

Informing Regional Planning in Alberta's Oilsands Region with a Land-use Simulation Model

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Abstract: Planning for regional sustainability requires strategic understanding of ecological and socioeconomic trade-offs associated with alternative land use options. We discuss a scenario analysis being undertaken to assess trade-offs for a 93,000 km² region in northeastern Alberta containing the world's second largest oil deposit. Due to its immense economic and ecological value, the region presents both an opportunity and challenge for the objectives of sustainable prosperity and healthy ecosystems put forth by the Alberta government's Land-Use Framework. ALCES[®] simulation and mapping software are being applied to inform government planners and stakeholders about possible future outcomes associated with land-use options. Two characteristics of the modelling process in particular have contributed to its success: the comprehensive and integrative nature of ALCES; and reliance on government and stakeholders for model inputs and scenario development. The scenario analysis provides a case study to discuss the technical aspects of ALCES and the Alberta Land-Use Framework's approach of facilitating learning through iterative scenario analysis.

Keywords: *scenario analysis, cumulative effects, regional planning*

1. INTRODUCTION

Environmental degradation has increased in frequency and intensity in recent decades due to expanding development and population growth. Responses to the environmental impacts have typically been reactionary and focused on specific symptoms rather than systemic drivers and effects (Reagan 2006). The result is fragmented government policy that is ill-suited to deal with environmental problems that are typically complex, multidimensional, and broad in spatial and temporal scale (Bellamy et al. 1999). Integrated resource management (IRM) was conceived to address the discordance between the complex problems yet simplistic management regimes. Rather than focusing on single developments or environmental issues, IRM seeks to manage all human activities in a system to balance a broad range of objectives (Cairns and Crawford 1991).

Practitioners of IRM are likely to encounter trade-offs when diverse environmental and socioeconomic goals come into conflict due to finite natural resources. An important component of IRM is scenario analysis to assess trade-offs associated with a range of contrasting but plausible assumptions about a region's management regime and ecological

processes (Peterson et al. 2003). The scenario analysis should be broad enough in scope to consider the impact of all potentially influential anthropogenic and natural disturbances and to incorporate the broad spatial and temporal scales that define many ecological processes. Computer-based land-use simulation models are well suited for such an analysis due to their capacity to track potentially complex inter-relationships among numerous variables. Although incapable of predicting the future state of an ecosystem due to the uncertain nature of key drivers (e.g., human behaviour and natural disturbances), computer models can foster an understanding of how an ecosystem may respond to human actions by trialing management strategies prior to real-world implementation (Ford 1999).

The province of Alberta in western Canada is a poignant example of the benefits and challenges created by rapid and uncoordinated economic development. Over the past century, Alberta's population has grown at a rate of 2.1% per year, driven first by the conversion of native prairie to agricultural production and then development of the abundant hydrocarbons of the Western Canadian Sedimentary Basin and harvest of the province's expansive forests. Alberta has transformed into a jurisdiction whose export economy is of international importance, but rapid development has also generated environmental liabilities (Timoney and Lee 2001). The uncoordinated growth mandates of multiple resource sectors have impacted not only ecosystems but also each other, with land uses such as energy and forestry competing for a limited land base (Ross 2002).

In response to mounting concerns that existing management regimes may be inconsistent with long-term sustainability, the government of Alberta is embarking on an IRM planning exercise to identify land use strategies better suited to balance long-term ecological and socioeconomic objectives (Alberta Land Use Secretariat 2008). The planning process, referred to as the Alberta Land-use Framework (ALUF), has been partly informed by scenario analyses for the first two regional plans undertaken to date. In this paper, we discuss the role of scenario analysis in the ALUF and describe *ALCES*[®], the land-use simulation model being applied to explore regional cumulative effects. As an example of how *ALCES* is informing the regional planning process, we draw from the ALUF's scenario analysis that focused on the oilsands region of northeastern Alberta. We conclude by discussing some of the challenges and opportunities of applying simulation models to inform IRM. In particular, we focus on the role of strategic modelling, the importance of stakeholder participation, and the need to apply models to inform society at large about land use issues.

2. *ALCES* AND THE ALBERTA LAND USE FRAMEWORK

The ALUF, mandated by the Alberta Land Stewardship Act in October 2009, represents a shift from project-specific to regional environmental management. The focus is on strategic level issues and solutions such as the desired balance between ecological and economic performance and how provincial strategies such as economic development, protected areas, and regulations should align at the regional scale. While regional plans require approval from Cabinet, the plans are designed by multi-stakeholder groups through an iterative process informed by scenario analysis. The multi-stakeholder groups, referred to as regional advisory councils (RACs), are populated with a diverse collection of individuals who are collectively knowledgeable of the full range of land-use issues relevant to a region. With ongoing guidance from the RAC, a regional planning team (RPT) consisting of experts from relevant provincial government ministries structures a series of scenarios intended to demonstrate the implications of a range of management options. The process is fluid, with each subsequent scenario being informed partly by learnings from previous scenarios. Ultimately, the RAC applies learnings from the iterative scenario analysis, along with additional information and analysis supplied by the RPT, to recommend a regional land use strategy to Cabinet. If accepted, the regional strategy is then used to guide the development of subregional municipal plans that are

consistent with regional objectives. More information about the ALUF is available at www.landuse.alberta.ca.

ALCES is being applied to inform the ALUF due to its capacity to examine inter-relationships among the full range of relevant land-use sectors and natural disturbances, and explore their environmental and socioeconomic consequences at large temporal and spatial scales (Hudson 2002, Salmo Consulting et al. 2001). ALCES is a stock and flow model built using the Stella modelling platform (www.iseesystems.com). The model was first developed by Dr. Brad Stelfox in the mid 1990's and has gradually expanded in scope to meet the needs of various regional planning initiatives in western North America. The following description provides an overview of ALCES structure and function. More details can be found on the ALCES Group website (www.alces.ca).

To achieve a synoptic view of regional cumulative effects, a wide-range of land uses and ecological processes are incorporated into the model as drivers. The various land uses and ecological processes can be turned on or off depending on the needs of the scenario analysis. For each land use operating in a region, the user defines development rates, the portion of the landscape available for development, and management practices such as the intensity and lifespan of associated industrial footprints. The influence of natural disturbances (fire and insects) and plant succession on landscape composition are also tracked. Hydrological processes are addressed with surface and groundwater modules, and climate change effects can be incorporated by defining temporal changes in natural disturbances rates, successional trajectories, landcover, meteorology and hydrology.

The first-order effects tracked by ALCES are landscape composition and resource production/supply. Using an annual time-step (although monthly time steps can be used for the meteorology module) the model modifies the area and length of up to 20 landcover and 15 anthropogenic footprint types in response to natural disturbances, succession, landscape conversion, reclamation of footprints, and creation of new footprints associated with simulated land-use trajectories. ALCES is a spatially stratified model, meaning that it tracks the area, length, and quantity of each footprint separately for each landscape type. ALCES does not, however, track the explicit geographic location of these features (e.g., latitude and longitude), a feature that greatly speeds up processing time (less than 1 second per simulation year) relative to a spatially explicit modelling approach. ALCES also tracks resource production and supply using approaches that are typical of sector-specific models such as forestry timber supply models and the Hubbert-Naill life cycle approach for simulating exploitation of hydrocarbon deposits (Naill 1973). By tracking resource supply, ALCES can reduce or stop the expansion of a land use if resource supply becomes inadequate. Changes to water quantity are also tracked by applying water use coefficients associated with each land use.

Land base composition and resource production attributes are translated into indicator variables using coefficients. A wide range of indicators are available so that trade-offs between diverse ecological and socioeconomic objectives can be assessed. Types of indicators that can be tracked by ALCES include wildlife habitat and populations, water quality and quantity, biotic carbon storage, air emissions, employment, gross domestic product, and social indicators such as family income and educational attainment.

By applying ALCES Mapper, ALCES tabular and graphical output can be augmented with maps illustrating the plausible future condition of landscapes and indicators. ALCES Mapper is a companion tool to ALCES developed by Alberta Innovates Technology Futures (formerly Alberta Research Council) as an ArcGIS application (www.esri.com). The tool divides the study area into grid cells of user-defined size, and calculates the initial landscape and footprint composition within each cell. Footprint growth and reclamation, landcover change, natural disturbances, commodity production and other variables as reported by ALCES are then applied to each cell, tracked, and displayed spatially. ALCES Mapper allows users to specify the

general location (i.e., where specified land-use footprints can or cannot occur) and pattern (e.g., dispersed versus contiguous) of future development. This feature provides flexibility to map transformations of landscapes through time according to different spatial rules, and is useful for visualizing the implications of different zoning or resource utilization strategies. Maps of future landscape condition can then be analyzed to evaluate the spatial response of indicators such as wildlife habitat to potential future landscapes associated with land-use scenarios.

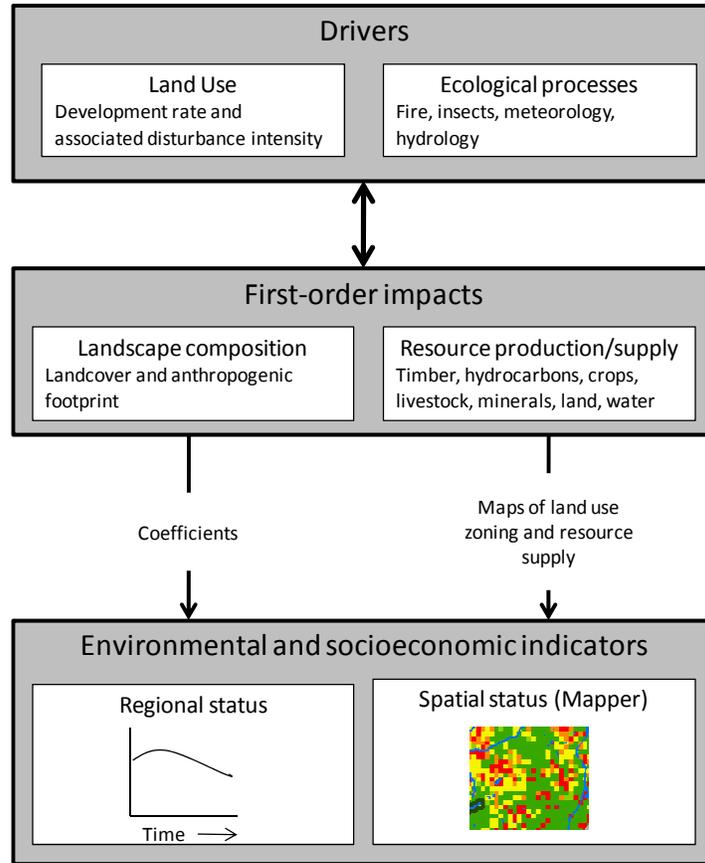


Figure 1. Overview of the ALCES land use simulation tool.

3. CASE STUDY: THE LOWER ATHABASCA REGIONAL PLAN

The Lower Athabasca Regional Plan (LARP) is the first of the seven regions in Alberta to be assessed as part of the ALUF. We do not attempt to summarize scenario analysis outcomes because LARP will not be completed until later this year. Rather, the scenario analysis approach is described to demonstrate how ALCES and ALCES Mapper can be applied to inform regional planning. ALCES simulations for LARP are being completed by the ALCES Group, under direction of the RPT. The scenario analysis approach used for LARP evolved over the course of the plan development and continues to be evaluated to seek refinements in how it can best inform development of future plans.

The Lower Athabasca Region occupies a 92,000 km² boreal landscape in northeastern Alberta. The region's forests, fen and bog complexes, lakes, and extensive lotic system support a diverse range of species. Although this region has supported First Nation communities for thousands of years, it is only during recent decades that large-scale industrial development has emerged

including forestry, energy, and agriculture. The region contains the Athabasca Oilsands, one of the largest bitumen deposits in the world.

Land uses and ecological processes included in the simulations were energy, mining, forestry, agriculture, settlements, transportation, protected areas, fire, succession, and meteorology. To support a transparent modelling process, information to model these processes and define the initial composition of the landscape was either provided or vetted by government ministries, and modelling assumptions are extensively documented for each scenario. Further, the model has been previously validated and calibrated through expert review and comparison with outcomes from more detailed, sector-specific models (Hudson et al. 2002). The scenario analysis reported on approximately 50 indicators related to landscape composition, terrestrial and aquatic habitat and biota, water quality and quantity, air quality, and economic health. Indicator coefficients were defined by subject experts, and vetted by the RPT. Indicator coefficients were empirically derived when data were available from sources such as the province's biodiversity monitoring program (www.abmi.ca), and were otherwise based on literature review or expert opinion gathered during workshops.

As described previously, scenarios are being structured by the RPT based on input from the multi-stakeholder RAC. Scenario outcomes are presented to the RAC in a workshop setting, and feedback from the RAC is utilized by the RPT to structure the subsequent scenario. Scenario development by the government (RPT) and stakeholders (RAC), rather than the modelers, helps ensure that the scenario analysis considers land-use options that are relevant to the planning process. The first scenario evaluated sensitivity of indicator outcomes to the rate of bitumen development, the most important land use in the region. The next scenario assessed the "best available" management strategies, within technological and economic constraints, for limiting environmental degradation per unit of resource production. The suite of strategies, referred to as best practices, was identified through consultations with experts from government and industry. Included were strategies for minimizing the size and duration of industrial footprint, old forest protection, water conservation, and emissions reduction. A subsequent scenario focused on the potential of mitigating impacts to wildlife species through vehicular access management. The scenario analysis is ongoing, with land-use zoning being one potential scenario yet to be assessed.

A series of fifty 200-year simulations of stochastic fire and meteorology regimes in the absence of land use were completed to estimate the range of natural variability (RNV) for ecological indicators as a comparative benchmark to help interpret scenario results. The likelihood and severity (i.e., risk) of negative impacts to native wildlife and ecosystem services increase as environmental conditions depart from natural conditions. As such, natural conditions are a relevant benchmark for assessing the compatibility of land-use strategies with the ALUF's outcome of "healthy ecosystems and environment". For indices of wildlife abundance, departure from natural conditions was categorized into four zones of risk based on species evaluation thresholds used by Alberta's Endangered Species Conservation Committee (ESCC): stable (within 10% of RNV), low risk (10-50% from RNV), moderate risk (50-70% from RNV), and high risk (>70% from RNV). The quantity of information associated with outcomes for approximately 50 indicators has the potential to obscure key strategic lessons conveyed by land-use simulations. We therefore aggregated indicators into a small set of indices by converting outcomes to a common scale (percent departure from RNV) and averaging across indicators. Although useful for summarizing results, the indices must be carefully interpreted because of the potential to gloss over declines in specific species or ecosystem services.

When creating maps of simulation outcomes with ALCES Mapper, a variety of spatial map themes were applied to direct the location of future land-use features. These themes included bitumen deposits, the area allocated for timber production, towns and cities, the agricultural zone, and protected areas. Land-use expansion followed anchored, contagious, or dispersed growth patterns depending on the type of footprint. Levels of access management differed

across the region depending on sub-regional management priorities. An example of map output is presented in figure 2.

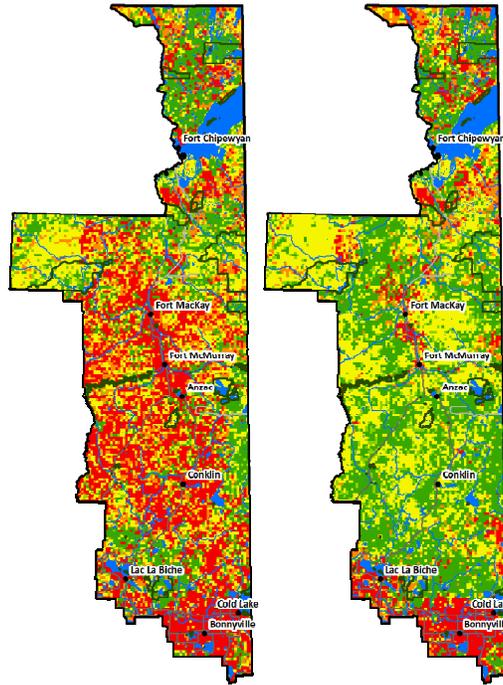


Figure 2. Potential response of a wildlife habitat suitability index at simulation year 60 in the Lower Athabasca Region without (left map) and with (right map) access management. Colours reflect the following levels of risk to moose: stable (green); low risk (yellow); moderate risk (orange), and high risk (red).

4. CONCLUSIONS AND RECOMMENDATIONS

The Alberta government has initiated the ALUF to identify land-use strategies capable of achieving: a healthy economy supported by land and natural resources; healthy ecosystems and environment; and people-friendly communities with ample recreational and cultural opportunities. Doing so requires decisions to address conflicting values and competing interests. Although the LARP process is still incomplete, we believe that the scenario analysis is succeeding in its role as an interactive learning tool to assist the RAC in identifying regional strategies capable of achieving a suitable balance between ecological and socioeconomic objectives. Two characteristics of the modelling process have contributed to this success: its focus on strategic rather than operational issues; and reliance on government and stakeholders for model inputs and scenario development.

To facilitate learning, a model should suit the characteristics of the planning process and the needs of its participants. The complexity of IRM and the need to evaluate strategic trade-offs calls for models that are broad in scope with capacity to integrate the effects of numerous land-uses via indicators that span the diverse outcomes of interest. The integrative capacity of models may be their most important contribution to public policy processes such as land-use planning (Sterk et al. 2009). Accordingly, ALCES has been designed to be comprehensive and reviews of the model have concluded that it is unique with respect to its capacity to integrate the cumulative effects of various land uses existing in western Canada (Hudson 2002, Salmo Consulting Inc. 2001).

To achieve a comprehensive scope, ALCES sacrifices detail relative to many models. ALCES's spatially stratified approach tracks the cumulative effects of multiple land-uses and natural disturbances on landscape composition but not juxtaposition impacts of these disturbances. The focus on composition rather than configuration is appropriate given that biodiversity is primarily affected by habitat loss rather than fragmentation (Fahrig 2003). Experts engaged in the modelling process to help parameterize ALCES do voice concerns about the coarse nature of ALCES relative to the detailed models that they are familiar with. However, comprehensive strategic modelling is an appropriate focus during land-use planning where the task at hand is visioning potential futures to support political decision processes (Couclelis 2005). Narrower, more detailed models are better suited for operational issues like planning specific developments once a land-use plan is in place.

The regional focus of ALCES is not without its limitations, and opportunities exist to enhance the modelling process with more spatially detailed information. Stakeholders and government staff frequently desire that scenario results be reported subregionally to better understand issues in their "own backyard". ALCES Mapper results can be summarized at these sub-regional scales to highlight issues that should be the focus of subsequent, more detailed sub-regional planning. In addition, an exciting opportunity exists to integrate ALCES with more tactical modelling tools to assess specific issues (e.g., water use or acid deposition) in greater detail within the strategic regional scenario assessment.

The scenario analysis process has relied on government and stakeholders to provide the information needed to parameterize the model and define scenarios. Active participation of planners and stakeholders in the modelling process has created trust in the validity of simulation outcomes and helped to ensure that the modelling results have played a meaningful role in the RAC's decision making. A model is unlikely to contribute to multi-stakeholder problem solving unless it is involved in the interactions between participants (Sterk et al. 2009). While effective, participatory modelling can be hard to make operational because planners and stakeholders may be reluctant to engage in modelling due to unfamiliarity or competing time demands (Borowski and Hare 2005). The commitment of the RPT, RAC and modelling team to invest substantial time communicating with each other about modelling assumptions and results has been essential to the success of the LARP modelling process to date.

The modelling process is structured such that substantial effort is applied to develop a small set of scenarios that are supported by government and stakeholders as being representative of a plausible future trajectory. A drawback of this participatory approach is that little opportunity is given to explore a broader spectrum of possible futures. As an example, the implications of rare but potentially influential events such as very large fire years, severe weather events, or catastrophic industrial accidents have not been evaluated. Future ALUF regional analyses would benefit from the inclusion of a sensitivity analysis to assess the potential implications of a wider range of future events, thereby creating greater resilience in the plan.

Even if modelling succeeds in informing planning process, its influence on land use is uncertain. The general public will ultimately determine the acceptability of land-use strategies and modelling should therefore strive to build societal awareness of the benefits and liabilities of land use. With support from a range of industry, nongovernment, and government organizations, we have developed free, web-based modelling tools including an educational version of ALCES (www.albertatomorrow.ca), an urban growth simulator (<http://www.abll.ca/aref/>), and a library of the historical trajectories of ecological, landscape, and land-use attributes in the province (http://www.abll.ca/library/Library_Home). We believe that such tools will help foster broad public support for tough decisions that must be made during regional planning by informing the broader public about the long-term effects of land use in Alberta.

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