HISTORICAL LAND COVER CHANGE IN ALBERTA AND THE EFFECTS OF GOVERNMENT INTERVENTION ON FUTURE LANDSCAPE ALTERATION

Kayla Stan[1], Arturo Sanchez-Azofeifa[1]

1. University of Alberta, Department of Earth and Atmospheric Sciences, Edmonton, Canada; stan@ualberta.ca

ABSTRACT

The Edmonton to Calgary corridor in Alberta, Canada, contains rich agricultural land and is experiencing high rates of alteration due to urban expansion. Long-term land cover change (LCC) assessments have not been created for the province's agricultural belt despite rapid population growth and urbanization in the region and the resulting fragmentation of farmland and natural ecosystems. This study allows for the assessment of change in the province over the next decade and projects the impact of potential government policies using the Dinamica Environment for Geoprocessing Objects (EGO) platform.

Satellite imagery taken from Landsat was classified to create an LCC history of the Edmonton to Calgary area. Biogeophysical variables, used in conjunction with the landscape maps, were utilized to develop a baseline projection model in Dinamica EGO. Current provincial environmental policy has few restrictions on urban expansion and subsequent fragmentation of croplands and grasslands. This policy gap provides an opportunity to explore the effects of implementing legislation over the next decade. Three scenarios were developed: i) business as usual (BAU); ii) an upper boundary condition utilizing high growth rates as predicted for the Edmonton and Calgary metropolitan zones, and iii) a lower boundary condition parameterized by government intervening and restricting growth of all developed land to their current borders.

Over the past 40 years, urban area has nearly doubled in size, especially due to an increase in rural subdivisions, and this expansion has targeted farmland in the Edmonton and Calgary regions. The study found that if development is left to market conditions, much of the best farmland will be fragmented and these frontiers will subsequently damage the province's remaining natural land. Government intervention of restricting urban sprawl can have a large impact on the resulting landscape.

INTRODUCTION

Human-induced landscape alteration is a major theme in the study of regional and global earth systems due to the extensive impact that it has on environmental integrity and sustainable economic development (1,2). Large-scale studies have become increasingly prevalent given the rapid improvement of openly available aerial and satellite imagery products over a longer temporal period (1,3). LCC models previously focused on biophysical factors, including carbon stocks, ecosystem stability, and degradation of the natural biomes (1-4), but have recently started incorporating socioeconomic data for a more holistic simulation scenario (5).

Over the past few decades, Alberta has been a hub of economic development through the utilization of land-intensive industries. Over 70% of exports are linked to the extraction of oil, followed by agriculture and forestry (6,7), with agriculture accounting for over 30% of the province's areal extent and over $6 billion in trade (7,8). Economic advancements have resulted in rapid population growth, especially in the urban areas. Despite this use of the environment and natural capital for anthropogenic gain, there are no policies or legislation in place to effectively regulate and promote sustainable development (6). Land-use planning in the province is integrated resource planning, which optimizes economic revenue over the short term and mainly offers environmental protection to an area if it does not interfere with industry (6,9). Forest management is left to the market, resulting in the loss of the ecosystem services and natural habitat (6,9,10).

Over ¾ of the protected areas in Alberta were formed by the federal government prior to 1930 and still permit industrial activity including logging, oil, mining, agriculture, and recreational use (6). Reclamation projects post oil and mining disturbance still have 90% of sites listed as disturbed and only 0.1% as reclaimed (10). Standards do not require a return to pre-disturbance conditions, only recovery of an equal land capability, leading to reduced recuperation of ecosystem services (10).

Despite the extensive demographic change, economic advancement, and few regulatory measures in place, land cover change in Alberta has only been tracked in localized areas (3,4) or in regard to a specific process or environmental concern (i.e. carbon, hydrology) (4,11). There is a gap in understanding the historical landscape alteration on a regional scale and predicting what may happen under different future scenarios. This study endeavours to fill this gap by modelling and analysing the land cover change in the Edmonton to Calgary corridor since the 1980s and projecting these changes into the future under different expansion and boundary condition scenarios. The objectives of this study are to i) create a regional land cover change history of the Edmonton to Calgary corridor from the past 30 years, and ii) utilize the Dinamica EGO platform to integrate biophysical and socioeconomic data and project the boundary conditions of future LCC in the corridor based on potential political and economic scenarios.

The open platform Dinamica EGO, originally developed for predicting deforestation in the Amazon (12), is utilized because it is able to integrate biogeophysical, socioeconomic, and policy data, and project future land cover change under multiple scenarios. By creating a model which can test the impact of potential legislation, governments will have an additional tool which can optimize economic interests and environmental integrity, ultimately assisting in developing sustainable resource management policies.

METHODS

Study Region

The study site is located in the Province of Alberta, Canada, encompasses the two largest cities, and accounts for roughly 8% of Alberta's area, over 5 million hectares (Figure 1). The region includes the parkland and grassland biomes (6) and is dominated by agricultural activity. This area holds the majority of the population, and is one of the most rapidly changing in the province (6,10). The historical intensity analysis utilized three major urban centres in this spatial extent, while the whole region was used for the future LCC projections.

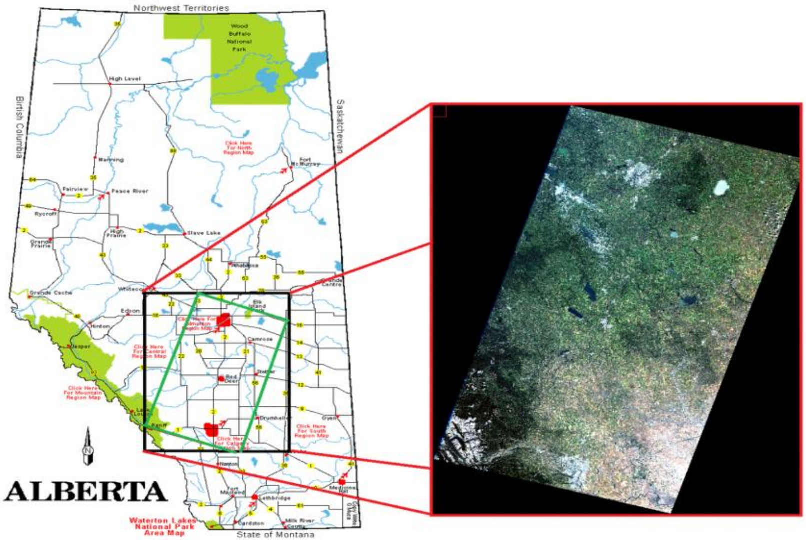

Figure 1: The study area is located in the Edmonton to Calgary corridor, spanning Landsat images.

Model Data

Two Landsat images were required to cover the area of interest and were acquired in the growing seasons of 1984, 1992, 2001, and 2013, as they provided the least cloud cover. These images were then classified via the machine learning platform See5 (13) using 800 training points obtained through Google Earth, 100 of which were ground-truthed in 2013 and 2014. All four images validated well in their classifications, between 78 and 82%. The maps were utilized as base inputs for the historical change and LCC future projections in Dinamica EGO. Originally, 7 cover types were classified, but due to model efficiency (12) and study objectives, the categorization was consolidated into Urban, Agriculture/Cropland, and Natural areas. Natural areas may also include unmanaged pasture, as these zones are difficult to separate from grasslands at an intermediate resolution. The resolution of the classification is 120m and for noise reduction in the model the maps are resampled to 480m.

Additional information is required to train the Dinamica EGO model for simulating the future (12). The base model also included biogeophysical variables (topography, geology, soils), climatic variables (mean annual temperature, precipitation), and human impact variables (infrastructure, population, management units, distances to urban/agriculture). These variables were obtained from government sources (StatsCan, AB Gov), GIS databases (Altalis, GeoBase), and climate predictions (Andreas Hamann). A separate dataset of the water management units in Alberta was used to regionalize the model to allow for separate LCC drivers to dominate in their respective regions, a methodology which has been utilized in other large-scale Dinamica EGO studies (12).

Modelling Scenarios and Parameters

The historical LCC is evaluated using the intensity analysis, which creates a unified framework for tracking land cover change patterns over multiple time steps (14). Three levels of alteration, the interval (rate and area of change), category (losses and gains in each land cover class), and transition (the targeting or avoidance of change between classes), are combined and assessed by this methodology (14). A submodel add-in, implemented in Dinamica EGO by the developers (15), is used for the analysis between 1984 and 2013 in the Edmonton to Calgary corridor. The total areal extent and patch metrics of each class type are analyzed and compared between decades for a more complete history of alteration.

The Dinamica EGO platform is then utilized to complete a comprehensive land cover change model by determining the probability of each individual cell changing from one land cover to another (12,16). Landscape maps are input to calculate a transition matrix which outlines annual rates of change between each cover type. Variables, including any relevant spatially explicit datasets, are used to identify where change is most likely to occur. The probability is calculated by giving each variable a relative importance (weight of evidence) based on a Bayesian algorithm which identifies likelihoods of transition compared to the categories on the static variable maps (12,16). A probability of change map is created for each land cover, and the chance of each pixel being altered is determined through the weights of evidence. Two functions, Patcher and Expander, are used to train how continuous and connected the new islands of land cover type will be. The pixels with the highest probability of alteration, which comply with the conditions set by Patcher and Expander, will change.

The initial land cover change model is created between the 1992 and 2001 landscape maps, and validated against the 2001 and 2013 time steps. Originally, the model was created for six landscape categories, but the categories of grassland, shrubland, and forest were consolidated to reduce noise in the model. The separation of these classifications was not pertinent to the goals of tracking urban expansion and changes in the farmland; therefore, enhanced model functionality and efficiency were optimized instead.

The model validated at over 90% accuracy within 2.5 pixels (1.5 km) which is sufficient given the spatial and temporal extent covered. Due to the lack of environmental policy in Alberta (6,9,10), the future projections are created under three main concepts. The first is a Business As Usual

(BAU) scenario which projects the continuation of the historical rates of change up until 2022. In the second, an extreme upper boundary condition is created by modifying the rates of change across the whole area. Edmonton urban expansion is predicted to be the highest in the province over the next decade, outpacing Calgary in 2014 (17). This is expanded to all of the corridor's urban areas for the upper boundary limit. In the third scenario, if a government was to intervene with a policy which restricted the growth of urban areas to their current extents, or if this effect was to occur due to economic problems (i.e. severe drop in oil prices), this would create the lower boundary condition. The development of these scenarios provides the possible scope of feasible growth, and the range of impact that policies developed by legislators may have. If there is a pro-expansion mindset embraced by the government, then the upper boundary limit may occur, but if an environmentally conscious approach is taken, the lower limits are probable. The three scenario outcomes are compared in terms of total areal extent of each land cover classification so that any additional scenarios tested in the future can be accommodated within this overarching framework.

RESULTS

Intensity Analysis and Historical Change

Since the 1980s, Alberta's urban extent has nearly doubled (Figure 2), with an expansion in the large cities and in smaller towns. There has also been an increase in the number of small islands and a decrease in the overall mean patch size. This phenomenon is consistent with an increase in the number of small subdivisions that are being built after subdividing land to developers.

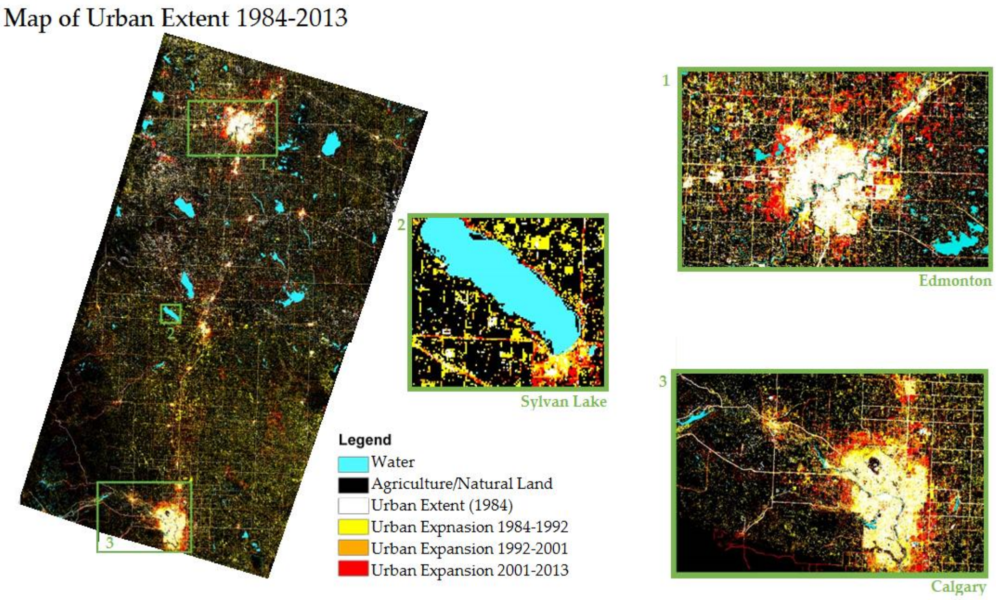

Figure 2: The urban expansion by decade from 1984 to 2013. There is an increase in the size of the major cities, a build-up of smaller towns, and an increase in the number of small, unconnected urban islands.

Local farmers have indicated that their lands are being encroached upon by developers, and this is supported by the intensity analysis. Agricultural land has been targeted over natural areas in the greater Edmonton and Calgary regions since the 1980s. In Red Deer, originally natural land was cleared, but in the past decade this has shifted to cropland. The total areal extent of farmland, however, has stayed consistent over the past 30 years, indicating that as cities expand, agricultural frontiers overtake and fragment the surrounding natural ecosystems.

Future Modelling Scenarios

The three scenarios present a range of future possibilities for south-central Alberta (Figure 3). The BAU results in the further expansion of urban areas, increasing the number of small islands and the area of the major cities. Edmonton and its surrounding towns consolidate into an area larger than Calgary, consistent with predictions that Edmonton will continue to be the fastest growing region in the province (17). East of the Queen Elizabeth II (QE II) Highway, which connects Edmonton and Calgary, has more development than the western part of the study region.

In the upper boundary, cities and subdivisions accrue 300,000 ha more than the BAU scenario, with both agricultural and natural areas being used equally. The lower boundary results in a reduction of urban area compared to 2013. This is due to no new expansion and the abandonment of small farms and subdivisions that will not be able to grow to include services for residents. In this scenario, the urban sector is consolidated into well-established cities, and there are the greatest agricultural and natural extents remaining.

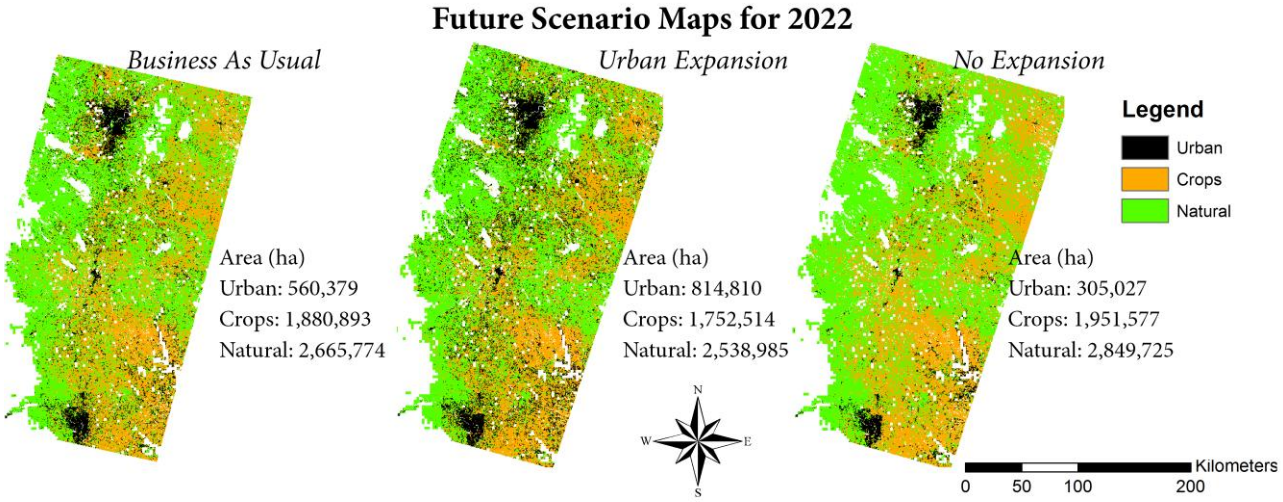

Figure 3: Future modelling scenarios of the Edmonton to Calgary corridor including BAU (left), Urban Expansion (centre), and No Expansion (right).

CONCLUSIONS

Landscape alteration has been occurring at a rapid and unsustainable pace in Alberta over the past 30 years and is unlikely to stop without political intervention. This study provides a framework to parameterize the effects of action taken by governments. If left to the markets, urban development will fragment the best farmland in the corridor, but if pro-conservation legislation is enacted, there is the potential to stem the destruction of natural land and provide a sustainable farming revenue source in the corridor. With the development of a model which incorporates biophysical, socioeconomic, and legislation variables, the future can be simulated and policies can be tested before they are implemented.

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