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Loss or gain: A spatial regression analysis of switching land conversions between agriculture and natural land

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ABSTRACT

This article comprehensively investigates the gains and losses between agriculture and natural land in the case of the Edmonton–Calgary Corridor, Canada. Using remote sensing data from 2000 to 2012, factors that drive land-use conversions, including environmental and socio-economic characteristics, are explored. This study also adopts spatial techniques to allow for neighborhood effects from land-use activities in neighboring areas. Key findings include the following: higher land suitability hinders the process of agricultural land abandonment; road density prohibits agricultural land conversion to natural land; the implementation of conservation sites protects land in its natural status; and land-use activities have strong neighborhood effects on nearby regions. Incorporating spatial interactions can generate less biased empirical results and provide more accurate policy recommendations. In addition, an investigation of bi-directional land-use transitions helps to better understand the associated gains and losses between agriculture and natural land and offers further insights into the effectiveness of preservation programs that aim to protect wild space and maintain ecological balance.

1. Introduction

In the study of land-use/land-cover changes (LULCCs), the conversion of agricultural land has received considerable attention (Beilin et al., 2014; Di'az et al., 2011; Zhang et al., 2014). Typically, agricultural land conversion can be grouped into three categories: urban encroachment onto agricultural land, farmland conversion to non-agricultural production (e.g., forest), and agricultural land transition to natural landscapes. The transitions differ greatly in their degree of reversibility as well as associated environmental and socio-economic consequences. For example, a shift from agricultural land to development, such as residential uses, is unlikely to be reversed. In contrast, the conversion of agricultural land to natural land, such as grassland and shrubland, may represent a temporary change to preserve current production capability for future purposes (MacDonald et al., 2000).

Losses of agricultural land to developed uses have been widely discussed (Francis et al., 2012; Irwin and Bockstael, 2007), and recent literature has given considerable attention to the issue of agricultural land conversion to a natural land base, which may simply represent farmland abandonment due to unprofitability (Baumann et al., 2011; Gellrich et al., 2007) or wild land preservation as a result of certain conservation programs (Claassen et al., 2008; McGranahan et al., 2015). Although the reasons behind these two types of transitions are quite different, the observed land-use/land-cover changes (in terms of changing the earth's terrestrial surface) are often the same, representing a tract of land that is converted from agricultural uses to a natural land base.

In literature, agricultural land abandonment is found to be associated with a variety of ecological ramifications. For instance, positive impacts include the stabilization of soils and carbon sequestration (Laiolo et al., 2004; Tasser et al., 2003), while negative influences include the gradual loss of landscape complexity and an increased risk of natural disasters (Bielsa et al., 2005; Serra et al., 2008). Meanwhile, agricultural land expansion onto natural or wild land has been increasingly investigated (Hatna and Bakker, 2011; Izquierdo and Grau, 2009). Such land conversions also deserve attention, as they can result in serious ecological and environmental ramifications. For example, the loss of natural land leads to reductions in biodiversity and landscape complexity, increases the probability of flooding and the emergence of desertification (Flez and Lahousse, 2004; Monteiro et al., 2011). The transitions between agricultural land and natural land have therefore led to a key question: What has been gained or lost due to these bi-directional changes?

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Increasingly, policy makers and the general public are particularly concerned with neighborhood effects associated with land preservation programs. Such effects occur when a conservation program influences land-use decisions outside the targeted area. For example, agricultural land of relatively low quality has been removed from production under a conservation program in one region; meanwhile, a substantial amount of land with even lower agricultural suitability has been brought into agricultural production as a result of the conservation program (e.g., to compensate for the decreased farmland supply in the marketplace). Such effects may or may not be able to offset environmental and ecological benefits of the conservation programs. Therefore, the identification of the pattern and location of both transitions of agricultural conversion to natural land and agricultural land expansion onto natural land constitutes a first step for further in-depth analyses. As a second step, following the assessment of detailed transitions, an investigation of the inherent drivers behind these two types of land-use transitions is of significant interest to researchers and policy makers in their attempts to develop corresponding policies and plans regarding sustainable land-use management.

Although recent reviews have incorporated elaborate discussions of agricultural land abandonment (see van Vliet et al., 2015), the majority of these cases were reported in Europe, the United States and South America (e.g., Di'az et al., 2011; Izquierdo and Grau, 2009; Munroe et al., 2013). Few studies have explored the context of Canada, especially the prairie region, where agricultural land conversions commonly occur. In this study, we implement a spatial regression analysis of switching land conversion between agriculture and natural land in the Edmonton–Calgary Corridor of Alberta to better understand the spatial, environmental, and socio-economic factors that drive such land-use conversions. We also contribute to the current literature by quantifying both agricultural land abandonment and agricultural land expansion from natural land in order to investigate underlying mechanisms from a more nuanced perspective. Furthermore, although previous studies related to agricultural land abandonment have been conducted, no empirical work has included spatial interactions to allow for neighborhood effects from neighboring areas' land-use activities. Land conversion is often considered to be spatially auto-correlated due to the similarity of nearby resource attributes such as soil quality and climate conditions, as well as socio-economic determinants including public policies such as taxes and planning and zoning regulations in neighboring areas (Zhang et al., 2014). Ignoring spatial interactions may lead to biased estimates, which may in turn lead to misleading implications and policy recommendations. We therefore utilize three spatial regression models, as opposed to the classic ordinary least squares (OLS) technique, to investigate more detailed drivers of agricultural land conversions incorporating spatial effects.

Combining remote sensing data on land-use/land-cover changes with environmental characteristics and socio-economic attributes between 2000 and 2012, the objectives of this article are twofold: (1) to quantify agricultural land conversion to natural land and agricultural land expansion onto natural land; and (2) to investigate the effects of multiple drivers from both the environmental and socio-economic sides on the two types of land-use transitions, taking spatial interactions into consideration.

2. Literature review

2.1. Transitions between agriculture and natural land

Agricultural land abandonment is driven by a mix of biophysical, ecological and socio-economic factors that can differ based upon local land-use history, climate, and landscape composition (Beilin et al., 2014). MacDonald et al. (2000) reviewed a literature of agricultural land abandonment, and provided a comparative analysis of case studies in Europe (e.g., Austria, Finland, France, Germany, Greece, Italy, Portugal, Spain, Sweden, Switzerland) to assess environmental impacts and policy responses. Renwick et al. (2013) also performed a comprehensive analysis of agricultural land abandonment in the European Union (EU), with a focus on policy reform, and discussed possible solutions to the issue.

More recent studies have investigated the drivers of agricultural land abandonment. For example, Baumann et al. (2011) explored the patterns of post-socialist farmland abandonment in Western Ukraine and considered environmental variables, population impact, and accessibility as potential drivers. Prishchepov et al. (2013) explored the determinants of agricultural land abandonment in post-Soviet European Russia and suggested that biophysical and socio-economic attributes are the key drivers. One specific study conducted by Zhang et al. (2014) focused on cropland abandonment in mountainous areas of China. The process of cropland abandonment was detected at three levels, including parcel, household, and village, with demographic and socio-economic determinants.

In conjunction with the research on agricultural land abandonment, the issue of agricultural land expansion (e.g., conversions from natural land) has also been acknowledged and quantitatively assessed (Hatna and Bakker, 2011; Pazu'r et al., 2014; Sluiter and de Jong, 2007). For instance, Caraveli (2000) explored agricultural intensification and extensification in Mediterranean countries in response to the less favored area (LFA) policy. Storkey et al. (2012) investigated the impact of crop management and the expansion of agricultural land use on the threat status of plants adapted to arable habitats in 29 European countries. Their results indicated a positive association between wheat yields and the number of threatened or recently extinct arable plant species.

Despite the popularity of spatial regression models as tools for investigating impacts caused by certain factors of LULCCs, no study to date has adopted this technique in the context of agricultural land abandonment and expansion especially when investigating the two transitions simultaneously in the same study area.

2.2. Environmental and socio-economic factors associated with specific locations

Previous literature has considered multiple factors that have important influences on agricultural land-use decisions (Hansen and Naughton, 2013; Li et al., 2013). When investigating underlying drivers of agricultural land-use changes in Europe, van Vliet et al. (2015) divided the factors into several groups, among which location factors (such as climate and other topographic elements that are typically associated with specific locations) are most commonly adopted and assessed in the existing studies involving spatial analyses.

Some studies further group location factors into environmental and socio-economic streams. Environmental location factors primarily include land quality or capability (Lubowski et al., 2008; Monteiro et al., 2011), precipitation and temperature (Cabanillas et al., 2012; Marti'nez et al., 2011), and elevation or altitude (Nahuelhual et al., 2012; Trincsi et al., 2014). Land quality or capability acts as a proxy for land's suitability for agricultural uses. In other words, land with higher quality or capability is considered to be more likely to remain in agricultural use (Di'az et al., 2011). In contrast, impacts from elevation, precipitation and temperature may present more mixed effects, varying from region to region (Alix-Garcia et al., 2012; Hatna and Bakker, 2011).

Recognizing the importance of the above environmental constraints does not preclude socio-economic location factors from influencing landowners' decisions regarding the use of