MAINSTREAMING CLIMATE CHANGE

Integrated Landscape Assessment, Decision-Support Process & Tool Kit

Guidebook to implementing the quantitative and qualitative aspects of the assessment

Authors:
Ruth Waldick, Livia Bizikova, John Bolte, Dan MacDonald, Anna Zaytseva, Kathy Lindsay, Denis White, Pierre Yves Gasser, Scott Mitchell, Kellie Vache, Sampsa Hamalainen, Darren Swanson

Design:
Ann Wilkings

IISD
International Institute for Sustainable Development

OSU
Oregon State University

Carleton University

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Environment Canada | Environnement Canada

CONTENTS

TABLES & BOXES

FIGURES

ACRONYMS

AAFC	Agriculture and Agri-Food Canada
AESB	Agri-Environmental Services Branch
ANSI	Area of Natural & Scientific Interest
BAU	Business-As-Usual Scenario
BMP	Beneficial Management Practice
CA	Canada
CC	Climate Change
CFIA	Canadian Food Inspection Agency
CFS	Canadian Forest Service
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DEM	Digital Elevation Model
DSS	Detailed Soil Survey
EC	Environment Canada
EO	Eastern Ontario (Canada)
F2R	Farms to Regions
GF2	Growing Forward 2 Policy Framework (Canada)
GIS	Geographic Information System
IDUs	Integrated Decision Units
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
IROWC-N	Indicator of Risk of Water Contamination by Nitrogen
IROWC-P	Indicator of Risk of Water Contamination by Phosphorus
NAESI	National Agri-Environmental Standards Initiative
NAHARP	National Agri-Environmental Health Analysis and Reporting
NAPP	National Agricultural Profiling Project
NGIS	National Geographic Information System
OCCIAR	Ontario Centre for Climate Impacts and Adaptation Resources
OECD	Organisation for Economic Co-operation and Development
OMAFRA (OMAF)	Ontario Ministry of Agriculture, Food and Rural Affairs
OMNR	Ontario Ministry of Natural Resources
OSU	Oregon State University
SARA	Species at Risk Act
SLC	Soil Landscapes of Canada
SOLRIS	Southern Ontario Land Resource Information System
WEBs	Watershed Evaluation of Beneficial Management Practices

ACKNOWLEDGEMENTS

We are grateful for Agriculture and Agri-Food Canada for providing support for this project. We are also thankful to our colleagues from participating institutions and regional partners for the time and help in the design and implementing of this project, and for contributing expertise, data inputs and reviews.

INTRODUCTION

1.1 Mainstreaming Climate Change Adaptation

On average, the rate of warming in Canada since 1948 has been double the global average[1]. Most future warming is expected to occur in the spring and winter months. However, extreme conditions, such as heatwaves, droughts, and severe storms, are expected to increase in frequency during the summer months (Intergovernmental Panel on Climate Change [IPCC], 2013). Although these trends help contextualize potential future changes, there is limited information available regarding how extreme conditions will change in the future, making it difficult for regions to develop adaptation plans tailored to their communities and sectoral groups. For instance, how will the frequency and magnitude of droughts and floods change within and across years? Will such changes impact regional infrastructure, like roads? And, how will changing conditions during the growing season affect agricultural production? Will new varieties and practices be required, and to what extent are our existing systems sufficiently robust (resilient) to withstand these changes? To help people and sectors prepare for future change, information regarding historic, present and future conditions needs to be considered in the context of key regional drivers, not only climate change. Global economics, tradition, migration and other factors are also critically important.

Adaptation, simply stated, is defined as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, in order to reduce harm or take advantage of opportunities. For agriculture, this could include any of a range of activities, such as raising river or coastal dikes, promoting more temperature-shock-resistant plants instead of sensitive ones, or improving the effectiveness of pest-management practices (IPCC, 2007). However, responding to climate change adaptation is not just a stand-alone activity presented as specific climate change adaptation strategies and plans. Crucial to adaptation planning is ensuring that all necessary adaptation actions, policies and measures are effectively mainstreamed into sectoral (and other) planning strategies.

Mainstreaming adaptation will help to further coordinate adaptation planning across scales—from national, to regional, sectoral and program/project levels—and is increasingly recognized as critical to the implementation of adaptation measures. Mainstreaming is currently regarded as an innovative instrument replacing stronger—and often ineffective—mechanisms of coordination (Halpern et al., 2008). Further, it is proposed as an effective tool to enhance policy development by increasing sectoral policy coherence, addressing trade-offs between different sectoral objectives and capturing the opportunities for synergistic results in a way that will meet social, economic and environmental priorities (Kok & de Coninck, 2007). In this respect, mainstreaming may be seen as a way of integration giving equal importance to different sectoral properties and finding ways to maximize benefits across the involved sectors. This is highly relevant for climate adaptation, as it aims to maximize capacities for adaptation while achieving aims and priorities related to agriculture, environmental protection and others. In the context of adaptation, mainstreaming helps highlight important development/climate

1. See http://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/assessments/2008/ch2/10321.

change issues and linkages, whether they are sector-specific, or span jurisdictions and/or landscapes. They thus assist in: identifying weaknesses in policy, legal and institutional frameworks for ensuring resilience; and prioritizing targeted actions, research and policy regarding potential adaptations.

Lastly, improving national and regional information related to climate change impacts is critical to building a resilient agricultural system. Gathering and creating information on vulnerability to climate change and improving collaboration between researchers, policy-makers and other stakeholders will be instrumental to achieving adaptation outcomes (Gagnon-Lebrun & Agrawala, 2007; Howden et al., 2007; OECD, 2009; Swart et al., 2009).

Given these urgent issues in adaptation planning, the objective of this guidebook is to present an integrated landscape assessment and decision-support process to aid in mainstreaming climate change adaptation into regional policy and planning via agriculture policies and best management practices with a focus on the landscape level. Addressing climate change at the level of strategic planning, policy design and implementation across sectors and jurisdictions is becoming an integral part of the policy and planning process. In this guidebook we focus on providing a detailed overview of how to construct such an integrated model based on the development of scenarios for use as a basis for mainstreaming climate adaptation.

1.2 Purpose and Potential Users of the Guidebook

Land managers and planners have to adapt and choose their practices according to what is going on in their region. Agricultural landscapes are complex mosaics of land use, production, and multifaceted communities that are uniquely defined by each region's specific biophysical, social, cultural, and economic conditions. Agriculture, like all sectoral activities, is affected by a range of external factors, including demographic changes, economic trends, and ecological functions. In the case of farmers, this includes local weather conditions, year-to-year expectations of change, as well as regulations and other management objectives. Planning on a year-to-year basis is becoming more difficult as land-use dynamics and pressures become more complex, and the rate of change increases due to new technologies and globalization.

This guidebook provides an overview and application of scenario approaches as a method to conduct complex regional and place-based assessments and provide information to support planners to develop longer-term adaptation plans. An important aspect of the approach, however, is that it considers future change in the context of whole regional systems. This guidebook describes how to characterize changes and measure, evaluate, and map climate change impacts in the context of quantitative data on the agricultural sector in the light of developed qualitative scenarios.

The key rational for the approach to mainstreaming adaptation presented here are as follows:

- Stakeholder engagement combines local stakeholders' understanding of what has happened in the past with what might happen in the future, and can assist in establishing the range of possible futures. By setting the focus in a geographically bounded and familiar area, stakeholders (including regional experts) express priorities and constraints that are often shared by other stakeholders simply by way of geography. Together, mixed stakeholder groups can quickly identify desirable outcomes for the region, key drivers of change, and appropriate indicators to track outcomes. These multidisciplinary discussions allow different scenarios to be defined, and identify quantitative measures that can be used to compare and contrast scenarios and explore the utility of different policy and management adaptation options.

- Scenario-based alternative futures methodologies provide established processes for identifying and defining different sectoral objectives and considerations using a "place-based" approach. As scenarios are storylines or narratives of possible future conditions, they make no prior judgment about what is good or bad, but provide informed estimates derived from current and historic information and assumptions about alternative paths to the future.

- Quantitative models development and use that simulate scenarios and their consequences over time and space can enhance the analysis of planned adaptations and needed polices by providing visual maps of how each of the alternative futures influences change overall, and from one municipality or farm in the region to another. Models allow best available scientific and socioeconomic information to be considered geographically. In an agricultural context, the spatial component is especially important as landscape features like slope of land or soil quality will influence susceptibility to events like flooding and erosion under extreme weather conditions. In other areas, conditions might be quite different, and so require place-based sensitivity, which allows for more sensitive factors to be considered (e.g., distance to market, insurance rates, fuel costs, etc.).

1.3 Structure and use of the Guidebook

This guidebook was developed as an outcome of collaborations between a number of organizations, including government, academia and civil society, to identify adaptation needs and priorities for the region of Eastern Ontario (Canada) referred to as the Farms to Regions project for Eastern Ontario (F2R EO). This application was based on the previous experiences of the project team in integrated modelling, scenario analyses and policy-making. When using this guidebook for mainstreaming adaptation into agriculture, we suggest beginning with a review of the whole document by a smaller expert group and then working through the step-by-step sections that outline activities required to implement the approach presented. Some of the applications of the steps could take anywhere from a few days to many months depending on the status of modelling, collected data, and the development of collaborations in the specific area. Those more specifically interested in the dynamic spatial model used to simulate alternative futures are directed to the open-source software and tutorial information identified in the appendix. The time required to undertake work outlined within this document will depend on the focus or area of interest and the amount and types of resources and information that are available. We therefore encourage working with this document in a highly flexible way based on what the specific needs and situation of the practical application necessitates.

The next chapter of this guidebook provides a brief rationale for the approach taken and is followed by an overview of the key steps in project implementation supported by detailed technical documentation in the methodologies used (contained in the appendix).

Approach

The approach suggested for mainstreaming adaptation is to develop capacity and bring together tools that can be used to consider the impacts and interactions of policy and management choices on socio-ecological systems (Figure 1). The model and framework presented in this guidebook were established for an agricultural region but could be readily adapted to non-agricultural areas.[2] The framework was designed to address the following adaptation planning process:

- Provide a shared framework that would allow practitioners and stakeholders representing different interests and governing structures to engage in the collaborative planning processes.
- Enable synergies and identify trade-offs between different sectors and within sectoral activities to increase adaptive capacities.
- Create an iterative process that would allow integration of both qualitative and quantitative data when assessing adaptive capacities and needed adaptations and their mainstreaming when planning for future actions.

The process of the framework applications begins with identifying appropriate stakeholders, conducting a preliminary analysis of key issues and drivers affecting the region, and preparing for two parallel activities denoted as the two outer brown rings in Figure 1. The framework is operationalized through collaborations with two major groups and the interaction within and between the analysts & modellers and the stakeholders & decision-makers. These groups are engaged in parallel activities to: (i) acquire data and regional models and integrate available tools and information into a dynamic assessment tool and (ii) define the socioeconomic system and provide input and direction on alternative future scenarios, risk, potential adaptations, their relevance and needed policies. The two tasks, while technically different, require ongoing coordination and alignment (brown nodes linking the two outer rings). The overall project is orchestrated by a core working group comprising a subgroup with technical expertise in the sciences, including the use of climate change model projections, and geographic systems to populate the dynamic system platform—in our case a transferable system called Envision—and a second subgroup of risk and/or policy experts responsible for engaging stakeholders in order to characterize and define the current and future trajectories of change.

Figure 1. Farms to Regions – Adaptation & Innovation Framework

2. A hydrological application is currently underway through joint work between Carleton University, Department of Geography, and the Engineering Department, Dalhousie University, in conjunction with Agriculture & Agri-Food Canada.

Application of the framework

Climate change is expected to lead to a 2.5 per cent to 3.7 per cent warming in Ontario by 2050, compared with annual baseline average temperatures from 1961 to 1990 (Ontario Ministry of the Environment, 2011). Over the next 35 years, total precipitation is expected to undergo little change in the province, although extreme rainfall events will become more frequent (Expert Panel on Climate Change Adaptation, 2009). One of the major threats to Ontario agriculture is therefore an increased likelihood of intense dry periods. In addition to growth, climate change will affect a large array of factors, including propagation and introduction of weeds, pests and diseases, decreased soil fertility, excess moisture, among others.

3.1 Stakeholders' Participation and Collaborations

This step describes key actions to be undertaken with stakeholders to establish the scope and priorities in order to initiate the framework and ensure that it is properly focused during the early phases of the framework. This includes, for example, identifying stakeholders, defining the focus of the project, and reviewing available data sets, existing models, and regional information that will form the basis of future stages of the project. Approximate time for preliminary work: two to four months, depending on resources.

Creating a Project Team

This team will be responsible for ensuring that the day-to-day implementation of the project is done effectively. The larger the landscape considered, the greater the amount of outreach and coordination required to orchestrate the overall project. When setting up the project team, it is therefore crucial to cover the range of different areas of expertise required to lead the various tasks, which range from stakeholder engagement facilitation to quantitative modelling. It is also important that the team members come from different institutions so that they can provide information from a broader range of sources, and convey findings (and conduct peer review) with a diverse stakeholder group (i.e., with specific agencies representing different sectors and jurisdictions). This approach also allows for a number of key agencies to stay informed, representation of different views and preferences, and the provision of better access for broader stakeholder engagement.

We used a core team that ranged from four to six people to coordinate inputs and pursue external expert opinion and support from a much broader range of project stakeholders and external experts. For the decision-makers and stakeholder groups, if the audience has a spectrum of people ranging from public officials to members of the public, the project team members should represent some of this range. Ideally, the team will include natural resource managers, and data or subject matter experts (e.g., forestry companies, municipal governments) representing key disciplines, as well as a range of science, economic, and policy perspectives. The team should also include individuals from responsible authorities within the region.

Identifying the Focus Question

Prior to the first stakeholders' workshop a background scoping needs to be carried out by the project team. Information on previous or relevant work, available data and information,

and other useful context forms the basis for the first stakeholder engagement, during which basic parameters of the project (questions and priorities) are defined and agreed upon for the study region. A first critical step in any stakeholder-driven futures exercise is to clarifying the focus question. The focus question typically evolves in the early stages of the exercise as project partners and stakeholders begin to clarify in their own minds their desired outcomes within the mandate of the initiative. Examples of focus questions are listed in Box 1.

Box 1. Examples of focus questions in climate change adaptation initiatives using scenarios

- **What socioeconomic changes may influence the municipality most within the next 30 years? (Carlsen et al., 2012)**
- **What socioeconomic changes are important for the ability of the municipality to deal with the impacts from future climate change? (Carlsen et al., 2012)**
- **What socioeconomic changes are important for assessing and evaluating the appropriateness of the proposed options? (Carlsen et al., 2012)**
- **Given climate change projections, what are the priority actions under the climate change adaptation strategy for our municipality to address to climate change and to promote healthy and resilient region?**
- **How might future social, economic and ecologic conditions including climate change affect sustainability in Eastern Ontario (i.e., impacts on water, soil, habitat, biodiversity, forests, livelihoods, health, social relations), and how might agricultural policies and practices help maintain environmental services and enhance the ability of stakeholders to adapt to change now and in the future?**

Stakeholder Mapping

The main purpose of the participation is to ensure the legitimacy of the outcomes, build on stakeholders' expertise and preferences and promote mutual learning (Volkery et al., 2008). This is accomplished by assembling a good cross-section of participants, from citizens to experts and public officials. For highly technical initiatives, aimed at policy development in specialized fields of, for example, agriculture or forestry, stakeholders will also include technical staff from these sectors and, perhaps, outside scientists or technical specialists. Recently, the importance of broader stakeholder participation is being emphasized as key to ensuring cross-sectoral linkages, cross-checks for trade-off analysis and the recognition of potential synergies. This is especially important since even narrowly focused actions and policies can bring cross-sectoral co-benefits, including supportive learning and new collaborations among stakeholders.

The stakeholder mapping serves two key purposes. One is to identify a diverse group of stakeholders that are willing to participate within the project, and the second is to document any knowledge or information gaps that will need to be addressed – for example, by identifying missing expertise to ensure all necessary aspects of the project focus are represented.

Stakeholder involvement is fundamental, as it strengthens the assessment's relevance and legitimacy. As such, the framework is built around input from stakeholders, who provide assessments of vulnerability to key risks, in this example, climate change impacts. By including participants from different responsible authorities, and levels of management, both local and regional level mainstreaming adaptations will be considered. Stakeholder diversity (including community members, policy-makers, researchers, experts, civil society, non-governmental organizations and media) serves to increase the information base for the assessment. Local community members, farmers and producers have valuable knowledge about consequences of climate change impacts and many of the adaptation options are already familiar to stakeholders, even if they are not explicitly recognized as helping to reduce vulnerability to climate change (i.e., co-benefits). Building on the familiarity of these actions also increases the empowerment of stakeholders—including decision-makers—as they can see themselves as valuable sources of knowledge for developing responses to climate change.

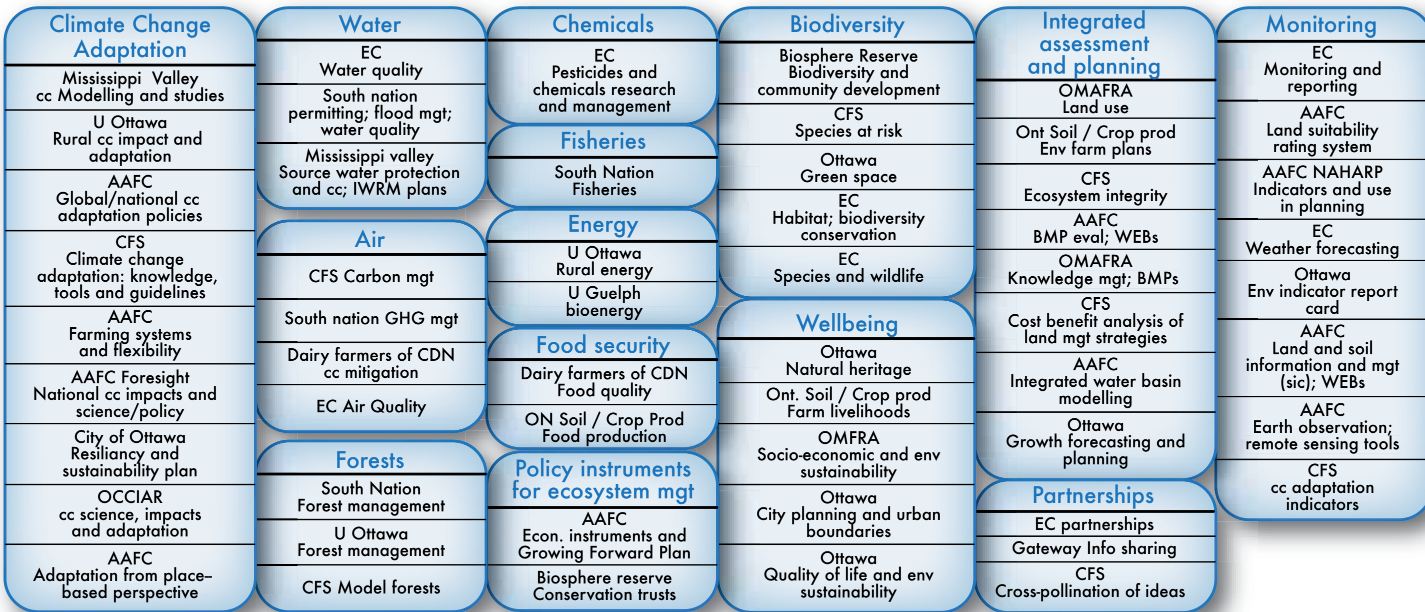
Overall, mapping serves to identify the needs systematically and thoroughly. We would like to suggest the following basic criteria in this exercise:

- Representativeness—expertise covering key sectors such as water, production, planning.
- Influence on policy—authorities from relevant jurisdictions involved in policy and planning.
- Knowledge of relevant science—subject matter experts in biology, agriculture, and engineering.
- Availability—experts with available time and interest to engage for duration of scenario process and/or some redundancy in expertise is represented in group as a whole.

In order to assure that the different stakeholders are represented, a stakeholder analysis is a very helpful tool. The analysis identifies key stakeholders, cross-checks criteria such as representation across sectors, gender and available capacities. It also helps to identify potential information or representation gaps (Figure 2). Usually, stakeholder analysis includes three elements:

1. Key issues or problems that will be discussed throughout the project, initiative. In the context of the discussed project we focused on vulnerability in the context of agricultural production and how this needs to be addressed in the context of climate change impacts and adaptation needs as well as market competition locally and globally while limiting its impacts on natural resources and biodiversity.
2. Key mandates and responsibilities that will be key to ensuring mainstreaming of adaptation into the policy process that will be identified throughout the project initiative. Based on the identified issues and focus we needed to identify stakeholders groups working on agricultural systems, policies, markets, diversity, water and soil as well as those focused on climate change impacts and adaptation issues.
3. Stakeholder “long” list. Preparing a detailed list of stakeholders, structured by general categories (such as public sector and private sector) as well as subcategories.

Figure 2. Examples of stakeholder mapping applied in adapation planning: Synthesis of involved organizations and their goals and mandates in the Eastern Ontario region



It is also helpful to keep membership open throughout the project, since new expertise and representatives can be included to better refine and improve the representation of perspectives and information, as well as establish new linkages. Open membership also acknowledges the reality that participant availability will ebb and flow over the lifetime of a project.

Choosing the Boundaries of the Study Area

The study area serves as the basis for all further discussion in the adaptation planning. There are two different types of spatial focus following either the political/jurisdictional boundaries and/or focusing on an eco-unit/ecosystem boundaries. A brief comparison between the two approaches is presented in Table 1.

In the application focused on Eastern Ontario, the boundaries of the areas were defined by established reporting boundaries—Statistics Canada includes eight census divisions used for national reporting which also correspond to recognized municipal and regional jurisdictions. The size of the Eastern Ontario study region is 31,297 square kilometres (Figure 3). This meant that we primarily aimed to cover a large landscape area in which changes could be monitored and assessed at subregional levels using established census data and reporting units. We also restricted our focus to the province of Ontario, so the area was fully within Canada. The chosen area stopped at the Canadian-U.S. border to make it easier to include current and future policies under the jurisdiction of national and provincial governments, rather than across international borders, which would be harder to do when working in two different countries. The boundaries were set during the first workshop.

Table 1. Comparison of advantages and disadvantages when focusing on an ecounit or political boundaries

Ecounit boundary	**Advantages** • More meaningful interpretation of environmental trends relevant to specific ecosystems. • Better understanding of ecosystems as functional units. • Direct connection to ecosystem-scale policies. **Disadvantages** • Limited availability of some data expressed at the scale of ecounit (particularly socio-economic data). • Political complexity arising from analysis of resources under shared jurisdiction.
Jurisdictional (political) Boundary	**Advantages** • More uniform regulatory environment. • More simple data collection. • Direct connection to jurisdiction-wide policies. **Disadvantages** • Resource-specific trends masked by data collected on the level of political jurisdiction. • Difficulty detecting differences in ecosystem impacts of specific policies.

Source: Pinter, Zahedi and Cressman, 2000.

Preliminary Data Availability Assessment /Core Data Sets Availability

When working with models, analysts and modellers will play key roles in translating and quantifying the scenarios, and in representing adaptations and landscape changes in the regional simulation model. As such, both groups of stakeholders but especially the analysts and modellers, will play key roles in gathering necessary data sets to run the simulation models, whether economic, biological, or physical.

The datasets used in spatially explicit simulation studies may include (1) landscape maps describing land uses in general, and crop, forest, and vegetation types, (2) human population by spatial regions and age classes, (3) agriculture and forestry practices and their prevalence, (4) water resources such as streams, rivers, lakes, reservoirs, and dams, (5) climate data both past, present, and future estimates, (6) soil maps with attributes relevant to agriculture, forestry, and human development, (7) land ownership parcel or lot boundaries, and (8) spatial distributions of plants and animals of interest for conservation or recreational purposes. The project team uses this information to identify key issues and approaches that serve as the guide for information and model requirements to feed into the integrated assessment and futures analysis tools. In our application, we focused on making use of data and information that was publicly available and would, therefore, create a base set of criteria for future project groups, including those with limited resources to purchase spatial data sets. This is particularly important in the use of climate change data, since many groups will not have the expertise in-house to process and analyze these types of specialized datasets.

Figure 3. Chosen area for integrated landscape-level assessment for Eastern Ontario region

Source: developed by the authors

Defining the Time Frame

The time horizon for a project is crucial in making the results of a study relevant for stakeholders. From the stakeholders' perspective, it is important to allow some distance from current trends and challenges, since this enables forward thinking that facilitates discussions regarding sensitive issues. Thus, it is important to choose a longer time span of at least 20 years, which avoids the current socioeconomic state of affairs and political circumstances, which might otherwise dominate the discussion. In contrast, a focus on, for example, the next 20 to 40 years is more likely to stimulate an open discussion that is broached in terms of system changes (van de Kerkhof & Wieczorek, 2005). This timeframe then can be broken up into medium- and short-term horizons when outlining specific actions and policies needed to get to the envisioned and preferred scenarios and pathways. This is important since the planning time frame for groups like farmers is short (one to two years) relative to forestry or urban planning communities (five+ years).

Analytical considerations: From the modellers and analysts' perspectives, there are a number of temporal parameters for a futures study:

(1) The baseline time, meaning the time from which the future scenarios are projected, and the time at which typically simulation models typically take as time zero.

(2) The ending time for the study, the time at which simulation models stop, and for which the most important outcomes are generated.

(3) Intermediate times for which outcomes are also measured in order to produce a trajectory of outcome behavior.

(4) The primary time step for simulation modelling, from which some models may deviate because of the time scales of the processes they simulate. An additional time parameter may be the time period in the past for which certain processes, such as weather or climate patterns, are calculated to prepare the appropriate parameters for initializing certain models.

For the Eastern Ontario study (F2R EO), the chosen endpoint for the scenarios that policy-makers were working with focused through 2035, which is approximately 25 years. This time horizon was divided into short-term horizons that recognized the timing for adaptations and needed policies to be implemented. The baseline time was in this case fixed to be 2010, corresponding to the intervals at which census data were available within the study region. Intermediate times for reporting model outputs have not been decided at this time; however, the Envision model allows for reporting at daily (and up to yearly) time intervals. The preliminary model uses primary time steps of one year.

An overview of stakeholder participation in this project is listed in the Appendix 6.1 and 6.2.

3.2 Developing Scenarios

We define a scenario as a story about the future that can be told in both words and numbers, offering a plausible and internally consistent explanation of how events unfold over time (Gallopín, Hammond, Raskin, & Swart, 1997; Raskin, Banuri, Gallopín, Gutman, Hammond, Kates, & Swart, 2002). Scenarios are neither predictions of socioeconomic development nor impacts of changing climate; rather, they are plausible descriptions of how the future may possibly develop, using recognizable signals from the present and assumptions on how current trends will progress (Jaeger, Rothman, Anastasi, Kartha, & van Notten, 2008). Scenarios can be used for multiple purposes, ultimately providing better policy or decision support and stimulating engagement in the process of change (Jaeger et al., 2008).

The use of scenarios or narrative descriptions of possible future trends started in a formal way in the middle of the 20th century when Herman Kahn assisted the military in thinking about the possibilities of nuclear war (Coates, 2000), and then by businesses and other organizations aided by Kahn and the Rand Corporation (Godet, 2000). In landscape planning, McHarg's Design With Nature (1969) popularized the application of the scenario approach to spatial problems. At the same time that McHarg was working, Lewis (1996) and Steinitz (2010) were also developing this approach to landscape planning.

A number of authors have recently emphasized the importance of using scenarios in adaptation planning. Recently, Shaw, Sheppard and Burch (2009) and Langsdale et al. (2009) in Canada, Carlsen et al. (2012) in Sweden, and Tompkins et al. (2008) in the United Kingdom applied scenario approaches with stakeholder participation using downscaled scenarios from the Intergovernmental Panel on Climate Change's Special Report on Emissions Scenarios (SRES). These scenarios included population changes, economic development and projected climate change impacts on local communities. Working with these trends the involved stakeholders discussed potential future pathways for relevant key sectors and identified adaptations in the context of these scenarios. Similarly, Langsdale et al. (2009) combined climate change projections with projected population trends, agricultural activities and conservation needs to identify adaptation options in the water sector using an integrated model developed through stakeholder collaborations. Shaw et al. (2009) also developed a series of visualizations of the future, with different severities of climate change impacts (depending on the chosen SRES scenario) and possible adaptation options.

The use of scenarios in adaptation planning also serves as a learning tool for those involved, which improves the collective understanding of how climate change affects the various regional sectors and priorities (van Aalst, Cannon, & Burton, 2008; Shaw et al., 2009; Tompkins et al., 2008; Tschakert & Dietrich, 2010). In the listed case studies, scenarios were explicitly used as learning and capacity-building tools for stakeholders (including decision-makers) to improve their understanding of consequences of climate change at the local level while helping them illuminate potential policy choices in the context of the future system (Tompkins et al., 2008; Shaw et al., 2009). Ultimately, however, scenario-based approaches also serve a pragmatic function, in identifying robust adaptation choices for future socioeconomic and climatic states (Carsen et al., 2012; Langsdale et al., 2009).

Identifying Key Drivers of Change Affecting the Landscape

To better understand potential future challenges, the major drivers of change need to be considered (Figure 4). This is necessary because certain drivers can influence how a region will change, and, in some cases, this may limit how resources are managed, or how decisions about public goods are determined. Such drivers can be local or regional, such as those based on available resources and infrastructure, population growth, and types of governance systems (Table 2). However, they may also be extrinsically based, in which case the region may have limited or no ability to influence them; global changes in market prices, trade agreements and barriers to trade, including changes in resource development in other countries that might have secondary impacts on locally based sectors are key examples. Although external factors may not be under local influence, the opening or closing of factories, or shifts in agricultural or other resource activities resulting from global factors will have significant ramifications for local economies and the types of choices that they need to consider in the future.

The drivers could be identified by the project team, but it is more relevant if they identify with the stakeholders, as doing so builds on their diverse perspectives and expertise and it also increases the legitimacy of the outputs that are created in the next steps of the project.

Figure 4. Understanding Regional Context in Adaptation Innovation & Learning Framework

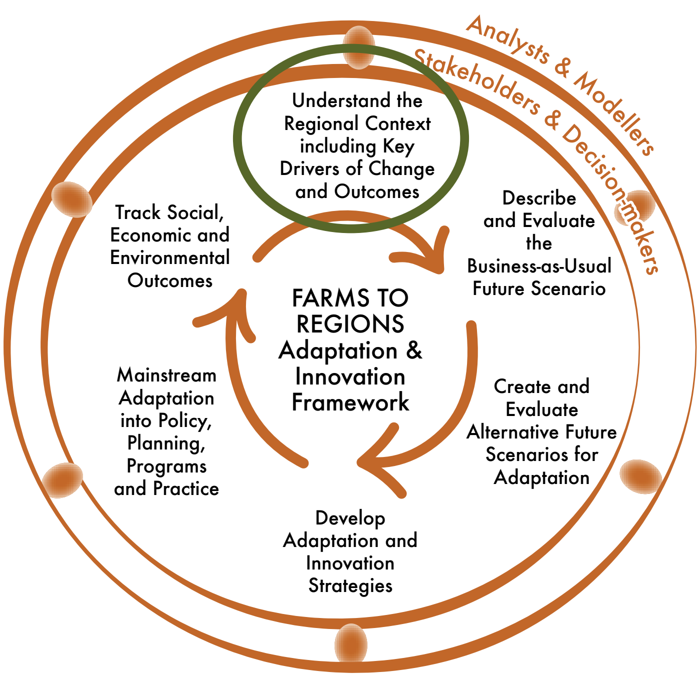


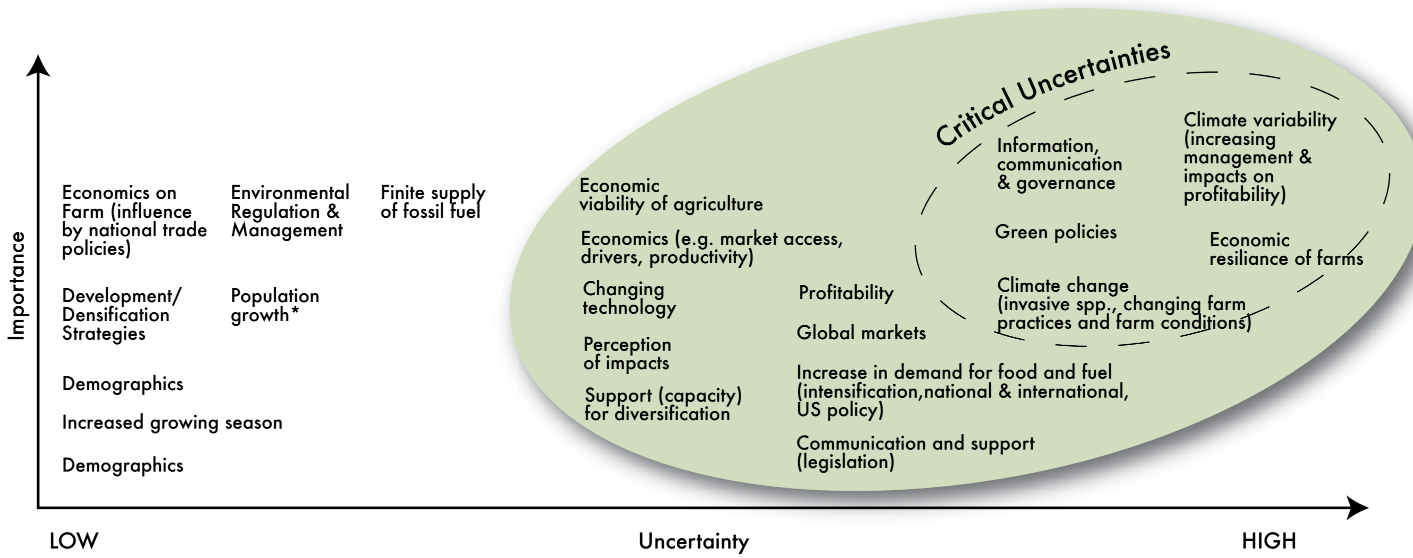
Table 2. Examples of drivers in applications focused on climate change adaptation

Identified key drivers of Interest	Place of application
Agriculture Nature and biodiversity; species at risk Water quality Policy	Corn Belt region in the Middle and Upper Mississippi sub-basin of the Mississippi River Basin (Nassauer, Santelmann, & Scavia 2007)
Population Governance Employment Energy infrastructure Air and water pollution	British Columbia, Canada (Tansey, Carmichael, VanWynsberghe, & Robinson 2002)
Freshwater quality Infrastructure Institutional changes Competition over land-use Regional administration organization	Sweden, municipal level (Carlsen et al., 2012)
Changes in precipitation Integration of land-use policies at the local level Participation in regional policy-making Population growth	Bras D'Or (Canada), regional (Bizikova & Hatcher, 2010)
Climate Change (overarching) Economics/Profitability/Variability (global market changes) Demographics/Densification Environmental Policy & Regulation Fossil Fuel Supply (cost, alternatives) Communication & Governance	Eastern Ontario Focus of this guidebook

In our Eastern Ontario study, the key drivers were developed during the first stakeholder workshop. Information gathered during the pre-project scoping formed the basis of a series of brief presentations of current trends (agriculture, economic and ecosystem health). During this session of the workshop the following key questions were asked:

1. What are the key drivers that affect achievement of the regional goals?
2. How important and uncertain are these drivers going forward?

Figure 5. Graph of importance versus uncertainty of drivers and other issues of concern from the stakeholders workshop



Discussions around these questions with the mixed expertise of the stakeholders resulted in a wide-ranging, but coherent picture of the drivers affecting this region (Table 2; Figure 5). Among these, those identified as the most important and most uncertain fell clearly under the headings of climate change; markets and the economy; and governance and policy (Figure 6). In addressing these two questions, the break-out groups synthesized these into seven key drivers, with climate being considered as an overarching driver with implications for all others.

By focusing on uncertainty, which is a shared concern among all sectors, the pathways of potential influence can more easily be described for a regional, socioeconomic system. Drivers in the upper right are referred to as "critical uncertainties" as they are both important in understanding change and high uncertainty with respect to the future. These provide the framework on which a series of alternative scenarios of the future are defined and differentiated. Drivers to the left are called "inevitables"—important for understanding change, but with greater certainty in how they will evolve over time. These provide a relevant backdrop for any scenario of the future.

Subsequent to the workshop, the project team together held further consultations with key stakeholders from a range of disciplines to distill the workshop results into a coherent set of drivers, systems of interest, and outcomes or endpoints. These were expressed in a system diagram (next section; Figure 6a/b).

Preparing a System Diagram

A valuable exercise at the beginning of a project is to visually represent the various issues, components, drivers, and outcomes as they are known, or as they become known in discussion, in a diagrammatic form. For the F2R EO project, this occurred in two stages. First, a free-flowing brainstorming session was held to try to connect the various issues from the first workshop into a concept map, showing issues in boxes and influences of one issue upon another as flows or arrows (Figure 6a). The second step was then to synthesize the information in the concept map into a system diagram that tried to capture all the relevant drivers and related factors. In our study in Eastern Ontario, our focus was on factors affecting the agriculture system, which included subsystems of production as principle concern, but also non-agricultural outcomes of interest to stakeholders (e.g., wildlife habitat, water quality; Figure 6b).

Figure 6a

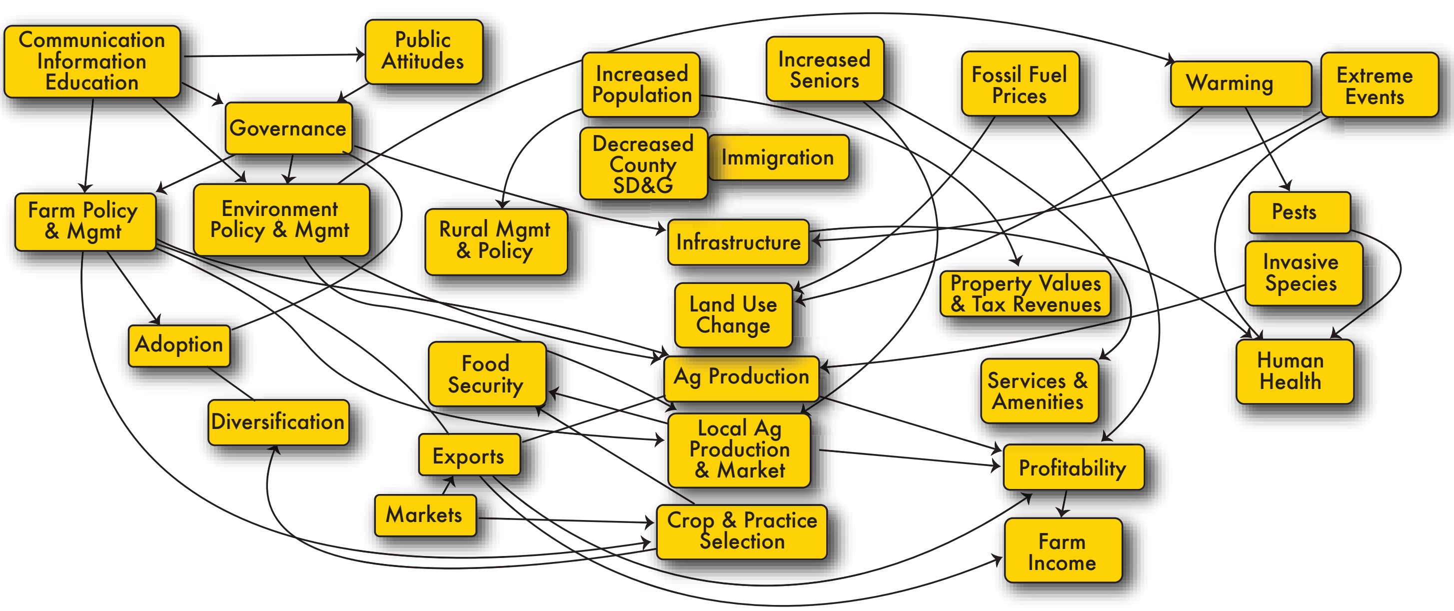
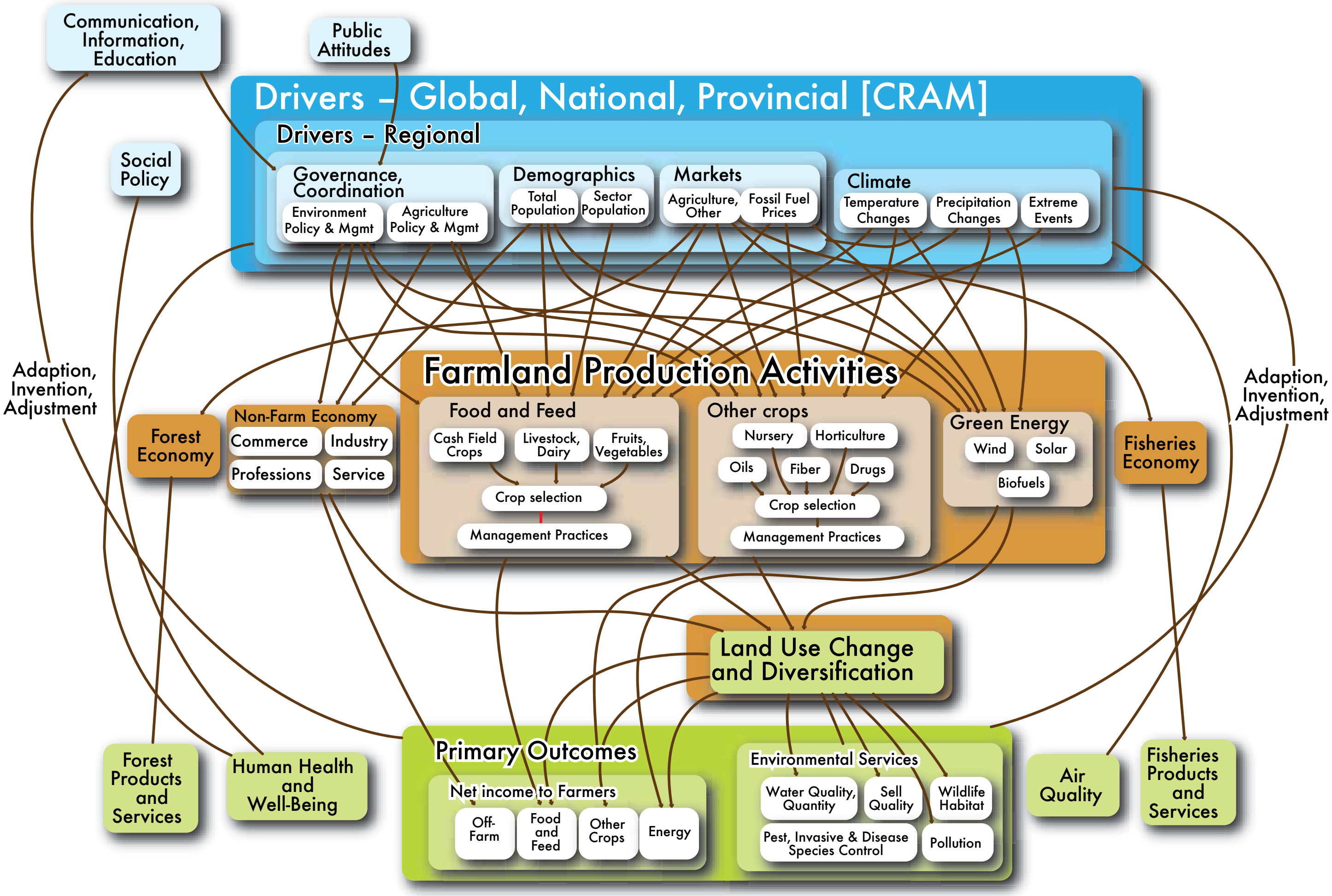


Figure 6b



Communication, Information, Education
Public Attitudes
Social Policy
Drivers – Global, National, Provincial [CRAM]
Drivers – Regional
Governance, Coordination
Environment Policy & Mgmt
Agriculture Policy & Mgmt
Demographics
Total Population
Sector Population
Markets
Agriculture, Other
Fossil Fuel Prices
Climate
Temperature Changes
Precipitation Changes
Extreme Events
Adaption, Invention, Adjustment
Adaption, Invention, Adjustment
Farmland Production Activities
Forest Economy
Non-Farm Economy
Commerce
Industry
Professions
Service
Food and Feed
Cash Field Crops
Livestock, Dairy
Fruits, Vegetables
Crop selection
Management Practices
Other crops
Nursery
Horticulture
Oils
Fiber
Drugs
Crop selection
Management Practices
Green Energy
Wind
Solar
Biofuels
Fisheries Economy
Land Use Change and Diversification
Forest Products and Services
Human Health and Well-Being
Primary Outcomes
Net income to Farmers
Off-Farm
Food and Feed
Other Crops
Energy
Environmental Services
Water Quality, Quantity
Sell Quality
Wildlife Habitat
Pest, Invasive & Disease Species Control
Pollution
Air Quality
Fisheries Products and Services

Three main levels of components were defined in the F2R EO case, arranged from top to bottom. At the top are the drivers, in the middle the production systems, and at the bottom the outcomes of interest. The drivers represent those identified by stakeholders as having the greatest impact and uncertain effect on the outcomes stakeholders care about. They are grouped into two components: climate drivers (on the right) and human social, political, and economic drivers on the left. These are represented a mixed assortment of drivers, including those over which the region has some control (e.g., agricultural and environmental policies) and those over which the region has limited, or no direct influence (e.g., climate change, global markets). These drivers form the basis for differentiating the alternative future scenarios, as they represent overarching change-drivers that will influence how the production systems change in the future.[3]

The second level describes three broad categories, local agriculture production systems: the non-farm economy, green energy farming, and food and feed farming. Also included were non-farm economies, such as commerce, industry, and services, along with other important regional sectors (i.e., forestry, and fisheries). We were able to develop details and models describing the agricultural system with the stakeholder expertise of participants, but were unable to engage participation from stakeholders from the non-farm, fishery, and forestry sectors. One of the reasons for using an adaptive management framework is that it establishes a cyclical process, in which new information and perspectives may be incorporated into the model, which is a "work in progress," rather than a final product. Consequently, by including these additional components into the system map, they are considered during the initial work, and can be more fully expanded into the maturing model and regional scenarios.

Since the purpose of alternative scenarios approaches is to evaluate the relative merits and limitations of alternative pathways of change, including adaptation, the primary outcomes play an important role in comparing the "performance" of different alternative futures and adaptation choices. In the Eastern Ontario project, two general categories of outcomes were considered: net income to farmers (from the three farm production systems described), and environmental outcomes, including those affected by agricultural production as well as other non-agricultural factors. Outcomes may be based or derived on sectoral or socioeconomic priorities, but should include measures that allow local stakeholders, land managers, and policy-makers to gain new insights regarding adaptation options, costs, and trade-offs. In Eastern Ontario this included, for example, incorporating established metrics and indicators of change that were used by municipal and other regional bodies in their reporting and analyses. We also factored in concerns regarding human health and air quality as priority outcomes to model in subsequent analysis.

3. For example, a global market scenario for the future describes local changes that are driven by international market prices, whereas a food security or in the F2R example, living locally scenario is more driven by local policies and practice change.

Figure 7. Describing and Evaluating the BAU in Adaptation Innovation & Learning Framework

Creating Alternative Future Scenarios

Planners, policy-makers and other stakeholders involved in adaptation planning are increasingly recognizing that the strategies needed are multifaceted and cross-sectoral, requiring stronger linkages between adaptation actions and future development priorities Figure 7). To address these challenges, scenario approaches were suggested for investigating potential future socioeconomic and environmental conditions to create the context for an assessment of climate change impacts and needed adaptations.

The scenario development was done in two steps. First the stakeholders focused on developing a business-as-usual (BAU) scenario, describing current interrelationships and dynamics, and secondly, a series of alternative scenarios were described as representing different trajectories of change. Change was considered from the perspectives of policy and regulation, external influences over which the region can respond but has no control, as well as more local influences of change. Both groups of scenarios focused on illuminating how the critical uncertainties would influence a region now, and in the future.

Creating a Business-As-Usual (BAU) Scenario

For the BAU, stakeholders identified what each driver was expected to do in the future, especially for environmental and agricultural policies, and extrapolated these impacts on of the various farming systems and non-farm activities within the region (following the categories of the system diagram). The BAU scenario was developed by each group during these workshops, to increase the scope of the BAU and provide robust results. These variants were discussed in a plenary session in order to agree on the final form of the BAU.

4. In EO, the project team has been expanded to include health and aquatic systems, which is being undertaken through a three-year research project supported by OMAF.

Example of the BAU developed for the EO project:

i. Climate change increases growing seasons but also increases the occurrence of extreme and catastrophic weather events. Climate change was considered an overarching driver that would have known, but unpredictable impacts on the regional socioeconomic, natural and agricultural systems in Eastern Ontario. Whereas regional climate models indicate that growing degree days and overall temperatures would become more favourable for crops generally, the increased incidence, intensity, and frequency of extreme weather events would ultimately influence the performance of regional production systems, urban centres, and sectoral activities. As such, it was expected that new cultivars and crops would be introduced into the region to take advantage of favourable growing conditions, but that their success would be linked to the occurrence of weather events. Risk management and insurance traditionally practiced by rural and agricultural communities would continue to be used in the future.

ii. No change in local governance (Figure 8). The BAU scenario narrative emphasizes the importance of both increasing demand for high-end products and increasing competition for cheaper products. From a governance perspective, the increasing demands and greater competition create a situation in which concerns about food and water insecurity will likely increase, and potential global energy crises could lead to political instability in some regions of the world, thereby impacting global market

Figure 8. Photo of the current landscape

prices and, consequently, local productions and socioeconomic systems. In this scenario, existing policies, regulations, agreements, and existing infrastructure and sectoral activity form the basis of what is (and is not) possible in the future.

In terms of agricultural policy it is envisioned that more interest will be directed at greening the food supply by, for example, the introduction of "greener" standards (by e.g., the Canadian Food Inspection Agency, CFIA).The use of certification programs for agricultural products is also expected to increase, driven by an emerging industry response to consumer demand. This trend is expected to continue into the future, and strengthen or expand existing regulation and enforcement. There could also be greater consumer interest in certified and uncertified organic products. Given potential future climate change impacts there is expected a continuation of business risk management and insurance by producers and farmers.

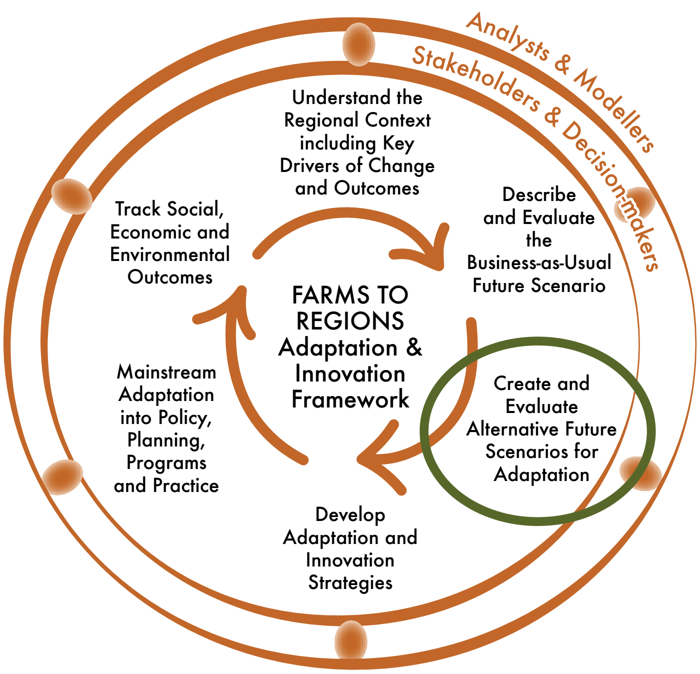
In terms of environmental policy, stakeholders felt there will be a greater emphasis on economic considerations over environmental protection, although the way this would manifest will depend on specific subsectors and the regional priorities. The trend, however, of streamlining environmental regulations is expected to continue, with new agricultural standards being introduced for agricultural production. Consideration was also given to what is expected as increased environmental risk, in that additional incentives and programs to encourage improvements of practices to support ecosystems good and services are expected. Finally, it is expected that biofuel production will increase in the region.

iii. Economies and markets are subject to international markets and climate extremes: Small and medium-sized farms will fare less well in the future. Increasing wealth, combined with a growing number of trade agreements are expected to increase the demand for meat exports, with some regions experiencing a comparative advantage due to their geography and the anticipated effects of future climate change (e.g., Brazil). Although these markets may open to Canadian producers, the rate at which they develop will influence their access to these global markets. In Canada, middle-sized farmers were felt to be at risk of losing their market share due to issues of scale, which make them less competitive than larger farms.

The demand for local foods will persist. The emerging trend for local markets (eat locally, urban agriculture, organic) will continue in the future, although it is also not clear if supply management systems (e.g., marketing boards) or subsidies will continue in the future. It is therefore expected that input costs of production will increase as the cost of energy remains high, driving up the costs of fertilizers. Growing costs to small-scale producers were also seen to be linked to potential costs related to environmental regulations, insurance and tax increases, and operations. As such, the price of locally produced goods was expected to remain relatively high.

Qualitative descriptions for the BAU scenario (and subsequently, the alternative scenarios) were developed (Appendix 6.4), and translated into quantitative terms for the dynamic runs using the Envision model.

Figure 9. Creating and Evaluating the Alternative Future Scenario in Adaptation Innovation & Learning Framework



Creating Alternative Qualitative Scenarios

Because there is uncertainty about how the future will unfold, plausible futures are depicted as a range of outcomes that could happen, rather than a "preferred" or "most likely" outcome as is often used in alternative future processes. By having multiple scenarios, the unknown future is expected to fall within the range of these alternative scenarios. And, in contrast to the BAU scenario, the alternative scenarios used for assessment incorporate multiple forces of change that are of particular interest, such as human population growth, climate change, the introduction of different or new technology, as well as new sectoral practices, including adaptation actions.

At this second step, a range of alternative "plausible" futures is described, taking into account not only the impacts of the various key drivers, but also how the region could choose to react to these drivers (Figure 9). The first step was to draft a set of brief scenarios, based on discussions from the first workshop, to describe several different trajectories of future development for the Eastern Ontario region. In this case study, the specific purpose being to make assumptions about the impacts, and best regional strategies to deal with the critical uncertainties facing the region. To do so, the following steps were completed:

- A summary of projected changes in global/regional population, global fuel prices, climate change trends for the region, as well as trends in economic growth and food prices was developed.
- A summary in which projected trends and foresights studies done for Canada were synthesized.
- The outcomes were compiled describing key policy priorities related to IPCC global scenarios, such as a focus on food security; establishing linkages between agricultural and energy markets (including changes in consumption patterns); describing trends in demand for agricultural products especially in fast-growing regions; increasing emphasis on economic development and regionalization; trade agreements, trade barriers and cooperation; promoting sustainability and local level actions (i.e., sustainable and beneficial management practices); developing new technologies to access markets (e.g., bioeconomy); increasing focus on ecosystem goods and services to improve environmental state;

and risk management and adaptations to risk.

- Implications of scenarios and foresight products developed in Canada were identified to single out priorities that will likely shape the future of the Eastern Ontario region.
- Experts were consulted to determine the potential of future trends relevant for the region.

Based on feedback from the workshop in November 2011, and discussions within the project team, a set of simple scenario narratives were developed. Narratives aimed to provide ideas about the types of future trends in governance and policy, markets, agriculture and environment or other legislation that could be developed in the future. In some cases these changes represented responses to drivers, like climate change, while in other instances, these trends reflected economic or other types of regional interests. In each of the four scenario narratives we assume that significant changes in climate will be present:

- Targeting foreign markets: International trade and market economics are key drivers in the agricultural system (Figure 10). Agricultural producers are interested in targeting growing global market opportunities. Large and specialized farms dominate the landscape to produce goods especially for foreign markets. Federal and provincial governments cooperate with industry in setting market-based incentives to enable meeting market needs both domestically and internationally. Efficiencies of scale are especially important for trade and competitiveness.

Figure 10. Illustrative vision for the Targeting foreign markets scenario

- Promoting the bioeconomy: International trade and markets are important in this scenario, but the emphasis shifts from traditional activities to more diversified and regionally based "life cycle" productions, with more direct impacts on regional socioeconomics and growth (Figure 11). The region will aim to explore opportunities from the bioeconomy including in energy production, pharmaceuticals, fabrics, cosmetics, plastics. The region aims to become a leader in the bioeconomy regionally, building on the opportunities in the area and exploring opportunities with local and provincial governments to develop this leadership. Economies of scale are important in this future, although to a lesser extent, since there tends to be more emphasis on regionally based industries and value-added products.

- Moving toward greener agriculture: Because of increasing pressures on natural resources, the impact of severe weather events, and increasing interest in promoting food security at regional, national and international levels, there will be a stronger focus on improving environmental performance of agricultural production (Figure 12). Different levels of government will be involved in directing these changes through targeted agricultural policy and other mechanisms. For agriculture this would mean balancing efficiency and environmental impacts. Agricultural outputs will be targeted mostly to local and North-American markets.

Figure 11. Illustrative vision for the promoting bioeconomy scenario

- Living locally: Local food security and environmental performance are addressed through a shift toward more regionally based production (Figure 13). Smaller farms and farm partnerships dominate the producers' group and create a diversified agri-landscape. They successfully explore niche markets, mostly regionally, and cooperate with local governments (municipal and watershed) on market incentives, rules and regulation. The trend toward larger farms continues on more traditional production systems that remain in the landscape. This scenario is strongly tied to policy, regulatory, and incentive programming by governments.

Figure 12. Illustrative vision for the Greening agriculture scenario

Figure 13. Illustrative vision for the living locally scenario

Each scenario represents one of several different trajectories of change that Eastern Ontario could realize, with some being more focused on markets and trade (Targeting Foreign Markets and the Bioeconomy) while others tend to be more regionally based, with varying reliance on policy, regulation and other incentive programs and tools (Moving Towards Greener Agriculture and Living Locally). In the F2R application, we used a three-step approach to translate these qualitative scenarios into explicit types of changes from one state to another, including the rate and nature of how these changes would be applied across the landscape. The steps are described below:

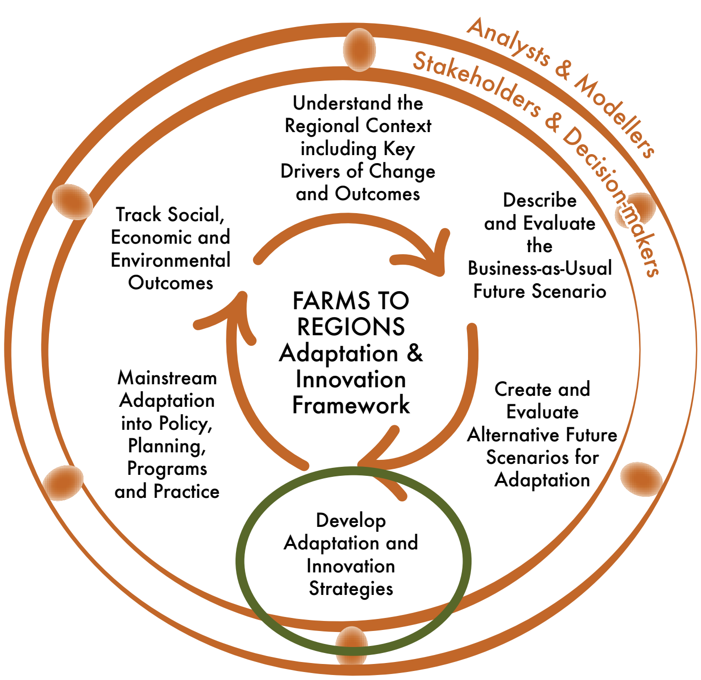
- Outline, in detail, how each of the key drivers would affect the practices and land use trajectories for each scenario. The goal here is to understand how the proposed future would respond to the critical uncertainties (e.g., extreme weather events, global market shifts, increase/decrease energy prices, etc.). This was conducted for the various process linkages described in the system diagram, such that the performance of the newly envisioned future would be considered in light of climate change impacts, environmental and agricultural policies, etc. Specific categories included the key drivers of the system diagram (e.g., trends in markets and sectoral policies), including: the type and nature of climate change impacts; environmental stewardship (environmental policy); landscape character; natural areas; agriculture (agricultural policy; agriculture markets/leading enterprise; technology; ecosystem services), and industry (energy and other industry).
- The second step was specifying these categories for modelling that could directly inform modelling—often described as changes compared to current trends: crop mix in production (annual and perennial including new), crop rotation (two major types of rotation), livestock feed supply, livestock production (types of livestock, intensive/extensive livestock operation); field management (irrigation, tillage; file-drainage; exiting and new); surface water management; agriculture inputs (chemicals, manure); pest and disease management; energy farms (size and planted crops); environmental stewardship (riparian/wetland buffers, freshwater quality an ground water protection; wildlife habitat and air quality and air quality (greenhouse gases).
- Finally, the third step was led by the project team that used this information and quantified it using the same categories as was provided to the stakeholders but expressing all of them in quantitative terms. For quantification, we used an integrated model—its setup is discussed in the next section.

An overview of the scenarios is listed in the appendix 6.3 and 6.4.

3.3 Development of Adaptation Options

One of the many challenges in developing adaptation plans is that there is no real way to know what future conditions will be like (Figure 14). In Eastern Ontario, our scenarios were defined along a sort of continuum of change that regional stakeholders felt they might need to prepare for. The use of different scenarios provides a range of potential future conditions or states (visually and quantitatively presented) for discussing adaptation needs and priorities both in general terms (e.g., where will conditions change?) as well as specific terms (e.g., what sector or land-use activities present the greatest benefits, or risks, to priorities for the region in the future?).

Figure 14. Developing Adaptation and Innovation Strategies in Adaptation & Innovation Framework



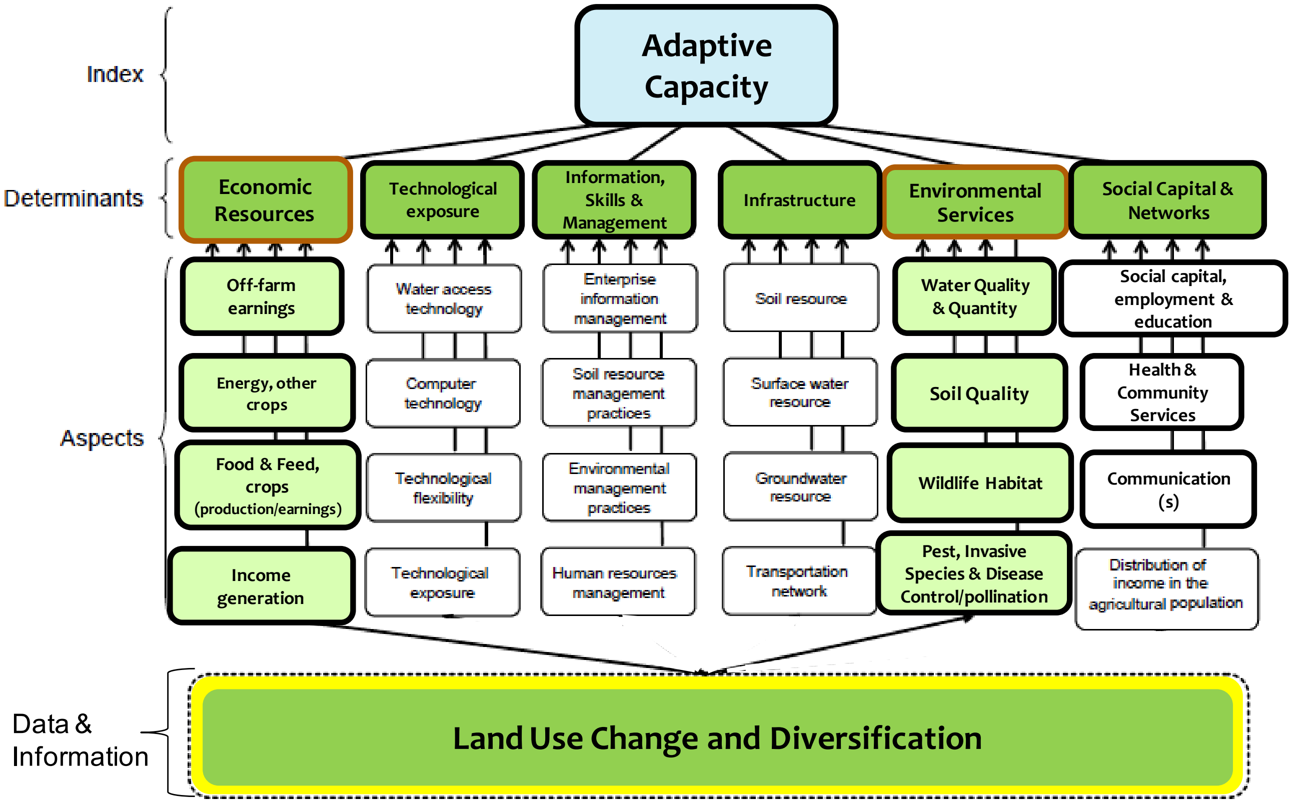
The four alternative scenarios were explicitly developed to quantitatively represent different trajectories of plausible future conditions, and land use, as well as providing a basis to allow specific adaptation options to be explored. For instance, the nature and prevalence of different agricultural management practices differed among the scenarios. Specifically, each scenario differed in the degree to which incentives were used to increase the extent of agricultural diversification and the representation of ecological services (e.g., wetland protection for flood management), thus allowing stakeholders to discuss the relative merits and strategic use of incentives with respect to particular production and socio-ecological objectives.

The scenarios were set up to allow stakeholders to consider development of the region in general and agricultural practices in particular. The differences in the importance of policy instruments, such as incentives and regulations, market forces, such as export and trade agreements, and the retention of local ecological services allowed stakeholders to consider how their adaptation priorities would be expected to differ under different plausible futures. In terms of agricultural change, the inclusion of different agricultural practices allowed us to characterize the type of agricultural adaptation needs and strengths within the region. This includes, for example, asking questions regarding the way in which the different trajectories of change in agricultural intensification would exacerbate or minimize the need for adaptations.

As part of our overall approach, each of the four scenarios will be quantitatively assessed, relative to each other, using the developed dynamic simulation model projecting 30 years into the

future under climate change. The agricultural and environmental outcome measures in each of the scenarios will be used to characterize the sensitivity of the region to conditions under the various future trajectories and to test how the use of different types of adaptation options can manage against such risks. Although we identified a number of different determinants of the region's adaptive capacity (Figure 15) for this project, our particular focus is on economic and environmental determinants. In other words, we focus on the issues that would enable the region to protect the things they identified as being important to them (e.g., water quality and supply, wildlife, environmental health, etc.).

Figure 15. Adaptive capacity framework modified for an agricultural region (adapted from IISD, PFRA, 2007; Smit et al. 2001). Adaptive capacity can be broken down into key aggregate components to identify key elements of vulnerability and what determinants are in play, such as economic, technological, information and skills, infrastructure, environmental services and social capital and networks.



Workshops were held with stakeholders wherein participants were asked to identify the three most important considerations for adaptation options with regard to practices, policies and specific actions. Based on these considerations, they were asked to identify both the capacity that would be required to respond, and what an effective adaptation option would be under future climate change. This was repeated for each of the future scenarios. For each of the scenarios, diverse elements of adaptive capacity were highlighted. A summary of the considerations raised is presented in Table 3.

Table 3. Examples of feedback to the scenarios and adaptation needs

	Key feedback on the scenario	Adaptation and adaptive capacity needs/preferences
Targeting global markets	Considered as having negative impacts on natural land cover and wildlife populations; however, the fact that farmers would be making more money could mean positive implications in terms of their health and overall well-being. The prevalence of monoculture could result in farmers and crops being more vulnerable to pest and disease outbreaks, resulting in crop loss and income decline	Large farms have higher adaptive capacity (e.g., access to insurance). It would require strong financial instrument coordination with policy to prioritize other types of measures (public infrastructure, data, natural resource management).
Promoting bioeconomy	This scenario was perceived as being the most relevant scenario for the region; it manages to balance environmental and economic priorities. It was flagged that this scenario would also require additional investments not directly to agriculture but to R&D, commercialization and to develop access new markets as the produced biomass cannot be only used regionally.	Highly resilient scenario, but it also includes a high level of public and private investments, which needs to be structured in a way that promotes adaptive capacity, environmental protection and business development.
Greening agriculture	This scenario was perceived on one hand as relevant for current agriculture in the region and it was seen largely surprisingly that the contributions to especially natural resource protection are not more significant. On the other hand, the surprise was also the gap between the BAU and this scenario was initially seen as one that is close to BAU but with some "green fixes." It was also indicated that under this scenario the change in the agricultural production is less significant and the changes in practices can be achieved through policy, private initiatives or both	This scenario indicated that significant changes (both at the level of practices and policy) are required to make the agriculture system resilient.
Living locally	This scenario would create a greater sense of community compared to other scenarios, enhancing social networks in the region. At the same time, restricted trade with partners outside the region could increase food insecurity and result in volatile prices. The feasibility of the scenario was questioned because of relatively low interest in small-scale farming currently. This scenario could become a component of any of the three scenarios in which the region maintains small farm sizes and other green production only around urban areas.	At the small scale, this scenario provides benefits for communities, natural environment and adaptation. It requires a maintained continuous policy support to sustain small-scale production, at least close to urban areas.

Working with the identified adaptation needs collectively, more than 50 types of adaptation actions were identified as either "needs" (those requiring responses not presently used) or targeted actions, all of which were grouped into five adaptation clusters covering diverse aspects of adaptive capacities. These clusters can be described as:

- Farm-level actions in response to identified vulnerabilities related to what they produce and where they are located. Farm-level actions are the responsibility of individual farmers and producers. They may, for example, choose to adjust livestock herd size or composition and/or acreage dedicated to livestock, change crop type or rotation (no new equipment necessary or minor alterations), or shift to different varieties, and modify pest-management practices. Ultimately, the actions taken by producers will build on the research, development and transfer work by industry and government researchers to identify shifts or adjustments in management practices (e.g., tillage, pest control, irrigation), and to provide the necessary information and/or tools to initiate change. Similar individual-level adaptations also need to be considered for non-agricultural land management of forest and woodlots, infrastructure development, etc.
- New actions, such as new technologies, or the introduction of new forms of crop insurance, to allow farmers to manage future risks presented by climate change. Given the high uncertainty in anticipating what future weather conditions will be, new actions would serve as a cushion to bridge gaps and mitigate surprises, especially those related to extreme weather events associated with climate change. This could include, for example, changing the way insurance premiums are calculated to consider vulnerability of flood risk (i.e., zones), or changes in farm size and crop diversity to provide a buffer against risk uncertainty. New actions may be applied at the individual, sectoral, or regional level.
- Support for maintaining ecosystem goods & services to reduce vulnerability at the farm and regional level. Ecosystem-based actions consider local effects within the context of the larger region, to ensure that natural systems are able to act as buffers to reduce the vulnerability of the agricultural and other human systems. Instituting and defining ecosystem-based actions may therefore be done through policy support and/or incentives to encourage actions, such as changing river set-back areas and stronger regulation on riverbank protection, changes in land use that increase runoff.
- Providing information to better understand vulnerability, identify risks and plan for adaptation. Regional land owners, such as farmers, homeowners, foresters, as well as operational groups (e.g., farmers' groups and regional and local policy-makers) all require regionally specific information for their day-to-day planning. In order to make appropriate information available, including spatial information (such as GIS data and tools) to help planners, and relevant weather prediction and seasonal forecasting tools both the availability (and timeliness) and sharing of information needs to be improved between the communities and local policy-makers

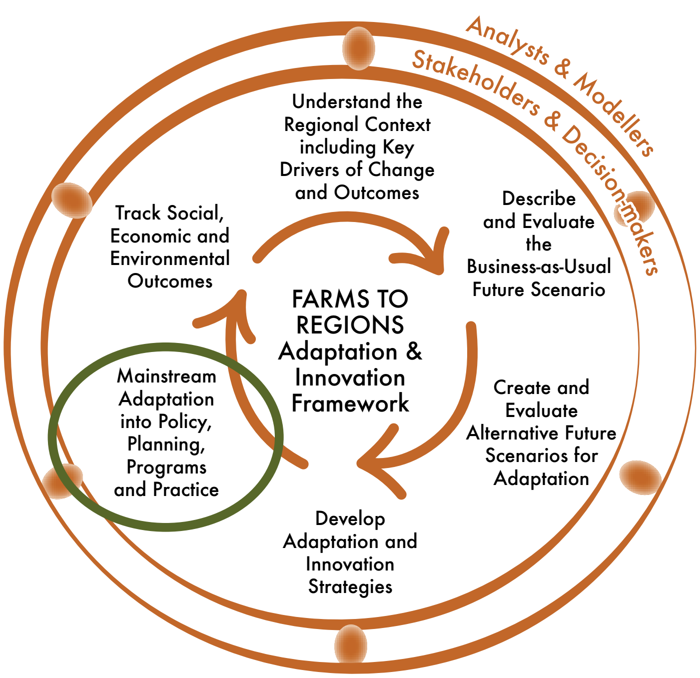
- Awareness raising and education for the public, and key stakeholders will also be required to create the local and regional support for acceptance of adaptation measures, whether in agriculture or other arenas. Acceptance is ultimately key to encouraging the necessary cultural shifts both in the farming and other communities as well as among policy-makers, where emphasizing the importance of mainstreaming adaptation into sectoral policy-making will be essential.

3.4 Mainstreaming Adaptation Into Policy, Planning, Programs and Practice

The developed scenarios and their assessment provide guidance for mainstreaming adaptation as well as insights into the types of policies and responses that will need to be developed (Figure 16). The use of the scenarios clearly showed that adaptation is a cross-cutting effort, and demonstrated the way in which the activities of one sector interact with those of other regional stakeholders. This includes not only agricultural practices and farm-level actions, but illustrates that adaptation planning requires an integrated approach covering business development, as well as the information needs and tools for regional and local decision-makers, in addition to the specific farm-level actions identified. In this context, Table 4 illustrates the importance of effective strategy development to address overall challenges in agricultural production and shifting markets.

The importance of integration and the challenges of mainstreaming climate change adaptation are now well recognized as key to preparing for future conditions. From the data and modelling perspective, integrated models like the Envision platform are important tools to help make use of myriad datasets with their potentially mismatching scales and purposes, and facilitate discussions among regional actors. The technical and coordination aspects of setting up these sorts of models require a mixed team of skillsets to execute. The adopting and implementing of adaptation actions into day-to-day decisions, programs, practices, as well as planning and policy processes, requires that they become "mainstream"—i.e., standard—considerations in these processes. One objective of mainstreaming is, therefore, to prevent harmful events where possible by encouraging adaptive planning to be anticipatory rather than reactionary.

Figure 16. Mainstreaming Adaptation in Adaptation & Innovation Framework



In practice, mainstreaming is an ongoing requirement of planning and policy processes. The use of an adaptive planning cycle helps to ensure these considerations by being a planned, iterative, knowledge-generating circuit. In the more immediate term, for example, a computer-based model can be used as a tool by farmers and other regional decision-makers to consider how their operations might be affected by future conditions, and look at some alternative options based on a range of considerations outside what they generally are able to consider. In eastern Ontario, the suite of stakeholders also included responsible authorities from a variety of sectors and scales; by being part of the initial prioritization process, these regional planners and policy developers were able to incorporate some of their priorities into the Envision model, which assured that the model and results of this project would provide them with information that would assist their planning purposes (Table 4).

The inclusion of regional organizations with mandates to manage or provide relevant information for planning purposes is a must from the beginning—not only to ensure that the most relevant priorities are included, but also because they play an important role in producing and disseminating information about the region. In Ontario, Conservation Authorities serve as official watershed management agencies, using integrated watershed approaches to deliver services and programs aimed at protecting and managing regional water and other natural resources.[5] In our Eastern Ontario study area, four Conservation Authorities, as well as different sectoral organizations and government representatives, helped to direct the priorities and features that were included in the scenarios and reported on as outputs from the model. Their participation is also key to mainstreaming, since their understanding of regional policy and programs can be used to identify the mechanisms (existing or needing to be established) by which actions could be implemented within the region.[6]

5. Conservation Ontario's website provides more detailed information on the role and priorities of Conservation Authorities, which is transboundary, and includes ecosystem as well as human health among its priorities: http://conservation-ontario.on.ca/.

6. A next step in this process would include the regional stakeholders generating a map detailing the mechanisms currently in place to support the various adaptation actions listed in Table 4, as well as those actions which would require new tools or programs to implement.

Table 4. Overview of types of adaptation needs at different stages of the scenario development

Adaptation action	Prior scenario development process	Based on the qualitative scenarios	Based on the quantified scenarios
Farm-level actions			
Tools for land owner to respond to CC – trade policy, remote/GIS data to help agriculture, weather prediction		X	X
Carbon tax		X	
Review of habitat allocations (especially species at risk) and this could mean changes in land-use/agriculture management practices and land allocations	X		
Methods of more efficient water delivery/irrigation	X		
Stronger regulation on riverbanks protection, land-use change that increases runoff	X		
Source protection measures in areas prone to water contamination, nutrient in-flows especially in areas that could be affected by heavy rainfall (may limit expiation of operation in these areas	X		
Crop-breeding programs	X	X	
New business models/longer contracts		X	X
New crop insurance to manage risks/ Alternative modes of insurance for smaller and larger farms	X	X	X X
New technology, outreach and education	X	X	X
Erosion protection measures in areas prone to erosion to reduce impacts on heavy rainfall	X		
Plant breeding – access moisture, dry weather		X	
Improved infrastructure – water retention, improved drainage, irrigation in place (when needed availability)		X	X
Incentivize rather than regulate – payment for ecosystem services for small farmers	X	X	X
Awareness and education			
Framing more as a support for rural life/lifestyle rather than CC adaptation; rural revitalization (mainstreaming adaptation		X	
New technology, outreach and education	X	X	X
Encouraging cultural shifts both in the farming community and between policy-makers			X

Adaptation action	Prior scenario development process	Based on the qualitative scenarios	Based on the quantified scenarios
Improving data availability and sharing between the communities and also ensuring that the data are regularly updated			X
Developing tools for decision-makers and farmers to plan for climate change impacts			X
Developing plans and support systems to implement new agricultural opportunities – biomass and related marketing and processing systems, local markets development etc.			X
Transition management and mitigation plans to address potential spread of forest pests such as Dutch Elm Disease and spruce budworm	X		
Investment into innovation – biotechnology		X	

3.5 Tracking Social, Economic and Environmental Outcomes

The final step in adaptation mainstreaming is to track the adaptation efforts and the social, economic and environmental outcomes of implemented measures (Figure 17). Indicators have been described as policy informing systems that provide a sound basis for decision making (Dovers 1996; Higgins & Venning). Integrated indicators that track social, economic and environmental issues in an inclusive manner, rather than in isolation, demand a reframing of purely environmental or economic problems towards so-called sustainability problems (Hezri, 2004). In this sense, climate adaptation indicators should be closely linked to policy processes, institutional setting and organizational structures to effectively advance related social, economic and environmental factors into policy and decision making (Dovers, 2003). Further, these indicator systems promote policy learning by uncovering what works and what doesn't by bringing knowledge into policy evaluation, problem identification and agenda setting (May, 1999).

Figure 17. Tracking Outcomes in Adaptation & Innovation Framework

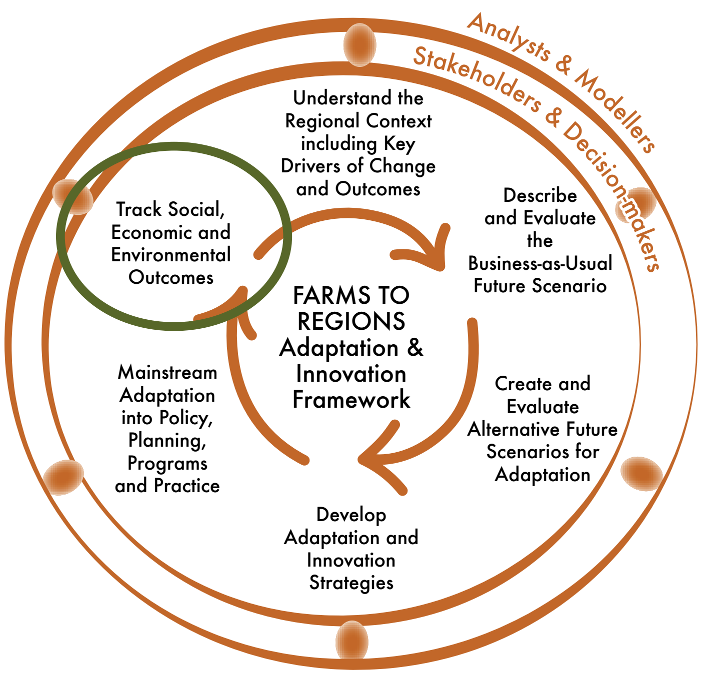


Table 5. Planned and autonomous adaptation

Adaptation type		Process	Outcome
Planned (adapting to anticipated climate impacts)	**Building adaptive capacity** (monitoring progress in implementing adaptation measures)	X e.g., crop insurance, social networks	
	Delivering adaptation actions (measuring the effectiveness of adaptation policies and activities)	X e.g., heat alert and accurate forecasts	X e.g. heat alert and forecast-related productivity
Autonomous (adapting to unanticipated climate impacts)	**Autonomous – good**		X e.g., crop patterns
	Autonomous – bad		X e.g. desalination

Adapted from: Harley, Lisa & Hodgson (2008).

Several studies have focused on the particular theoretical and practical bases for defining adaptation indicators within the context of climate change at the level agricultural producers and their communities (Harley, Lisa, & Hodgson, 2008). In these studies, adaptive capacity is composed of both planned/anticipatory and autonomous adaptation processes, while indicators are sought to measure both the procedural elements to facilitate adaptation and the outcomes of adaptation efforts (Table 5). These efforts put the ability of agricultural producers to adapt squarely within the context of external environmental factors, and thus provide a useful framework to assess how these operations may be affected by climate change. Within this framework, indicators can be further differentiated along the lines of process- and outcome-based indicators. While process-based indicators seek to define key stages and inputs within the adaptation process that may lead to the best endpoints (without specifying what that endpoint is), outcome-based indicators define explicit outcomes, or endpoints, of that adaptation (Harley, Lisa, & Hodgson, 2008). Specifically, process-based indicators include types of consultation processes, policy-development processes and management practices. Outcome-based indicators include agricultural production, earning and inputs (Table 6).

In addition to tracking whether adaptation is occurring, the social, economic and environmental outcomes of adaptation efforts may also be measured to proxy for the efficacy of these efforts. Climate change is expected to affect agricultural landscapes through issues such as soil erosion, water stress, susceptibility to pests and flooding, and hence ultimately the productivity measures of agriculture such as farm income and agricultural output. Maintaining productivity in the face of climate change requires that climate stressors are effectively addressed. For example, climate threats affecting soil fertility can be countered through measures to enhance soil nutrients, such as applying fertilizers and practicing integrated nutrient management. However, such adaptation measures are not all created equal. The further use of fertilizer can lead to adverse impacts on the environment, especially when coupled with increased agricultural runoff due to more frequent flooding. In comparison, integrated nutrient management practices, which are promoted by organic farming and environmental whole-farm management methods, can effectively mitigate such negative effects on the environment, but may also be more expensive than simple fertilizer use. Therefore, a monitoring approach that covers a wide range of environmental, social and economic benefits and risks of adaptation is required.

Table 6. Indicators to track adaptation and their outcomes

Indicator	Definition	Climate change linkage	Indicator type
Financial			
Crop insurance	The proportion of agricultural land that is under insurance systems that cover extreme weather events. These programs include drought assistance, natural disaster relief/mitigation, ex post aid for catastrophes, large loss contingency, and others.	Crop insurance buffers against the negative financial effects of climate change on agriculture, including those related to reduced yield and crop losses.	Planned adaptation
Farm income	Difference between the value of gross output and expenses (including depreciation).	Extreme climate events, which disrupt production volumes and agricultural output, can have a significant effect on the ability of farmers to generate income.	Economic outcome
Producer support	Producer support (gross transfers from consumers and taxpayers to agricultural producers) as a share of gross farm receipts (including support).	Support to producers helps producers to remain profitable in a changing environment.	Economic outcome
Agri-environmental projects and research	Public and private expenditures on agri-environmental projects and research.	Various landscape management and environmental projects can help mitigate the negative effects of agriculture on the environment and improve the adaptivity of operations against a changing climate.	Cross-cutting
Production			
Agricultural output	Value of final agricultural output (metric tonnes).	Since agriculture depends on climatic processes for inputs (rain, adequate temperatures, etc.), output may be significantly affected by a changing climate.	Outcome
Education			
Education level	Education level of farmers measures the percentage of farm operators that have a university degree.	Education can help foster a greater understanding of climate change, its effects on agriculture and ways to foster agricultural productivity and profitability.	Adaptation
Farm management			
Environmental whole-farm management plan	Total agricultural area under environmental whole-farm management plan.	Possibility of improved mitigation of climate change contributions and adaptation to climate change impacts.	Cross-cutting

Indicator	Definition	Climate change linkage	Indicator type
Organic farming	Total agricultural area under environmental certified organic farming system.	Possibility of improved mitigation of climate change contributions and adaptation to climate change impacts through the strengthening of agro-ecosystems, crop diversification, and the enhancement of producers' knowledge base on ways to best prevent and confront climate change effects.	Cross-cutting
Pests and diseases			
Pesticides	Use of pesticides (kilogram of active ingredients) per hectare of agricultural land area.	Climate change can increase the prevalence/ propagation of various pests.	Planned adaptation; environmental outcome
Veterinary drugs	Use of veterinary drugs (mg of active ingredients) per head.	Climate change can increase the prevalence/ propagation of various pests.	Planned adaptation; outcomes
Water			
Irrigation	Irrigated land area in total agricultural land. (Another potential indicator is irrigated water application rates.)	Climate change can induce greater evaporation of water/reduced availability of fresh water and variability in rainfall.	Planned adaptation
Water quality	Concentration of nutrients, chemicals and sediments from agriculture in water bodies measured in terms of the share of water monitoring sites that exceed recommended drinking/ bathing water quality threshold limits.	Climate change can increase the magnitude and frequency of storms and thus increase the loading of nutrients, chemicals and sediments into waterbodies. Climate change induces greater growth of algae, which interacts with nutrient loads in water bodies to create algal blooms.	Planned adaptation
Water stress	Ratio of water withdrawals to availability. (University of New Hampshire Water Systems Analysis Group's (WSAG) water stress index)	The rise in the mean temperature and extreme heat events increase evaporation and the increased variability in rainfall/low rainfall events increase the threat of drought and therefore water stress in areas where water availability is already an issue.	Planned adaptation
Water retaining capacity	Quantity of water that can be retained in the soil and on land (e.g., flood storage basins), and agricultural irrigation and drainage facilities.	The rise in the mean temperature and extreme heat events increase evaporation and the increased variability in rainfall/low rainfall events increase the threat of drought. Therefore, retaining capacity can help improve resilience to these changes.	Planned adaptation

Indicator	Definition	Climate change linkage	Indicator type
Infrastructure			
Storage	The percentage (in terms of capacity) of storage facilities that are weather proofed.	Stressors such as heat, cold, excess moisture and drought can reduce the efficacy of storage facilities.	Planned adaptation
Livestock housing	The percentage (in terms of capacity) of livestock facilities that are weather proofed.	Livestock and their housing facilities can be vulnerable to stressors such as heat, cold, excess moisture and drought.	Planned adaptation
Machinery			
Waterlogging operability	Share of cultivation machinery that is able to operate on waterlogged soils.	Erratic rainfall and flooding can lead to land being saturated with water.	Planned adaptation
Soil			
Soil fertility	Soil Organic Carbon (SOC) measure. (Other possible indicators: nutrients balance for nitrogen, phosphorous, potassium.)	There is some early/inconclusive evidence that climate change can reduce soil fertility (because i.e., climate change can alter microbial properties and thus the in/out flow of carbon in the soil).	Planned adaptation; environmental outcome
Soil erosion	Agricultural area that is subject to risk of soil erosion due to wind and water as percentage of total agricultural land.	Greater wind and water erosion can occur as a result of climate change due to, for example: decreased snow cover and greater winds in the winter; and more frequent and intense flooding in the spring and summer and thus soil runoff.	Planned adaptation; environmental outcome
Fertilizer use	Nutrient inputs (kg) per hectare of agricultural land.	Nutrient inputs may have to increase due to decreased fertility and increased soil erosion.	Planned adaptation; environmental outcome
Land			
Soil cover	Number of days in year that agricultural land is covered in vegetation.	Can help reduce evaporation and soil erosion from the effects of climate change.	Planned adaptation; environmental outcome
Crops			
Transgenic crops	Share of transgenic crop area relative to total agricultural area.	Increased water use efficiency and resilience to climate change effects, including related threats such as propagation of pests.	Planned adaptation

Indicator	Definition	Climate change linkage	Indicator type
Decision making			
Consultations during policy development	The percentage of agricultural policies that used multistakeholder deliberations in the scoping and design phases.	Can enhance two-way learning about the effects of climate change on agriculture. Can thus help farmers adapt to climate change, and ensure that policies themselves are adapted to the needs of producers and the expected to effects of climate change on their operations.	Autonomous adaptation; social outcome
Consultations during policy implementation	The percentage of agricultural policies that used multistakeholder deliberations in the implementation phase.	Can enhance two-way learning about the effects of climate change on agriculture. Can thus help farmers adapt to climate change, and ensure that policies themselves are adapted to the needs of producers and the expected effects of climate change on their operations.	Autonomous adaptation; social outcome
Policy reviews	The percentage of agricultural policies with a formal review process in place that can detect emerging issues.	Can enhance the effectiveness of policies by ensuring that they are achieving their intended purpose.	Autonomous adaptation; social outcome

Developing an integrated model to simulate alternative futures

Although assessments of scenario simulations may be made by using qualitative or quantitative methods, for the purposes of this guidebook, we focus on quantitative, computer-based approaches that combine existing data, reporting metrics, and scientific models. This includes some for water, production (agricultural, forestry, etc.), and natural systems (e.g., wildlife habitat) with the "levers" of policy and planning creating the basis for how each alternative future unfolds. This allows runs of different "what-if" scenarios to be evaluated relative to one another, using a common set of indicators of change (e.g., profits vs. expenses, water-quality measures, etc.). For this purpose, we used a GIS-based community and regional planning tool[7] to set up our scenarios, and to explore production, costs, and environmental states. Envision is built on an open, extendible architecture that can be adapted to a variety of locations and applications (Bolte et al. 2006).

Table 7. Key definitions and examples of integrated modelling frameworks

Definition	Examples
Envision	ENVISION is a GIS-based tool for scenario-based community and regional planning and environmental assessments. It combines a spatially explicit polygon-based representation of a landscape, a set of application-define policies (decision rules) that are grouped into alternative scenarios, landscape change models, and models of ecological, social and economic services to simulate land-use change and provide decision-makers, planners, and the public with information about resulting effects on indices of valued products of the landscape. http://envision.bioe.orst.edu/
Marxan	Marxan is freely available conservation-planning software. It provides decision support to a range of conservation-planning problems, including: the design of new reserve systems; reporting on the performance of existing reserve systems; and developing multiple-use zoning plans for natural resource management. http://www.uq.edu.au/marxan/
ALCES	ALCES Tool Kit is to facilitate Integrated Resource Management. An important objective of ALCES is to encourage diverse stakeholders to gather together and explore the economic, ecological, and social consequences of different land-use trajectories on defined landscapes. www.alces.ca
MetroQuest	The tool aims to provide an interface and modelling tool for eliciting stakeholders' preferences about future visions, key policy directions and specific measures relevant for their neighborhood/area of interests. http://www.metroquest.com/#

7. The Envision modelling framework , developed by Dr. John Bolte of Oregon State University (OSU), was selected as a candidate system for this project.; http://envision.bioe.orst.edu

A key purpose of the system diagram is to enable the project team to more clearly describe and delve into the key elements and interactions of the system of interest. This map also serves to identify a set of indicators that can be used to track and compare the outcomes from the different futures of interest to a region. In the case of Eastern Ontario, there is a high level of uncertainty in each of the key drivers (i.e., projections from regionally downscaled climate change, global and regional economic market forecasts, energy prices, etc.). As such, the framing of policy and management questions for analysis were directed and determined by the knowledge and priorities of experts using a combination of engagement and questionnaires. This information was used to:

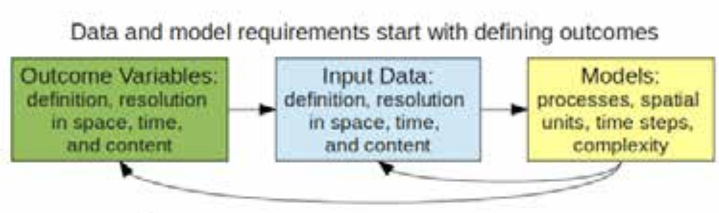
(i) Define regional conditions and trends surrounding drivers of change.

(ii) Describe interactions and relationships between drivers of change and potential vulnerabilities and opportunities.

(iii) Develop a series of scenarios of change and develop tools to explore management and policy responses.

The value of using appropriate models (Table 7) to simulate landscape change is that it allows several different "plausible" futures to be evaluated and used to understand the types of changes that the region may want to prepare for, or, to have a role in directing. Spatially explicit outcomes generated by GIS-based models also allow reporting measures to be represented at a range of scales, from the national, subnational and/or farm or landowner level, which can be used to better illustrate cross-boundary linkages and interactions. These outcomes can also be used as a set of outcome indicators/metrics that are then compared and contrasted among the various future scenarios to evaluate their relative benefits, costs, and risks, including those associated with specific policy and management options tested (Figure 18; e.g., climate adaptation policies).

Figure 18. The flow of information as decisions about data input, models, and outcomes are coordinated.



In F2R EO outcome variables were adjusted and added to throughout the duration of the project (three years) and in conjunction with data input and model development opportunities and constraints. We used a combination of existing spatial metrics in the Envision model, and metrics developed by municipal, provincial, federal agencies according to the availability of necessary data for their calculation, and whether or not they could be adapted (i.e., simplified) into a format that was meaningful and defensible in the model (done in consultation with the responsible authorities, indicator developers and/or research scientists). The two key outcome types for Eastern Ontario were: income to farmers, and environmental services (produced by or affected by agriculture). For both categories, we used measures already adopted by governments and organizations in the region to represent changes in the major crops in the region, as well as other agricultural or other land-use changes on environmental state.

4.1 Setting up the Integrated Model

This step summarizes the key activities to assemble an integrated model that addresses the key drivers and issues presented in the system diagram and create databases to run the model with the data representing the landscape. The Envision platform used in our F2R EO case study was selected because it is a highly scalable and transferable modelling platform that provides a base on which to spatially and temporally integrate models, data and indicators. This GIS basis of this dynamic system model also means that outcomes can be visualized (time series plots, dynamic maps).

Envision is a "framework for constructing alternative future scenario applications" and consists of a dynamic spatial engine for representing landscape characteristics that allows the system to operate a number of evaluative and process models, visual analysis modules used for data processing and model generation. The framework includes a representation of policies that guide actor decisions and scenarios that describe alternative strategies for land management. It is based on "plug-in" architecture and written in open-source C++ code. The fundamental spatial framework in ENVISION consists of integrated decision units (IDUs)—GIS polygons that are homogeneous with respect to particular attributes (e.g., soils, land cover classes etc.) and are used for modelling processes that are important for the region (e.g., population dynamics, changes in climate, land cover etc.). The platform developed for Eastern Ontario is transferable to other regions, and the specifics of the code development are not presented here.

To put together the data, available datasets were collected and catalogued. Preliminary data gathering was conducted over a period of around three months, with supportive and targeted additions made as required throughout the duration of the project. Sources of data ranged from local municipalities to conservation authorities to provincial and federal departments to national databases, including those available to the general public and ones whose use is restricted to Agriculture and Agri-Food Canada employees (e.g., NGIS). General census data and data from the Census of Agriculture were also integrated in a Geodatabase for the project. Overall, we attempted to consult primary sources that are publicly available at the regional and provincial level; however, datasets produced at the national level were also used. Consultations with experts were particularly valuable at this stage of the project as they not only provided relevant datasets but also pointed out new data and data sources that had not been considered prior to the consultations.

Considerations that guided data assembly and use included the spatial resolution of data (and year the data was produced), proper geometric representation (validation) of landscape characteristics in the datasets and availability of appropriate attributes that go along with them. The choice of data was made by the project team, in consultation with subject matter experts, as determined by data quality considerations, as well as the goals and potential modelling needs of the project. A geodatabase was developed and used to organize data, which was uploaded to the Eastern Ontario repository housed at Oregon State University. This facilitated data access from a centralized location for the project's working group and version control.

The organization of the geodatabase includes a grouping of key datasets by feature class using the structure found in Table 8. All datasets with the exception of climate were first projected to a common coordinate system (NAD 83 UTM Zone 18N) and clipped to the Eastern Ontario boundary.

Table 8. F2R EO: Geodatabase feature classes and key datasets

	Data integrated into Envision	**Data developed, but not integrated into Envision**
Land cover/ Land use	Southern Ontario Land Resource Information System (SOLRIS); Agri-Environmental Services Branch 2011; Cadastral Zoning;	Tile drainage area; Drain Connection; Constructed drain; Area of Natural & Scientific Interest (ANSI); Provincial parks; Crown game preserves
Soil/Terrain	Soil Landscapes of Canada (SLC); Detailed Soil Survey (DSS);	10 m Digital Elevation Model (DEM)
Census	Population counts by Dissemination Block; Ag Census variables by Census Consolidated Subdivision; National Agricultural Profiling Project (NAPP) variables by Dissemination Area	
NAHARP	Indicator of Risk of Water Contamination by Phosphorus (IROWC-P); Indicator of the Risk of Water Contamination by Nitrogen (IROWC-N)	
Hydrology		Watershed boundaries; Sub-watershed Boundaries; Rivers; Lakes; Wetlands; Floodplains
Transportation		Rail; Major roads; Secondary roads
Climate	Projected daily data on minimum and maximum temperature and precipitation; Baseline daily data on minimum and maximum temperature and precipitation; 2011 daily data on minimum and maximum temperature and precipitation	

4.2 Preparation of IDUs and Data for Envision

Transitions in how areas of land are used over time, whether representing maturation of forests, growth of crops, or the expansion of urban centres, must be delineated at scales appropriate to local decision-makers. The criteria for determining the size and boundaries of the IDUs must consider how land is managed, including the size of areas managed for different purposes, as well as aspects of how changes will be tracked over time. This is to say, both the area at which decisions are made, and the geographical aspects of the desired output indicators of the project (e.g., wildlife habitat, crop yield, land use, etc.). It is important to have spatial units small enough to represent fine-scale features of interest, as well as larger units that can be aggregated to represent larger landscape processes. Envision runs change transitions across the landscape using "Integrated Decision Units," which are chosen to be scalable according to features of importance in the landscape. The minimum size should meaningfully represent a decision-making unit, while also being adequately large such that the total number of units allows model runs to occur with a reasonable response time when conducting real-time modelling (i.e., using Envision to foster engagement/discussion).

In the agricultural region used in Eastern Ontario, a desirable type of spatial unit (and many other agricultural locations) would be the farm field. In our study, we used farm fields containing a homogeneous crop or cropping system. For F2R EO it was determined that this would be possible by combining a spatial crop layer (based on remote sensed cover of crops) with a spatial soil layer, as well as a land use and land cover layer detailing other land uses. Also included was a land parcel layer to delineate the scale at which individual actors make decisions on this landscape. This four-way combination provided homogeneity in crops, soils, land use and land cover, and ownership such that one IDU is assigned to a single crop, soil type, land cover and one ownership decision unit.

The data chosen for IDUs created individual polygons. These included: data for crops, originating from federal agricultural data on crop and vegetation (Land Cover; representing crop conditions as of 2011 within 78,306 polygons); soils data from the Detail Soil Survey dataset, also federal, representing soils conditions as of 2009 (9,021 polygons); land use and land cover for non-agricultural land, based on SOLRIS dataset (provincial, representing the landscape as of 2006 in 111,566 polygons); and land parcels, from the province of Ontario, with cadastral data representing ownership as of 2007 for 10,328 polygons.

To develop the IDU geometry, three input datasets were included: the 2007 AAFC Cadastral Data, 2011 AAFC-AESB Land Cover (2011) and the 2009 Detailed Soil Survey dataset (see Figure 19).

Methodological considerations: In order to create the IDU dataset geometry, three input datasets including the 2007 AAFC Cadastral Data, 2011 AAFC-AESB Land Cover, and the 2009 Detailed Soil Survey dataset were combined using a Union process within GIS. The union process allows for each unique IDU polygon to include detailed information from each of three input datasets. After the union process was completed, small, irrelevant "sliver" polygons (smaller than 1 hectare [ha]) were eliminated. These polygons resulted from the boundaries of the three input datasets not identically overlapping each other's boundaries. When these spatial datasets were combined in the union process, a total of 112,488 IDUs were created (see Figure 20). Approximately 34 IDU polygons intersect each 1 km2 region within the IDU framework with an approximate 6 ha average area and 1–30 ha range. This number of IDUs was considered feasible for computation within Envision to obtain reasonable response times for scenario analysis and experimentation.

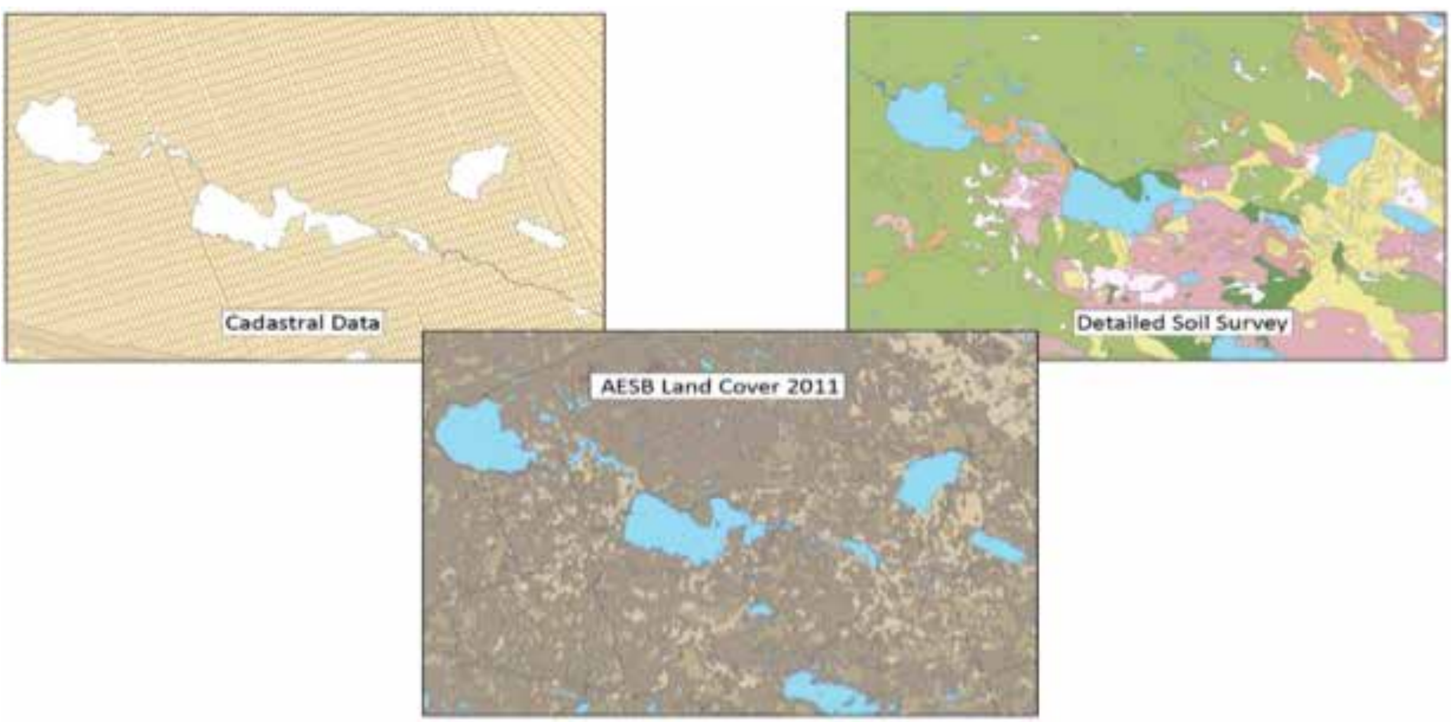
The attributes of the original datasets were maintained in the combination process such that the first version of the IDUs had crop types, other vegetation types, other land use and land cover types, many soils variables, and a Land Ownership parcel identifier.

Population

The population-growth model used in our Envision platform was developed by Envision staff for general application. It is based on provincial data on population growth. The model allocates population at the IDU scale to meet an overall target population that represents the projection by counties as growth to 2036, as developed by the Ontario Ministry of Finance.

Methodological considerations: the growth was represented as a rate based on an estimated target, defined as the 2036 population size. The distribution of the population within the study area was allocated according to the population capacity of three major land-use types

Figure 19. IDU Geometry Input Datasets: AAFC Cadastral, AAFC-AESB Land Cover, and Detailed Soil Survey data.

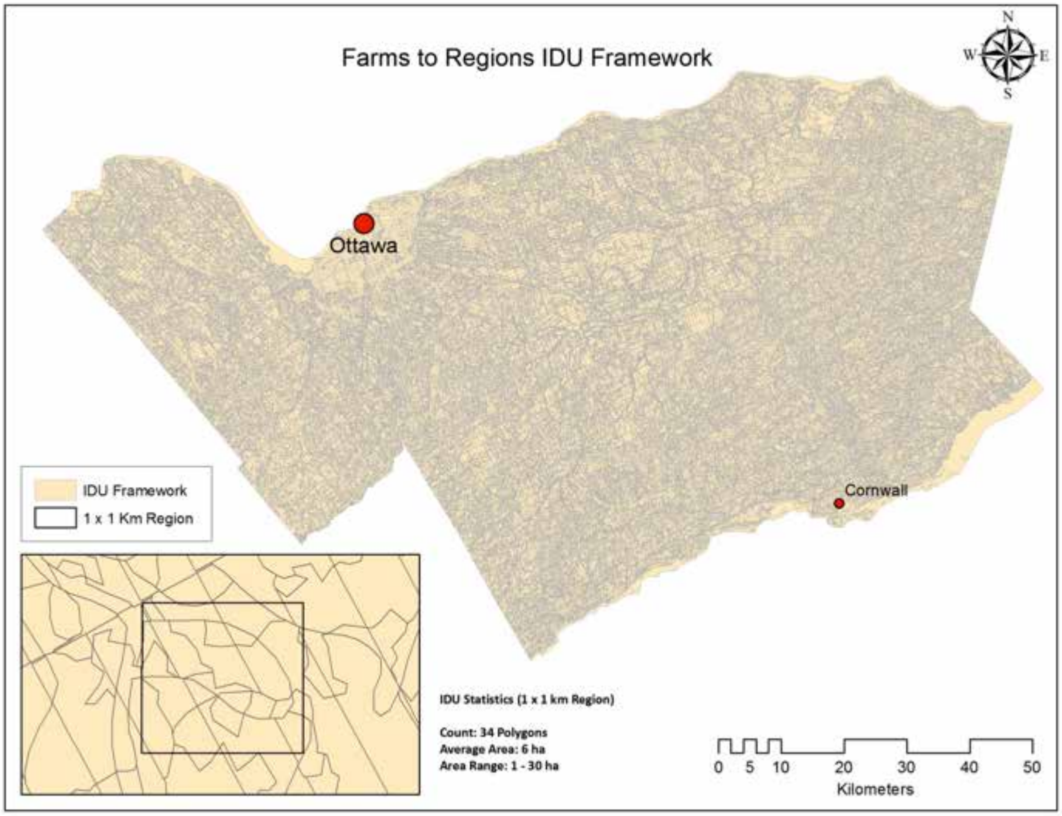


(urban, agriculture, forestry). These values are expressed as the population density in dwelling units per acre, where the number of people per dwelling is set as a constant. The portions of new growth in the three major land uses and the overall population values represent the outputs of this model. These values may be represented at any scale from the IDU to region.

Crop Allocation

The crop allocation model represents the placement and total area in various crops in any particular year. The model was developed by staff at AAFC and the Envision staff, and represents a modified application of a more general spatial allocation model that exists in the Envision system. It allocates crops at the IDU scale to meet a targeted crop distribution, which is derived from the scenario specifications for the BAU, and each of the alternative future scenarios (see next sections). This model allocates according to a set of constraints determined at the IDU level. The baseline crop distribution is based on 2011 data, as reported by agricultural census records in combination with remote sensed cover data. The types of crops included in the model are corn, cereals (buckwheat, grains), horticulture and vegetable (fruit, vegetables, herbs), oilseed crops, pulses (beans, peas, soybeans), forage/cover Crops (alfalfa, silage, hay/pasture) and bioenergy crops.

Figure 20. Farms to Region Integrated Decision Unit (IDU) Framework.



For the F2R EO application, the primary constraint for crop allocation is that the land use must be zoned for agriculture. Year-to-year rotations were also considered among three key crops: corn, soybeans, and hay (pasture). The rotations were established through consultation with provincial and regional crop specialists: corn/soybeans/cereal, corn/soybeans/cereal/alfalfa/alfalfa, and corn/soybeans/alfalfa/alfalfa/alfalfa.

Methodological considerations: farmers are able to switch from one crop or rotation to another, according to a set of determinants known for the region (e.g., market prices). For each future scenario, each crop and each rotation have preference scores which indicate the priorities in crop allocations, crop choice, and rotation. These preference scores are tied to IDU attributes and are specified in a user-definable input file, which allows preferences to be modified to reflect alternate patterns of choice by farmers and farming sectors. At each time step, the allocator scores all IDUs for their preferences, according to specific IDU attributes, for each crop and each rotation. The allocator then coordinates the score tables for each crop or rotation, allocating the high-scoring IDUs for each crop (or rotation), until either the target area for the crop (or rotation) is achieved or no addition land is available to satisfy the constraints for the crop or rotation. Adjustments and new or modified constraints, as well as novel crops, can be added to represent alternative adaptation responses in Envision. The allocator handles all possible conflicts and double counting that could occur.

NAESI-Recommended Standards

A biodiversity model was defined using a set of standards developed under the NAESI National Priorities.[10] It is built using multiple lines of evidence such as guidelines, targets, thresholds for landscape analysis, as well as areas of potential natural vegetation, outputs from habitat suitability models and population viability analysis. The NAESI biodiversity standards used in our model are a set of habitat standards defined for agriculture. The standards represent four types of habitat: forest, wetland, riparian, and farmland.

Model considerations: for the initial development of the model, only habitat standards defined for forested areas were integrated into Envision. Forests were considered both by size and type, with the final assessment representing the size of the forested area(s) being compared to that defined as a standard for particular biodiversity value. This included having more than one patch from 200 to 1000 ha in size, as well as considering the presence of a range of forest cover types and age classes.

Note: further habitat types could be included such wetland (groups of wetlands within 500–1000 m of the centre of each); riparian (100 per cent natural and semi-natural to 5–15 m; 75 per cent natural vegetation to 30 m, 10 per cent natural vegetation to 300m, associated with core

10. NAESI National Priorities: Conserve regional ecosystem services dependent on native ecosystems; Conserve ecosystem services in a pattern benefiting agriculture; Conserve ecosystem diversity; Conserve unique landscape; Features; Conserve habitat quality of natural areas; Conserve species composition typical of region; Reverse negative trends in populations; Conserve contribution of agricultural areas as habitat; Conserve habitat for species at risk; Consistent with legislation (Neave Baldwin, & Nielsen, 2008; Lindsay, 2012).

riparian forest (>100 ha) and farmland (50 to 200 ha patches in grassland and cultural habitats for area-sensitive species by watershed).

These indicators are currently implemented in Envision. The Envision models for the indicators primarily use the coarse land use, land cover attribute in the IDUs. A population viability assessment of key taxonomic groups and aquatic biodiversity models is being developed

Preparation of Simulation Models for Envision

Envision is a platform, meaning that it may be used to integrate different sectoral or disciplinary models such that they interact dynamically. This allows for landscape change to be modelled and indicators of change to be tracked over time. The models prepared for the Envision F2R EO study area include three adapted models representing agriculture, wildlife, and nutrients. Additional inputs were used as fixed or fixed rate changes in Envision, such as, for example, increasing population growth in rural and urban centres, and weather trend information derived from downscaled regional climate models (the latter of which was used as a modifier of yield on crops).

For the actual models incorporated into the platform, peer-reviewed models developed and adopted for use by authoritative bodies were selected. This included a subset of those developed within the National Agri-Environmental Health Analysis and Reporting Program (NAHARP) of Agriculture and Agri-food Canada (Lefebvre, Eilers, & Drury, 2007), as well as models developed by Envision staff, and biodiversity- based models from standards previously developed through The National Agri-Environment Standards Initiative (NAESI).[11] The NAHARP models were designed for wildlife, nitrogen, and phosphorus in agrarian landscapes. Tree models were also developed by Envision staff for climate indicators, human population, and crop allocations and associated changes (e.g., rotations, crop choice in planting, etc.). The NAESI biodiversity standards were used to establish conditions favourable to biodiversity using five recommended sets of conditions for forest, wetland, and farmland habitats, and four sets for riparian habitat. The F2R EO project decided to focus on the biodiversity component of the standards, in particular habitat conservation, in the categories of habitats in forests, and farmland. All models were configured for use in Envision in consultation with the developers of these models.

NAHARP Wildlife

The inputs for the Wildlife model include the list of terrestrial vertebrate species, as well as 31 habitat classes, and the stage for each habitat (i.e., primary, secondary, or tertiary, coded as 1, 2, 3). For each habitat class, six habitat use types were defined for population viability modelling and to assess wildlife habitat quality; these included reproduction, feeding, cover, wintering, loafing and staging. Information regarding the presence or absence of each species in each group for each habitat area was also incorporated. Because we were interested in modelling species range shifts under climate change, the model includes estimations of major shifts based on bioclimatic modelling as developed in Lawler et al. (2009). This was

11. See http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1209128121608&lang=eng

represented for individual species that were further categorized into taxonomic groupings of amphibians, reptiles, birds, and mammals. Additional groups—such as the status denoted by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC)[12] or The Species of Risk Act (SARA)[13]—may be added as additional data columns for each species, as desired.

Methodological considerations: the habitat classes devised for the NAHARP and biodiversity models are not identical to the classes developed for the decision-making unit used for transitions in the Envision model. Rather, these IDUs are based on established crop classes, such as those used by AAFC for agriculture, and the SOLRIS land use and land cover classes used in the land-use land cover classification (see section 4.1.X). These differences are managed through use of a cross-reference table that assigns each habitat class to one (and only one) of the Envision IDU land-use land cover level classes.

The wildlife model methodology is a modified version of the approach described in Javorek and Grant (2011). Their model uses the Soil Landscapes of Canada (SLC) polygons for reporting, while the Envision model, analysis and mapping uses IDUs using regional cover maps, as noted above:

> For each SLC, species-specific habitat availability (SSHA) was calculated for breeding and feeding requirements, by generating a weighted average of habitat use based on the relative proportion of cover types used and the value of that habitat to the species... Habitat Capacity is based on breeding and feeding and is the average of SSHAs [for each IDU] per SLC polygon. (Javorek and Grant, 2011, p. 5).

NAHARP Nitrogen

The nitrogen model is adapted from the NAHARP nitrogen model by Drury et al. (2007) and Yang et al. (2007). Nitrogen inputs to soil include those from fertilizer, manure, atmospheric deposition, as well as nitrogen fixed by legumes. Fertilizer N is calculated from the recommended total N application by crop minus the available manure N, while manure N is calculated from the number of farm animals of different types and their respective excretion rates. Atmospheric deposition N is simply the sum of wet and dry deposition and is taken as a constant per unit area. The fixed N is calculated using constant fixation rates per unit area for each type of leguminous crop as reported from regional research.

Methodological considerations: Working with the model developers, the nitrogen model used in Envision was designed to represent the total incoming nitrogen to soil. This is calculated as the sum total from all sources minus nitrogen losses from soil due to crop uptake and gaseous emissions. Crop uptake is further calculated for each crop type, as the yield in mass per unit area x total area in crop x the N concentration. The proportion of N emitted as gas from crops was based on data from the IPCC. Finally, the remainder from input N minus losses of N is then the residual soil N. Residual soil N is calculated at the IDU scale and reported at the SLC scale. These units and values may be calculated at

12. See http://www.cosewic.gc.ca/eng/sct5/index_e.cfm
13. See list of species - SARA Registry

annual, monthly, weekly or other time steps, as required.

NAHARP Phosphorus

The phosphorus model is adapted from van Bocheve et al. (2007). Due to the complexity of the components of the NAHARP phosphorus model, the adaptation for Envision takes as inputs the values of the IROWC-P variable previously calculated by AAFC scientists for SLCs in Ontario. The output indicator is the area in each SLC considered according to the various major land uses (agriculture, developed land, and pasture/grass) for high-risk soils.

Methodological considerations: the model values are calculated by summing the area in each of the major land uses at the scale of the SLCs for those IDUs where the IROWC-P value is in the upper 20 per cent of the total range of the values. Further refinements to the phosphorus model are in development.

Climate Indicators

A series of extreme weather event indicators are used to approximate the future conditions as estimated using future climate data prepared at a daily time scale. Use of a finer temporal scale would significantly increase the amount of data processing time in the Envision runs, and, therefore, require longer modelling processing times.

Methodological considerations: daily data, while providing sufficient detail, allowed us to manage processing time, which was particularly useful when using “real-time” runs to facilitate discussions with team members. If coarser time scales are also required, values can also be aggregated at the monthly time scale and represented in this way. These values may be mapped to represent indicator distributions at the IDU or coarser aggregate scales.

The indicators were calculated for temperature and precipitation events and are listed in Table 9.

Table 9. Extreme event indicators calculated in Envision

Index	Definition	Source
Temperature		
Corn Heat Units	Seasonally accumulated heat units	Brown and Bootsma (1993)
Seasonal temperature range	Seasonal mean of diurnal temperature range	Gachon (2005)
Intra-annual extreme temperature range	Difference between the highest temperature observation of any given calendar year (Th) and the lowest temperature reading the same calendar year (Tl)	ETCCDMI (2009)
	Percentage of days with freeze and thaw cycle (Tmax>0°C, Tmin<0°C)	Gachon (2005)
Growing season length	Annual count between first span of Tday>5°C more than five days and first span of Tday<5°C more than five days	Gachon (2005)

Index	Definition	Source
Temperature		
Frost season length	Annual count between first span of Tday<0°C more than five days and first span of Tday>0°C more than five days	Gachon (2005)
Hot weather extremes	Number of days where Tmax>27°C	Gachon (2005)
Cold weather extremes	Number of days where Tmin<-20°C	Gachon (2005)
Precipitation		
Per cent wet days	Seasonal percentage of wet days (Threshold=1 mm)	Gachon (2005)
Simple daily intensity index	Sum of daily precipitation/number of wet days	Gachon (2005)
Consecutive dry days	Maximum number of consecutive dry days per season (<1 mm)	ETCCDMI (2009)
Maximum three-day precipitation	Seasonal maximum three-day precipitation total	Gachon (2005)
R10mm	Count of days when precipitation is above a 10mm threshold	Gachon (2005)
Total precipitation	Annual total precipitation in wet days	ETCCDMI (2009)

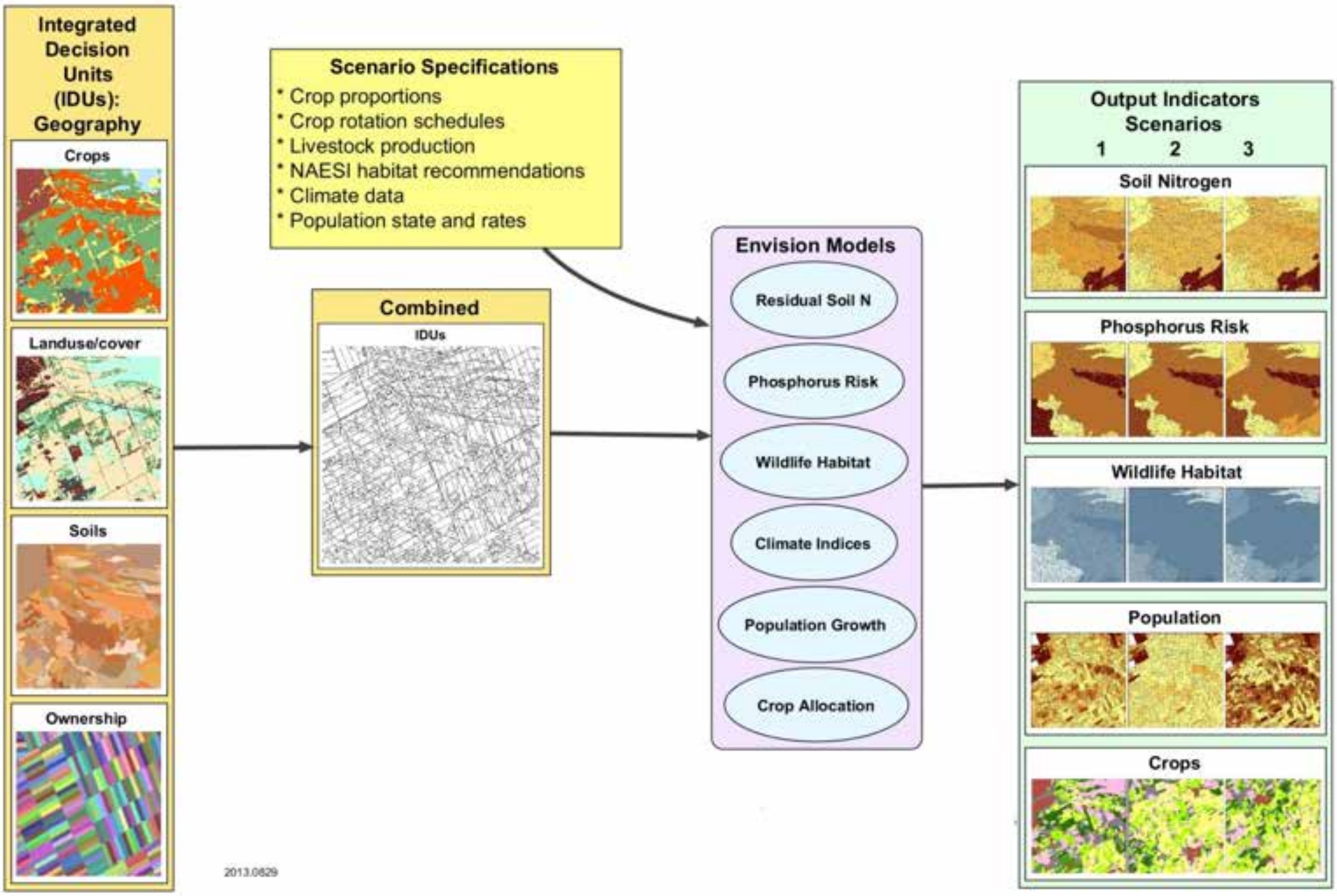
Details on the integrated modelling are also presented in Appendix 6.5 and 6.6.

4.3 Quantifying the Developed Scenarios

Once the basic architecture of the model was set up we focused on representing—through modelling—the different qualitative scenarios. Linking quantitative and qualitative scenarios into an integrated model is a challenging process that requires combining stakeholders' qualitative inputs with quantitative models. The inclusion of qualitative information provides a much-needed context for what is actually possible, both with regard to how actors on the landscape behave, as well as context regarding important drivers, such as, for example, facts and trends regarding different possible technology options (Carlsen et al., 2012 in Sweden), considerations regarding land-use change (in British Columbia by Shaw et al. 2009) and other considerations (e.g., environmental variables). Furthermore, these integrated models provide a context to generate discussion with stakeholders about priorities and what is feasible (Langsdale et al., 2009), and provide a mechanism by which the stakeholders most directly involved in regional decisions can review, translate and refine the models to better represent their region (for example Volkery et al., 2008).

As suggested in Figure 21, the development of models and data for Envision was based on existing models capable of providing the output variables of interest. Data or information constraints will always set the limits of resolution and define both what can be feasibly (and reasonably) calculated. As scenario models are developed to assess relative implications of

Figure 21. Overview of quantification of data for the scenarios using the integrated Envision model



future changes, the outputs are not predictions of future conditions, but assessments of risk and impacts "given what is presently known." It is essential to document assumptions and data or model constraints, since it is the level of uncertainty around the outputs that allow management and adaptive actions to be prioritized (e.g., by identifying issues of high uncertainty or risk). These assumptions and data or model constraints also serve to document areas in which further refinement or better models will be required. The overall interactions between management, environmental, and system components can be illustrated in terms of flows in a process diagram. Key elements of the qualitative scenarios, including their translation into quantitative terms for the Envision model is described in Appendix 6.4.

The Envision modelling platform provides the ability to integrate existing models and/or to prepare individual plug-in models for Envision. This requires some degree of coding and data input development, starting with the defining of the unit of scale at which dynamic changes will occur (that is, integrated decision units, or IDUs). The scale will differ depending on what processes are being run in the model. In the case of Eastern Ontario, our agricultural interests emphasized field-scale changes, which would reflect changes in management practices, crop selection and overall land use. IDUs may also be bundled, or scaled up, to represent changes at larger scales, such as soil land classification units (SLCs) or watersheds. The IDU forms the basic spatial basis of the Envision application, with each IDU carrying with it a series of attributes describing various conditions or properties of that area. These attribute data may be extensive, although subsets will be selectively used as inputs for each of the various plug-in models. For example, not all soil types will be suitable for different crops; therefore, the soil attribute for each IDU may be used to delineate where different crops are allocated. Ultimately, it is the differences in how the various parameters change that form the basis for differentiating among the scenarios (see for example, chart showing differences in aggregated regional nitrogen levels over time for the scenarios, Figure 22).

Figure 22. Relative change in IROWC-N over time across scenarios (kg/ha)

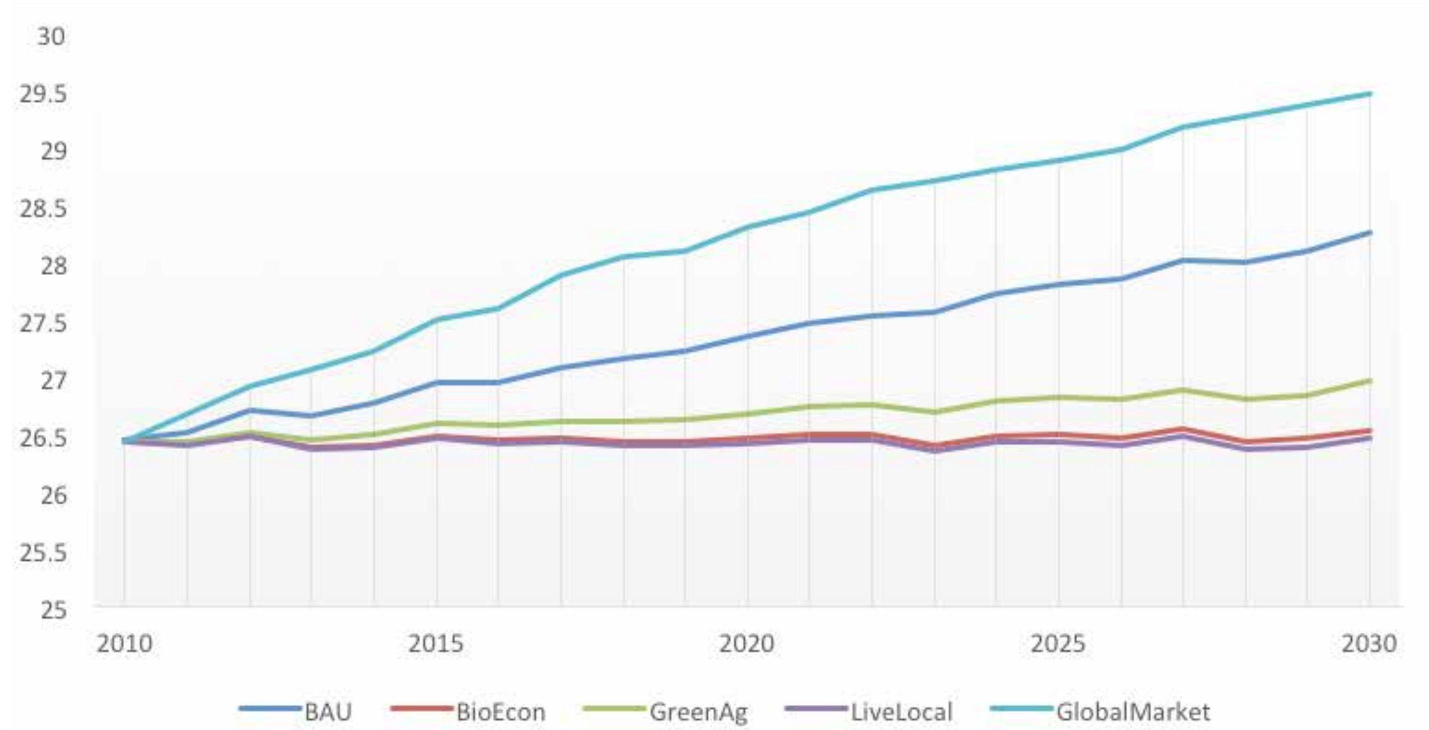


Figure 23. Nitrogen Risk and NAHARP Habitat outputs

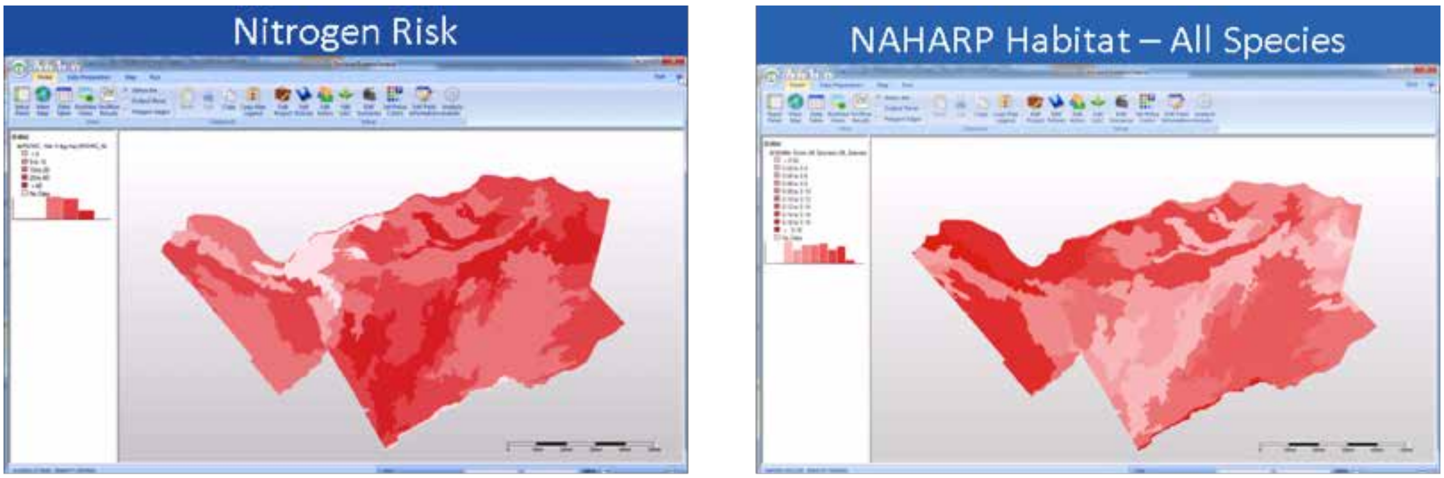
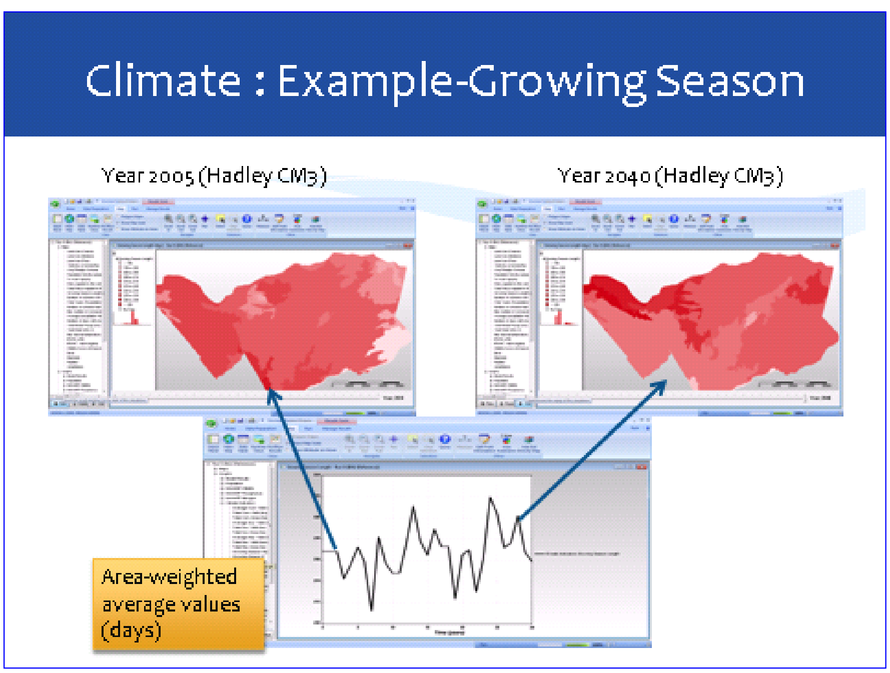


Figure 24. Climate impacts on growing season



Once the scenarios were run, we used the model outcomes to evaluate the relative "performance" of the different scenarios.[14] These may be variously determined for subregions or the entire study area to reflect the various outputs on daily, monthly, annual or other time steps. For example, to contrast the total yield (per crop) among the different scenarios, or to consider regional differences in performance or overall change (e.g., land use, population growth, etc.).

Using the different measurable outcomes, we were able to evaluate the consequences of different land-use and management regimes (as defined for each scenario) on key indicators, such as the level of phosphorous and nitrogen levels, changes in habitat and biodiversity, as well as crop production (Figure 23 – 25; Table 10). General weather trends from downscaled regional models were included in the form of future climate change, both as a series of daily indices' values that would reflect day-to-day temperature and precipitation levels, as well as in the form of an interactive factor affecting crop yields. Regionally relevant climate model projections were used to represent variance.

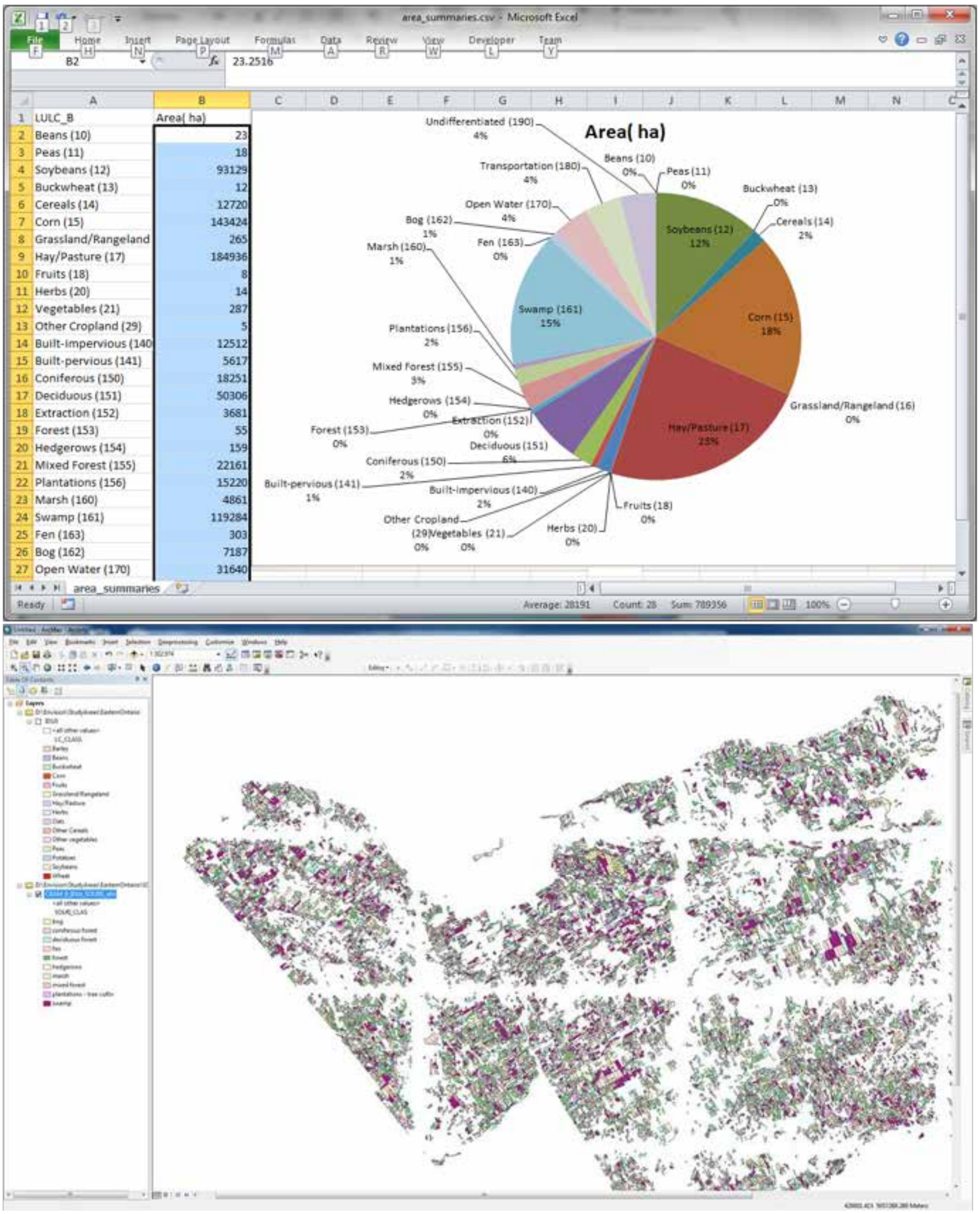
Table 10. Overview of the impacts of the scenarios on primary outcomes indicators

	Brief description	**Potential measurement and policies to consider**
Targeting foreign markets	Agricultural producers are interested in targeting growing global market opportunities. Large and specialized farms dominate the landscape to produce goods, especially for foreign markets. Federal and provincial governments cooperate with industry in setting market-based incentives to enable meeting market needs both domestically and internationally.	Considerable challenges in linking environmental and social issues (climate change impacts and vulnerability, water quality, food security), market opportunities and policies Role of trade agreements—the role of policies to promote wildlife conservation, to regulate air and water quality, are examined to see whether export agriculture is unfairly restricted. Changes in rural landscape and population and potential urban-rural tension over environmental externalities attributable to agriculture and/or producer resistance to environmental regulation
Promoting bioeconomy	The region will aim to explore opportunities from bioeconomy, including in energy production, pharmaceuticals, fabrics, cosmetics, plastics. The region aims to become a leader in bioeconomy regionally, building on the opportunities in the area and explores opportunities with local and provincial governments to develop this leadership.	Policies are developed to provide incentives for bioeconomy agriculture. It requires investments; well-planned but flexible strategy will be crucial as not all products will be successful or find robust markets. Significant implications for innovation, education and new types of jobs and their locations

14. Model outputs may be downloaded for viewing at: http://envision.bioe.orst.edu/StudyAreas/EasternOntario/Outputs/.

	Brief description	Potential measurement and policies to consider
Moving towards greener agriculture	Because of increasing pressures on natural resources, the impact of severe weather events, and increasing interests in promoting food security regionally, nationally and globally there will be stronger focus on improving environmental performance of agricultural production by different levels of governments. For agriculture this would mean balancing efficiency and environmental impacts. Agricultural outputs will be targeted mostly to local and North-American markets.	New incentive policies and regulations could be considered to improve environmental performance and natural hazard protection. Agencies (incl. government) develop methods and practices to optimize outcomes for environmental performance and agricultural output. Fundamental considerations will be water management to address increasing variability in water supply and related needs for agriculture and environment
Living locally	Smaller farms and farm partnerships dominate the producers' group and create a diversified agri-landscape. They successfully explore niche markets mostly regionally, and they cooperate with local governments (municipal and watershed) on market incentives and rules and regulation. Some large farms remain on a small proportion of the landscape.	Producers' groups and governments promote through educational programs the value of local agriculture. Community-based biorefinery and other operations—community organizations own and operate the facilities for value addition to production.

Figure 25. Example of Quantitative Metrics Output from Envision Simulation Runs



5. Conclusions and Lessoned Learned

We used an integrated application of alternative futures and climate change scenario modelling to create a dynamic model describing a series of plausible futures in a rural agricultural region of Canada. Our purpose in doing so was to develop and test the use and transfer of an open-source platform (Envision) as a tool to run simulations of future conditions. Specifically, the aim was in testing the feasibility and usefulness of this type of combined, stakeholder-quantitative modelling approach in evaluating future risks, options, and considerations with respect to future climate uncertainty. Whereas the initial data and context development stages of our Eastern Ontario prototype spanned three years, this represented the initial transfer and adaptation of the platform to Canada, including the initial outreach to stakeholders, as well as a series of multistakeholder workshops, the technical setup, reconfiguring and data collection.

The stakeholder engagement and workshop component of the work required additional time, but the overall process could reasonably be compressed using an expert-driven team. However, the contribution and perspectives represented by regional experts and stakeholders, particularly at the level of regional industry, government, and sectoral associations, provides specific context for the design, use (i.e., choice) and implementation of adaptation actions, using knowledge of both existing and proposed regulatory and other mechanisms available in the region that would otherwise be difficult to understand. As such, it is the inclusion of stakeholder (decision-maker) input that helps to ensure that the findings will: i) represent realistic adaptation options that are likely to be implementable/accepted; ii) recognize existing mechanisms to implement appropriate changes; iii) identify potential complications or obstacles that might confound particular adaptation strategies; and iv) help integrate cross-sectoral priorities within the context of common regional priorities.

Our choice of using an adaptive management framework for these sorts of geographically based studies of future climate change impacts could easily be considered as a flexible risk-based framework, as both are designed to identify risk and options using an iterative, learning cycle. In our application, this approach allowed us to incorporate models and metrics already in use by regional governments or organizations. Building on this previous work, the Envision modelling platform allowed the stakeholders to begin to identify pathways of interaction within the region between sectors and quantitatively explore cause and effect using a series of “what-if” scenarios. In Eastern Ontario, this process of developing the regional model and discussing risk and uncertainty led to a few important discoveries, including, that the priorities among regional representatives are highly complementary (i.e.., concerned with socioeconomic stability and environmental health), and that one of the major challenges to medium-term planning is uncertainty.

Scenario-based methods, particularly those considering future climate change, are necessarily focused on uncertainty, and the scoping of the type and range of future conditions that might come to pass. The value of a gaming type of approach—provided that assumptions and caveats in a model are well documented with regard to data and data limitations—is that it begins the process of scoping the upper and

lower bounds of uncertainty, which allows for discussions of what and where the priority areas of concern are likely to be. In the case of Eastern Ontario, the broad uncertainties probably match those of many rural regions of Canada (climate change, economics, demographics, environmental policy and regulation, fossil fuel supply, and governance/communication). The spatial aspect of this approach, however, means that the explicit outcomes, or impacts, of different drivers of change can be mapped across the landscape to show areas of relative sensitivity. This allows high-risk or high-value areas to be visually (geographically) identified. It also enables these changes and outcomes to be considered at the scale at which decisions are made. Identifying responses according to operational boundaries is important, since these represent the jurisdictional boundaries at which various responsible authorities are able to act. By choosing plausible futures, rather than extremes, or alternative global climate projections, the aim of stakeholders was to understand the resilience or outcomes associated with different future directions in land use and management decisions in the region. In other words, those things under their "control." However, key drivers tend to be those that are not under local control, or those over which where local stakeholders have little or no authority.

Among the greatest challenges in representing uncertainty was that associated with climate change and the use of climate change projections. Global and regional climate models need first to be scaled down to a resolution that has meaning to communities, industry and individual land owners. The validation and interpolation requires good historic weather station records, not only with respect to the frequency of recordings, but also with regard to their distribution spatially. At each level of effort, the number of assumptions and compounding errors increases. Yet this uncertainty, specifically with respect to the timing (season) and intensity of events, is what planners, farmers, and municipal governments need to understand. In order to understand extremes, and how to characterize and express them based on validated climate projections, additional analyses and study is required[15]. Weather is an important consideration for agricultural communities, but also for other non-agricultural communities, all of which are affected by water quality, availability, and weather conditions. Also important are global and regional economics, trade, and technological developments, all of which influence the future of local economies. Spatial mapping allows outcomes to be contrasted and compared against future choices such that these may be scaled to the level at which actual operational

15. Presently, additional project teams are undertaking further analyses to understand the methods and limitations of deriving and using climate model data to characterize and "bound" extremes. This includes a new AAFC-funded project (Climate Change Crop Sensitivity Project, GF2), in which soil, agricultural system, and practices are being considered with explicit consideration of extreme weather; OMAF-funded work on climate impacts with a focus on water modeling as joint research with Carleton University, IISD, regional Ontario Conservation Authorities, and AAFC (Scenario-based risk assessment decision support modelling tools for regional climate change and climate extremes, impacts and adaptation in agricultural watersheds). Preparation of collaborative submission to Call for Proposals: Quebec-Ontario Cooperation for Agri-Food Research Competition. These projects are expanding the model and work represented in this Guidebook in Prince Edward Island, Eastern Ontario, Peel Region (with the Ontario Climate Consortium and Toronto Regional CA).

choices or decisions would be implemented (e.g., adaptation actions, municipal, watershed, or agricultural planning, land-use zoning).

The modular nature of the platform we worked with allowed us to incorporate existing, accepted sub-models together, which helps to tailor an application to a particular geographic area by relying on information already used to describe it. Our next phase of work extends to more explicit treatment of extreme weather events, and how to consider and represent them across temporal and spatial dimensions, under the Climate Change Crop Sensitivity Project (Growing Forward II), which will integrate extreme events into the Envision modelling platform. The objective is to identify appropriate scale and types of downscaled data that can be used to represent changes in the timing, intensity and frequency of critical extremes (i.e., those exceeding tolerance thresholds of attributes, such as individual cultivars, livestock, hydrological systems, natural and otherwise, etc.). These conditions will not represent the way "future climate" will behave; they are not predictions, so our focus is on testing the use of the climate projections to identify critical changes that would need to be taken into account by municipal planners, farmers, and others as they plan for medium- and long-term investments and management strategies. Our starting point is to conduct sensitivity analysis to see how production, environmental and economic measures respond to particular extreme weather events. This sort of "risk-based" approach continues to focus on defining and describing the nature of "critical uncertainties."

Continued analysis and characterization of climate model projections of extremes is now considering extremes by crop and risk factor, with a particular focus on plant growth stages. It is therefore important that we expand our evaluation of the use of downscaled climate data and its limitations. We are therefore adding additional agricultural and non-agricultural parameters into the Envision platform in Eastern Ontario, as well as in an application in Prince Edward Island. Climate-extreme modelling is continuing through graduate student support (two MSc and one PhD students) at Dalhousie and Carleton University. Characterization of thresholds is being done through expert-based consultation and supported graduate student projects, which also provide us with the opportunity to evaluate the transferability and resource requirements for the prototype to novel rural areas. A further trial is also planned in Southern Ontario, which would add additional non-agricultural sectors such as fisheries, urban parks and recreation, tourism, as well as expand agricultural considerations (e.g., livestock, fruit and greenhouse crops). Additional indicators and risk indices are also being defined for communities, including considerations around water, human health, pests and disease.

Looking Forward

Climate change represents only one of a number of challenges that local governments, land owners, businesses and sectoral organizations must understand and prepare for. The processing and analysis of climate datasets, particularly the variance and nature of critical extremes is not trivial. This project is part of a multi-phase larger project that has been ongoing since 2011. This detailed guidebook represents a first product of the work, providing context and relevant information on the scenario-development work and mainstreaming of adaptation needs into decision making. All information, including datasets and the model with code will be published and made available.

Presently, the Canadian application of Envision, for Eastern Ontario, is available for download at http://envision.bioe.orst.edu/caseStudies.aspx. Additional reports, peer-reviewed publications, and updates to the Eastern Ontario modelling platform, and appendices to this Guidebook will be made periodically, including new submodules and technical information and information regarding the level of resources and time requirements to use the platform. Ultimately, understanding climate change impacts and adaptation planning are ongoing processes, however. As such, work on this larger project continues.

6.1 Overview of the Stakeholders' Participation Conducted in this Project

Focus	Type of participation	Notes
Setting context to project and identifying key stakeholders and drivers of change in EO (Workshop 1)	One-day workshop with 40 to 50 experts Small groups and plenary sessions	It included representatives of local, provincial and federal government as well as groups working on agricultural production, policy and management and small-scale agriculture.
Developing a business-as-usual (BAU, or baseline) scenario and reviewing available data sets for the area (Workshop 2)	One-day workshop with 30 participants Small groups and plenary sessions	It included representatives of local, provincial and federal government as well as groups working on agricultural production, policy and management and small-scale agriculture.
Consultation on key scenario elements and how they can manifest themselves in the future (Workshop 3)	Series of phone interviews with selected 20 experts that were involved in the previous phases	The research team developed a questionnaire and four brief scenario narratives and key experts were consulted on these narratives and the questions were used to begin the scenario narrative
Developing a series of alternative (future) scenarios (Workshop 4)	One-day workshop with 30 participants Small groups and plenary sessions	It included representatives of local, provincial and federal government as well as groups working on agricultural production, policy and management and small-scale agriculture.
Reviewing modelled scenarios and identifying policy recommendations	One-day workshop with 15 participants Small groups and plenary sessions	It included representatives of local, provincial and federal government as well as groups working on agricultural production, policy and management and small-scale agriculture. Most of the stakeholders were involved in the previous phases of the projects .

6.2 Sample Workshop Agendas

Time	Workshop 1 Agenda Item
9:30 – 10:00	**Registration**
10:00 – 10:30	**Welcome and Introductions** • Welcome • Project Overview and AAFC objectives • Warm-up Exercise
10:30 – 11:30	**Session 1: Understanding Goals and Mandates in the Region** • Overview and instructions • Plenary and Synthesis
11:30 – 12:30	**Session 2: Identifying Key Drivers Affecting Goals and Mandates - Exploring Plausible Futures** • Overview and instructions • Break-out Group Thinking: –– Q1: What are the key drivers that affect achievement of the regional goals and mandates discussed in Session 1? –– Q2: How important and uncertain are these drivers going forward? • Plenary and Synthesis
12:30 – 13:15	**Lunch**
13:15 – 14:45	Session 3: Assessing Vulnerabilities and Opportunities • Overview and instructions • Break-out Group Thinking: –– Q1: What vulnerabilities and opportunities are likely to emerge in response to the key drivers from Session 2 in the future, including through interactions with climate change? • Plenary and Synthesis
14:45 – 15:00	**Nutrition Break**
15:00 – 16:15	**Session 4: Identifying Pathways for Resilience and Mainstreaming Adaptation into Regional Planning and Policy-making** • Overview and Instructions • Presentation: Resilience and sustainability pathways • Break-out group Thinking: –– Q1: Given the vulnerabilities and opportunities identified in Session 3, what should a resilient and sustainable landscape of the future look like – i.e., what are its key elements? –– Q2: What might the pathway to your landscape of the future look like (in terms of broad strategies and even specific actions)? –– Q3: How might your strategies and actions be mainstreamed in the regional planning and policy-making of your departments/organizations? What might the barriers be and how might they be overcome? • Plenary Discussion: to synthesize key elements of pathways for sustainability
16:15 – 16:45	**Summary and Next Steps** • Synthesis of the days discussion • Overview of next steps

Time	Workshop 2 Agenda Item
8:30 – 9:00	**Registration**
9:00 – 9:30	**Welcome and Introductions** • Objectives of the workshop • Reviewing the progress so far • Introducing the scenario framework
9:30 – 10:30	**Task 1: Policy mapping** • Overview and instructions • Seed Presentation • Break-out Group Thinking • Plenary and Synthesis
10:30-10:45	**Nutrition break**
10:45 – 12:00	**Task 2: Creating BAU** • Seed Presentation – Population projections, Q&A • Instructions • Break-out Group Thinking • Plenary and Synthesis
12:00 – 13:00	**Lunch**
13:00 – 14:00	Task 3: Boundary conditions for BAU: climate change • Overview and instructions • Seed Presentations on Projected Climate Change Impacts in Eastern Ontario • Break-out groups to review the BAU in the context of climate change • Plenary and Synthesis
14:00 –14:15	**Nutrition Break**
14:15 – 15:00	**Task 4: Identifying key indicators to measure the progress toward BAU** • Introduction • Seed presentation on indicators to measures scenarios elements – different types of indicators • Break-out groups to identify desired and available indicators • Plenary discussion to agree on the set of indicators
15:00 – 16:00	**Task 5: Outlining alternative scenarios** • Reintroducing the scenario framework • Identifying what are the relevant scenarios from the possible scenario • Specifying/reviewing the scenarios • Plenary
16:00 – 16:15	**Summary and Next Steps** • Overview of next steps • Closing remarks

Time	Workshop 3 Agenda Item
8:45 – 9:15	**Registration**
9:15 – 9:30	**Welcome and Introductions**
9:30 – 10:45	**Session 1: Presenting the Reference Scenario** • Review of the Envision modelling and outputs • Presentation – Climate change impacts in EO • Envision outputs – scenario with and without climate change
10:45 – 11:00	**Nutrition break**
11:00 – 12:30	**Session 2: Developing alternative future scenarios** • Introduction for the group exercise • Developing scenario narratives in groups
12:30 – 13:30	**Lunch**
13:30 – 15:15	**Session 3: Specifying alternative future scenarios** • Presenting the narratives of the scenarios
15:15 – 15:30	**Nutrition break**
15:30 – 16:45	**Session 4: Identifying key actions and policies within the alternative future scenarios**
16:45 – 17:00	**Summary and Next Steps** • Overview of next steps • Closing remarks

Time	Workshop 4 Agenda Item
8:45 – 9:15	**Registration**
9:15 – 9:30	**Welcome and Introductions** • Objectives of the workshop • Reviewing the progress so far
9:30 – 10:30	**Session 1: Quantifying the Alternative Scenarios** • Presentation of Envision model adopted of EO: –– Overview of scenario development to include in Envision –– Overview of scenario quantification to include in Envision and including approaches to adaptation –– Reflections of creating the Envision • Brief plenary discussion combinations of adaptations
10:30 – 11:30	**Session 2: Comparing the Alternative Scenarios** • Making the Envision work for EO, example of results • Overview of the outcomes of the key scenarios • Reflection on economic dimension of the scenarios and other scenario processes in agriculture • Reflection on impacts of climate extremes on the scenarios • Plenary discussion on key outcomes and consequences of the developed scenarios
11:30 – 12:30	**Session 3: Reviewing alternative future scenarios** • Brief group discussion about the preferred alternative scenario and adaptations; voting by groups • Plenary discussion about key differences between the scenarios and identifying elements of a preferred pathway for EO
12:30 – 13:30	**Lunch**
13:30 – 14:45	**Session 4: Specifying actions to achieve the pathway indicated in the preferred alternative future scenario(s):** –– what can be done now –– what needs to be done in the future • Group and plenary discussion
14:45 - 15:00	**Nutrition break**
15:00 – 16:00	**Session 3 cont.** • Identifying key gaps and opportunities to address needed actions
16:00 – 16:45	**Feedback from key experts and policy-makers on the project, used approaches and their relevance for policy-making**
16:45 – 17:00	**Summary and Next Steps** • Overview of next steps and outputs • Evaluations • Closing remarks

6.3 Overview of the Developed Scenarios Narratives

	Scenario A: Targeting global markets	Scenario B: Bioeconomy	Scenario C: Greener agriculture	Scenario D: Living Locally
Key considerations	An assumption is that climate change better positions Canada to be more competitive internationally. Increasing reliance on technology to enable the sector to be competitive and focus on niche markets. The role of government in producing and providing data information to farmers. Crop choice still largely driven by markets and market access. No real expectations of dramatically different farms or farming practices.	The total number of farms continues to go down as result of demographics and economics, nothing specific to bioeconomy; on one hand as farms get larger field sizes also tend to get larger as part of existing trend, but at same time there may be opportunities for small niche markets, creating finer-grained diversity on the landscape; there will be new emerging bioeconomy crop clusters.	Switch in livestock production systems away from dairy and beef to non-enteric digestion animals. Cropping systems. Forage based and biomass based crops in flood-prone areas (FPAs) (extreme event adaptation) or water management (diking of FPAs).	From drier weather arises need to consider irrigation at the community gardens, small farms, and costs related for farms. Small farms would need to be supported through incentive programs and pay for service, as most farms even in this scenario would continue to increase in size.
Environmental Policy	Little conservation on agricultural landscapes. Where present, these are driven by or feed back into Canadian branding of “green” on the international market. Certification emerges through various NGOs.	Freeing up of grazing lands for bioeconomy stocks. Conservation may become an emphasis as a result of the above; not specifically about the specific lands in production for bioeconomy, but there can be conservation benefits from efficiency measures, from side effects such as decreased grazing, and from BMPs that are compatible / ensuring this system is sustainable.	Encourage more crop residue. Encourage cover crop in fall and less tillage. Encourage rotational grazing. Encouraging providing natural heritage corridors, protection of. Move from just wetlands and woodlots to include ag landscapes.	Including ecosystem services as a legitimate environmental investment; incentives for wood log management; additional benefits for contributing to agricultural services; limited access to energy grid; and investments into grid.

	Scenario A: Targeting global markets	Scenario B: Bioeconomy	Scenario C: Greener agriculture	Scenario D: Living Locally
Landscape character	Farms are getting bigger but more diversified, varieties of cash crops and livestock likely to change over time as farmers use adaptive responses that balance climate-extreme risks with export and market influences (choice will be shifting in time and spatial use of farms will vary/shift). Since monoculture is risky, even when prices are high, farmers would want to avoid it (eggs not all in one basket). Focus on optimizing land use (productivity).	Mosaic landscape dotted by many, small and diverse biorefinery facility clusters. Clusters of farms around processing centres; loss of hay & pasture, but overall trend continues toward larger fields. Natural area on class 6/7 soils will go up as grazing decreases, potential competition between aggregate reserve zoned lands to bioproduct production, otherwise not part of the planning.	Trees are integrated into field systems, agroforestry is promoted.	Similar to current.
Natural areas	Conservation policies limited but vary regionally – Frontenac arch/west has less successful agriculture. Therefore it is easier to implement conservation there than in the west. Natural areas are likely to be lost due to shift to annuals combined with overall intensification.	Confined to Class 6/7 soils – rock and rocky. Probably the minimum required, except that co-location of perennial bioeconomy crops will often make sense—see soil nutrient retention. Therefore effective widening of functional buffers may occur even though it involves production. It COULD be used in a policy change on buffers, widening the buffers but allowing changes in the composition.	Restored wetlands for flood protection and habitat.	Similar to current; small farms located around smaller rural centres; protected areas are also in between farms and farmers receive money for maintaining protected areas.

	Scenario A: Targeting global markets	Scenario B: Bioeconomy	Scenario C: Greener agriculture	Scenario D: Living Locally
Agricultural Policy	Climate change risks: variety of production activities are affected (livestock directly and indirectly through feed prices). Emphasis on yield over "double croppping" with longer growing season. Trade agreements and policy incentives to increase export market diversity and opportunities (role of feds). Improved release of information and data to increase access to other export markets (certification, meeting other countries and/or trade agreement "green" or "non-GMO" standards, etc.).	Focus on sustaining feedstock production for the bioeconomy while being resilient to climate impacts; Outreach and education on transforming traditional/ current farming regimes to the new bioeconomy; feedstock produced through long-term contracts.	More policies supporting BMP implementation.	Planning at the municipal level to prevent selling the land to large farms; mostly supporting communication and skills; higher policy support is needed to change from support large farms; support for renting lands; cash incentives on the cost-sharing basis; support on crop insurance for the smaller farms
Agriculture markets/ Leading enterprise	Shift to faster breeding and growing breeds of livestock (beef and chicken emphasis) which can respond to and be managed on shorter time frames (to respond to pest and diseases associated with climate extremes) than dairy or other longer-housed livestock - ie., dairy. Look to creating diversity, capturing the diversity of foreign markets; reducing trade barriers, improving access to markets;	Leading opportunity is biorefineries for production of high-value products Not a food-producing landscape; Bioecon crops replacing liverstock.	Leading enterprise, similar to today, less beef and dairy, animal component becomes pork and poulty. Biomass/ bioenergy crops, nutrient extraction from crop residues.	Selling on the premium; using local inputs, farms co-ops that are farming together; packing different products including and meat and plants; increasing selling on markets; better marketing of the products; supplying local restaurants; multiple production woodlot, maple syrup
Technology	Emphasis on adaptable shifts to tap into emerging and new niche markets (etc., hay from EO to eastern U.S. niche for horses rather than soybeans (bulk) to China for EO. Bioeconomy will be important e.g., harvesting crop residues, use of digesters, etc. But, these will be introduced into existing operations.	Capacity for real-time crop management; increasing automation	Move from broadcast fertilizer esp. phosphorus; Biodigestion of manure.	

	Scenario A: Targeting global markets	Scenario B: Bioeconomy	Scenario C: Greener agriculture	Scenario D: Living Locally
Ecosystem services	Focus on how "green" Canadian agr. products are – much less (and will stay relatively less) pesticide and fertilizer requirements as compared to United States.	Wetlands constructed to regulate water quantity and quality and harvested for bio-products	Production practices that improve water quality. More trees, better wildlife. Restored wetlands for flood protection, nutrient capture habitat.	Limitation of the soil because of the quality, but also by the because we are more focused to feed conventional livestock.
Energy production	Considered part of the bioeconomy shift (i.e., farmers may/will adopt local energy production as part of a suite of tools to diversify). Biodigesters used to sell power to grid to augment incomes, could be used to run greenhouses	Biorefinery process residues used for energy production; solar not part of this future	Biodigesters on farm. Bioenergy crops	Processing low quality wood in energy production; small-scale renewable energy production for the farm itself
Other markets	Livestock impacts of trade and climate are unclear, less total reliance by farmers on livestock production and increase diversity to other productions (e.g., some cash cropping etc.).	R&D on genomics and technology development co-located with biorefinery clusters	Biomass markets.	
Quality of life	Expected to continue as usual, since farmers and ag sector are highly responsive to shift and adapt to market influences and climate in real time. Increasing conflict in water use and access between rural and urban users, as well as other non-ag industry. Increase food prices due to dependency on importing food.	Farming communities are more prosperous; more jobs around biorefinery clusters.	Better esthetics on landscapes opportunities for recreation.	We need to account for larger size organic farms that could supply to Loblaw's/Wal-Mart; suburban type of lifestyle to commute to work (bedroom communities).

	Scenario A: Targeting global markets	Scenario B: Bioeconomy	Scenario C: Greener agriculture	Scenario D: Living Locally
Public attitudes	Expect crop insurance and other programs to persist to manage extreme losses. Focus on “greenness” of Canada, and EO to access special niche markets with targeted products from this region. Increase taxes, conflict between urban and farm in water demand/use. Environmental values not represented in this ag landscape, either not appreciated by public, or may create conflict in values between segments of society.	Diet shift to poultry rather than beef; higher level of public sophistication on value of the bioeconomy.	General support for a policies, willingness to pay for EGS.	Rural/urban divide is not sharp, programs to work on farms. Policy to build the market; importance of eating locally, supporting education; we need to teach people how to grow locally and to buy locally; need to have a successional planning to maintain the villages and small-scale production.

6.4 Overview of the Quantified Scenarios to Be Modelled in Envision

	Current 2006	Targeting global markets	Promoting bioeconomy	Greening agriculture	Living locally
Crop Allocation	56% Annual Cash Crop 44% Hay and Pasture (Envision 58/42)	1) Of IDUs of hay or pasture that were affected by dairy or beef reductions, change LULC to a corn/soy rotation, starting with IDUs in CLI classes 1 to 5 successively until all areas affected are reallocated. 2) Change any forest IDU with CLI class 1 to 5 to corn/soy rotation.	See livestock production and crop rotation changes.	See livestock production and crop rotation changes.	See livestock production changes.
Crop rotation	58% Corn, 37% Soybeans, 5% all other crops. (Note: We are lacking soybean data in the initial coverage	Change the rotations for hay and pasture IDUs that were converted to corn/soy by livestock reductions to corn/soy/corn/soy/cereal rotations. For all other IDUs, change corn/soy/cereal to corn/soy/corn/soy/cereal, and change corn/soy/cereal/hay/hay to corn/soy/corn/soy/hay/hay.	Change 25% of corn/soy/cereal in CLI classes 4 and 5 (that are not tile-drained) to bioenergy crop.	Change 5% of corn/soy/cereal in CLI class 5 (that are not tile-drained) to bioenergy crop.	See livestock production changes.
Livestock production	Wait for IDU split between hay and pasture, and corresponding herd size for cattle. Pigs and Poultry do not affect crop ratios or IDUs in ag(?)	Reduce dairy operations (IDU of hay within cadastre unit) by 25% and reallocate dairy cattle to surviving dairy operations. Reduce beef operations (IDU with pasture within cadastre unit) by 25% and reallocate 50% of beef cattle to surviving operations.	Change 60% of pasture area to bioenergy crop. Change 1/15th of 60% of hay area to bioenergy crop. Eliminate one beef cow for every two acres of pasture area changed.	Reduce beef cattle numbers by 10%. For every beef cow eliminated change two acres of pasture to bioenergy crop. Reduce dairy cattle numbers by 10%. Change 10% of hay area to bioenergy crop. Increase number of pig barns by 60% and number of poultry barns by 60%.	Reduce beef cattle numbers by 15%. For every beef cow eliminated change two acres of pasture to fruits/vegetables. Change 1/15th of 15% of hay to fruits/vegetables.

	Current 2006	Targeting global markets	Promoting bioeconomy	Greening agriculture	Living locally
Chemical, manure fertilizer	See Huffman et al. paper from Ruth email 18 January 2013	Determined by crop type and animal numbers	Determined by crop type and animal numbers	Determined by crop type and animal numbers	Determined by crop type and animal numbers
Forest Composition		N/A	N/A	N/A	30% mature; 5% old-growth
Forest Cover		N/A	N/A	Maintain current 2006	30% by watershed; 40–60% in one or more watershed unit.
Forest Patch Size		N/A	N/A	N/A	1+ patches 200 to 1000 ha per watershed. Representation of cover types and age classes.
Wetland Area		N/A	N/A	Maintain current 2006	10% by watershed; 6% by sub-watershed.
Wetland Landscape Comple-mentation		N/A	N/A	N/A	100m natural habitat width surrounding wetlands; 10% with 200–300 m width.
Wetlands in the Land-scape		N/A	N/A	N/A	Groups of wetlands within 500–1000 m of the centre of each.
Wetlands Patch Size		N/A	N/A	N/A	At least one marsh patch size > 200 ha.
Riparian Represen-tation		N/A	N/A	N/A	Representative of forest cover types and age classes

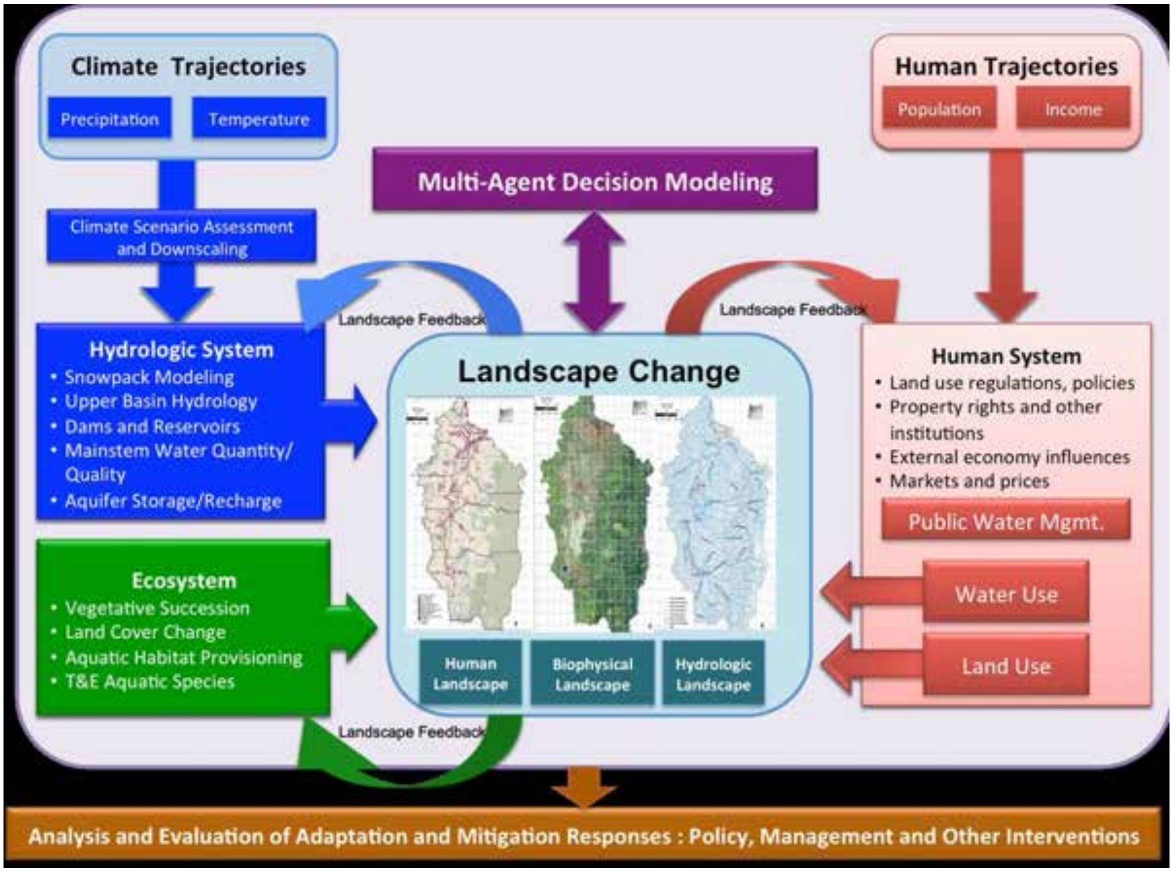
	Current 2006	Targeting global markets	Promoting bioeconomy	Greening agriculture	Living locally
Riparian Width		N/A	N/A	15m on a side in perennial cover (50% willow, perennial herbaceous)	100% nat/semi to 15m; 75% nat veg to 30m; 10% nat veg to 300m
Impervious-ness in Watershed		N/A	N/A	N/A	< 10% imperviousness in an urbanizing watershed
Farmland Grassland Habitat Area		N/A	N/A	Convert CLI 5-7 to grassland	10% grassland in watershed for area-sensitive species
Farmland Grassland Patch Size		N/A	N/A	N/A	50 to 200 ha patches in grassland and cultural habitats for area-sensitive species by watershed
Farmland Agriculture Ecosystem Services		N/A	N/A	10% natural/semi-natural veg within 1km of farm fields	40% in natural or semi-natural habitats within 3 km of farm fields for full pollinator services

6.5 Envision Model Overview

Envision is a GIS-based tool for scenario-based community and regional planning and environmental assessments. As a modelling platform, it combines a spatially explicit polygon-based representation of a landscape, a set of application-define policies (decision rules) that are grouped into alternative scenarios, landscape change models, and models of ecological, social and economic services to simulate land use change and provide decision-makers, planners, and the public with information about resulting effects on indices of valued products of the landscape. Envision is built on an open, extensible architecture that can be adapted to a variety of location and applications (Bolte et al. 2006; http://envision.bioe.orst.edu/).

Envision has been used to develop alternative futures analyses in eight or more studies investigating the effects of climate change, changes in agriculture or forestry practices, or changes in human population numbers and development patterns. As an example, one current project sponsored by the U.S. National

Figure A1. Schematic design of the Willamette Water 2100 project. Envision integrates all components above the lowest bar. That bar, "Analysis and Evaluation of Adaptation and Mitigation Responses," indicates actions that the project hopes to influence.



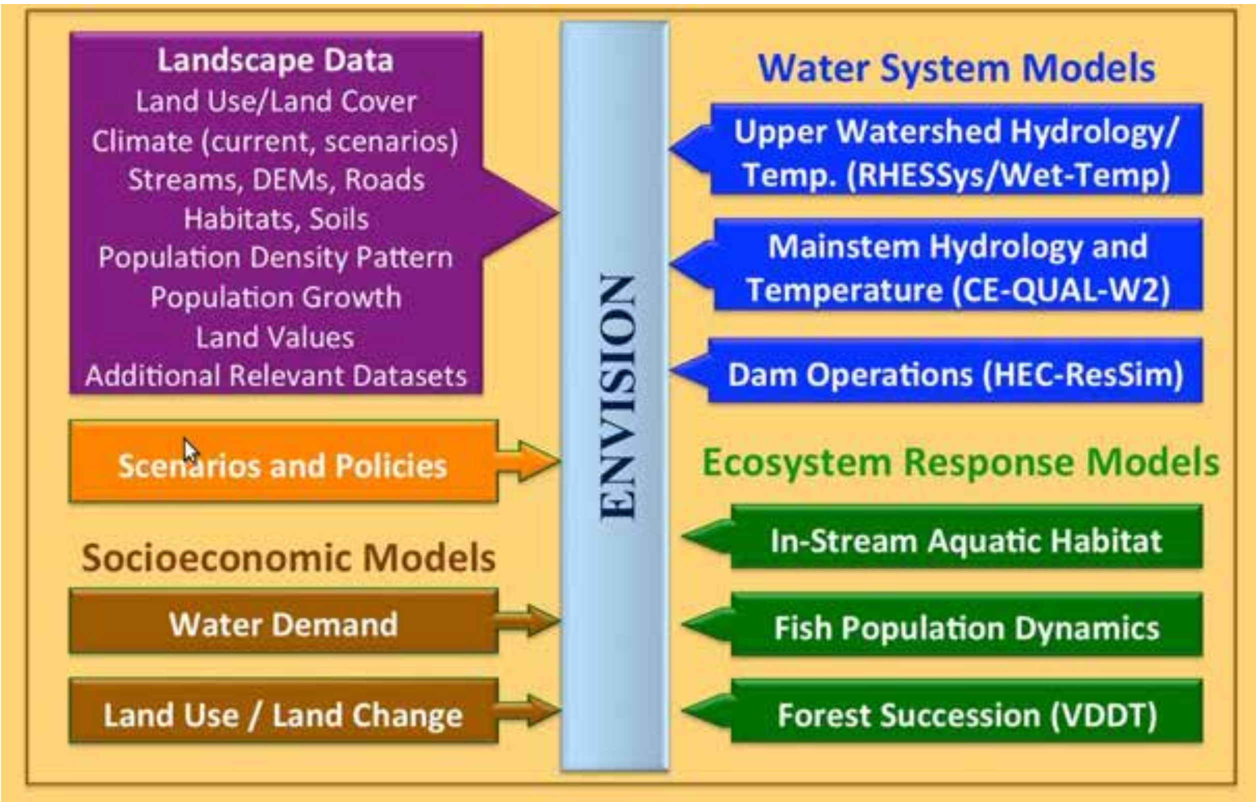
Science Foundation seeks to "identify the communities and ecosystems whose water systems are most vulnerable or to specify how these communities and ecosystems can best adapt" as water supplies change (http://envision.bioe.orst.edu/caseStudies.htm). A diagram of how Envision fits into the context of an alternative futures study shows human and bio-geophysical factors influencing the system, the landscape change process of human decision making that is affected by these factors, and the feedbacks from human change decisions to the bio-geophysical and human parts of the system (Figure A1). A second diagram shows how Envision integrates both complex and simple dynamic models into its simulation platform (Figure A2).

6.6 Overview of Integrated Model Development

For climate effects in the simulation of future agriculture, a set of indicators of extreme weather events was selected by the climate team. These were implemented in a plug-in model for Envision as described in the preceding section.

After an extensive search and consultations with climate experts, Future Climate Datasets Web Application by OMNR (Ontario Ministry of Natural Resources) has been selected as the source for future projections data and baseline data.

Figure A2. Data and plug-in models for the Envision system for the Willamette Water 2100 project.



Model selection includes two versions on the Regional Canadian Climate Model (MRCC.3.7.1 and MRCC.4.2.0), HADCM3 (Hadley Centre Coupled Model, version 3), IPCM4 (IPSL-CM4, Institut Pierre Simon Laplace Climate Model, version 4), MPEH5 (ECHAM5/MPI-OM, Max Planck Institute for Meteorology Climate Model, version 5), NCCCSM (CCSM3, National Center for Atmospheric Research Climate Model, version 3) among others. The first two models offer a high spatial resolution and take into account local physiographic features (EBNFLO Environmental AquaResource Inc 2010). In the case of the latter four models, a stochastic weather generator (LARS–WG) was used to create time series of daily weather at each location. This weather generator has an improved simulation of extreme weather events and has proven produce simulations suitable for assessing agricultural and hydrological risks (LARS–WG stochastic weather generator, 2012). The A2 high emissions scenario was selected in consultation with experts, taking into account past and current trends in global greenhouse gas emissions.

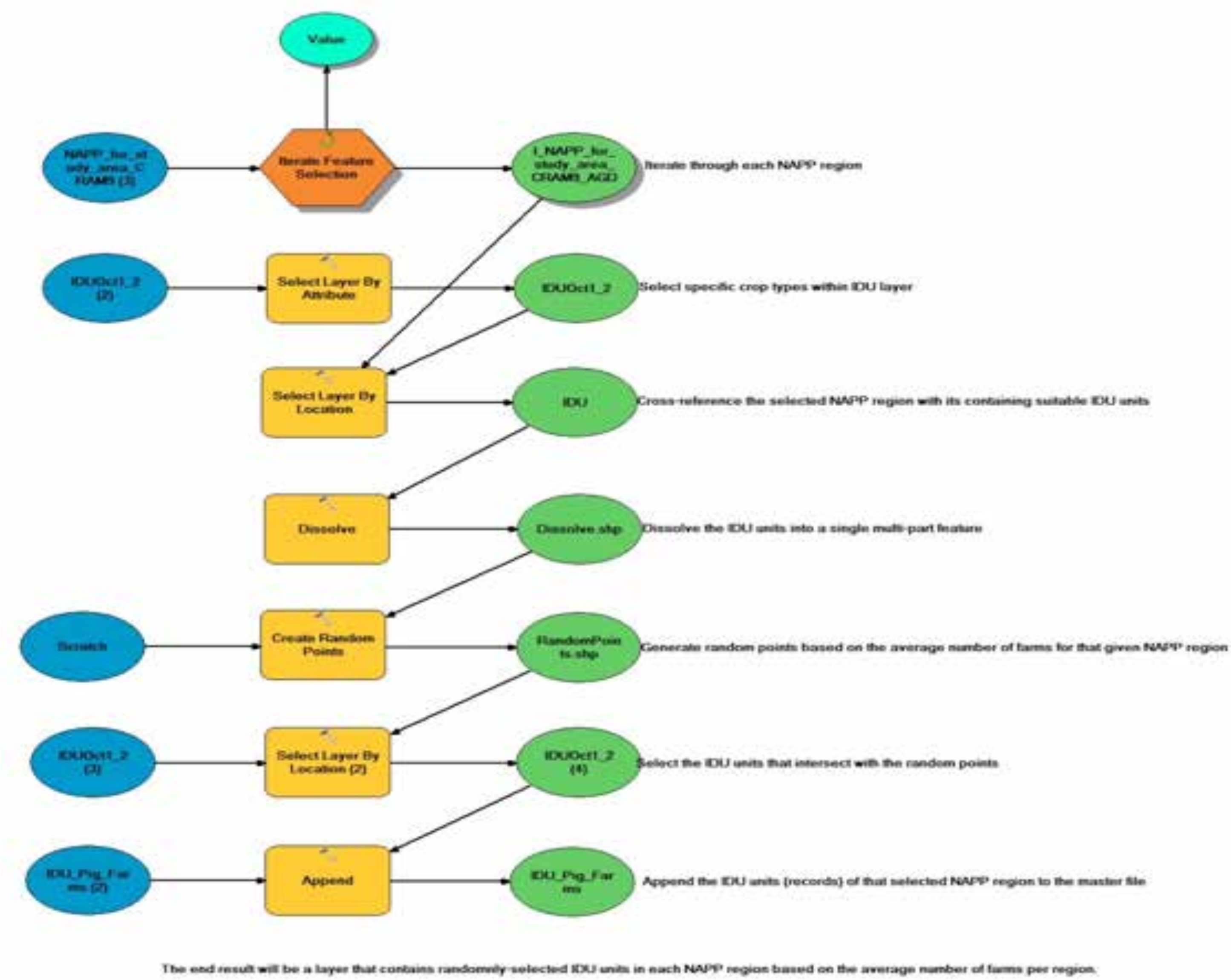
Due to the spatially limited characteristics of available climate data, interpolation was necessary to make sure all of the key agricultural areas in the region are included in the analysis. Due to the large number of IDUs in the study area (over 110,000 polygons) and the size of climate datasets, interpolation at the IDU scale appeared to be non-feasible due to time constraints. It was decided to use Soil Landscapes of Canada polygons (SLCs) to set the interpolation scale, and this speeded up the interpolation process significantly. Baseline climate data and future climate projections were interpolated using the IDW method that "interpolates a raster surface from points using an inverse distance weighted (IDW) technique" (IDW [Spatial Analyst], ArcGIS Resource Center, 2011). The output of the interpolation process is one .csv file per year: 30 files for the baseline and 30 files for each of the GCMs for the projections. Within each .csv file there is a field for each day of the year and variable (Tmin, Tmax, and Precipitation) and a record for each SLC. This facilitates the incorporation of climate data into the Envision system (by joining them to the IDU attribute table) to develop future agro-climatic scenarios at a regional scale.

Two groups of indices were identified as appropriate for the project and include universal indices developed by the World Meteorological Organization (ETCCDMI indices) and regional indices developed for Eastern Canada by researchers at Environment Canada (Gachon indices). ETCCDMI indices are widely used as a tool to assess and monitor changes in extremes and the ability of climate models to simulate extremes (Klein Tank, Zwiers, Zhang, 2009); Gachon indices were designed specifically for Eastern Canada and can be adapted to the main characteristics of climate conditions at the regional scale so that they recognize seasonal variability and other specifics of the study area (Gachon 2005). Each of the indices, when calculated, provides an account of the frequency, length or intensity of a particular event, such as a heat wave, an extreme rainfall event etc.

In subsequent stages of modelling and scenario-development sensitivities of locally grown crop varieties will be taken into consideration when identifying specific thresholds of heat, moisture and drought tolerance. Informal consultations with crop experts at AAFC are ongoing and are expected to help validate the choice of thresholds. The focus is on extreme events occurring during the growing season as these are known to be most damaging to crops (Qian et al 2010). To better account for extremes that occur during different phenological stages of crop development, selected indices can be calculated at annual, seasonal and monthly time steps.

For livestock distribution in the baseline data for IDUs, since no database giving the exact locations of livestock operations existed, it was necessary to randomly allocate the farm locations to IDU's. Two separate databases were

Figure A3. ArcGIS Model Builder Steps performed to randomly select IDU Polygons for potential Pig and Poultry Farm locations.



used to accomplish this. The NAPP database[16] gave numbers of farms reporting Pigs, Poultry and Cattle at the smallest aggregation. The Ag Census database allowed us to determine average herd/flock sizes for each farm location at a larger allocation and apply that herd/flock size to each identified farm in each NAPP polygon. To determine the acceptable locations for Pig and Poultry Farms, ArcGIS model builder was used to perform a random selection on the IDU Polygon Framework incorporating suitable Land Cover of where Pig and Poultry manure could be applied. In Figure A3, a step-by-step technical description of each Geoprocessing step is defined.

To determine acceptable locations of Beef and Dairy Farms, the farms reporting cattle had to be further allocated to beef and dairy operations. A ratio of farms reporting beef cows to farms reporting dairy cows was created for each Ag Census region. This ratio was then applied to farms reporting a cattle attribute within the NAPP database to give numbers of beef farms and numbers of dairy farms for each NAPP region. ArcGIS model builder was also used to perform a random selection on IDU Polygon Framework. Based on the average Pasture size derived from the National Agriculture Profiling Project (NAPP) and locations of Hay/Pasture polygons within the AAFC–AESB Land Cover, we have applied an average Hay:Pasture ratio to select Pasture Polygons using a random selection tool (Python Script) within ArcGIS Model Builder to determine appropriate locations for Beef and Dairy Cattle herds.

16. AAF database based on Census Canada data

*The method used to define the Hay:Pasture ratio; Grassland Area in hectares (A1) was defined from Land Cover dataset of AESB for each IDU. Pasture in hectares (B1) from the National Agriculture Profiling Project (NAPP) was then subtracted from the previous area (A1) to estimate Hayland in hectares for each individual IDU polygon. Pasture defined by the National Agriculture Profiling Project (NAPP) (A2) was then defined and the grassland located within each IDU (B2) was then subtracted from the pasture (A2). This provided an estimate of Pasture in each IDU (C2).

A1 - B1 = C1
A2 - B2 = C2
Hayland in IDU (C1) : Pasture in IDU (C2)

EXAMPLE for NAPP Region AGDA_NAPP_: 35061385
Ratio (example) = 1 : 3

Steps:
1) 1/3 = 2.93
2) 1/2.93*100=34.1
3) 34.1/100=.341%
4) .341 x Pasture_Fa (38)
5) = 12.96

Therefore, 12.96 pastures would be randomly selected from within NAPP region 35061385 for polygons that are classified as Hay/Pasture within the AESB Land Cover (2011).

The average size Beef herd (20.5) for the respective NAPP region (35061385) was then attributed to those selected IDU's. For Dairy Cattle herds, the remaining IDU Hay/Pasture polygons were then used within a second random selection. Only one Beef or Dairy herd could be attributed for each cadastral polygon within the IDU Framework.

REFERENCES

Adger, W.N., Brown, K., Nelson, D.R Berkes, F., Eakin, H., Folke, C.6, . . . Tompkins, E.L. (2011). Resilience implications of policy responses to climate change. Wiley Interdisciplinary Reviews: Climate Change, 2(5), 757–767. doi:10.1002/WCC.133

ArcGIS Resource Center. (2011). IDW (Spatial Analyst). Retrieved from http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//009z0000006m000000.htm

Bizikova, L., & Hatcher, B. (2010). Scenario-based planning for a changing climate in the Bras d'Or Ecosystem. Winnipeg: International Institute for Sustainable Development. Retrieved from http://www.iisd.org/pdf/2010/scenario_based_planning_bras_dor.pdf

Bolte, J.P, Hulse, D.W, Gregory, S.V, & Smith, C. (2006). Modeling biocomplexity - actors, landscapes and alternative futures. Environmental Modelling & Software, 22, 570 – 579.

Brown, K. (2011). Sustainable adaptation: An oxymoron? Climate and Development, 3(1), 21–31. doi:10.3763/cdev.2010.0062

Bochove, E.V., Thériault, G.V., Dechmi, F., Leclerc, M. L., & Goussard, N. (2007). Indicator of risk of water contamination by phosphorus: Temporal trends for the Province of Quebec from 1981 to 2001. Canadian journal of soil science, 87(Special Issue), 121-128.

Brown, D.M. & Bootsma A. (1993) Crop heat units for corn and other warm season crops in Ontario. Ontario Ministry of Agriculture and Food Factsheet 93–119, Agdex 111/31, 4 pp. [Available online athttp://www.omafra.gov.on.ca/english/crops/facts/93-119.htm]

Carlsen H., Dreborg, K.H., & Wikman-Svahn, H.P. (2012). Tailor-made scenario planning for local adaptation to climate change. Mitigation and Adaptation Strategies for Global Change, 18(8). doi:10.1007/s11027-012-9419-x

Carter J. (2009). Stakeholder mapping for climate change adaptation. Manchester: University of Manchester. Retrieved from http://www.adaptingmanchester.co.uk/sites/default/files/Stakeholdermappingreport-finalversion.pdf

Coates, J.F. (2000). Scenario planning. Technological Forecasting and Social Change 65, 115–123. Retrieved from http://lampsacus.com/documents/Scenario_Planning.pdf

Dalal-Clayton, D.B., & Bass, S. (2009). The challenges of environmental mainstreaming (Environmental Governance Series, No.1). International Institute for Environment and Development. Retrieved from http://pubs.iied.org/pdfs/17504IIED.pdf

Dovers, S. (1996). Processes and institutions to inform decisions in the longer term. In R. Harding, (Ed.), Proceedings of the Australian Academy of Science Fenner Conference on the Environment. University of New South Wales, 29 September–3 October 1996.

Dovers, S. (2003). A policy orientation as integrative strategy. In S. Dovers, D.I. Stern, & M.D. Young, (Eds.), New dimensions in ecological economics: Integrated approaches to people and nature (pp. 102–117). Cheltenham, U.K.: Edward Elgar.

Drury, C.F., Yang, J.Y., De Jong, R., Yang, X.M., Huffman, E.C., Kirkwood, V., & Reid, K. (2007). Residual soil nitrogen indicator for agricultural land in Canada. Canadian Journal of Soil Science, 87, 167–177. Retrieved from http://pubs.aic.ca/doi/pdf/10.4141/S06-064

EBNFLO Environmental AqueResource Inc. (2010). Guide for assessment of hydrologic effects of climate change in Ontario (Report prepared for the Ontario Ministry of Natural Resources and the Ontario Ministry of Environment). Retrieved from http://www.waterbudget.ca/climatechangeguide

ETCCDI/CCD. (2009). Climate change indices. Retrieved from http://www.clivar.org/panels-and-working-groups/etccdi/etccdi.php

Expert Panel on Climate Change Adaptation. (2009). Adapting to climate change in Ontario. Retrieved from http://www.climateontario.ca/doc/publications/ExpertPanel-AdaptingInOntario.pdf

Gachon, P. (2005). A first evaluation of the strength and weaknesses of statistical downscaling methods for simulating extremes over various regions of eastern Canada. Montreal: Environment Canada. Retrieved from http://www.ouranos.ca/media/publication/46_Rapport_Gachon_climat_2005.pdf

Gagnon-Lebrun, F., & Agrawala, S. (2007). Implementing adaptation in developed countries: An analysis of progress and trends. Climate Policy, 7, 1–17

Gallopín, G. Hammond, A., Raskin, P., & Swart, R. (1997). Branch points: Global scenarios and human choice. Stockholm: Stockholm Environment Institute. Retrieved from http://www.tellus.org/publications/files/branchpt.pdf

Godet, M. (2000). The art of scenarios and strategic planning: Tools and pitfalls. Technological Forecasting and Social Change, 65, 3–22.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., . . . Watson, R. (2008). A global map of human impact on marine ecosystems. Science, 319(5865), 948–952.

Harley, M., Horrocks L., Hodgson N., & Van Minnen J. (2008). Climate change vulnerability and adaptation indicators. European Topic Centre on Air and Climate Change (ETC/ACC) Technical Paper 2008 9.

Hezri, T. (2004) Sustainability indicator system and policy processes in Malaysia: a framework for utilisation and learning. Journal of Environmental Management, 73: 357-371. Retrieved from http://ftp.utalca.cl/redcauquenes/Papers/sustainability%20indicator%20and%20policy.pdf

Higgins, J., & Venning, J. (2001). Introduction. In J. Venning, & J. Higgins (Eds.), Towards sustainability: Emerging systems for informing sustainable development (pp. 1–22). Sydney: UNSW Press.

Howden, M.S., Soussana, J.F., Tubiello, F.N., Chhetri, N., Dunlop, M., & Meinke, H. (2007). Adapting agriculture to climate change. Proceedings of the National Academy of Sciences, 104, 19691–19696. Retrieved from http://www.pnas.org/content/104/50/19691.full

Huser, B. (2011). Integrated spatial planning. Geomatica Special Issue, 65(3), 9–14. Retrieved from http://pubs.cig-acsg.ca/doi/abs/10.5623/cig2011-042

IPCC (Intergovernmental Panel on Climate Change). (2007). Summary for policymakers. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor and H.L. Miller (Eds.), Climate Change 2007: The Physical

Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge, UK and New York, NY: Cambridge University Press.

Jaeger, J., Rothman, D., Anastasi, C., Kartha, S., & van Notten, P. (2008). Training Module 6. Scenario development and analysis. GEO Resource Book. A training manual on integrated environmental assessment and reporting. Retrieved from http://www.unep.org/ieacp/iea/training/manual/module6.aspx

Javorek, S.K., & Grant, M.C. (2011). Trends in wildlife habitat capacity on agricultural land in Canada, 1986-2006 Canadian Biodiversity: Ecosystem Status and Trends 2010 ,Technical Thematic Report No. 14). Ottawa, ON: Canadian Councils of Resource Ministers. Retrieved from http://www.biodivcanada.ca/137E1147-146B-4E0D-844C-BA1E5BEAFA17/4671No.14_Wildlife%20Habitat%20Capacity_Jun2012_E.pdf

Klein Tank, A.M.G., Zwiers, F.W., & Zhang, X. (2009). Guidelines on analysis of extremes in a changing climate in support of informed decisions for adaptation., Geneva, Switzerland: World Meteorological Organization. Retrieved from http://www.wmo.int/datastat/documents/WCDMP_72_TD_1500_en_1_1.pdf

Kok, M.T.J., de Coninck, H.C. (2007). Widening the scope of policies to address climate change: directions for mainstreaming. Environmental Science & Policy, 10(7–8), 587–599. doi:10.1016/j.envsci.2007.07.003

Langsdale, S., Beall, A., Carmichael, J., Cohen, S., Forster, C.B., & Neale, T. (2009). Exploring the implications of climate change on water resources through participatory modeling: Case study of the Okanagan Basin, British Columbia. Journal of Water Resources Planning and Management, 135(5), 373–381. doi:10.1061/(ASCE)0733-9496(2009)135:5(373)

LARS-WG stochastic weather generator. (2012). Retrieved from http://www.rothamsted.ac.uk/mas-models/larswg.php

Lefebvre, A., Eilers, W.D., & Drury, C.F. (2007). Canadian agri-environmental indicators. Canadian Journal of Soil Science, Special Issue, 119–120.

Lewis, P. (1996). Tomorrow by design. New York: Wiley.

Lindsay, K. (2012). Summary of Habitat-based Landscape Targets for Biodiversity Conservation from the National Agri-Environmental Standards Initiative (NAESI) for inclusion in the Farms 2 Regions modeling platform for eastern Ontario, unpublished presentation.

May, P.J. (1999). Fostering policy learning: A challenge for public administration. International Review of Public Administration 4, 21–31.

McHarg, I. (1969). Design with nature Garden City, NY: The Natural History Press.

Nakicenovic, N., et al. (2000). Special Report on Emissions Scenarios. Report of the Intergovernmental Panel on Climate Change. London: Cambridge University Press.

Nassauer, J. I., Santelmann, M. V., & Scavia, D. (2007). From the Corn Belt to the Gulf: Societal and environmental implications of alternative agricultural futures. Washington, D.C.: Resources for the Future Press.

Neave, E., Baldwin, D., & Nielsen, C. (2008). Tiers 2 And 3 Standards – Habitat-Based Biodiversity Standards Decision Support Process and Results of Eastern Ontario Pilot Project (National Agri-Environmental Standards Initiative Technical Report No. 4-14).

Ontario Ministry of the Environment. (2011). Climate ready: Ontario's Adaptation Strategy and Action Plan. Retrieved from http://www.climateontario.ca/doc/workshop/MVC_Workshop/DesRosiers-O_Neill-MVC_Workshop.pdf

Organisation for Economic Co-operation and Development (OECD). (2009). Integrating climate change adaptation into development cooperation – policy guidance. Paris: OECD. Retrieved from http://www.oecd.org/dac/43652123.pdf

Pinter, L., Zahedi K., & Cressman, D. (2000). Capacity Building for Integrated Environmental Assessment and Reporting. Nairobi: UNEP and IISD.

Qian, B., Gameda, S., de Jong, R., Falloon, P., & Gornall, J. (2010). Comparing scenarios of Canadian daily climate extremes derived using a weather generator. Climate Research, 41, 131–149. Retrieved from http://www.int-res.com/articles/cr_oa/c041p131.pdf

Raskin, P., Banuri, T., Gallopín, G., Gutman, P., Hammond, A., Kates, R.W., Swart, R.J. (2002). Great transition: The promise and lure of times ahead. Boston, Massachusetts: Stockholm Environment Institute–Boston. Retrieved from http://rwkates.org/pdfs/b2002.01.pdf

Schröter, D., Acosta-Michlik, L., Arnell, A.W., Araújo, M.B., Badeck, F., Bakker, M., Bondeau, A. . . . Cramer, W. (2004). ATEAM Final report. Detailed report, related to overall project duration. Reporting period: 01.01.2001-30.06.2004. Potsdam: Potsdam Institute for Climate Impact Research (PIK).

Shaw. A, Sheppard, S., Burch S et al. (2009). Making local futures tangible—synthesizing, downscaling, and visualizing climate change scenarios for participatory capacity building. Global Environmental Change, 19(4), 447–463. doi:10.1016/j.gloenvcha.2009.04. 002

Smit, B., Pilifosova, O., Burton, I., Challenger, B., Huq, S., Klein, R.J.T., & Yohe, G. (2001) Adaptation to climate change in the context of sustainable development and equity. Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of the Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, McCarthy, J.J., Canziani O., Leary, N.A., Dokken, D.J, & White, K.S., Eds., Cambridge University Press, Cambridge, 877-912.

Steinitz, C. (2010, September). Matters of Scale. Landscape Architecture, 206–208.

Swart, R., Biesbroek, R., Binnerup, S., Carter, T. Cowan, C., Henrichs, T., Loquen, S., Mela, H., Morecroft, M., Reese, M., & Rey, D. (2009). Europe adapts to climate change: Comparing national adaptation strategies (PEER report No 1. Partnership for European Environmental Research). Retrieved from http://www.peer.eu/fileadmin/user_upload/publications/PEER_Report1.pdf

Tansey J., J. Carmichael, VanWynsberghe , R., & Robinson, J. (2002). The future is not what it used to be: Participatory integrated assessment in the Georgia Basin. Global Environmental Change, 12, 97–104.

Tompkins, E.L., Few, R., & Brown, K. (2008). Scenario-based stakeholder engagement: incorporating stakeholders preferences into coastal planning for climate change. Journal of Environmental Management , 88(4), 1580–1592. doi:10.1016/j.jenvman.2007.07.025

Tschakert, P.K., & Dietrich, A. (2010). Anticipatory learning for climate change adaptation and resilience. Ecol Soc 15(2):11. Retrieved from http://www.ecologyandsociety.org/vol15/iss2/art11/

van Aalst, M.K., Cannon, T., & Burton, I. (2008). Community-level adaptation to climate change: The potential role of participatory community risk assessment. Global Environmental Change 18(1), 165–179.

van Bochove, E., Thériault, G., Dechmi, F., Leclerc, M-L., & Goussard, N. (2007). Indicator of risk of water contamination by phosphorus: Temporal trends for the Province of Quebec from 1981 to 2001. Canadian Journal of Soil Science, 87, 121-128. Retrieved from http://pubs.aic.ca/doi/pdf/10.4141/S06-067

van de Kerkhof, M., & Wieczorek, A. (2005). Learning and stakeholder participation in transition processes towards sustainability: Methodological considerations. Technological Forecasting and Social Change 72(6). 733–747

Volkery, A., Ribeiro, T., Henrichs, T., & Hoogeveen ,Y. (2008) Your Vision or My Model? Lessons from Participatory Land Use Scenario Development on a European Scale. Syst Pract Action Res, 21, 459–477

White, D. (2012). Alternative future scenarios (Unpublished report provided to Environment Canada, Kathryn Lindsay, project officer).

Yang, J.Y., De Jong, R., Drury, C.F., Huffman, E.C., Kirkwood, V., & Yang, X.M. (2007). Development of a Canadian Agricultural Nitrogen Budget (CANB v2.0) model and the evaluation of various policy scenarios. Canadian Journal of Soil Science, 87, 153–165. Retrieved from http://pubs.aic.ca/doi/pdf/10.4141/S06-063

Published by the International Institute for Sustainable Development.