may arise to harm agricultural production.

In most countries, including Canada, population census provides a detailed statistical picture of population characteristics and population distribution every five or ten years. Analysis of Census results in conjunction with other scientific monitoring data and economic data can provide a detailed picture of emerging patterns. These data will serve policy makers in designing adaptive strategies. Labour force surveys can also provide useful data. Though not as detailed as census data, labour force data are available frequently and so are useful for current monitoring.

Information on changes in agricultural practices and changing farm characteristics will be important. In Canada, these come from the *Census of Agriculture* every five years. Water consumption in agriculture may become an issue if rainfall patterns are significantly altered from the present. Depletion of groundwater aquifers and melting of mountain glaciers that provide summertime stream flow are also concerns. These issues have prompted the creation in Canada of an *Agricultural Water Use Survey* to ask farmers directly about their water use.

Increased temperatures and more carbon dioxide in the atmosphere may increase agricultural and forestry production in areas of currently marginal production. This may lead to additional settlement in these locations. Population census data will again be helpful in assessing if this is happening.

Changes in water temperatures and ocean currents may have impacts on fish and other aquatic species. If fish populations decrease, there will be a follow through effect on those depending on fishing for their income. Impacts on incomes and population distributions could be assessed using population census and labour force data.

Climate change may increase movement of people seeking security and a better standard of living outside their home countries. In Canada, the *Longitudinal Survey of Immigrants* could provide some information on such arrivals. While it does not ask the reason for emigration, some countries will be more affected by climate change than others, so persons arriving from these locations might be considered, at least in part, as climate change refugees.

4.3 Economic impacts

The economic impacts of climate change will be, to a large extent, functions of the biophysical and sociological impacts outlined above. The economy is a subset of society which is itself situated within the physical world, so economic impacts from climate change are inevitable. It is worth noting that these impacts may affect the economy in both positive and negative ways, with the overall impact being difficult to determine *a priori*.

The economic impacts of climate change can be grouped three main headings; namely impacts on natural capital, produced capital and labour. Changes in the availability of these types of capital, and the productivity with which they can be exploited may influence the structure and output of the economy. The discussion below focuses just on data needs associated with the impacts on natural capital, as these are likely to be the weakest link in statistical systems today.

4.3.1 Impacts on natural capital

Natural capital provides resources to the economy, space in which the economy operates, navigation and transportation routes, and ecosystem services that are vital to economic functions. Natural capital has been divided below into the subheadings of water, land, biological resources and ecosystem services. The capacity of statistical offices to measure the impacts on these types of capital is briefly discussed.

Water

Water is an essential input into many production processes. It can be used as an intermediate input, as a carrier for heat energy, to generate electricity, and as a route for the transport of passengers and economic goods and services. Statistical agencies are well placed to measure the use of water by businesses and households, which by extension can serve as a measure of the impact of climate change should the availability of this resource change in quantity or location.

Statistics Canada conducts an *Industrial Water Survey* to measure the role of water in industrial production. It also conducts surveys of electric power generation that include hydro-electric plants. In addition, Statistics Canada is working on geographically-based water availability accounts that will provide a measure of changes in water availability as time passes. Various surveys also measure the role of water as a conveyance for goods and services, including surveys of domestic and international shipping and a separate financial survey of water carriers. Changes in water availability can influence other aspects of natural capital including land, biological resources, and ecosystem services.

Land

Land provides the space within which economic activities are carried out. The impact of changes in the quality and availability of land as an economic resource is another area where statistical offices are well placed for measurement. Agricultural production is a significant economic activity that is measured by statistical offices. Changes in land availability for agricultural production will show up as an economic impact via changes in agricultural production (similar to changes in water availability above). Statistical offices are well placed to measure this economic impact. Statistics Canada, for its part, conducts a *Census of Agriculture* every five years, and also produces quarterly and annual estimates of livestock production and farm income and expenses.

Land itself has value from an economic perspective. It contributes to national net worth as land around buildings and structures and as agricultural land. Changes in the value of land will be reflected as changes in national net worth. This is another area where statistical offices are well placed to measure the potential impacts of climate change, particularly if they produce environmental accounts.

Non-renewable resources

It is not expected that sub-soil resources (other than groundwater) will be impacted by climate change. However, the ability of the economy to exploit them may change due to impacts on the infrastructure required for their exploitation (this is discussed further under produced capital below). The value of sub-soil assets is calculated in Statistics

Canada' environmental accounts taking into account their economic viability. To the extent that climate change alters this viability, the impact should be captured through the asset valuation, though it would prove challenging to attribute the changes directly to climate change.

Biological resources

Forests, fisheries, and other biological resources yield economic benefits once harvested. Since these are long-standing economic activities, statistical offices are generally well placed to measure changes in the economic output of the industries that depend on these resources. From an analytical perspective, statistical offices are also well placed to measure the downstream economic impacts of changes in the production of goods based on biological resources.

Timber assets are part of Statistics Canada's environmental accounts. Changes in the economic value of these assets will be reflected in these accounts, though again it will be difficult to attribute changes in value directly to climate change.

5 Conclusions

Basic social and economic statistics generally collected by statistical agencies should go a long way toward understanding the impacts of climate change in the future. Population, agriculture, economic, health and social data all can be used to tell part of the story and to suggest areas where more data and analysis are required.

Statistical agencies with an environment program already have some of the expertise, or access to it through partnerships with environmental and resource policy departments, to assist with the interpretation of trends resulting from climate change.

It is Statistics Canada's view that environmental accounts hold the most promise as the analytical framework for assessing climate change impacts. These accounts ensure the coherence of the data, both across different categories of environmental data and also with economic and social data. When we engage in new research, we always therefore ask, "Where will this fit in the environment accounts?"

Given this view, we offer a prioritized checklist for statistical agencies to assess their readiness to track the impacts of climate change:

- Is there an environment statistics program? Does this program have strong linkages in terms of sharing data and knowledge with environment, health, agriculture and natural resource departments? Is there analysis of the environmental factors in social and economic trends?
- Does the environment statistics program adhere to standard classifications for industry, goods and geography? Is there a spatial analysis capacity as part of the environment statistics program and are social and economic data spatially-referenced?
- Does the environment statistics program conduct its own surveys? Does it monitor other health, social and economic surveys for opportunities to add questions on environmental issues?

- Does the environment statistics program have a set of environment accounts linking social and economic activities with environmental pressures (emissions, effluents, protection expenditures, production of environmental goods and services, etc.)? Do the accounts include detailed information on land, forests and water?
- Are official social and economic statistics already being used to assess environmental impacts? Is there an ongoing working relationship between economic and social units in the statistical office environmental, health, agriculture and natural resource statistics units?

Perhaps this checklist could be used as a starting point for international discussion on the statistical agencies' contribution to the understanding of the impacts of climate change. Success in this endeavour will ultimately require the determination of individual statistical agencies and their clients to encourage a role that goes much beyond that of statistical agencies in the past.

References

Dumuth, Michael. Natural Resources Canada. Personal communication June 19, 2007.

Field, C.B. et al., 2007, "North America," *Climate Change 2007: Impacts Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry et al. [eds.], Cambridge University Press, Cambridge, www.ipcc.ch/ (accessed January 11, 2007).

Natural Resources Canada. 2004. *Climate Change Impacts and Adaptation: A Canadian Perspective*. Ottawa, Ontario.

Natural Resources Canada. 2007. *From Impacts to Adaptation: Canada in a Changing Climate 2007*. Ottawa, Ontario.

Natural Resources Canada. ND. Canada's Geospatial Data Infrastructure (www.geoconnections.org).

Solomon, S. et al., 2007, "Technical Summary", *Climate Change 2007:The Physical Science Basis, Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon et al. [eds.], Cambridge University Press, Cambridge, United Kingdom and New York, www.ipcc.ch/ (accessed January 11, 2007).

Statistics Canada, Environment Canada and Health Canada. 2007. *Canadian Environmental Sustainability Indicators*, Statistics Canada Catalogue no. 16-251, Ottawa.

Statistics Canada. 1979. *Human Activity and the Environment*, Ottawa.

Statistics Canada. 1994. *Human Activity and the Environment*, Ottawa.

Statistics Canada. 1997. *Concepts, Sources and Methods of the Canadian System of Environmental and Resource Accounts*. Cat. no. 16-505-GIE.

Statistics Canada. 1998. *The St. Lawrence River Valley 1998 Ice Storm: Maps and Facts*. Cat. no. 16F0021XIB.

Statistics Canada. 1999. *The Preparedness of Canadian Business for the Year 2000 Computer Problem*. Cat. no. 61F0057MIE.

Statistics Canada. 2000. *Econnections: Linking the Environment and the Economy-Indicators and Detailed Statistics*. Cat. no 16-200-XKE.

United Nations, European Commission, International Monetary Fund, Organization for Economic Co-operation and Development, World Bank. 2003. *System of Economic and Environmental Accounts*. New York.