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The Edmonton–Calgary corridor: Simulating future land cover change under potential government intervention

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ABSTRACT

The region connecting Edmonton and Calgary, the two largest cities in Alberta, contains rich agricultural land and is one of the most rapidly changing areas in the province. There is little legislation to restrict urban sprawl or adequately protect agricultural land or native grasslands, and there has been little research to predict future alteration. The main study objectives are, therefore, to assess historical changes in the Edmonton-Calgary corridor from 1984 to 2013 and simulate the future landscape change to 2022 under potential government intervention scenarios. Satellite imagery from Landsat, used in conjunction with biogeophysical variables, was used to create a history of cover in the Edmonton-Calgary area. This history of the environment can be used as a baseline to project changes into the future. Testing different legislative scenarios under two major branches of modifying rates of change or locations of change can be used to identify effective policies for limiting damage to the environment while still allowing for urban growth. Five scenarios were created for this purpose: 1) business as usual, 2) increased rate of urban expansion, 3) no urban expansion, 4) implementation of greenbelts around urban areas, 5) protection of the best agricultural land. This study finds that over the past 30 years, urban area has nearly doubled in size, targeting predominately farmland, especially due to an increase in rural subdivisions. Each scenario impacts growth differently, however, greenbelts and the no expansion model decease growth the most, while the agricultural protection is comparable to the business as usual scenario.

1. 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 (Fischer and Lindenmayer, 2007; Vedkamp and Lambin, 2001; Meyer and Turner, 1992; Lambin et al., 2001). Large-scale studies have become increasingly prevalent given the rapid improvement of openly available aerial and satellite imagery products over a longer temporal period (Fischer and Lindenmayer, 2007; Linke and McDermid, 2012). LCC models previously focused on biophysical factors, including carbon stocks, ecosystem stability, and degradation of the natural biomes (Fischer and Lindenmayer, 2007; Vedkamp and Lambin, 2001; Meyer and Turner, 1992; Lambin et al., 2001; Linke and McDermid, 2012; Arevalo et al., 2009), but have recently started incorporating socioeconomic data for a more holistic simulation scenario (Burton et al., 2014).

There are many LCC models that have been developed and put on the market for research and industrial use. Six main types of models (equation based, system, statistical, expert, evolutionary, and cellular automata) are the most commonly used, although there has been some effort to combine platforms into a multi-agent system (Parker et al., 2003). Each system has strengths and weaknesses attached to it. Equation-based models seek to form an equilibrium or steady state and can be used to optimize the distribution of land cover, but this often limits the complexity of variables that can be added due to its need for a feasible set (Parker et al., 2003). Temporal variation is divided discretely to create feedback loops in system models, but the ecosystem feedbacks require a priori knowledge of causation and its explicit incorporation in the platform (Parker et al., 2003; Baker, 1989; Sklar and Costanza, 1991). Statistical models utilize spatial statistics and regression, compared to expert models which allow for outside expert knowledge or Bayesian statistics to drive how the model produces simulated landscapes (Parker et al., 2003). Evolutionary or cellular models are very proficient at determining ecological alteration, but are limited in providing insights into causation or decision making (Parker et al., 2003). Combining systems into multi-agent models has been touted as integration, but often, these platforms should be con-

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sidered hybridized, as they are unable to seamlessly incorporate the strengths of multiple agents into a single entity (Parker et al., 2003). More recently a third spatial dimension has been explored in research, especially in urban and agriculture setting with building height and crop intensity utilized, respectively (Lambin et al., 2000; Lin et al., 2014).

Some of the most common platforms include CLUE and IMAGE, with statistics-based approaches recently becoming popular as well (Turner et al., 2007). These models, however, only focus on a single aspect of LCC by either recreating the spatial distribution of change or accurately assessing the total quantity of alteration on the landscape (Turner et al., 2007). In Alberta, two models that have been commonly used in environmental work are ALCES and GYPSY, but these models are extremely limited in applicability, projection capability, and transferability between different project goals (Table 1).

The Dinamica Environment for Geoprocessing Objects is a recently developed platform that is uniquely able to focus on both the abundance and pattern of change landscape change (Soares-Filho et al., 2002). The model environment employs a cellular automata algorithm to simulate the alterations with two main functions – Expander and Patcher, which sort the pixels to change based on the highest probability of transition, a set of pattern parameters, and the amount of cells allowed to change based on a stochastic statistical procedure (Berberoglu et al., 2016). Expander relates to the expansion and contraction of pre-existing patches, while Patcher is the development of new land cover fragments, and an appropriate spatial pattern can be recreated through the patch statistics that can be explicitly defined (Berberoglu et al., 2016; Soares-Filho et al., 2002). This system improves on other styles of models by combining the cellular automata strengths with statistical models, utilizing Bayesian statistics to calculate the probability of change for each pixel while also allowing expert opinion to modify these computed values (Soares-Filho et al., 2002).

Other urban growth models, such as SLEUTH, are weaker than Dinamica because they do not provide provisions to study causation and LUCC dynamics as a system, in addition to ecological patterns (Berberoglu et al., 2016). Incorporating policy both in terms of rates as well as patterns is also built into the model functionality which is a unique component of the Dinamica platform. Policies can be dynamically built with investment predictions, dynamic population expansion, and infrastructure growth models (Soares-Filho et al., 2002), as well as direct modification of the transition matrices, weights of evidence, or probability map. By increasing the flexibility in functionality and model structure, Dinamica is applicable for a wide range of research questions, including those of this study which deal both with the history and future of a region. Despite being originally implemented for deforestation (Soares-Filho et al., 2002), Dinamica EGO has since been used internationally to project the impacts of a variety of environmental concerns, including carbon stocks, urban growth, wildfires, and economic impacts of government policy (Soares-Filho et al., 2014; Leite et al., 2012; Nunes et al., 2012; Silvestrini et al., 2011). Application in Canada has not previously been completed, but could potentially provide an effective solution for projecting environmental change in the country on a regional scale that has been limited in other modelling platforms.

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 (Government of Alberta, 2015a,c), with agriculture accounting for over 30% of the province's areal extent and over $6 billion in trade (Government of Alberta, 2015a,c). 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 (Timoney and Lee, 2001). Land-use planning in the province is based on an approach called "Integrated Resource Planning (IRP)." This style of planning is common in power consumption and focuses on meeting the anticipated needs of the demand side in the short term instead of conserving supply for long periods (Swisher et al., 1997). In Alberta, IRP is based on regional plans, under the Ministry of Environment and Parks, but only applies to public land, not those which are privately or federally owned (Alberta Ministry of Environmental Protection, 1993). Plans clearly outline parameters for the government's role in assisting areas with approval procedures and allocating manpower and fund and the private sector for providing the appropriate information and regulatory constraints that will apply to projects (Alberta Ministry of Environmental Protection, 1993). Short term economic optimization is the primary goal of IRP while environmental protection is afforded if it does not interfere with industry (Timoney and Lee, 2001; Parkins, 2006). Extraction of all goods with economic value is prioritized, with a special emphasis on oil, agriculture, and forestry in Alberta (Timoney and Lee, 2001). 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 (Wijeskara et al., 2012). Forest management is left to the market, resulting in the loss of the ecosystem services and natural habitat (Soares-Filho et al., 2014; Timoney and Lee, 2001; Parkins, 2006). Reclamation projects post oil and mining disturbance still have 90% of sites listed as disturbed and only 0.1% as reclaimed (Audet et al., 2015). Provincial standards do not require a return to pre-disturbance conditions, only recovery of an equal land capability, leading to reduced recuperation of ecosystem services (Audet et al., 2015).

This study endeavours to fill the gaps by modelling and analysing the land cover change in the Edmonton-Calgary corridor between 1984 and 2013 and projecting these changes into the future until 2022 under different expansion and policy-based scenarios. The open platform Dinamica EGO, despite not being previously employed in Canada, is utilized because it is able to integrate biophysical, 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.

2. Methods

2.1. Study region

Alberta is the fourth largest province in Canada and has an average temperature range of −20 ° Celsius to + 20 ° Celsius. Days of sunshine are the highest in Alberta with over 2300 h of sun each year (Government of Alberta, 2015b). The Mean Annual Precipitation is between 350 and 600 mm (Wright and Huggins-Rawlins, 2015), and the southern part of the province is considered to be mainly semi-arid.

The study site is located in Alberta, encompasses the two largest cities, and accounts for roughly 8% of the province's area, over 5 million hectares (Fig. 1). The region includes the parkland and grassland biomes (Timoney and Lee, 2001) and is dominated by agricultural activity. Farming extends through much of south and central Alberta, especially within the original extent of the grassland biome (Martellozzo et al., 2015). This area holds the majority of the population (over 75%) and is one of the most rapidly changing in the province (Timoney and Lee, 2001; Audet et al., 2015; Martellozzo et al., 2015; Statistics Canada, 2012). The area encom-