Calculating the Costs of Farmland Conservation: Case Study of Alberta, Canada

by

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Abstract:

For the last two decades the Canadian province of Alberta has experienced rapid conversion of former farmland into residential and industrial uses. The resulting loss of prime agricultural land and the low density of housing and industry have prompted new interest in farmland conservation. Although authorities at the provincial and local level have recognized the importance of farmland conservation, at this point they have not implemented any efficient policy tools to fulfill the conservation goal partly due to the insufficient knowledge of farmland conservation. This thesis aims to explore the private costs of farmland conservation in Alberta and provide useful input into policy discussions. First, we analyse the factors that influence farmland values using a spatial hedonic price model. We find that residential value, recreational value, development potential, and suitability for agriculture all have significant impacts on farmland price. Second, using agricultural rental rates as a measure of agricultural value, we estimate the value of development rights for 615 sample plots by subtracting capitalized agricultural value, recreational value and residential value from farmland list prices. Third, using the Co-Kriging interpolation technique, we predict the value of development rights for farmlands throughout the province of Alberta. Our results suggest that land around the Calgary and Edmonton metropolitan areas would be the most expensive to conserve in agricultural uses, while land in the central-east Alberta would be the least expensive. We use those results to derive a hypothetical supply curve for farmland conservation.

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Table of Contents

List of Figures

List of Tables

Chapter 1 - Introduction

1. Background

Farmland conservation first aroused public interest in the early 1960s in North America because of problems with soil degradation and urban sprawl (Bunce, 1998). The State of Maryland was the first jurisdiction in the United States to take action to alleviate the pressure of urban development on farmlands. Since then, different jurisdictions in the United States have employed various tools such as Transfer of Development Rights, Conservation Easements and much stricter Urban Growth Boundaries to conserve farmlands in urbanizing areas. In addition to farmland conservation programs led by states and land trusts, national programs in the United States are also been put in place such as the Farmable Wetlands Program and the Grassland Reserve Program (USDA, 2016).

Farmland loss could cause negative externalities such as the loss of open space, valuable biodiversity, or vegetation or landscape features that affect air and water quality. New development areas would also require urban services such as roads and fire/police protection, whereas privately owned agricultural land would require relatively few services (Conservation Easement for Agriculture in Alberta, 2012). Negative externalities would result in more farmlands converted than the optimal social quantity. Therefore, farmland conservation is an economic problem worthy to be explored.

Parts of Canada also face intense farmland conversion pressure from development growth. The Statistics Canada report *Human Activity and the Environment* (Statistics Canada, 2014) indicates that nearly 1 million of Canada's 50 million hectares of good quality agricultural land was converted to developed uses between 2001 and 2011. Provinces like Alberta, British Columbia, Quebec and Ontario are all experiencing great pressure on good quality farmland and are looking for efficient tools to better manage the allocation of land between agriculture and developed uses. At the present time, Canada has the nation-wide Eco-Gift program that provides federal tax incentives to landowners to conserve environmentally sensitive areas. Lands must meet certain criteria (e.g., lands shall have ecological value) before being recognized as eco-gifts (Environment and Climate Change Canada, 2010) and thus cultivated farmlands are not explicitly targeted under the Eco-Gift Program. Some farmland conservation in Canada is done by not-for-profit conservation institutions such as land trusts (e.g., Ontario Farmland Trust) and municipalities faced with rising land use conflicts (e.g., Alberta Capital Region; Capital Region Districts in British Columbia). Some charities have made great contributions to farmland conservation such as the Genesis Land Conservancy in Saskatchewan (CR-FAIR, 2012).

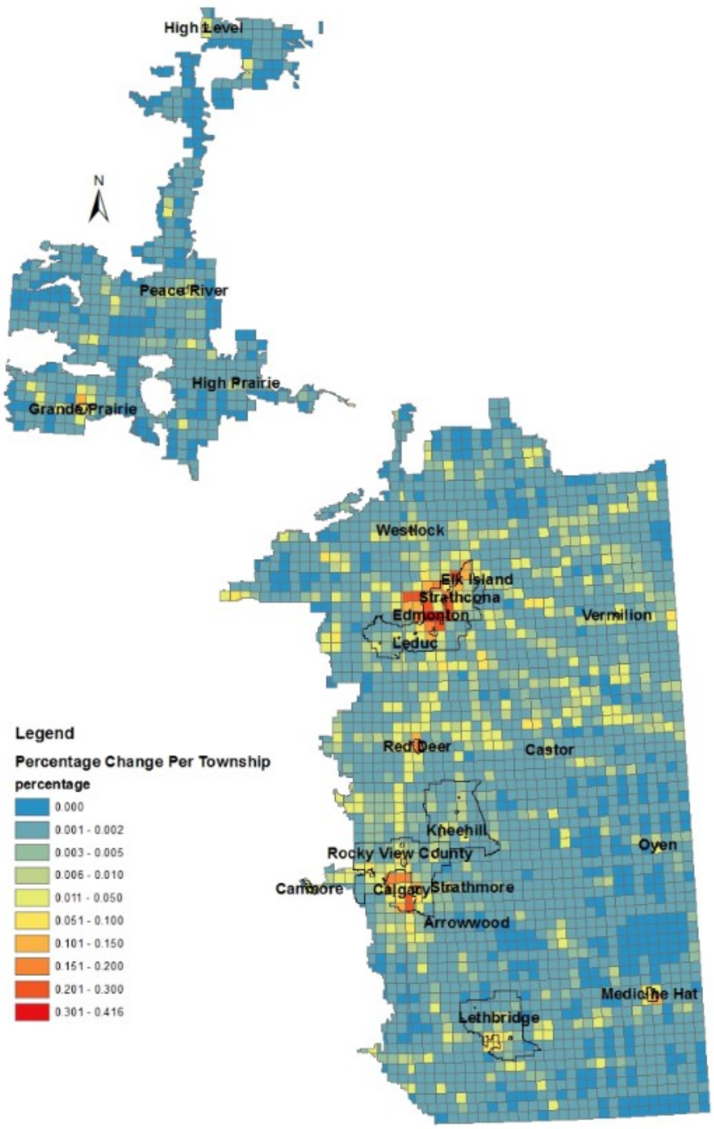
Strict zoning has been done in some provinces of Canada. In Ontario, the Greenbelt boundary was approved by the provincial Government of Ontario in 2004. The Greenbelt program employs strict agricultural zoning and aims to protect a large area of agricultural land from urban development (Deaton and Vyn, 2010). The effect of the Greenbelt on farmland values outside the boundary is complex, but fortunately well studied. Vyn (2012) found that strict agricultural zoning in the greenbelt results in a leapfrog effect, causing urban sprawl to extend further than it otherwise would. The Government of British Columbia established the Agriculture Land Reserve (ALR) in 1973, which strictly restricts subdivision and non-agriculture activities on reserved lands. Currently, the ALR has reserved 5% of the total land area in British Columbia (ALC, 2016). Eagle et al. (2015) examined the effectiveness of ALR in British Columbia. They found that the influence of the ALR varies over time by improved and unimproved land types and concluded that zoning alone is probably not enough for agricultural land protection.

Relatively little policy attention has been given to conservation of agricultural land in the province of Alberta. Alberta has seen increasing farmland conversion pressure for the past decade. Overall, 0.82% of Alberta's agricultural land base was converted from agriculture to developed uses between 2000 and 2012 (Haarsma, 2015). But some areas have experienced much higher rates of farmland conversion. Figure 1-1 shows the proportion of farmland in each township that was converted to development uses in Alberta between 2000 and 2013. Figure 1-1 clearly shows that almost 30% of farmland in Edmonton, Calgary and immediate surrounding areas was converted to developed uses between 2000 and 2013. Meanwhile, population density is relatively low in both Edmonton and Calgary compared to other urban areas in Canada. In terms of urban population density, Edmonton ranks 22 out of 33 census metropolitan areas in Canada while Calgary ranks 12 out of 33 (Statistics Canada, 2011). Figure 1-2 provides the rank of population density of 33 metropolitan cities in Canada. Other Canadian cities of similar size to Edmonton and Calgary such as Ottawa-Gatineau, Quebec City, Winnipeg and Hamilton rank 16, 14, 20 and 5 respectively. The relatively low population density of Edmonton and Calgary illustrates that urban sprawl might be a problem in Alberta. Without more effective land use planning, the province stands to lose even more farmlands in the future, which will bring more negative externalities and higher social costs.

Partly due to the concerns over farmland loss, the Alberta provincial government created and adopted the Land Use Framework (LUF) in 2008. The LUF explicitly prompts the provincial and municipal governments to reduce farmland conversion and develop conservation strategies. The Alberta Land Stewardship Act (ALSA) was created in 2009 to support the implementation of the regional planning system under the Land Use Framework (Capital Region Board, 2016). In addition, regional land use plans such as the Capital Region Land Use Plan (2009) were created to preserve agricultural lands in the Alberta Capital Region. On 8 May, 2016, a draft of the Modernized Municipal Government Act (2016) was released for public comment and legislative review. The act would require the Lieutenant Governor to establish mandatory Growth Management Boards for the Edmonton and Calgary regions that would be required to develop growth plans to preserve agricultural lands in the metropolitan regions (Alberta Government, 2016a). Under the new MGA, Conservation Reserves are created to protect environmentally significant lands. Municipalities would be required to provide appropriate compensation to developers who will lose development opportunities because of the Conservation Reserve (Alberta Government, 2016b).

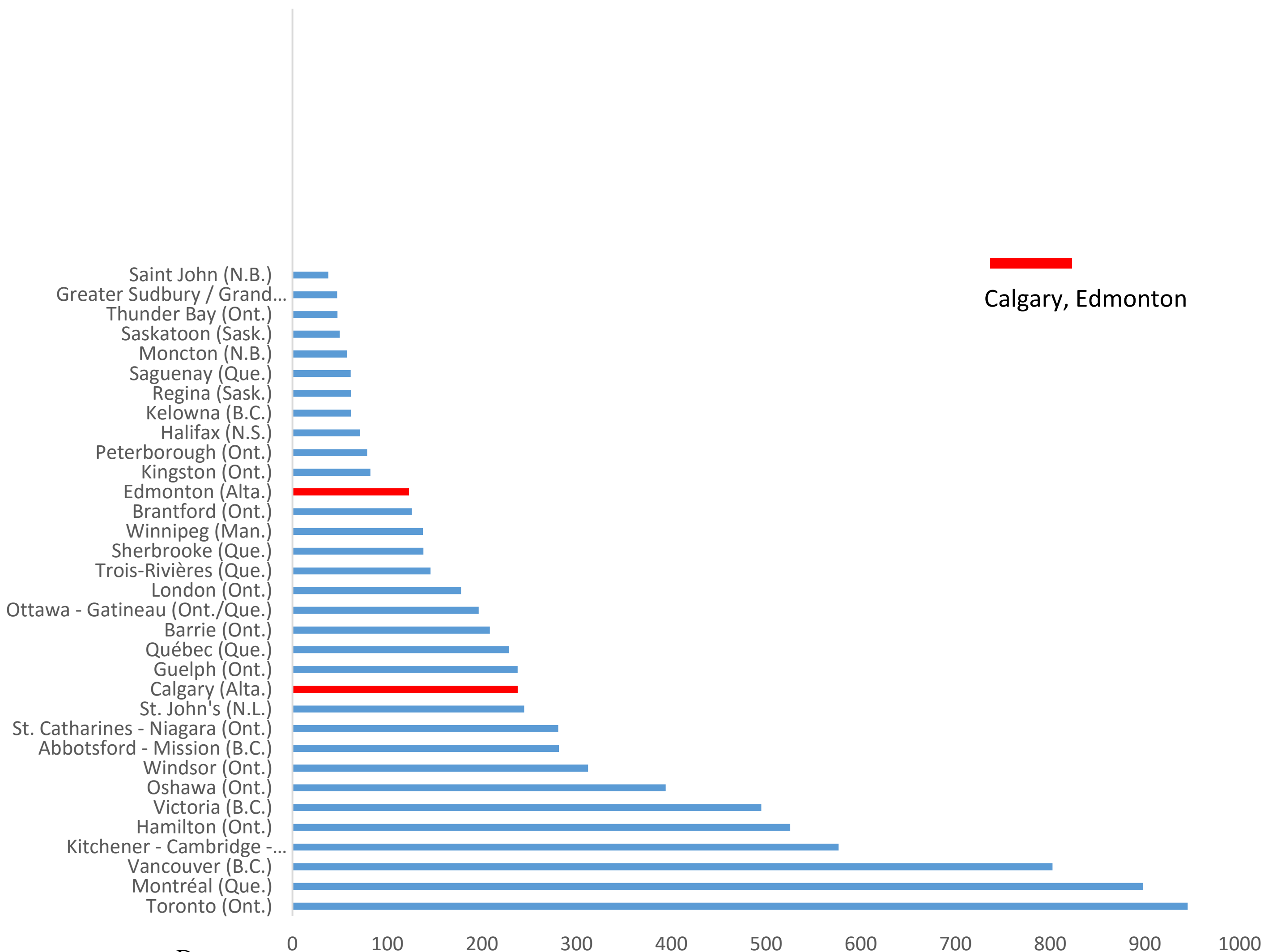
To sum up, farmland conservation is becoming increasingly important in Alberta. But little is known about the associated costs. One early attempt to estimate costs is Wang and Swallow (in press) who used assessed and market values of land as upper-bound estimates of cost. However, Plantinga and Miller (2001) clarify that the cost of farmland conservation is the value of development rights, which they defined as the conversion option value. Similarly, Nelson et al. (2013) maintain that the cost of farmland conservation through Transferred Development Rights is the farmland’s development rights value. Besides, the main legal mechanism for conservation of private farmland is the conservation easement, which is a legal instrument that restricts property rights. Purchase of Development Rights (which can be implemented through a conservation easement) is popular in some states of the United States (e.g., New York State, Michigan and Virginia). Daniels (1991) argues that Purchase of Development Rights might be controversial because of the sizable costs of purchasing the development rights. In conclusion, existing conservation tools achieve conservation goals by restricting development rights. Value of development rights is the financial cost of farmland conservation.

Figure 1-1: Agricultural Land Change in Alberta (2000-2013)



Data Source: Agriculture and Agri-Food Canada, 2013

Figure 1-2: Population Density (per km2) of Main Metropolitan Cities in Canada (2011)



Data

Source: Statistics Canada, 2011.

The challenge to estimate farmland cost is to extract out the development rights value from the market price. Farmland can be used for agricultural production, recreation, residence, and other development (Gulling et al., 2009). Some previous studies also recognize multiple uses of farmlands (e.g., Capozza et al., 1989; Plantinga and Miller, 2001; Plantinga et al., 2002). Correspondingly, the farmland value can be decomposed into recreational value, residential value, agricultural production and urban conversion option value. To separate out agricultural value, residential value and recreational value, we adopt the Hedonic Price Model approach. A Hedonic Price Model can be used to estimate the implicit price of certain attributes. Therefore, by including variables in the Hedonic Price Model that could affect the four values, we are able to decompose the farmland value into four components (residential, recreational, agricultural and option value).

2. Research Objectives and Thesis Structure

The primary goal of this thesis is to estimate the cost of farmland conservation across the agricultural zone of Alberta by decomposing farmland price into values for agricultural production, recreation, residence and development.

More specifically, the objectives of this thesis are as follows:

1, Empirically examine the determinants of farmlands value;

2, Decompose farmland value and map the value of development rights across the province;

3, Evaluate the cost implications of alternative farmland conservation policies.

To achieve these objectives, this thesis is composed of this introduction, two substantive papers, and a conclusion. Chapter 2 presents an analysis of factors determining the value of farmlands in rural Alberta. Chapter 3 uses results from Chapter 2 to predict the value of development rights in the agricultural zone of Alberta. Chapter 3 involves several steps. We first apply the model from Chapter 2 to decompose the elements of farmland value into agricultural value, recreational value, residential value and conversion option value. Through this decomposition, we can calculate the value of development rights. Next, we generate a VDR map for the whole province using an interpolation technique from geo-statistics (Co-Kriging). By looking at the VDR predictions, policy makers can predict with greater certainty the cost of protecting agricultural land, and thus making effective land use policies. In Chapter 4, we summarize the main findings and conclusions.

3. References

Alberta Government, 2016a. http://www.alberta.ca/release.cfm?xID=4185154FA551C-A8F9-F963-537250BD1AE2EBEF. Accessed on 14th July, 2016.

Alberta Government, 2016b. http://mgareview.alberta.ca/whats-changing/plan-for-growth/. Accessed on 15th July, 2016.

Agriculture Land Commission, 2016. Provincial Agricultural Land Commission Annual Report 2015-2016. http://www.alc.gov.bc.ca/assets/alc/assets/library/commission-reports/annual_report_2015-2016.pdf. Accessed on July 1st,2016.

Bunce, M., 1998. Thirty years of farmland preservation in North America: discourses and ideologies of a movement. *Journal of Rural Studies*, *14*(2), 233-247.

Capital Region Board, 2016. Understanding the Land Use Framework. http://capitalregionboard.ab.ca/-/toolkit/module1-understandingthelanduseframework.pdf.

Capozza, D. R., & Helsley, R. W., 1989. The fundamentals of land prices and urban growth. *Journal of urban economics*, *26*(3), 295-306.

Conservation Easement for Agriculture in Alberta., 2012. https://landuse.alberta.ca/LandUse%20Documents/Conservation%20Easements%20for%20Agriculture%20in%20Alberta%20-%202012-03.pdf.

CR-FAIR, 2012. Regional Farmland Conservation and Access Program. http://www.communitycouncil.ca/sites/default/files/CRFAIR-Farmland_Access_and_Conservation_Policy_Discussion_Paper_0.pdf. Accessed on 21st, May, 2016.

Daniels, T. L., 1991. The purchase of development rights: preserving agricultural land and open space. *Journal of the American Planning Association*, *57*(4), 421-431.

Deaton, B. J., & Vyn, R. J., 2010. The effect of strict agricultural zoning on agricultural land values: The case of Ontario's greenbelt. *American Journal of Agricultural Economics*, aap022.

Eagle, A. J., Eagle, D. E., Stobbe, T. E., & van Kooten, G. C., 2015. Farmland Protection and Agricultural Land Values at the Urban-Rural Fringe: British Columbia's Agricultural Land Reserve. *American Journal of Agricultural Economics*, *97*(1), 282-298.

Environment and Climate Change Canada, 2010. http://www.ec.gc.ca/pde-egp/default.asp?lang=En&n=3B7034EA-1. Accessed on July 1st, 2016.

Guiling, P., Brorsen, B. W., & Doye, D., 2009. Effect of urban proximity on agricultural land values. *Land Economics*, *85*(2), 252-264.

Haarsma, D., 2014. "Spatial analysis of land conversion and its associated drivers in Alberta" (Master dissertation). Retrieved from: https://era.library.ualberta.ca/downloads/5138jg191.

Land-use Framework, 2008. https://www.landuse.alberta.ca/Documents/LUF_Land-use_Framework_Report-2008-12.pdf. Accessed on 14th July, 2016.

Nelson, A. C., Pruetz, R., & Woodruff, D., 2013. *The TDR handbook: Designing and implementing transfer of development rights programs*. Island Press.

Statistics Canada, 2011. 2011 Census Profile: https://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/download-telecharger/comprehensive/comp-csv-tab-dwnld-tlchrgr.cfm?Lang=E#tabs2011. Accessed on 3rd July, 2016.

Plantinga, A. J., & Miller, D. J., 2001. Agricultural land values and the value of rights to future land development. *Land Economics*, *77*(1), 56-67.

Plantinga, A. J., Lubowski, R. N., & Stavins, R. N., 2002. The effects of potential land development on agricultural land prices. *Journal of Urban Economics*, *52*(3), 561-581.

Statistics Canada, 2014. Human Activity and the Environment. http://www.statcan.gc.ca/pub/16-201-x/16-201-x2014000-eng.pdf. Accessed on 15th July, 2016.

USDA, 2016: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/. Accessed on July 1st, 2016.

Vyn, R. J., 2012. Examining for evidence of the leapfrog effect in the context of strict agricultural zoning. *Land Economics*, *88*(3), 457-477.

Wang, H., 2015. "Analyzing nonmarket values of agricultural land conservation in the Alberta capital region, Canada"(Master dissertation). https://era.library.ualberta.ca/files/1r66j351v#.Vr4cqpMrLVo.Accessed on 18th July, 2016.

Wang, H. & Swallow, B.M. (in press). "Optimizing expenditures for agricultural land conservation: spatially-explicit estimation of benefits, budgets, costs and targets." Land Use Policy.

Chapter 2 - Determinants of Farmland Values

1. Introduction

In 2013, farmland and buildings accounted for approximately 61.42% of total farm assets in Canada (Statistics Canada, 2013), up from 44% in 1993 (Farm Credit Canada, 2015). The increasing proportion of farmland value in the total farm assets implies higher concentration risk for farm owners because they allocate a much higher proportion to a single asset. Therefore, it is critically important to understand the driving forces of the increasing farmland values.

Farmland values are affected by temporal and spatial factors. Over time, population growth, high farmland income and economic growth all increase the demand for farmland and thus contribute to rising farmland values in Alberta (Serecon, 2015). Besides, expectations about future income and the opportunity costs of funds would affect farmland price (Gloy et al., 2011). Across space, farmland values are affected by a series of factors such as urban proximity, access to recreational amenities (Gulling et al., 2009), and soil quality (Miranowski et al., 1984). Overall, the driving forces behind increasing farmland value are complex and include factors of both the macro economy and the agricultural economy (Farm Credit Canada, 2015).

Several relevant studies have already been done in the province of Alberta. Some studies concentrate on factors affecting farmland conversion (e.g., Haarsma et al., 2015; Wang et al., 2016; Ruan et al., 2016) and fragmentation (eg., Qiu et al., 2015). Young et al. (2006) examined land cover change in the Beaver Hills area (east of Edmonton) from 1977 to 1998 and proposed possible causes. Rashford et al. (2011) examined agricultural land use changes in the Canadian Prairie region to help better implementation of effective wetland conservation. Qiu et al. (2015) examined the impacts of farmland fragmentation and the drivers of farmland conversion. They found significant impacts of farmland values, road density, population density, agriculture suitability and elevation on farmland conversion. Some studies focus on the non-market value of farmland conservation. Wang (2015) estimated residents' willingness to pay for farmland conservation in the Alberta Capital Region. He showed that people are willing to pay the most to conserve commercial vegetable farmlands that are adjacent to major highways and within a 10-km buffer from the currently developed land.

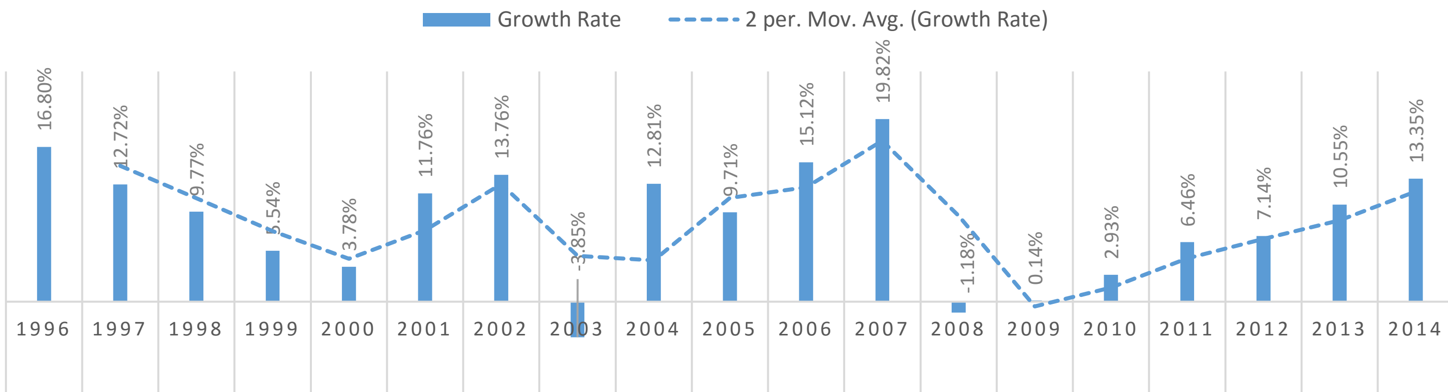
The objective in this chapter is to explore the determinants of farmland value in the province of Alberta through an analysis of disaggregated farm-level data. As argued by Chicoine (1981), farmlands are heterogeneous goods and the hedonic price model might be better than the conventional supply and demand approach, which assumes homogeneous products. Therefore, we will use a hedonic price model to analyse the determinants of farmland value in this study. Following Qiu et al (2015) we also consider spatial spillovers through the use of spatial regression models.

The rest of this chapter is organised as follows. In section 2, we review the situation in some Alberta municipalities with particularly high and low farmland values. By comparing the situations in these municipalities, we will select possible influential attributes and include those attributes in the empirical model. Section 3 provides the theoretical foundations of our farmland value analysis. Section 4 describes the data and discusses the empirical methods. Section 5 and section 6 present the results and draw conclusions.

2. An Overview of Farmland Values in Alberta

Farmland value in Alberta has increased steadily since 1996, but with fluctuating growth rates. Figure 2-1 depicts the annual growth rate of farmland value in Alberta (*Agricultural Real Estate Transfer, 2014).* The dotted line is the two-year moving average. On average, the annual growth rate of farmland value was about 8.8% between 1996 and 2014. Between 1996 and 2000, the growth rate decreased steadily from 16.8% to 3.78%. The growth rate fluctuated between 2000 and 2007 and in 2008, the rate decreased sharply from 19.82% to -1.19% partly due to the global financial crisis. Since then, the annual growth rate kept increasing from 2.93% in 2010 to 13.35% in 2014.

Figure 2-1: Growth Rate of Farmland Value in Alberta (1996-2014)

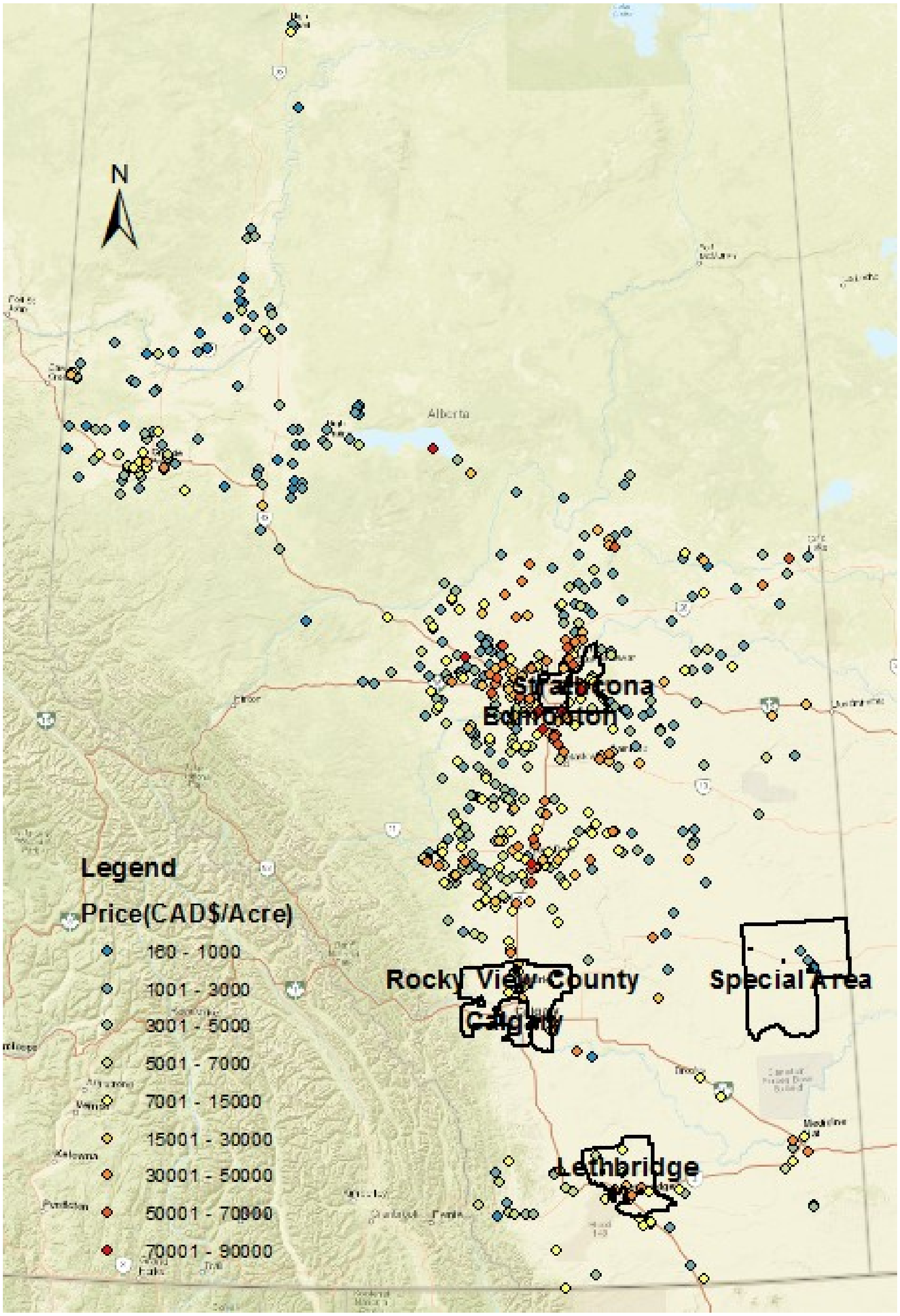


Data Source: Alberta Real Estate Transfer, 2014

Farmland value varies greatly across Alberta. Figure 2-2 depicts the current farmland price ranging from below CAD$1,000 /acre to above CAD$70,000 /acre. The data depicted in Figure 2-2 is the farmland listing data collected by the authors from public listings such as Kijiji (http://www.kijiji.ca/b-land-for-sale/alberta/) and Real Estate Maximum (ReMax, http://www.remax.ca/ab/) . More details about the data are presented in Section 4. Strathcona County to the east of the City of Edmonton has high farmland values in Alberta. Sales in Rocky View County and Lethbridge are also high, as are other sales in municipalities along the Calgary-Edmonton Corridor[1]. In contrast, farmland in counties southwest of Edmonton and in Northern Alberta is relatively inexpensive. Sales in Special areas in the southeast Alberta have relatively lower prices (below 1500 dollars/acre). It is helpful to understand the reasons behind the price variation across municipalities. Next in this section, we will compare prices in some high farmland value counties (such as Lethbridge and Strathcona County) and some low farmland value counties (such as Special Areas) to develop a qualitative understanding of the possible spatial determinants of farmland values.

[1] Edmonton Calgary Corridor refers to the most urbanized areas along Highway 2 from Edmonton to Calgary. The map is provided in figure C-5 in Appendix C.

Figure 2-2: Farmland Price in Alberta (2015)



Data Source: Remax and Kijiji.

Strathcona. Strathcona County is a thriving community in the centre of Alberta. As a member of Alberta Capital Region, Strathcona is going through rapid urbanization and farmland conversion. The 2011 population of Strathcona was 92,490 (Statistics Canada, 2011). Between 2000 and 2007, the population growth rate in Strathcona was around 19.1%, which is higher than the growth rate in the City of Edmonton and the City of Calgary (12.7% and 18.5% respectively) (Alberta Government, 2016). In 2007, Strathcona County announced plans to create an entirely new urban community (on farmlands east of Highway 21 and north of the Yellowhead Highway) from scratch in order to reduce the pressure of population growth on Sherwood Park (Strathcona County, 2016). Sherwood Park, a large hamlet in Strathcona County, is located to the immediate east of Edmonton and has attracted both residential and industrial development. The Strathcona County Development Plan intends to attract more residents (up to 200,000 people). But that plan will also lead to the conversion of land of high agricultural value. In addition to the conversion pressure caused by population growth, Strathcona's agricultural land is also threatened by industrialization. Strathcona is Canada's energy engine with 75% of oil refining in Western Canada and is a strong partner in the Alberta Heartland Association (Strathcona Stats and Facts, 2016), which is Canada's largest hydrocarbon processing region and home to more than 40 companies. Approximately 6.89% of the lands in Strathcona County are used for industrial use in 2016, higher than any other Alberta municipality (Strathcona Stats and Facts, 2016). Therefore, both population growth and industrial growth cause conversion pressures on agricultural lands in Strathcona County.

The Agriculture Master Plan (AMP) was accepted by the Strathcona Council in 2015 to cope with the increasing land use competition between agriculture and other development sectors. The plan suggests the use of two policy tools: Zoning and Transfer of Development Credits (Agriculture Master Plan, 2016). The former tool suggests that before the approval of any development applications, the applicants are required to undertake an Agricultural Impact Assessment (AIA) and the results will be a key consideration in the final zoning decision. Transfer of Development Credits allows for the transfer of development from eco-sensitive areas to areas more suitable to increased development (TDC in Alberta, 2016). According to Packman et al. (2013), the Transfer of Development Credits strategy might work well in Strathcona because of its spatial characteristics. The Beaver Hills Initiative promotes greater density in the north east and lower density in the south west of Strathcona County (www.beaverhills.ca). In March 2016, the

Beaver Hills was designated as a Biosphere Reserve by the United Nations Educational, Scientific and Cultural Organization (www.beaverhills.ca).

Rocky View. The Municipal District of Rocky View is located in the south of Alberta, surrounding three sides of the City of Calgary and home to 36,461 people as of 2011 (Statistics Canada, 2011). Its geographical situation makes Rocky View county one of the fastest growing urbanizing areas in Alberta. As shown in Figure 1-1, farmlands in Rocky View were converted at a higher rate than the neighbouring rural counties such as Kneehill County. Major highways like Highway 2 and Trans-Canada No 1 and other highways like highway 22 and 560 all pass through Rocky View County. Besides, Farmers' Markets in the City of Calgary provide ready outlets for the sale of agricultural products produced in Rocky View. Therefore, the proximity advantage and the good transportation of Rock View play an important role in its prosperous agricultural sector and high development pressure (Agricultural Profile of Rocky View County, 2004).

Lethbridge. Lethbridge County is in the heart of southern Alberta, home to 10,061 residents (Statistics Canada, 2011) and featuring a prairie landscape with vast stretches of golden fields (County of Lethbridge, 2013). The population of Lethbridge County declined by 1.9 percent between 2006 and 2011. The high farmland value in Lethbridge is mostly due to the high agriculture rent. The economy in Lethbridge County is primarily agricultural, especially the intensive cattle feeding operations. It is estimated that agriculture sector in Lethbridge contributes CAD$1.1 billion annually to the local economy (Serecon, 2014).

The high agricultural revenue produced in Lethbridge is partly promoted by the irrigation infrastructure of the area. The Agricultural Intensity Index[2] in 2014 was CAD$1509.18, second only to Edmonton at CAD$2717.4 per acre. Lethbridge is served by two irrigation districts, providing a stable water supply for agricultural producers. In addition to the vital role in agricultural water supply, the irrigation infrastructure also creates recreational opportunities (County of Lethbridge, 2013). For example, Henderson Park in Lethbridge has man-made lakes created by the water reservoirs originally constructed for storage of irrigation water. What's more, irrigation supports the intensive production of forage, grain crops, canola and sugar beets. These products are then processed and support local intensive livestock operations (The Canadian

[2] The index is defined as the total gross farm receipts divided by the total farmed acres (Agriculture Master Plan, 2016).

Encyclopedia, 2015). All of these benefits brought by irrigation sector promote the agricultural growth in Lethbridge, and consequently increase farmland values.

Special Areas. Special Areas, including Special Areas No.2, No.3 and No.4, are in southeast Alberta. The Special Area Board was established in the 1930s in response to a prolonged drought that devastated the region. Special Areas have almost the lowest population density in the agricultural zone of Alberta. Population per square kilometer in Special Area No.2, No.3 and No.4 was only 0.22, 0.17 and 0.31 persons / km^2 respectively in 2011 (Statistics Canada, 2011). Road density is only 423 meters per square kilometers in the Special Areas, ranked 387 out of the 431 census subdivisions[3] in Alberta. What's more, the Special Areas constitute the majority of the Alberta portion of the Dry Belt, which is characterized by arid conditions and soils unsuitable for cultivation (Marchildon, 2006). Therefore, low farmland value in the Special Areas can be partly explained by the aridity and low cultivation value of lands there.

In conclusion, we can learn the following aspects of the geographical determinants of farmland from the experiences of Strathcona, Rocky View, Lethbridge and the Special Areas. First, in the case of Strathcona, we can see that development pressure mainly comes from population and industrial growth. The resulting development pressure causes a conflict between agricultural land use and developed land uses. Second, the benefits of close urban proximity in Rocky View County make agricultural land valuable there. Third, agriculture suitability is also a primary factor that accelerates the growth of farmland price. Lethbridge is a good example that well illustrates the importance of irrigation infrastructure. In contrast, the Special Areas have low population density, dry weather, arid land, and as a result, low farmland value. Therefore, we could conclude that both agriculture suitability and development potential might play important roles in determining farmland price in Alberta. Accordingly, the empirical estimation in the later session includes both types of factors.

[3] Census Subdivision is the area that is a municipality or an area that is deemed to be equivalent to a municipality for statistical reporting purposes (see the definition by Statistics Canada: https://www12.statcan.gc.ca/census-recensement/2011/ref/dict/geo012-eng.cfm).

3. Theoretical Foundations

3.1. Present Value Model

The present value model is widely used in the empirical study of land price (e.g. Gulling et al., 2009; Capozza & Helsley, 1989). Farmland is real property that can generate income in continuous subsequent periods. So farmland can be appraised as the sum of the discounted value of all of the returns expected in the future. Equation (1) mathematically depicts the present value model:

$$P_t = \sum_{i=1}^{\infty} \left(\frac{E(R_{t+i})}{(1+r)^i}\right) \tag{1}$$

where E(R) is the expected value of revenue in the future, r is the discount rate, t is current period, i is the number of a following period. Equation (1) is the basic form of the land price decision. However, in the real world, the situation is always more complex and require some extensions to the basic form.

First, farmland generates returns from more than one source because lands can be used for various purposes like recreation and residence. The formula can then be written as (2):

$$P_t = \sum_{k=1}^{n} \sum_{i=0}^{\infty} \frac{E(R_{k(t+i)})}{(1+r)^i} \tag{2}$$

where k is the kth use of agricultural lands, i, r and t are the same as defined before. The multiple-use present value theory is applied in some studies of farmland value. Gulling et al. (2009) proposed that agricultural land values can be written as the sum of multiple returns divided by the discount rate. Plantinga et al. (2001) and Plantinga et al. (2002) also suggested that farmland value is the sum of agricultural returns and development returns.

Second, landowners will choose the best time to convert their farmlands and the conversion time is different from each other depending on the land characteristics. The previous two present value models do not explicitly account for the facts that farmland conversion is irreversible and that the revenue from development only begins after conversion. The idea of holding the farmland until the best time of conversion is the essence of option value.

Option value was first discussed by Weisbrod (1967). Weisbrod argued that in a specific case of the destruction of a national park, we must realize that people would want to preserve the park and thus retain the option to visit it in the future. Although stated informally by Weisbrod (1967), the idea of option value has been widely accepted ever since.

Option value could exist when making farmland preservation decisions. As landowners do not know their future payments with certainty, they have incentive to delay joining a conservation program now that would commit the land to a specific purpose for several future periods (Vercammen, 2014). However, when they decide to change to a development use, the revenues after the conversion will come from development revenue. The fact of the existence of option value extends equation (2) to equation (3) which means that the landowners will not convert the farmland immediately at time 0 but prefer to convert their farmland sometime in the future t^* (landowners would convert only if R>A, otherwise no conversion). A is the expected return from agriculture and R is the expected revenue from development.

$$p = \begin{cases} \int_0^{t^*} A\, e^{-rs} d_s + \int_{t^*}^{\infty} R e^{-rs} d_s \,, if\ R > A \\ \int_0^{\infty} A\, e^{-rs} d_s, \qquad\qquad\qquad if\ R < A \end{cases} \tag{3}$$

As far as we know, Plantinga et al. (2002) is the only paper that directly addresses the option value problem and provides an empirical analysis of agricultural land value, although they didn't explicitly define option value. They decomposed farmland value into 2 components, one is agriculture value while the other is development value. They assumed that landowners choose the optimal time t^* to convert from agricultural land to development land with the objective to maximize their land price in the current period t. They also assumed that the development value will follow a standard Brownian Motion, which is a stochastic process with certain properties such as the initial value is zero and the increment has a normal distribution. The option value is then defined as a function of two factors: time t and location z. This study provides a good framework to analyze the impact of option value.

3.2 Hedonic price model (HPM)

Rosen (1974) firstly formulated the theory of hedonic prices. According to Rosen, the model is a further exploration of traditional product differentiation theory and structurally explains the mechanisms of competitive prices. Consumers have a bid function of utility-bearing characteristics while producers have an offering function. When the offer is equal to the bid, there is market equilibrium and the price of each attribute is decided. The reduced form of the hedonic price model is

$$P = f(X) \tag{4}$$

where,

P =the observed price of commodity,

X =the characteristics of the commodity.

As we can see, the hedonic price model states that the values of heterogeneous goods are differentiated by their attributes. Hedonic price equations are estimated by regressing a commodity price on its characteristics, and the coefficients are interpreted as the implicit prices of each characteristic.

Although the HPM was proposed in the context of a housing market, the theory is very popular in other fields of study. In its early stage, several papers used the approach to analyze drivers of house price/rent (e.g. Mok et al., 1995; Goodman et al., 1978) and the structure of demand and supply for housing (e.g. Bartik, 1987; Witte, Howard and Homer, 1989). Later, the hedonic price model was widely applied to estimate the value of non-market goods such as environmental amenities (e.g. Garrod et al., 1992; Kong et al, 2007). Recent papers have used the hedonic price approach to examine prices for commodities as divergent as mobile phones (Mostafavi et al., 2013) and restaurant meals (Yim et al, 2014). New methods have been used to resolve different econometric problems in HPM estimation. For example, Wheeler et al. (2014) adopt a Bayesian econometric approach for predicting housing prices, while Suparman et al. (2014) developed a constrained autoregression–structural equation model (ASEM) to deal with omitted variable and measurement error problems.

The Hedonic Price Model approach remains popular in the study of farmland values. To our knowledge, Chicoin (1981) was the first to apply the hedonic price model in farmland value. Their work provided empirical evidence that urban proximity significantly affects farmland values in urban fringe areas of Chicago. Plantinga and Miller (2001) analyzed three determinants of agricultural lands value in New York State (distance to the closest metropolitan areas, population change in the closest metropolitan area, and net return on agricultural lands) using county level aggregated data. Huang, et al. (2006) used county-level panel data (101 counties in the U.S. state of Illinois, 1979-1999) to explore the impacts of land productivity, parcel size, distances to

Chicago, and income. Bastian et al. (2002) estimated a hedonic price model for agricultural land price in Wyoming, USA. They found a significant positive relationship between land price and environmental amenities.

There are also studies on the effects of policy on agricultural land value. For example, different land governance regimes lead to different land use regulations. Land use regulation is very special in planned economies such as China, where land is owned by the state and current landowners only have temporary use rights. Therefore, farmland value is much more likely to be affected by government policies (Dong Zhiyong et al., 2010). Burger (1998) analyzed the effect of land privatization on the land price. Her study uses data from Hungary to show that a free market in land promotes the concentration of land holdings. Weersink et al. (1999) examined the extent to which agricultural support programs have been capitalized into farmland prices. They empirically showed that income from government support would discount at a lower rate than the market return.

To sum up, previous studies of farmland value can be categorized into 2 streams. One focuses on traditional land characteristics such as soil quality, climate and urban proximity (e.g., Miranowski et al., 1984; Guiling et al. 2009; Palmquist et al., 1989; Bastian et al., 2002). The other examines the impacts of amenity values and regulations on farmland price (e.g., Lynch et al. 2007; Kline et al., 2005; Weersink et al, 1999).

There are some challenges involved in estimating hedonic price models. Here we discuss some most common challenges, and how they are treated in this study.

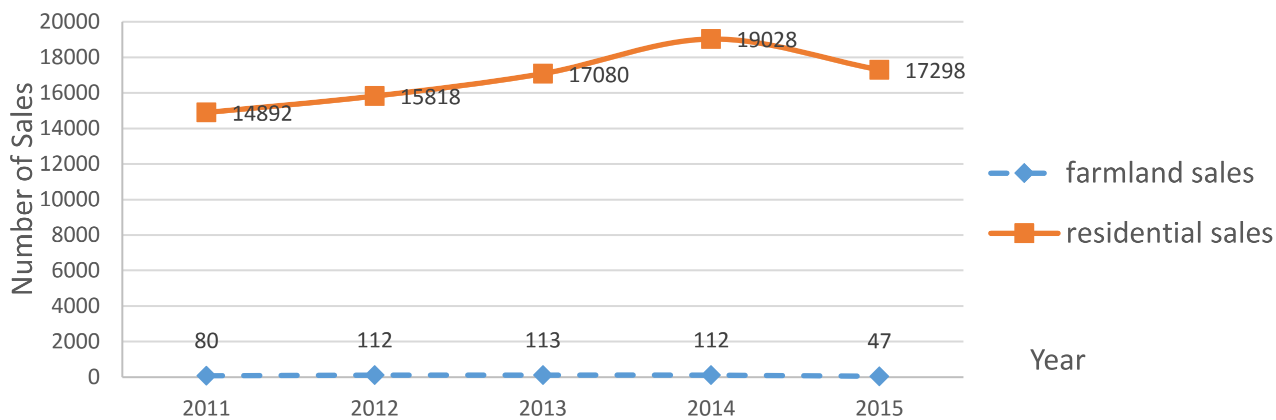
Market extent. The hedonic price model assumes that transactions are derived from one single market. It is important to clearly identify that market before we do the hedonic price analysis. Malpezzi (2002) reviewed previous hedonic price papers and distinguished between those that were conducted at the state level, metropolitan level, and below the metropolitan level. We observe HPM studies conducted at the national level (Plantiga et al., 2002; Borchers et al., 2014), province/state level (Plantinga et al., 2001; Guiling et al., 2009), and county level (Chicoine, 1981). Farmland sales are not as frequent as house sales in urban areas. For example, data from the Edmonton Real Estate Board (Figure 2-3) illustrates that there are far fewer active farmland transactions than residential transactions in the metropolitan area. So, it might be difficult to get enough data to estimate a hedonic price model for a specific rural area such as the Alberta Capital

Region. It may be necessary to collect panel data to complete a hedonic price analysis for a small region. The appropriate market extent mainly depends on the goals of the study, and on the data that can be accessed. For our study, the market is limited to the so-called "white" zone[4] of the province of Alberta for two reasons:

1, we are not able to get enough data on some specific areas of the province, and

2, we are interested in the overall perspective on farmland conservation because farmland conservation is an important issue at local, provincial, national and even global level.

Figure 2-3: Farmland Sales and Residential Sales in Edmonton (2011-2015)



Data source: Edmonton Real Estate Board, 2015.

Multicollinearity. Multicollinearity might be a problem when we employ HPM because we usually include many relevant attributes and some of the variables measure the same phenomena to some extent. For example, distance to Edmonton and distance to a major highway are correlated because both can measure the development potential to some extent. Or, there might be a strong correlation between road density and the health points within a 10kms radius of the land. The steps we take to deal with multicollinearity are: calculate the correlation coefficient and variance inflation factor (VIF), find out those highly correlated variables and change the form of the variable or delete one of the variables as necessary.

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[4] White zone refers to the settled area in Alberta. The rest area in Alberta is green zone, including forests and crown lands. http://aep.alberta.ca/recreation-public-use/recreation-on-public-land/public-land-use-zones/documents/PLUZ-GreenWhite-Jul07-2014.pdf. Accessed on 26th, July, 2016.

Functional form. As argued by many scholars (Rosen, 1974), it is very important to identify the functional form for the hedonic price model even though economic theory provides little guidance. A popular way to test the appropriate functional form is to compare the goodness-of-fit of the estimated equations. Some common functional forms are: semi-logarithmic, double-logarithmic, linear, box-cox transformation and transcendental logarithmic. Semi-logarithmic form is commonly used in hedonic price studies because several studies have shown it to have superior goodness-of-fit (Boxall et al., 2005).

Spatial dependence. Spatial dependence is the spatial relationship of outcomes. In our case, it is the clustering of land prices in a certain area. Spatial dependence would exaggerate the test statistics and invalidate the tests (Legendre, 1993). A variety of spatial techniques can be used to overcome this problem, such as the Spatial Autoregressive Model (SAR), Spatial Error Model (SEM), Spatial Durbin Model (SDM) and Spatial Autocorrelation Model (SAC). Each of these spatial regression models has different assumptions and applications. How to select a spatial model that suits our dataset will be discussed later in the next section.

4. Data and Methods

4.1 Data

Quality of farmland sales data is extremely important in doing empirical price analysis because the accuracy and implications of the study depend directly on the quality of data. The ideal data is a plot level panel data in a single market. However, available databases all have advantages and disadvantages. Data from Farm Credit Canada is the real transaction data, but no spatial information is provided. The aggregated data are not well suited for spatial analysis due to the lack of spatial information. The goal of this study is to estimate the cost across the province, the disaggregated data are preferred for the purpose of prediction. Data from Alberta Real Estate Transfer are the plot level data with location, but the reported value is the assessed farmland value, which means the price mainly includes the agricultural value of the farmland. Our purpose is to decompose the farmland value into agricultural, conversion option, residential and recreational value. Assessed farmland value data are not appropriate for this study.

The source for the disaggregated data for Alberta, the Multiple Listing Service (MLS) database, is expensive and /or very hard to access because of privacy issues (Shultz et al., 2001).

At the beginning of the study, we tried to acquire MLS data but were told the data could not be provided. Eventually, we decided to assemble a database of farmland sales data through examination of listing sales information for individual farm plots in Alberta.

In total we collected data for 633 farmlands for sale in Alberta in 2014 and 2015 from the public sales listings (Kijiji and Realtors websites). The original information in the dataset includes the location of the farmland, size, asking price, and sellers' comments. Some limitations of the data need to be discussed here. First, our price is the asking price. At the present time, we assume that asking price is a linear function of the final sale price. But the estimation would not be affected. Second, since the data are across the province, we might have the problem of single market. However, as we have discussed, we are not able to collect enough data in a specific region. Third, we recognize that even for the most ideal MLS data, data quality is still a concern. Sellers would not report all of the attributes accurately in their advertisements. We tried our best to approximate the attributes and recognize the possible measurement errors. For the lands that lacked information, we take the following strategy.

First, for sales lacking important information such as location, size and price, we contacted the landowners directly. Some sales advertisements said: "… *contact us for more information if you are interested*". We tried to contact the owners and asked them questions about the missing information by email or text message. Some answered our questions and some didn't. We only kept the records of those who replied to us and eliminated the observations for plots whose owners did not share information on the land characteristics.

Second, we developed best approximations for some characteristics from the comments for cases that were not described clearly. For example, some descriptions did not provide information on the dominant land use (e.g. cropland or pasture?). In that case we first took a look at the land (if we have the spatial location) in Google Earth and observed the land use type from the satellite image. If we could not determine the land use from the images, we would overlay the plot boundaries with the boundary file from Agriculture and Agri-Food Canada Annual Crop Inventory.

Among the 633 farmlands for sale, 18 records were excluded. Three of them already have conservation easements imposed, which would reduce land prices by the value of the development right. Next, we excluded 11 lands that are primarily used for agricultural business operations such as tree farms or sold together with much equipment. We excluded those 11 observations because agriculture business generates higher income than the normal agricultural lands and the manufacturing equipment could account for a significant part of the total price. Two plots were eliminated that have gravel pits on the land, and two others were eliminated because they were located outside of the Alberta white zone.

After selection, we have 615 observations, 146 from the individual owners who published their sales information on Kijiji, and the other 469 from professional realtors. According to the comments from each land sale, we distinguish the farmland use types into 6 categories by their primary land use. Since we cannot get more details about each parcel like how many acres are used as hay, crop and building sites, we proxy these characteristics by using dummy variables with cropland as the base type. The definition of each farmland type is displayed in Table 2-1.

Table 2-1: Primary Land Use Types

Land use Type	Number of observations	Definition
Cropland	162	The land is grown by crops (canola, oat, wheat, etc.).
Pastures	185	Either the land is for hay production, grazing, grassland or pastures.
Bare	113	Most of the farmland is covered by bush and trees, or simply bare land.
Developing lot	50	The land is zoned agricultural, but is in the process of conversion to residential, industrial, recreational or commercial use.
Rural property	81	The land has good recreational amenities (e.g., very close to the lake, built with good condition houses as, or used as hobby farm).
Livestock	24	The land was used for raising high value livestock (poultry and horses specifically in our samples).
Total	615	-

4.2. Explanatory Variable

Gulling et al. (2009) indicated that typically farmland has four types of returns: agriculture production, recreational return, residential return, and option value. Therefore, we set k to be 4 in equation (2). Combing equation (2) and (4) yields

$$\ln(\text{P}) = \ln(\sum_{k=1}^{4} E(R_k)) - \ln(\text{r}) = f(\text{X}) \quad (5)$$ [5]

where P, k, R, r and X are farmland price, kth expected return, discount rate and a vector of explanatory variables.

Equation (5) allows us to include factors other than those only influencing farmland productivity and conversion option value. In other words, since k =4, X should include factors that affect all of the four components of farmland values: agricultural production value, conversion option value, residential value and recreational value.

Farmland can generate agricultural return, which is defined as the agricultural production value. Factors such as precipitation, average growing season days, soil quality and size will affect agricultural production. Favorable climate conditions would improve the productivity (Robertson, 2012) and thus increase agricultural return.

Recreational value refers to the value of recreational amenities on the farmland. For instance, farmlands located near recreational lakes can increase landowners' utility because landowners might enjoy the beautiful views beside the lake. Therefore, variables such as recreational lakes and Rural Property could affect recreational value.

Residential value measures the value of living on the farmland. For example, a farmland with a residence would be more expensive than the same farmland without a residence. The price difference is not only due to the house construction costs, but also due to the utility of living on the farmland. Therefore, variables such as the number of rooms and rural property can increase farmlands' residential value.

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[5] Note that this equation is the farmland price at the present (t=0). Equation (2) shows that $P_0 = \sum_{k=1}^{n}\sum_{i=0}^{\infty}\frac{E(R_{k(i)})}{(1+r)^i} = \sum_{k=1}^{n}\frac{E(R_k)}{r}$. So $ln\ P_0 = \ln(\sum_{k=1}^{n} E(R_k)) - \ln(r)$. Use the semi-log form of Hedonic Price Model, lnp=f(x), then $\ln(\text{P}) = \ln(\sum_{k=1}^{4} E(R_k)) - \ln(\text{r}) = f(\text{X})$

Conversion option value is the return that landowners will earn once the land is converted. Whether the land is subdivided or not, the population in the census subdivision and the distance to a metropolitan area (e.g., Edmonton) would affect the conversion possibility, and thus affect the conversion option value. For example, farmlands in the Sherwood Park area of Strathcona County are facing high conversion pressure (see the discussion in section 2) partly due to its proximity to the City of Edmonton. Farmlands that have closer urban proximity, higher population density and, better infrastructures are more easily converted to development uses.

The summary and definition of each variable are shown in Table 2-2. Each of these explanatory variables would mainly affect one of the farmland values.

Table 2-2: Summary of Explanatory Variable (N=615)

Category	**Variable**	**Definition**	**Max**	**Min**	**Mean**	**Signs**	**Source**
Option Value	Pop	Population in the census subdivision in 2011.	812201	79	21729.78	+	Statistics Canada.
	DTE (km)	Distance to Capital City (Edmonton), in km.	373.59	8.60	190.31	-	Calculated by Authors.
	Roadensi (km)	Sum length of roads in the township where the farmland is located in.	1100	0	167.11	+	Road Network Files (Statistics Canada,2011)
	DisNear (Km)	Distance to the nearest town or city (excluding Edmonton and Calgary).	82.95	0.71	19.30	-	Calculated by authors.
	Health point	Number of the health points in 10 km around the land.	20	0	4.13	+	Delivered by University of Alberta Library.
	Highway distance (km)	The minimum of the distance to highway 1, 2, and 16.	260.98	0.01	36.03	-	Calculated by authors.
	Devloping	Dummy variable, it is 1 if the land is a developing lot, otherwise it is 0.	1	0	0.08	+	Sales comments.
	Subdiv	Dummy variable, it is 1 if the land is subdivided, otherwise it's 0.	1	0	0.14	+	Sales comments.
Agricultu-ral Value	Size (acres)	The size of the parcel.	14740	1	195.78	-	Sales comments.
	SLR (CAD$)	Surface lease income per year for oil or gas.	67000	0	727.32	+	Sales comments.
	Pastures	Dummy variable, it is 1 if majority of the land is pasture, otherwise it's 0.	1	0	0.30	-/+	Sales comments.

	Bare	Dummy variable, it is 1 if the land is a vacant lot, otherwise it's 0.	1	0	0.19	-/+	Sales comments.
	Livestock	Dummy variable, it is 1 if the land is used for horses, otherwise it is 0.	1	0	0.04	+	Sales comments.
	Landclass	CLI classification of agriculture suitability.	8	0	3.27	-	Agriculture and Agri-Food Canada.
	avr_prep (mm)	4-year average annual precipitation (2010 to 2013).	747.98	318.19	453.24	+	Delivered by Alberta Government.
	avr_days	4-year average growing annual season days (2010 to 2013).	207.75	154	175.11	+	Delivered by Alberta Government.
Residential & Recreational Value	Rooms	Sum of bedrooms, bathrooms and garages.	24	0	2.60	+	Sales comments.
	Ruralproperty	Dummy variable, it is 1 if the land is a rural property, otherwise it is 0.	1	0	0.13	+	Sales comments.
	Lakearea	Dummy variable, it is 1 if the land is in 10 km of the 10 popular recreational lakes[6], otherwise it is 0.	1	0	0.12	+	Calculated by authors.
Data Source	Kijiji	Dummy variable, it is 1 if the data is from Kijiji,otherwise it is 0.	1	0	0.24	+/-	Calculated by authors.

4.3. Model

4.3.1. Model 1: Non-Spatial Hedonic Price Model

Model 1 is the semi-log form of the linear regression. We have some reasons to recommend semi-log regression. First of all, the coefficients are easy to interpret as elasticities. Second, the law of diminishing marginal returns in economic theory indicates that it is impossible for land price to be a linear function of each characteristic. For example, the increased price with one additional bedroom will decrease when the house has more and more bedrooms. Third, the semi-

[6] The ten recreational lakes are listed in: http://frugaledmontonmama.com/2014/07/top-ten-family-friendly-beaches-water-destinations-alberta/. Accessed on 15th July, 2016.

logrithmic functional form is very common and used in many studies of land values (e.g., Boxall et al., 2005; Campbell, 2014) for its superior goodness of fit.

However, there might be some econometric problems associated with using OLS regression. It is highly possible that heterogeneity exists in our model since our dataset is not well diversified in some regions. Breusch-Pagan and White tests were both conducted and the results show that heterogeneity does exist (the tests were all passed at 1% significance level). As suggested by Greene (2003), robust standard errors can be used to correct this problem. Another issue is multicollinearity. As we noticed from Table 2-2, we have around 20 explanatory variables. So it is possible that those variables are correlated with each other. We checked the correlation matrix for all these variables (coefficient matrix can be found in Appendix A) and find that the biggest correlation coefficient is between Health Points and the sum length of roads in the local township. The correlation coefficient is 0.58, which is usually regarded to indicate moderate correlation. We also calculated the variance inflation factor (VIF) to detect the multicollinearity in our data and the results are provided in table A-2 in Appendix A. The VIF for the explanatory variables are all slightly above 1, far less than the critical value of 10 (Greene, 2003). Therefore, the heterogeneity and multicollinearity are not major problems in the model and we can continue our analysis.

4.3.2. Model 2: Spatial Autocorrelation

Spatial autocorrelation is a common issue in spatial analysis. Positive spatial autocorrelation would result in an increased tendency to reject the null hypothesis when it is true (Daniel, 1987). Therefore, variables are more likely to be found significant without correction. Figure 2-2 on page 12 is the map of farmland price in our dataset. We can draw the following conclusions from Figure 2-2. First, land transactions are more active in some regions than others (e.g., active in Edmonton Calgary Corridor, Grande Prairie, Peace River, High Prairie and Lethbridge), which shows that our data might be clustered. Second, some “hot” spots and “cold” spots can be seen from the figures. An obvious pattern in the figure is that farmland around Edmonton is the most expensive in Alberta as displayed in red or orange. For the Edmonton surrounding areas, farmland price decreases with increasing distance to Edmonton (as we can see the color turns gradually from red to dark orange, yellow, light green and eventually blue).

The features discussed above suggest that there might be spatial autocorrelation in our dataset. Moran's I test was conducted to see if there is spatial autocorrelation. The null hypothesis of Moran's I test is that the data doesn't have spatial dependency. Our results show that Moran's I statistics is 0.19 and thus we passed Moran's I dependence test at 0.01 significance level. This means spatial autocorrelation does exist in our data.

The Spatial Lag Model and Spatial Error Model are commonly used to address the spatial autocorrelation problem. The Spatial Lag Model assumes that farmland price is affected by the neighborhood around the farm. The Spatial Error Model assumes the unobserved disturbances are spatially correlated. Both of these assumptions may hold in our study. For example, the price of a parcel is affected by the price of its neighboring lands. It is also possible that the factors we don't observe such as landowners' attitudes towards land sales are dependent on each other. The equations for the Spatial Lag Model and the Spatial Error Model are shown in equation (6) and (7), respectively.

Spatial lag model:

$$y = \rho w y + X\beta + \varepsilon \tag{6}$$

Spatial error model:

$$y = X\beta + z\theta \tag{7}$$

where $z = \lambda w z + \varepsilon$.

y is the farmland value, X is the vector of explanatory variables, w is the weighting matrix, ρ and λ are scalar parameters, β and θ are vector parameters, ε is a vector of independent and identically distributed disturbances. As we can see, the Spatial Lag Model uses the neighbour farmlands' price as an explanatory variable and the Spatial Error Model uses the neighbour farmlands' error term as an explanatory variable.

To estimate the function, we need to choose an appropriate weight matrix w. We have two fundamental forms of the weight matrix (Bailey et al., 1995). One is based on distance, which includes k-nearest neighbor weights, radial distance weights, power distance weights and exponential distance weights. The other one is based on boundaries, such as spatial contiguity weights, shared-boundary weights, and combined-distance boundary weights. Suppose we have n observations, our weight matrix is n by n and w_{ij} is the element of row i and column j in matrix W, we write W as

$$W = \begin{bmatrix} w_{11} & \cdots & w_{1n} \\ \vdots & \ddots & \vdots \\ w_{n1} & \cdots & w_{nn} \end{bmatrix}, \text{ where W is a symmetric matrix with } w_{ij} = w_{ji}.$$

A list of the weight matrixes is shown in Table 2-3. The distance based weight matrix is appropriate for point data while the boundary based weight matrix is good for polygons (Bailey, et al., 1995). We used radial distance weights as it fits our data better. Compared with k-nearest neighbor weights, radial distance weights and power distance weights can overcome the problem of abnormal distance. For example, some farmland sales are in remote rural areas and have sparse distribution. The closest neighbor is very far away, and thus the price of the neighboring lands cannot significantly affect the target lands.

Power distance weights are adopted in this study. A default value of α = 2 is used in the weight matrix. Radial distance weights assume that all the neighbours within the threshold distance would have the same effects. However, it is more realistic to assume that price of farmland A would be affected by all its neighbours. But the closer these neighbours are, the bigger the impacts would be. We also did a robust test using different threshold distance of Radial Distance Weights. Results are provided in Appendix A (Table A-3).

Table 2-3: Summary of Weights

Weight Matrix	Definition	Notes
k-nearest neighbor weights	$w_{ij} = \begin{cases} 1, j \in N_k(i) \\ 0, \text{otherwise} \end{cases}$	If unit j is in the k-nearest neighbor of unit I, w=1.
Radial distance weights	$w_{ij} = \begin{cases} 1, 0 \leq d_{ij} \leq d \\ 0, \quad d_{ij} > d \end{cases}$	The threshold distance is d, if unit j is within d distance of I, w=1.
Power distance weights	$w_{ij} = d_{ij}^{-\alpha}$	α can be any positive exponent, d is the distance between i and j.
Exponential distance weights	$w_{ij} = \exp(-\alpha d_{ij})$	Parameters have the same definitions as power distance weights.
Spatial contiguity weights	$w_{ij} = \begin{cases} 1, \text{if i and j share a boundary} \\ 0, \quad otherwise \end{cases}$	If the spatial units share the same boundary, w=1.

Shared-boundary weights	$w_{ij} = \frac{l_{ij}}{\sum_{k \neq i} l_{ik}}$	l_i is the length of boundary (i) that is shared with other unit j.
Combined distance-boundary weights	$w_{ij} = \frac{l_{ij} d_{ij}^{-\alpha}}{\sum_{k \neq i} l_{ik} d_{ik}^{-\alpha}}$	Parameters are the same as above.

Technically, we use robust LM test to see which model is more suitable to our data (Anselin, 2004, pp 198). The test results are shown in Table 2-4.

Table 2-4: Robust LM Tests for Spatial Dependence

	Robust LM (spatial lag)	**Robust LM (spatial error)**
LM Statistics	1.31	2.55
p-value	0.19	0.01

Table 2-4 shows that Spatial Error Model is better because it passes the robust LM test at the 1% significance level while Spatial Lag Model doesn't. As a result, we decided to choose a Spatial Error Model. Now, rewrite equation (7) into (8). Equation (8) is the function that needs to be estimated.

$$y = X\beta + (1 - \lambda w)^{-1} \varepsilon \theta \tag{8}$$

Where, w is the weight matrix, lambda (λ) is the spatial coefficient, β and θ are the coefficients to be estimated.

The results of the spatial regression, including marginal effects are provided in Table 2-5. Marginal effects are defined as how much the Y variable will increase with the increase of X. So, marginal effect in this study is the implicit price of a certain attribute.

The Marginal Effect in semilogarithmic regression is shown in equation (9) (see Coulson, 2008, chapter 2):

$$\frac{\vartheta_p}{\vartheta_{x_k}} = \beta_k p \tag{9}$$

Equation (9) can be used to calculate the marginal effects for continuous variables. p is the farmland price, x is the control variable and we used the median price of CAD$5645 / acre in the calculation of equation (9).

We also have some binary variables in the regression. For the discontinuous variables, equation (9) still works if the coefficient is very small. Halvorsen et al. (1980) argued that the interpretation of dummy variables in semilogarithmic equations depends on the value of the coefficients. If the coefficient is small, we can interpret the coefficient as the normal percentage change. If not, the relationship between the coefficient of the dummy variable(c) and the relative effect (g) is given by:

$$c = \ln(1 + g) \tag{10}$$

5. Results

Results from the Ordinary Least Squares (OLS) and Spatial Error Model (SEM) are provided in Table 2-5. Overall, the SEM has a superior goodness of fit, with R^2 of 0.63 compared to 0.61 for the OLS. The coefficient of the SEM (lambda) is also significant at the 5% level, indicating that the error term has spatial autocorrelation. As discussed above, OLS estimators with the spatial autocorrelation problem might be biased and the significance test might be misleading. This is supported by the finding that significance changes in two variables: Highway and SLR. These two variables become insignificant in the Spatial Error Model.

More specifically, the results show that all factors have the expected signs except SLR and land class. It is interesting to see a negative sign of SLR (significant at 95% level) in model 1 (OLS). This result suggests that surface lease revenue does not increase the value of farmland but instead significantly decreases it. One possible explanation is landscape damage. Disturbance on farmlands from oil or gas companies is not welcome as it might damage the productive or amenity values of the landscape. Farmers also might lose income from production around the leased area. However, the negative effect of SLR disappears in the spatial autocorrelation model. The same thing happens with Health Points whose impact changes from significant to insignificant in the Spatial Error Model. The other variable Landclass has an opposite sign to our expectation but is not significant. The insignificant impact of land quality might be due to the investment behavior on the farmland. Farmlands included in our dataset are not often purchased only for farming, but also for residence or speculation opportunities. For example, buyers might like the rolling landscape because the view is more pleasant than the view from on flat land. But rolling land is usually less suitable for agricultural production.

Variables that measure conversion option value are significant. First of all, all else equal, the price of farmlands that were subdivided is 74.94% higher than those that were not subdivided, which is a huge effect compared with the effect of the other control variables. Actually, we encountered some cases in our data in which the narrative description of a subdivided parcel emphasized the beautiful landscape view that could be used for rural residence. In other words, at least in our case, farmlands are subdivided for other development uses such as residence. Therefore, the subdivided farmlands might fetch higher prices than those that are not subdivided. Second, the closer the land is to Edmonton and major highways in Alberta, the higher the farmland value. To be more precise, price of farmland will increase by CAD$2.93 per acre if the land is one kilometer closer to Edmonton and CAD$10.67 if the land is one kilometer closer to the major highways. In addition, road density around the land also plays an important role. This is supported by the positive significant impact of Roadensi: farmland price will increase by CAD$12.08 if the road length in the corresponding township increases by 1 kilometer.

Despite the insignificance of landclass, we find other evidence that agricultural suitability affects farmland price. Both average growing season days and average precipitation have a significant positive effect. In addition, recreational value and residential value are important components of the total land value. Better recreational amenities, as measured by Lakearea, push up the farmland price. Compared with farmlands that are further away, farmlands within 10 km of the recreational lakes have a price of CAD$1429.96 / acre higher. Similarly, the implicit price of one additional bedroom in the residence is CAD$374 / acre higher.

Primary land use is important too. As we can see from Table 2-5, Livestock, Developing and Rural Property are all significantly more valuable than cropland, which may be partly due to the impact from agricultural, residential, recreational or conversion option values. For example, rural property usually has higher residential and recreational value than cropland because the property is located in a convenient open space and is built with a comfortable house. Besides, price per acre decreases as parcel size increases which is indicated by the significant negative impact of parcel size. The negative impact of size is also supported by the study from Huang et al. (2006), who found a negative relationship between parcel size and farmland value. List price of farmlands collected from Kijiji is significantly higher than those collected from Remax. Owners could ask higher on Kijiji because there is no cost to put advertisements on Kijiji. But for realtors, they have knowledge about the market and might ask close to the market price.

Table 2-5: Results of Hedonic Price Model

	OLS	**SEM**		
Variables	Coeff.($\times10^{-4}$) S.E. ($\times10^{-4}$)	Coeff.($\times10^{-4}$) S.E. ($\times10^{-4}$)	Marginal Effects	Value Impact
Size(acre)	-1.98*** (0.49)	-1.96*** (0.41)	-1.11	-ag
avr_prep(mm)	12.13* (6.46)	12.49** (5.267)	7.05	+ag
avr_days	159.30*** (41.70)	161.79*** (43.28)	91.33	+ag
subdiv	7266.47*** (1136.52)	7494.37*** (991.33)	4230.57	+option
SLR($)	-0.08** (0.04)	-0.07 (0.08)	-0.04	-ag
rooms	687.54*** (93.04)	662.53*** (94.66)	374.00	+residence
population	9.64*** (3.18)	10.50** (4.36)	5.93	+option
DTE(km)	-5.33*** (1.58)	-5.20*** (1.59)	-2.93	+option
landclass	109.31 (225.44)	77.81 (233.86)	43.92	-ag
Roadensi(km)	21.90*** (5.26)	21.40*** (4.14)	12.08	+option
DisNear(km)	-103.71***	-100.48***	-56.72	+option

	(27.00)	(26.22)		
healthpoint	135.91** (58.84)	136.19** (55.56)	76.88	+option
lakearea	2572.28** (1007.56)	2533.14*** (947.79)	1429.96	+recreation
developing	9763.80*** (1380.42)	10025.02*** (1366.83)	5659.12	+option
livestock	12070.16*** (1602.62)	12000.05*** (1645.67)	6774.03	+ag
pastures	-2341.80*** (741.23)	-2389.04*** (808.31)	-1348.61	-ag
ruralproperty	6802.67*** (1105.54)	6359.99*** (1083.36)	3590.21	+residence +recreation
Bare	-991.28 (1047.55)	-989.20 (943.73)	-558.40	-ag
Highway(km)	-16.40 (10.30)	-18.90* (10.30)	-10.67	+option
Kijiji	3037.19*** (874.22)	3220.53*** (796.77)	1817.99	/
CONSTANT	49176.11*** (7150.25)	52852.82*** (8087.48)		
Lambda	-	0.375***	-	
Adj.R^2	0.61	0.63		

6. Conclusion

This study provides both descriptive and empirical analysis of farmland values in Alberta. The descriptive overview of farmland value in Alberta suggests that farmland price varies across the province because of differences in access, urban proximity, population, agricultural rent, subdivision and climate. The empirical results show that farmland values are spatially correlated. Regarding which type of spatial dependency (error or lag), we conducted a robust LM test and found that the Spatial Error Model is better. Results from the Spatial Error Model indicate that agriculture suitability, recreational value, residential value and urban influence are the driving forces of farmland value in Alberta. Farmlands that are close to Edmonton, major highways and recreational lakes tend to be more valuable. Rural property and farmlands built with a residence also tend to have higher prices. Surprisingly, soil quality and surface lease revenue don't significantly affect farmland values.

We can draw two key implications from our results. First, our results can predict the effect of certain drivers and thus have implications for property assessment. For example, all else equal, farmland 1 km closer to Edmonton shall be valued CAD$2.93 higher. Second, interested authorities shall take actions to respond to the farmland investment behavior. Previous studies show a positive relationship between soil quality and farmland value because high quality farmland is more productive (Miranowski et al., 1984). But we didn't find any impact of soil quality on farmland values in this study. As we have already discussed, this insignificant impact is partly because farmland is also bought for residential, recreational or development uses. Smythe (2015) found that a large amount of the speculative investments in farmland have increased the challenges of building a local food system in Edmonton. Therefore, authorities are advised to take the farmland investment behavior into account when making decisions affecting land use and speculative investment.

7. References

Agriculture Profile of Rocky View County, 2004: http://www.rockyview.ca/Portals/0/Files/Business/Invest/RVC-Agriculture-Profile.pdf. Accessed on 1st July, 2016.

Agricultural Real Estate Transfer, 2014: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sdd1504. Accessed on 20th April, 2016.

Agriculture Master Plan, 2016. http://www.strathcona.ca/files/files/at-tas-agriculture-master-plan-2015.pdf. Accessed on 21st April, 2016.

Alberta Government, 2016. Municipal Census and Population List. http://www.municipalaffairs.alberta.ca/mc_official_populations. Accessed 15th July, 2016.

Anselin, L., 2004. Exploring spatial data with GeoDaTM: a workbook. *Urbana*, *51*, 61801.

Bailey, T. C., & Gatrell, A. C., 1995. *Interactive spatial data analysis* (Vol. 413). Essex: Longman Scientific & Technical.

Bartik, T. J., 1987. The estimation of demand parameters in hedonic price models. *Journal of political Economy*, *95*(1), 81-88.

Bastian, C. T., McLeod, D. M., Germino, M. J., Reiners, W. A., & Blasko, B. J., 2002. Environmental amenities and agricultural land values: a hedonic model using geographic information systems data. *Ecological Economics*,*40*(3), 337-349.

Borchers, A., Ifft, J., & Kuethe, T., 2014. Linking the price of agricultural land to use values and amenities. *American Journal of Agricultural Economics*,*96*(5), 1307-1320.

Boxall, P. C., Chan, W. H., & McMillan, M. L., 2005. The impact of oil and natural gas facilities on rural residential property values: a spatial hedonic analysis. *Resource and energy economics*, *27*(3), 248-269.

Burger, A., 2001. Agricultural development and land concentration in a central European country: a case study of Hungary. *Land Use Policy*, *18*(3), 259-268.

Campbell, B. A., 2014. Aggregate Resource Extraction: Examining Environmental Impacts on Optimal Extraction and Reclamation Strategies. (Master dissertation). Retrieved from https://era.library.ualberta.ca/downloads/cz30pt96v.

Capozza, D. R., & Helsley, R. W., 1989. The fundamentals of land prices and urban growth. *Journal of urban economics*, *26*(3), 295-306.

Chicoine, D. L., 1981. Farmland values at the urban fringe: an analysis of sale prices. *Land Economics*, *57*(3), 353-362.

Coulson, E. N., 2008. Hedonic Methods and Housing Markets, Chapter 2. Retrieved from: http://grizzly.la.psu.edu/~ecoulson/hedonicmonograph/chapter2.pdf.

County of Lethbridge, 2013. 2013-2015 Budget. Retrieved from: http://www.lethcounty.ca/home/showdocument?id=982.

Daniel, G. A., 1987. Spatial Autocorrelation: A Primer. In *Association of American Geographers*.

Dong, Z., Guan, H., & Ming, Y., 2010. "Real Estate Price Influencing Factors: An Empirical Study of China's provinces and cities based on panel data." *China University of Geosciences: Social Sciences* 10.2: 98-103.

Farm Credit Canada, 2015. Farmland Value Explained: https://www.fcc-fac.ca/fcc/about-fcc/corporate-profile/reports/ag-economist/ag-economics-farmland-values-explained-summer-2015.pdf. Accessed on 5th July, 2016.

Garrod, G., & Willis, K., 1992. The Environmental economic impact of woodland: A two-stage hedonic price model of the amenity value of forestry in Britain. *Applied economics*, *24*(7), 715-728.

Gloy, B., Boehlje, M. D., Dobbins, C. L., Hurt, C., & Baker, T. G., 2011. Are economic fundamentals driving farmland values ?. *Choices*, 26(2).

Goodman, A. C., 1978. Hedonic prices, price indices and housing markets. *Journal of Urban Economics*, *5*(4), 471-484.

Greene, W. H., 2003. *Econometric analysis*. Pearson Education India.

Guiling, P., Brorsen, B. W., & Doye, D., 2009. Effect of urban proximity on agricultural land values. *Land Economics*, *85*(2), 252-264.

Halvorsen, R., & Palmquist, R., 1980. The interpretation of dummy variables in semilogarithmic equations. *American economic review*, *70*(3), 474-75.

Haarsma, D., & Qiu, F., 2015. Assessing neighbor and population growth influences on agricultural land conversion. *Applied Spatial Analysis and Policy*, 1-21.

Huang, H., Miller, G. Y., Sherrick, B. J., & Gomez, M. I., 2006. Factors influencing Illinois farmland values. *American journal of agricultural economics*, *88*(2), 458-470.

Kline, J. D., 2005. Forest and farmland conservation effects of Oregon's (USA) land-use planning program. *Environmental Management*, *35*(4), 368-380.

Kong, F., Yin, H., & Nakagoshi, N., 2007. Using GIS and landscape metrics in the hedonic price modeling of the amenity value of urban green space: A case study in Jinan City, China. *Landscape and Urban Planning*, *79*(3), 240-252.

Legendre, P., 1993. Spatial autocorrelation: trouble or new paradigm?.*Ecology*, *74*(6), 1659-1673. Lynch, L., & Carpenter, J. (2003). Is there evidence of a critical mass in the Mid-Atlantic agriculture sector between 1949 and 1997?. *Agricultural and Resource Economics Review*, *32*(1), 116-128.

Marchildon, G. P., 2007. Institutional adaptation to drought and the special areas of Alberta, 1909–1939. In *Prairie Forum* (Vol. 32, No. 2, pp. 251-272).

Malpezzi, S., 2003. Hedonic pricing models: a selective and applied review.*Section in Housing Economics and Public Policy: Essays in Honor of Duncan Maclennan*, 67-74.

Miranowski, J. A., & Hammes, B. D., 1984. Implicit prices of soil characteristics for farmland in Iowa. *American Journal of Agricultural Economics*, *66*(5), 745-749.

Mok, H. M., Chan, P. P., & Cho, Y. S., 1995. A hedonic price model for private properties in Hong Kong. *The Journal of Real Estate Finance and Economics*, *10*(1), 37-48.

Mostafavi, S. M., Roohbakhsh, S. S., & Behname, M., 2013. Hedonic price function estimation for mobile phone in Iran. *International Journal of Economics and Financial Issues*, *3*(1), 202.

Newburn, D. A., Berck, P., & Merenlender, A. M., 2006. Habitat and open space at risk of land-use conversion: targeting strategies for land conservation. *American Journal of Agricultural Economics*, *88*(1), 28-42.

Packman, K., Weber, M., and Boxall, P.,2013. Poster presented at Canadian Agricultural Innovation and Regulation Framework: http://www.ag-innovation.usask.ca/policyconference/pdfs/2013/PDFposters/LEARN%20Poster%20Packman.pdf. Accessed on 15th June, 2016.

Palmquist, R. B., & Danielson, L. E., 1989. A hedonic study of the effects of erosion control and drainage on farmland values. *American Journal of Agricultural Economics*, *71*(1), 55-62.

Plantinga, A. J., & Miller, D. J., 2001. Agricultural land values and the value of rights to future land development. *Land Economics*, *77*(1), 56-67.

Plantinga, A. J., Lubowski, R. N., & Stavins, R. N., 2002. The effects of potential land development on agricultural land prices. *Journal of Urban Economics*, *52*(3), 561-581.

Qiu, F., Laliberté, L., Swallow, B., & Jeffrey, S., 2015. Impacts of fragmentation and neighbor influences on farmland conversion: A case study of the Edmonton-Calgary Corridor, Canada. *Land Use Policy*, *48*, 482-494.

Rashford, B. S., Bastian, C. T., & Cole, J. G., 2011. Agricultural Land-Use Change in Prairie Canada: Implications for Wetland and Waterfowl Habitat Conservation. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, *59*(2), 185-205.

Roertson, M. S., 2012. A Spatial Model of Agricultural Land Use with Climate Change for the Canadian Prairies. (Phd Thesis) Retrieved from: https://era.library.ualberta.ca/downloads/p5547s23c.

Rosen, S., 1974. Hedonic prices and implicit markets: product differentiation in pure competition. *Journal of political economy*, *82*(1), 34-55.

Ruan, X., Qiu, F., & Dyck, M., 2016. The effects of environmental and socioeconomic factors on land-use changes: a study of Alberta, Canada.*Environmental Monitoring and Assessment*, *188*(8), 1-31.

Serecon, 2014. Economic Impact of Agriculture in Lethbridge County: http://www.lethcounty.ca/home/showdocument?id=2246. Accessed on 1st July, 2016.

Serecon, 2015. Farmland Values: Bargain or Bubble: http://aaea.ualberta.ca/Portals/50/Documents/Conferences/2015/2015Visions_2_David_Weber_Farm_Land_Values.pdf?ver=2015-07-27-144801-253. Accessed on 4th July, 2016.

Shultz, S. D., & King, D. A., 2001. The use of census data for hedonic price estimates of open-space amenities and land use. *The Journal of Real Estate Finance and Economics*, *22*(2-3), 239-252.

Smythe, E. A., 2015. Local food, farmland, and urban development: A case of land grabbing North American style. *Canadian Food Studies/La Revue canadienne des études sur l'alimentation*, *2*(1), 48-74.

Statistics Canada, 2011. 2011 Census Profile: https://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/download-telecharger/comprehensive/comp-csv-tab-dwnld-tlchrgr.cfm?Lang=E#tabs2011. Accessed on 3rd July, 2016.

Statistics Canada,2013. Farm Financial Survey, Canadian and Regional Agricultural Balance Sheet: http://www5.statcan.gc.ca/cansim/pick-choisir. Accessed on 5th July,2016. Accessed on 3rd July, 2016.

Strathcona County, 2016. In *Wikipedia, The Free Encyclopedia*. https://en.wikipedia.org/w/index.php?title=Strathcona_County&oldid=723911687. Accessed on 15th July, 2016.

Strathcona Statistics and Facts, 2016: http://www.strathcona.ca/files/files/at-comc-factsandstats2016.pdf: 3-5. Accessed on 1st July, 2016.

Suparman, Y., Folmer, H., & Oud, J. H., 2014. Hedonic price models with omitted variables and measurement errors: a constrained autoregression–structural equation modeling approach with application to urban Indonesia.*Journal of Geographical Systems*, *16*(1), 49-70.

TDC in Alberta, 2016. http://www.tdc-alberta.ca/. Accessed on 28th June, 2016.

The Canadian Encyclopedia, 2015. http://www.thecanadianencyclopedia.ca/en/article/lethbridge/. Accessed on 3rd, August, 2016.

Vercammen, J. (2014). A Welfare Analysis of Conservation Easement Tax Credits.

Wang, H., 2015. "Analyzing nonmarket values of agricultural land conservation in the Alberta capital region, Canada"(Master dissertation). https://era.library.ualberta.ca/files/1r66j351v#.Vr4cqpMrLVo.Accessed on 18th July, 2016.

Wang, H., Qiu, F., & Ruan, X., 2016. Loss or gain: A spatial regression analysis of switching land conversions between agriculture and natural land.*Agriculture, Ecosystems & Environment*, *221*, 222-234.

Weersink, A., Clark, S., Turvey, C. G., & Sarker, R., 1999. The effect of agricultural policy on farmland values. *Land Economics*, 425-439.

Weisbrod, B. A., 1964. Collective-consumption services of individual-consumption goods. *The Quarterly Journal of Economics*, *78*(3), 471-477.

Wheeler, D. C., Páez, A., Spinney, J., & Waller, L. A., 2014. A Bayesian approach to hedonic price analysis. *Papers in Regional Science*, *93*(3), 663-683.

Witte, A. D., Sumka, H. J., & Erekson, H., 1979. An estimate of a structural hedonic price model of the housing market: an application of Rosen's theory of implicit markets. *Econometrica: Journal of the Econometric Society*, 1151-1173.

Yim, E. S., Lee, S., & Kim, W. G., 2014. Determinants of a restaurant average meal price: An application of the hedonic pricing model. *International Journal of Hospitality Management*, *39*, 11-20.

Young, J. E., Sánchez-Azofeifa, G. A., Hannon, S. J., & Chapman, R., 2006. Trends in land cover change and isolation of protected areas at the interface of the southern boreal mixedwood and aspen parkland in Alberta, Canada.*Forest Ecology and Management*, *230*(1), 151-161.

Chapter 3- Costs of Farmland Conservation

1. Introduction

Duke et al. (2013) explained that a large amount of funds have been devoted to farmland conservation in the United States (e.g., the U.S. Farm Bill covering 2008-2012 allocated over $15 billion to various agricultural land preservation and conservation programs) and thus why the wise use of those funds warrants study. Some scholars have argued that considering both costs and benefits of conservation would increase conservation efficiency (e.g., Ando et al., 1998; Naidoo et al., 2006; Wang, 2015; Machado et al., 2006). While Wang (2015) focused on the potential benefits of farmland conservation in the Alberta Capital Region, this study concentrates on potential costs in the Capital Region and across the agricultural zone of Alberta.

Naidoo et al. (2006) summarized five types of conservation costs for conserving lands for ecosystem services: acquisition costs, management costs, transaction costs, damage costs and opportunity costs. Conservation costs depend on how the intervention is conducted (Naidoo et al., 2006). For example, if the conservation is conducted through a payment by conservation organizations, there is an acquisition cost such as the purchase of land or development rights to land. If the conservation is done by zoning regulation, there is no acquisition cost but an opportunity cost of the foregone development values. Therefore, it is necessary to analyse farmland conservation costs under different tools. Conservation tools that are available for local municipalities in Alberta include transfer of development credits, conservation easements and zoning (Efficient Use of Land Implementation Tools Compendium, 2014). The Revolving Land Conservation is also an innovative program that is currently conducted by private land trust such as Ducks Unlimited.

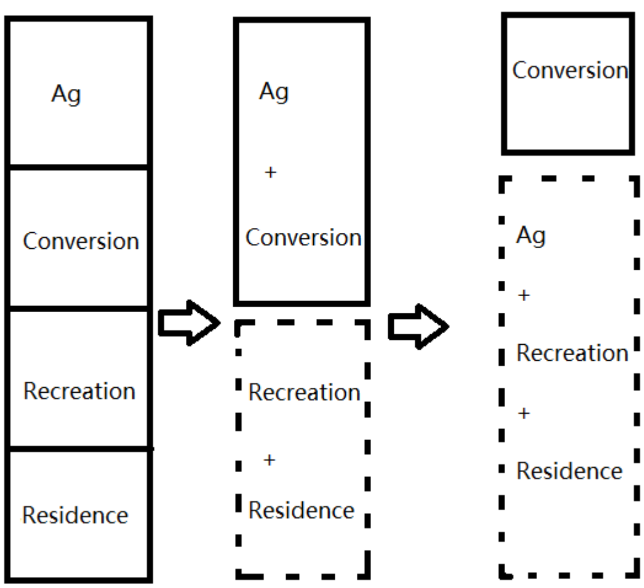
Value of development rights[7] is the difference between the fair market value of land without an easement and its value as restricted by the easement (Miller et al., 2004). Development value is likely to be the principal cost of farmland conservation (Plantinga et al., 2001). For

[7] The term, "Value of Development Rights" implies that a land owner has full rights to develop their lands and transfer those rights to others. But as suggested by the Colleen Shepherd, Executive Director of Calgary Regional Partnership, VDR might not be the best term because some lands do not have development "rights," depending on the local zoning restrictions. Value of development potential might better illustrate our idea. However, the term VDR is commonly used in the current literature. To be consistent, we will use VDR instead of value of development potential in this study.

example, consider a farm located close to a recreational lake, and built with a rural residence. If a conservation organization would like to place a conservation easement on the land to restrict its future development, landowners will only lose the conversion option value because the land can still be used for agricultural production, while its proximity to the recreational lake and rural residence are not changed. Therefore, to be more precise, the cost of farmland conservation is the option value to convert the farmlands to a developed use sometime in the future.

It is challenging to extract conversion option value only from farmland price. Empirical results from Chapter 2 show that agriculture production, residential value, recreational value and conversion option value are the four components of farmland value. To derive the conversion option value from total farmland value, we need to exclude the other three values. The first step is to decompose the farmland value into two parts: residential plus recreational value, and agriculture production plus conversion option value. Then, we remove recreational and residential values by applying the hedonic price model estimated in Chapter 2. Second, following Plantinga et al. (2001), we decompose the remaining two values into agricultural value and development value (conversion option value). Figure 3-1 illustrates this process.

Figure 3-1: Process to Derive Conversion Option Value



The objective pursued in this paper is to estimate the cost of farmland conservation in Alberta. Economic costs in conservation planning have been studied in some papers such as Duke et al. (2013), Duke et al. (2002) and Naidoo et al. (2006). One of the most relevant studies is

Plantinga et al. (2001), who empirically decomposed farmland value into agriculture value and development value using aggregated data. But as we discussed, development value and agriculture production are two of the four components of total farmland values. Since we have disaggregated plot-level data and a hedonic price model of land values, we are able to further decompose farmland values. Lawley et al. (2014) used propensity score matching to examine the effects of conservation easement on the bare land value. They found that the eased land values in the prairie areas of Canada would fall by $86 per acre. We have only three eased farmlands in our original dataset, it is not possible for us to estimate the price difference (value of development rights) by the treatment models.

The remainder of this paper is organised as follows. We review the current conservation tools and programs in Alberta in Section 2. Section 3 and 4 present theoretical foundations, data and empirical approaches. Section 5 provides the results and summarizes the main findings.

2. Costs of Farmland Conservation under Different Tools

2.1 Transfer of Development Credits (TDCs)

TDCs allow increased development in places where a community wants more growth in exchange for reduced development in place where it wants less (Pruetz et al., 2007). In Alberta, the Cypress Hills area was the first to explore Transfer of Development Credits. But the program was eventually abandoned due to the lack of knowledge and experience with TDCs (Overview of Environmental Tools Fact Sheets, 2015). Red Deer County, the Municipal District of Foothills and Strathcona County are examining the feasibility of using the tool but have not yet set up a specific program. In the Municipal District of Big Horn, the TDCs program was established in 2007 with only one landowner. But the positive results convinced the Municipal District to extend the program steadily (Greenaway, et al., 2008). The municipality is currently considering carrying out the program throughout the whole municipal district. Also, Wheatland County implemented a Subdivision Credit Area Transfer (SCAT) program in 2006 which provides landowners with the opportunity to voluntarily transfer development credits. Table 3-1 summarizes the current TDCs program in Alberta.

Table 3-1: An Overview of TDCs Programs in Alberta

Municipalities	TDCs Program Status
Cypress Hills County	Abandoned
Red Deer County	Exploring, under consideration
M.D of Foothills	Exploring, under consideration
Strathcona County	Exploring, under consideration
M.D of Big Horn	Adopted and expanding
Wheatland County	Adopted

Source: Greenaway et al. (2008).

It is challenging to create and implement a TDCs program (Greenaway et al., 2008). At the beginning of TDCs program, it is necessary to investigate program feasibility. A lot of effort is needed to explore the local land situation and involve landowners and developers. Investigation and public consultation are time consuming and costly to the local government. Second, when the program is created, the cost falls onto third parties who might want to purchase development rights. Price discovery is a challenge. How much should developers pay to obtain one unit of development credit? Actually, landowners will lose the value of development rights permanently because a conservation easement will be put on their lands right after they sell the credits. Therefore, the pricing of credits should be dependent on the value of development rights. After the credit transfer has been completed, costs related to surveillance are significant. Since the term length of a conservation easement is typically long, it is costly for the CE holders to ensure that the land remains in its agreed use. Therefore, the costs of maintenance and management after the program is implemented are also a concern.

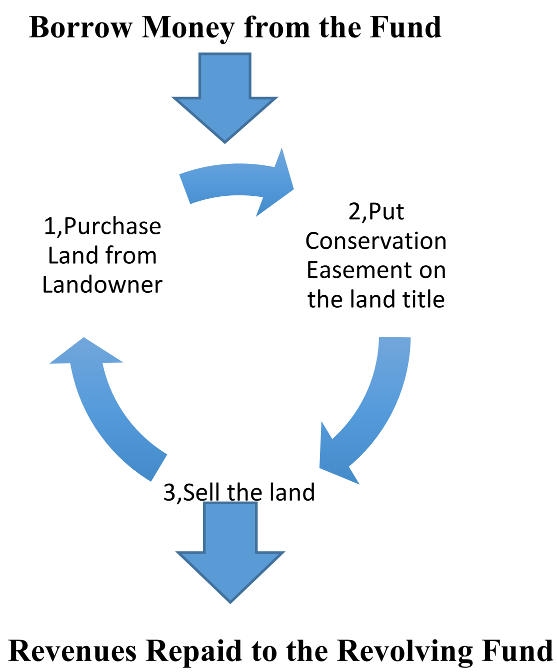
2.2 Revolving Fund

Revolving Fund finance is an alternative to traditional borrowing. Loans are lent at a below-market interest rate and the money repaid is put back into the revolving fund (Holcombe, 1992). In Canada, The Federation of Canadian Municipalities (FCM, 2016) has a revolving fund program that finances municipal infrastructure projects at a low interest rate. In the United States, the Clean

Water State Revolving Fund (CWSRF), which was created in 1987 to finance projects that improve water quality, has funded wetland conservation projects for over 30 years (State Revolving Fund and Wetlands Documents, 2015).

As far as we know, the Revolving Land Conservation Program conducted by Ducks Unlimited is the only revolving fund program that aims at land conservation in Canada (Ducks Unlimited, 2016a). The program is offered in three provinces: Alberta, Manitoba and Saskatchewan. Ducks Unlimited purchases land directly from landowners and restores the wetland and related upland habitat. A conservation easement is then put on the land title before the land is put back on the land market for sale. The revenues from the land sale are repaid to the revolving fund to help other projects on wetland conservation. The program is aimed to restore the wetland and habitat as well as safeguard the environmental functions of wetland. The process is illustrated in Figure 3-2.

Figure 3-2: Working Flow of Revolving Fund



Financial issues with revolving funds mainly arise in stage one and stage three. Before the institute purchases land directly from landowners, it needs initial capital. Therefore, the institute needs to raise money for its purchasing activities in the first stage. In the case of Ducks Unlimited, the initial capital was borrowed at a subsidized rate from ATB Financial. According to Ducks Unlimited, ATB has supported about 60 projects and 9,500 acres of wetland habitat across Alberta

(Ducks Unlimited, 2016b). In stage three, the land is sold with a conservation easement on the title. Generally speaking, the sale price in stage three is expected to be below the purchase price because the conserved land loses its development rights. The difference between the purchase price and sold price can be viewed as the value of development rights. Therefore, in addition to the cost of interest fees and administrative expenses, the conservation organization who conducts the revolving fund program also needs to cover the cost of development value.

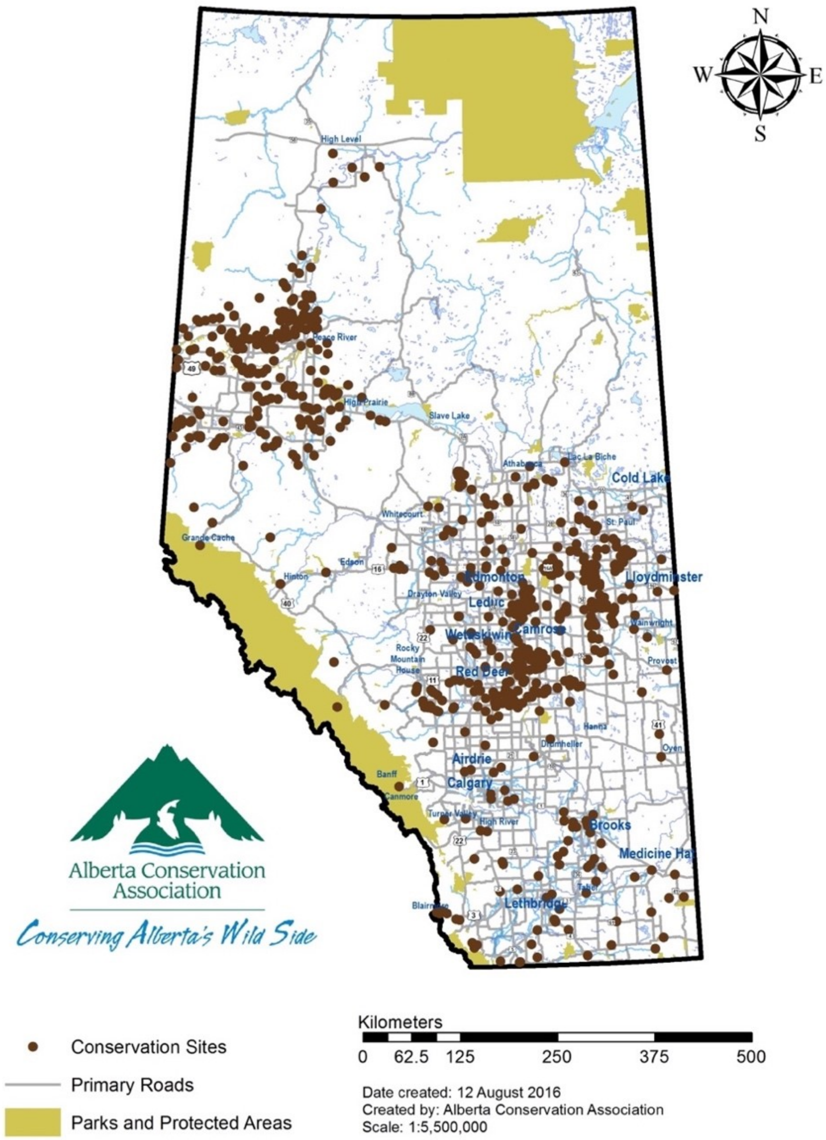
In conclusion, although Revolving Fund is created in a different way from TDCs, the logic of revolving fund is still to restrict land's development rights. Therefore, the value of development rights is the main cost of the Revolving Fund approach.

2.3 Purchase of Development Rights and Conservation Easements

Purchase of Development Rights (PDRs) is a viable approach that preserves farmlands by compensating landowners (Miller et al., 2004). In return, landowners are restricted from development on their land and a conservation easement is applied to the land title. Conservation easement is a "*device whereby a landowner gives up certain rights or opportunities in order to protect the conservation values of all or part of their land*." (Conservation Easement Alberta, 2016). Therefore, under a purchase of development rights program, the fundamental cost is the expenditure on development rights.

Although no systematic PDRs program has been done in Alberta (Alberta Government, 2016), Alberta has explored the use of agricultural conservation easements since 1996. Alberta legalized the use of conservation easements in 1996 under the Environmental Protection and Enhancement Act. In 2009, the Alberta Land Stewardship Act (ALSA) added the conservation easement as a possible conservation tool in agricultural land preservation. The eligible conservation organization or government agency may hold the conservation easements and is responsible to protect the land from other uses (usually residential, commercial and recreational uses). The holding period of CEs is theoretically permanent but is typically no less than 30 years which depends on the agreement between receivers and donors. According to Chiasson et al. (2002), there are about 1616 parcels with conservation easements on their titles in Alberta, among which 761 sites are conserved for wildlife, fish and responsible recreation (shown in Figure 3-3). Most of the conservation sites are in the east of Edmonton and Calgary Corridor and northern Alberta, while only a few conservation easements are sparsely distributed in southern Alberta.

Figure 3-3: Alberta Conservation Sites for Recreation



Source: Drawn by Roy Schmelzeisen from Alberta Conservation Association.

Compared with Transfer of Development Credits, Revolving Fund and Purchase of Development Rights, the Conservation Easement is a legal instrument that can be used to facilitate an explicit conservation program. A well designed program is necessary to protect targeted lands. The authorities are supposed to have a specific plan such as where and how many lands they want to protect, the financial budget of conservation funds, and how to wisely allocate the funding.

2.4. Zoning

Zoning in agricultural land conservation refers to restricting certain areas to be used only for certain types of agriculture (Gardner, 1977). As far as we know, strict land zoning for the purpose of agricultural land preservation has not been done in Alberta. But minimum lot size and cluster zoning have already been implemented as the policy tools in Alberta to promote efficient use of lands (Efficient Use of Land Implementation Tools, 2014).

Examples of farmland zoning in Canada include the Agricultural Land Reserve in British Columbia and the Greenbelt Boundary in Ontario (see the discussion in Chapter 1). In addition, Quebec also passed zoning laws (Bill 90) to protect agricultural lands in 1978 (Quebec Government, 1999). Similar to the zoning programs in the former two provinces, the Quebec program provided no compensation for the landowners. Farmlands are not allowed to be used for any of the development uses such as residential and commercial, nor to be subdivided. Vaillancourt et al. (1985) found that the restrictive land zoning in Quebec has decreased the price of the farmlands within the zoning area. Cost under agricultural land zoning is thus the lost development rights which are afforded by the landowners.

2.5. Summary

In this section, we discussed both market-based conservation approaches (TDCs, PDRs, and Revolving Fund) and mandatory approaches (Agricultural Land Zoning).

As noted above, market-based tools achieve conservation objectives through either compensation payments or voluntary actions. Under TDCs or PDRs, landowners receive compensation from relevant third parties for their loss of development rights. Under the Revolving Land Conservation Program (in the case of wetland preservation by Ducks Unlimited), landowners can get a full payment for their lands. It is the conservation organization that covers the cost of development value. Mandatory approaches such as Land Zoning differ from market-based approaches because the cost usually reverts to the landowners. From the perspective of government, one disadvantage of the former three tools is that they are usually voluntary and thus need direct funding to motivate owners (Pond, 2009). Although there seems to be no explicit costs associated with land zoning, as argued by Naidoo et al., (2006), opportunity cost, which refers to the loss of the revenues from future development, is the main cost of mandatory conservation interventions.

To sum up, the major cost of farmland conservation under each conservation tool falls onto the value of development rights. It is necessary to estimate the value of development rights in the province of Alberta to facilitate the exploration of any type of farmland conservation program.

3. Data and Methods

3.1. Value of Development Rights

As proposed by Capozza et al. (1989) and Plantinga et al. (2001), the compound discount present value model for agriculture return and value of development right can be written as:

$$Farmland\ Price = \int_0^t A\, e^{-rs} ds + \int_t^\infty R\, e^{-rs} ds \tag{11}$$

where t is the time when the landowners choose to convert their land from agricultural use to development use; r is the discount rate; A is the agricultural rent in time 0; R is the development revenue in time 0.

However, as already discussed in Chapter 2, farmland price also includes the residential and recreational value such as the value of the residence on the farmland. Therefore, it is necessary to exclude residential and recreational values from the original farmland price. In addition, it is reasonable to assume agricultural rent and development revenue would increase at a rate of g_1 and $g_2$respectively. We prefer a discrete discount model, not the compound discount rate because agricultural return is usually seasonal. So, we change equation (11) to (12)

$$P - RSV - RCV = \sum_{s=0}^{t} \frac{A(1+g_1)^s}{(1+r)^s} + \sum_{s=t}^{\infty} \frac{R(1+g_2)^s}{(1+r)^s} \tag{12}$$

where RSV is the residential value, RCV is the recreational value, s is the time period. In equation (12), we moved residential value and recreational value to the left hand side, leaving agriculture production and development value on the right. Suppose at time t, the landowner decides whether to develop the land or stay in agriculture. The value of development right is the difference between the price of farmland with development right (P_1) and the price of farmland without development right (P_0). If the farmland has development right, it can be converted to developed use at t. If not, the farmland can only be kept in agricultural use perpetually. We derived VDR in equation (13).

$$VDR = P_1 - P_0 = \left(\sum_{s=0}^{t} \frac{A(1+g_1)^s}{(1+r)^s} + \sum_{s=t}^{\infty} \frac{R(1+g_2)^s}{(1+r)^s}\right) - \sum_{s=0}^{\infty} \frac{A(1+g_1)^s}{(1+r)^s} \tag{13}$$

Although we don't exactly know how much the developers will pay for the landowners (R), we can get equation (14) by solving the system of equation (12) and equation (13):

$$VDR = P - RCV - RSV - \frac{A(1+g)}{r-g_1} \qquad (14)^{8}$$

However, VDR can be negative in equation (13) and (14). This means that landowners will never convert to development uses if the compensation is smaller than the agriculture rents. So, we modify equation (14) as equation (15).

$$VDR = \begin{cases} P - RCV - RSV - \frac{A(1+g)}{r-g_1} & if\ P - RCV - RSV > \frac{A(1+g)}{r-g_1} \\ 0 & if\ P - RCV - RSV \le \frac{A(1+g)}{r-g_1} \end{cases} \qquad (15)$$

Equation (15) is the equation we will use to calculate VDRs. Here, we excluded the recreational value and residential value. The farmland has a positive development value if the remained value is higher than agricultural value. Otherwise, the farmland has no development value, and VDR is 0.

3.2. A Brief Review of Interpolation Techniques

Following equation (15), we could decompose farmland value for the 615 observations. However, we are interested in predicting the value of development rights across Alberta. A central problem in geostatistics is how to estimate the key variable of interest from a limited number of sample points. In our case, the goal is to estimate the value of development rights in the non-sampled areas of Alberta. Interpolation techniques are used to fulfill our goal, which could include Kriging/Co-Kriging, Inverse Distance Weight, Local Polynomial Interpolation, and Global Polynomial Interpolation.

Kriging. Kriging, a term that honors the contributions of Daniel Krige, the pioneer of geo-statistics, generates an interpolation function from the covariance or variogram of the data.

---

[8] Equation (13) shows $VDR = P_1 - P_0 = (\sum_{s=0}^{t} \frac{A(1+g_1)^s}{(1+r)^s} + \sum_{s=t}^{\infty} \frac{R(1+g_2)^s}{(1+r)^s}) - \sum_{s=0}^{\infty} \frac{A(1+g_1)^s}{(1+r)^s}$.

Equation (12) shows $P - RSV - RCV = \sum_{s=0}^{t} \frac{A(1+g_1)^s}{(1+r)^s} + \sum_{s=t}^{\infty} \frac{R(1+g_2)^s}{(1+r)^s}$. So, $VDR = P - RCV - RSV - \sum_{s=0}^{\infty} \frac{A(1+g_1)^s}{(1+r)^s} = P - RCV - RSV - \frac{A(1+g)}{r-g_1}$. This equation holds as long as r $>g_1$. If r $<g_1$, the VDR would become infinite.

Common forms of kriging include Simple Kriging, Ordinary Kirging and Universal Kriging with different assumptions on the mean value and drift model. Table 3-2 lists the main forms of linear Kriging. Kriging interpolation is widely used in the earth sciences to predict spatial phenomena such as soil properties (e.g., Odeh et al., 1995; Hengl et al., 2004) and groundwater (e.g., Rouhani et al., 1989).

Table 3-2: Main Forms of Linear Kriging

Forms	**Mean**	**Drift Model**	**Prerequisite**
Simple Kriging	Known	None	Covariance
Ordinary Kriging	Unknown	Constant	Variogram
Universal Kriging	Unknown	Function of coordinates	Variogram

Source: Chiles and Delfiner (2012, pp148).

Inverse Distance Weighting. Inverse Distance Weighting (IDW) is more straightforward than Kriging and has no requirements for the input data (Lu and Wong, 2008). Sometimes, when data is not stationary, IDW is preferred over Kriging. The assumption of Inverse Distance Weighting simply emanates from Tobler's first law of geography: *"Everything is related to everything else, but near things are more related than distant things."* Formally, the formula for IDW is expressed in equation (16)

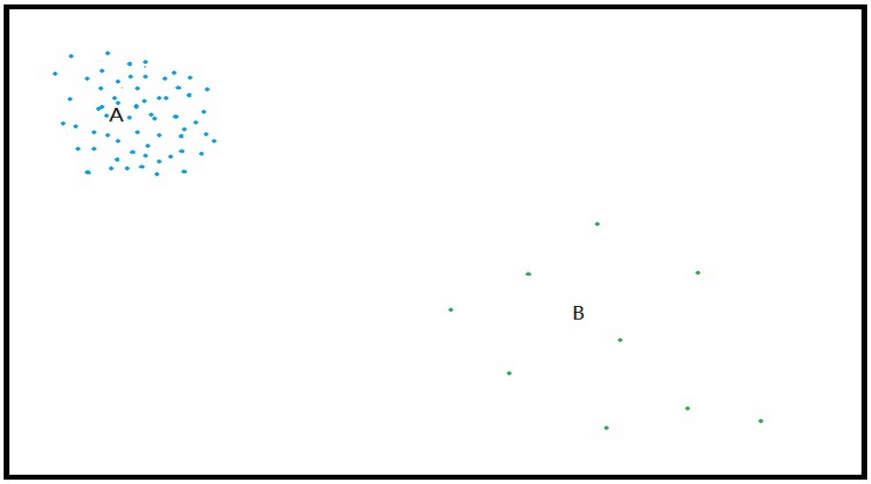
$$\hat{y}(s_0) = \sum_{i=1}^{n} \lambda_i \, y(s_i) \tag{16}$$

with $\lambda_i = d_{oi}^{-\alpha} / \sum_{i=1}^{n} d_{oi}^{-\alpha}$. $\hat{y}(s_0)$ is the prediction of the unknown value in s_0, $y(s_i)$ is the known value in location s_i, i is the neighbor of point s_0, and s_0 has a total of n neighbors. λ_i is the weight index where α is the power parameter. $d_{oi}^{-\alpha}$ is the inverse distance between point s_0 and point s_i. Here, we also have $\sum_{i=1}^{n} \lambda_i = 1$. Usually the recommended value of α is 2. When α is close to 0, $\lambda_i = 1/n$; when α is close to infinite, $\lambda_i = 0$ or 1 and $\hat{y}(s_0) = y(s_j)$, where $y(s_j)$ is the value of the closest point j (to point 0).

Although inverse Distance Weighting is a popular interpolation method and widely used by earth scientists (Ware et al., 1991), it does not provide prediction standard errors and thus is difficult to justify (Arc Map, 2016). IDW is also sensitive to cluster. As evident from equation (16), we assume a uniform estimation function with the same α over the whole area to be predicted.

However, points with different intensities should use different parameters. As shown in Figure 3-4, estimation around A needs a smaller α while estimation in B a bigger parameter. This is because points in area A have more available neighbors than those in area B.

Figure 3-4: Parameter in IDW

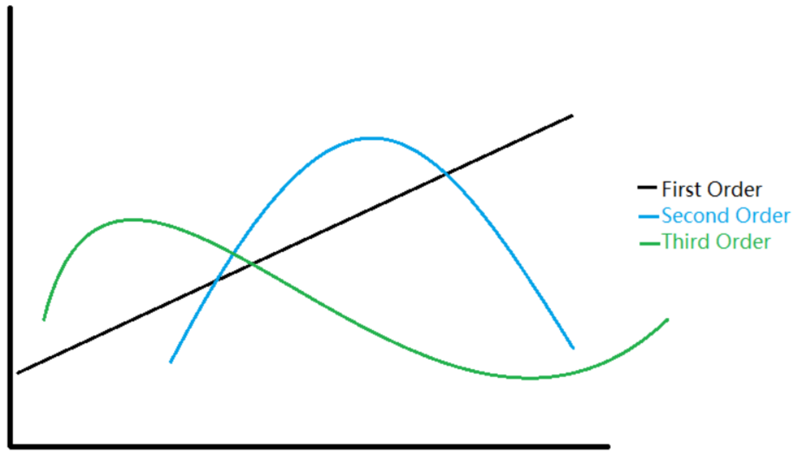


Source: Lu and Wong (2008).

Polynomial Interpolation. Two types of polynomial interpolation are commonly used in geostatistical analysis: Local Polynomial Interpolation and Global Polynomial Interpolation. They are both inexact deterministic techniques, which means that the analyst cannot assess the quality (error) of the interpolation. Local Polynomial Interpolation is similar to Global Polynomial Interpolation except that the former fits many polynomials within specified neighbours while the latter fits a polynomial to the entire surface.

First order polynomial is a linear function allowing no bend in the surface. Second order polynomial is quadratic allowing one bend in the surface. The higher the polynomial order, the higher accuracy we can achieve because more sample points are on the surface. However, when the order goes up, it becomes more complicated to explain the physical meaning of the surface. Therefore, Global Polynomial fits the situations that have a smooth varying surface and obvious global trend. For example, the pollution level varies slowly from region to region in a polluted industrial area. The pollution level is the highest in the centre of the industrial land and weakens gradually further from the centre. Figure 3-5 illustrates the idea of global polynomial interpolation.

Figure 3-5: Different Orders of Polynomial Interpolation



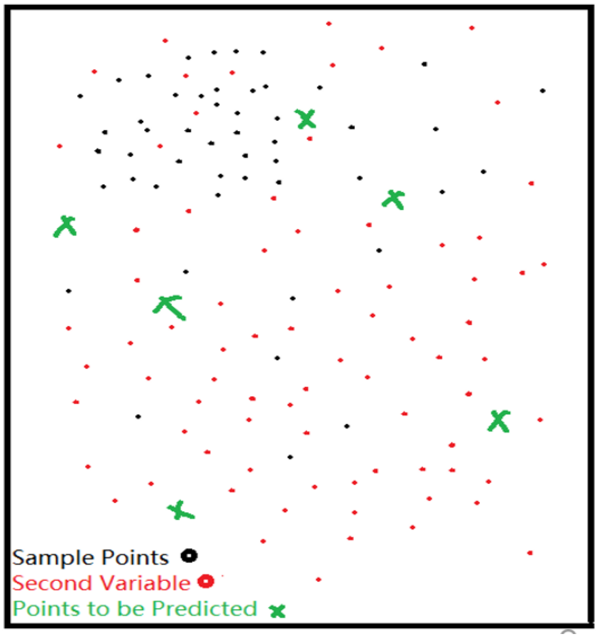
Source: Drawn by Authors.

3.3. Multivariate Interpolation: Co-Kriging

Multivariate Interpolation. So far we have been discussing univariate interpolation. Under the assumption of univariate interpolation, the only factor that affects the prediction of the variable of interest Z is the value of the sampled Z itself. It is common, however, that we have more observations on the factors that influence Z than for Z itself. As already discussed in Chapter 2, factors like distance to the nearest towns, population density, distance to major highways and road density all have significant effects on farmland price. Sometimes, we encounter the problem that the existing sample points are not evenly distributed so that there is only limited information in some locations. This might lead to large estimation errors. To overcome these problems, Bartier and Keller (1996) suggested several types of multivariate interpolation, including co-kriging and finite-difference interpolation.

Co-Kriging interpolation is a multivariate variant of Kriging that allows analysts to choose more than one variable when doing an interpolation. As it may be too expensive to get additional samples for the primary variable, a secondary variable is chosen that is easier to get and highly correlated with the primary variable. Thus, the secondary variable may provide useful information for the estimation of the variable of interest. Figure 3-6 illustrates these ideas. Available points (in black) are sparsely distributed in the bottom of the figure. The second variable (in red) is cheaper to get and is highly correlated with the primary variable. Co-Kriging takes advantage of the information from the second variable to help predict the value of the primary variable in other vacant locations (in green).

Figure 3-6: Co-Kriging Interpolation



Source: Drawn by Authors.

Uneven distribution does exist in our data set. As shown in the red circle of Figure 3-7, we have relatively fewer sample points around Calgary compared with Edmonton. If we continue using univariate interpolation, it will lead to very unrealistic results that farmlands around Calgary are not as valuable as those in the rural areas (The results from Ordinary Kriging are shown in Appendix C, Figure C-1). To address this problem and have a more realistic estimation of VDRs, we finally decided to use Co-Kriging interpolation.

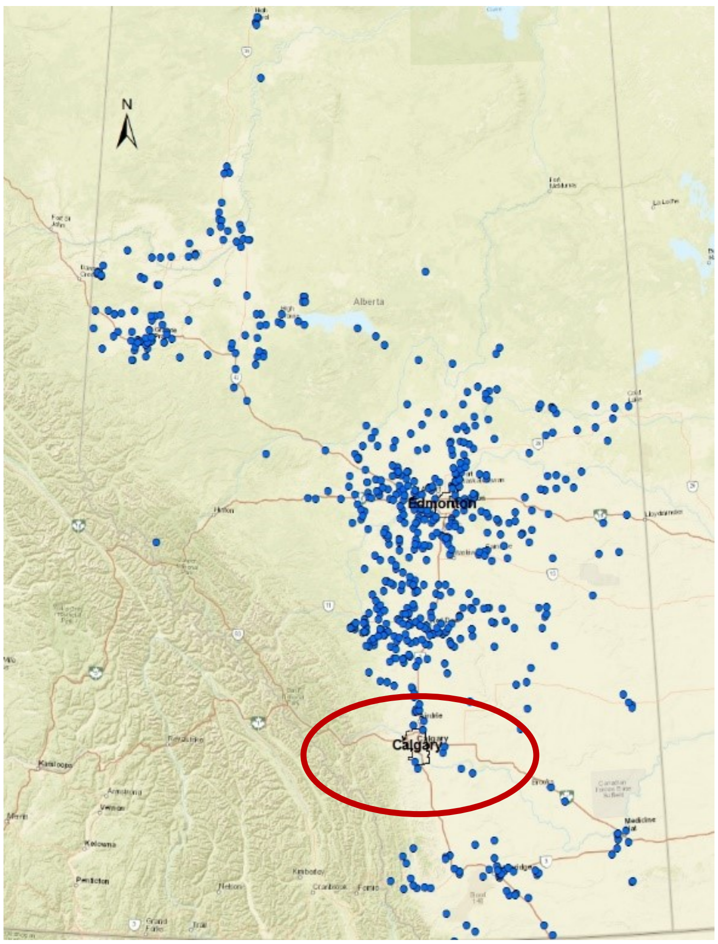
First of all, Co-Kriging has some requirements for the data. We checked our dataset to see if it meets the requirements of Co-Kriging. Stationarity in spatial interpolation means that the value of the variable of interest only depends on the relative distance between each other, not on the exact location. An Entropy Voronoi Map is employed to measure the local variation as shown in Figure C-2 in Appendix C. Orange or red color means higher local variation. If we had too many red and orange polygons, deterministic techniques (Inverse Distance Weighting or Local Polynomial) might be a better choice (ESRI, 2016[9]). In our Vonoroi Map, there is not too much

[9] ESRI Online Training. http://training.esri.com/Courses/GAInterpolate10_0/player.cfm?c=341. Accessed on 27th July, 2016.

red and orange (high local variation) areas which suggests that our data is stationary and thus suitable for Co-Kriging analysis.

We also need to ensure there is no global trend in the data and the data are normally distributed. Trend analysis is provided in Figure C-3 in Appendix C. It shows that there is no global trend in our dataset so that global polynomial doesn't fit our analysis. As discussed in Section 3.2, the global interpolation approach is suitable to data with clear trend such as chemical pollution. In terms of the normal distribution, we can use normal score transformation to transform our dataset.

Figure 3-7: Sample Distribution



Sources: Drawn by Authors

The steps to obtain a general Co-Kriging system are given below (Isaaks, 1989, p: 400-404).

First, the Co-Kriging estimation process can be stated as:

$$\hat{u}_0 = \sum_{i=1}^{n} a_i u_i + \sum_{j=1}^{m} b_j v_j \quad (17)$$

$\hat{u}_0$ is the estimation of VDRs at location 0. u_i is the primary variable at n nearby locations, and v_j is the secondary variable at m nearby locations. a_i and b_j are the co-kriging weights that we need to determine.

The estimation error is written as:

$$R = \hat{u}_0 - u_0 = \sum_{i=1}^{n} a_i u_i + \sum_{j=1}^{m} b_j v_j - u_0 \quad (18)$$

Second, the unbiasedness condition and minimal variance condition hold and we can get equation (19), (20) and (21):

$$E(\hat{u}_0) = E\left(\sum_{i=1}^{n} a_i u_i + \sum_{j=1}^{m} b_j v_j\right) = \widetilde{m_u} \sum_{i=1}^{n} a_i + \widetilde{m_v} \sum_{j=1}^{m} b_j \quad (19)$$

$$\sum_{i=1}^{n} a_i = 1 \quad (20)$$

$$\sum_{j=1}^{m} b_j = 0 \quad (21)$$

Where $\widetilde{m_u} = E(u_i)$ and $\widetilde{m_v} = E(v_j)$.

Then, to minimize the variance of the estimation errors subject to the unbiasedness condition, we can write the Lagrange function as:

$$L = Var(R) + 2u_1\left(\sum_{i=1}^{n} a_i - 1\right) + 2u_2\left(\sum_{j=1}^{m} b_j\right) \quad (22)$$ [10]

Deriving the first order conditions for optimization of equation (22):

$$\frac{\partial(Var(R))}{\partial a_i} = 2\sum_{i=1}^{n} a_i Cov(u_i, u_j) + 2\sum_{i=1}^{m} b_i Cov(v_i, u_j) - 2cov(u_0, u_j) + 2u_1 = 0, \quad for\ i = 1 \dots n \quad (23)$$

$$\frac{\partial(Var(R))}{\partial b_j} = 2\sum_{i=1}^{n} a_i Cov(u_i, v_j) + 2\sum_{i=1}^{m} b_i Cov(v_i, v_j) - 2cov(u_0, v_j) + 2u_2 = 0, \quad for\ j = 1 \dots m \quad (24)$$

To sum up, we acquire the Co-Kriging System with n+m+2 equations:

$$\sum_{i=1}^{n} a_i Cov(u_i, u_j) + \sum_{i=1}^{m} b_i Cov(v_i, u_j) + u_1 = cov(u_0, u_j), for\ i = 1 \dots n$$

$$\sum_{i=1}^{n} a_i Cov(u_i, v_j) + \sum_{i=1}^{m} b_i Cov(v_i, v_j) + u_2 = cov(u_0, v_j), for\ j = 1 \dots m$$

$$\sum_{i=1}^{n} a_i = 1$$

$$\sum_{j=1}^{m} b_j = 0$$

[10] $2u_1$and $2u_2$ are for simplification purpose in equation (23) and (24).

The system above is the general Co-Kriging system and explains the way we estimate the VDRs for the agricultural zone of Alberta. The analysis software used is ArcGis 10.0. The second variable is the road density in each township. As we can see in Appendix A, the correlation between VDRs and road density is 0.41, the second highest right after "developing lot" so that road density is a good choice for the second variable. Therefore, we generate a road density point map and create the road density dataset for the whole province automatically by using the conversion tools in ArcGis.

Then we undertake the following 2 steps to do the interpolation and generate the final map:

1, Do the Simple Co-Kriging Geostatistical analysis. We input two datasets: the original VDRs dataset and the second road density dataset. We can get a raster map for the whole province in this step.

2, Extract the value for the agricultural zone and spatially join the average VDRs for each township in the agricultural zone. The agricultural zone is not all covered by agricultural land, it also has developed land, grassland, shrub land and wetland. But since most of the agriculture land is in the agricultural zone, we don't specifically extract agricultural land.

3.4. Data

Equation (15) shows that agricultural rent (A), discount rate (r) and the growth rate of agricultural rent (g_1) are important inputs in our estimation for VDRs. Therefore, we will start by introducing agricultural rent, discount rate and growth rate.

We accessed agricultural rent data for Alberta from the Custom Rates Survey of the Government of Alberta (2005~2014).[11] The survey is available from 2005 to 2014 at the individual level and covers most of the municipalities in Alberta. The survey includes two types of farmlands: pastureland and cropland. Part of the survey table is provided in Appendix B for readers to better understand the nature of those data. However, some problems arose when we attempted to match the rent survey data with our land sales data. Below is the detailed description of the process we used for "best matching".

[11] Custom Rates Survey: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sdd12591.

First, not all of the municipalities in the land sales dataset have a corresponding rent in the survey data. For example, Special Area No.3 does not have records for cropland or pasture lease from 2005 to 2014, so we cannot match the agricultural rent to sales occurring in Special Area No.3. To deal with this problem, we approximate the rent in unavailable areas with the data from the closest available regions. Take Special Area No.3 as example, we used data from Newell County to represent the agricultural rent in Special Area No.3 because they are very close to each other. The matching records are provided in Appendix B (Table B-1).

Second, some municipalities have more than one record. Take Westlock County as example where 10 individual surveys on croplands are available in 2014. The price for these 10 observations varied from 40 dollars to 70 dollars per acre. Here we have the problem: which figure shall we use for the land sales happening in Westlock? Since the survey data also provides the soil type (e.g., brown soil; dark brown soil), we can compare soil types and use the one that has the closet soil type to the type of soil for the sales data.

Third, we categorized our samples into 6 farmland types: croplands, pastures, bare lands, developing lot, livestock and rural property. The Custom Rates Survey only has cropland rent and pasture rent. We cannot readily match the agricultural revenues of the other 4 farmland types (besides cropland and pasture) by using the survey data. Following are the steps we took to solve this problem.

1. Developing lot was zoned as agriculture and has great potential to be converted to developed uses. Cropland revenue on a comparable land is used to represent the agricultural rent of developing lot. Cropland rent is also used as the agricultural rent of rural property and livestock.

2. For bare lands, we assume that they are too hard to grow any grass or crops, and therefore we assume that agricultural rent for farmlands that are categorized as bare land is zero.

Fourth, we need to exclude residential and recreational values from the farmland price. The original price cannot be viewed as pure farmland value because it has residential and recreational values. Previously, to deal with the residence on the farmland, some researchers have excluded the samples with property (e.g., Chicoine, 1981), while other researchers have included dummy variables for the presence of improved property (e.g., Palmquist et al., 1989). To account for the improved property and recreational amenities in our dataset, we recalculate the farmlands' value by using our estimation results in chapter 2 (equation (9)). Equation (25) shows how we separate out recreational and residential values.

$$\hat{P} = P - \beta_1 \times rooms - \beta_2 \times Recreational\ Lakes - \beta_3 \times Rural\ Property \qquad (25)$$

where P is the list price of the farmland. β_1, β_2 and β_3 are the implicit price of "rooms, recreational lakes and rural property" from the hedonic price model. The new price $\hat{P}$ is the sum of agricultural value and development value ($\hat{P} = AG + VDR = P - RCV - RSV$) we will use in equation (15).

Finally, the VDRs are very sensitive to the discount rate and agricultural rent growth rate because the farmland agriculture value is calculated by $\frac{A}{r-g_1}$. Therefore, the choice of discount rate and growth rate is very important in our analysis. We base our discount rate on the 5-year mortgage rate which is one of the most popular mortgage rates in Canada. Table 3-3 lists Canada's 5-year mortgage fixed rate from 2009 to 2016. We take 5% (approximately the 8-year average rate) as the discount rate to calculate the costs of purchasing development rights. 5% is also suggested by Plantinga and Miller (2001) as a reasonable discount rate.

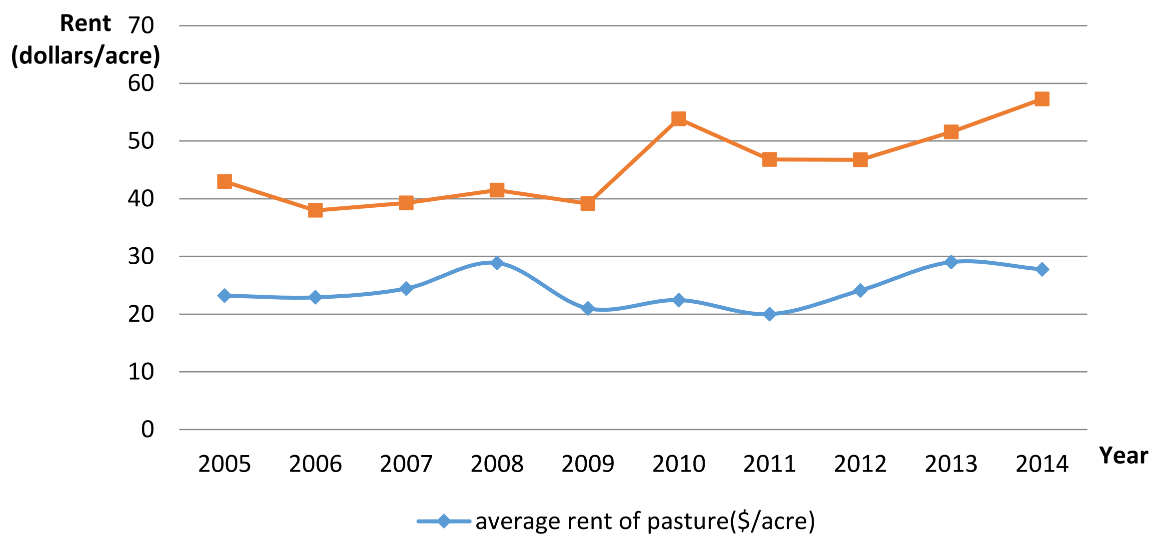
Table 3-3: 5-year Average Fixed Rate in Canada

Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Interest Rate	5.72%	5.57%	5.40%	5.27%	5.23%	4.91%	4.67%	4.64%

Data Source: Superbrokers.ca

For the agricultural rent growth rate g_1, we used the average annual growth rate of agricultural rent during 2005 to 2014 from Custom Rate Survey data. There are different rental arranges for farmland in Alberta. For cropland, there are cash rental (e.g., 30 dollars/acre) and share rental (e.g., landlord: tenant, 1/3:2/3). We only take the average of the cash rentals for each year. It turns out that the average annual growth rate of cash rental in cropland is 4.2%. For pasture, there are seasonal rental (e.g., 2000$/season), animal unit month (AUM) rental (e.g., 20$/head/month), and cash rental. We converted the seasonal rental and AUM rental into cash rental per acre by dividing the farmland size. The average annual growth rate of pasture is about 3.2% from 2005 to 2014.

Figure 3-8: Agricultural Rent in Alberta (2005-2014)



Data Source: Custom Rate Survey (2005-2014).

Following all the steps stated above, we get the value of development rights, agricultural rent, and the sum of recreational value and residential value. It is hard to separate residential and recreational values because the variable "rural property" affects both residential and recreational values. So, we report the sum of the two. A summary of the four values is provided in Table 3-4.

Table 3-4: Summary of VDRs, Agricultural Rent, Agricultural Value, Residential Value and Recreational Value (N=615)

Values	Max	Min	Mean	% of Farmland Value[12]
Value of Development Rights (CAD$/acre)	194,586	0	7752	41%
Agricultural Value (CAD$/acre)	12,500	0	3393	43%
Recreational and Residential Value (CAD$/acre)	178,231	0	4153	16%
Agricultural Rent (CAD$/acre)	125	0	34	-

[12] This is the mean percentage.

We tried to assemble a good quality dataset but recognize the limitations. One of the limitations is the list price. Usually, the list price is higher than the market price. This would lead to the overestimation of development value and underestimation of agricultural value. Results from Hedonic Price Model (Table 2-5) also show that there is a significant difference between two data sources (Kijiji and Remax). Therefore, we ought to be aware of the difference between asking and sold price. To understand the potential effects of the price difference, we did a sensitivity analysis. The results show that if the list price is 20% higher than the sold price, the mean percentage of Agricultural Value, Residential and Recreational Value, and Conversion Option Value is 47%, 15%, and 38% respectively.

4. Results

Results from Co-Kriging interpolation are displayed in Figure 3-9[13]. First, it is not surprising to see that VDRs are the highest in the capital city of Edmonton (above 30,000 dollars/acre). There is also a clear highlight along the Edmonton - Calgary Corridor. But the value of development rights decreases fast when it goes to the south east region of Alberta (Oyen) where the VDRs are around 1000 dollars per acre, the lowest of the province. The County of Vermillion River has higher VDRs relative to other surrounding municipalities such as Beaver County. The VDRs in Vermillion reaches up to 6,000 dollars per acre. Reasons behind the high value of development rights in Vermillion are: highway 16 goes through the Vermillion County making it convenient to get access to Vermillion; the county has a strong agriculture sector and energy sector (such as County Energy Park, Devonia Business Park, Kam's Industrial Park and Reinhart Industrial Park which all support the energy sector in Vermillion) (County of Vermillion River, 2016). In addition, farmlands around Cold Lake, which is located in Bonnyville County, are more valuable compared with other farmlands in the Bonnyville County. Cold Lake hosts a Canadian Forces Air Base, has a thriving energy sector, and offers recreational activities such as fishing and camping (City of Cold Lake, 2016).

[13] We did not provide the prediction for some municipalities in Figure 3-9 because of no observations in these regions. This includes Calgary Regions, Forty Mile County, Mackezie County, Special Area No.4, and Lac La Biche County.

Second, we derive a theoretical supply curve for market-based farmland conservation based on the estimated VDRs across the province. VDRs can be viewed as landowners' willingness to accept a conservation easement. We sort the farmland VDRs from the smallest to the largest, draw the VDRs on the Y axis and the accumulative farmland size on the X axis. The farmland supply curve for the province is given in Figure 3-10[14].

In total, we have around 34.6 million acres of crop lands and pastures in the white zone of Alberta[15]. Figure 3-10 shows that the price of development rights would be up to 10,000 dollars/acre if we want to protect almost all of the crop lands and pastures in the white zone of Alberta. This means, if there is a program that directly purchases development rights for all of the farmlands in Alberta, the market price for the development rights will be up to 10,000 dollars/acre and the total cost would be approximately 108 billion dollars. The total cost is calculated by integrating the shaded area in Figure 3-9 from original point to point A. We assume that the authorities will differentiate the purchase price of development rights instead of setting a uniform purchase price.

However, it would not be wise for authorities to preserve all of the current farmlands in Alberta. To be more realistic, we try to show how many hectares of farmland can be preserved under a budget of 20 million, 50 million, 100 million and 1 billion. Table 3-5 shows how many farmlands can be preserved with different budget levels.

Table 3-5: Conservation Budget and Preserved Farmlands

Budget (CAD$)	**Area of Preserved Farmland (Acres)**	**Average Price (CAD$/Acre)**
20 million	336,559	60
50 million	387,726	129
100 million	464,722	215

[14] Since the prediction for Calgary region is low, this supply curve might also be lower than the real costs.
[15] Calculated by authors according to Agriculture and Agri-Food Canada annual crop inventory data, 2013. http://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9. Accessed on 1st May, 2016.

1 billion	1,435,899	696

However, two points need to be clarified. First, the estimated cost could be higher than the real costs because we didn't consider the non-financial incentives of farmers to conserve their land in agricultural uses. At the extreme, landowners could voluntarily donate a conservation easement without financial incentives. Second, the hypothesis behind the supply curve is that the conservation program would give priority to the farmlands with the lowest VDRs. For example, given the conservation budget, the supply curve assumes that the fund will be allocated to the cheapest farmlands first until the total costs reach the budget. As a result, the conservation areas are maximized under this strategy.

Figure 3-9: Value of Development Rights across Alberta

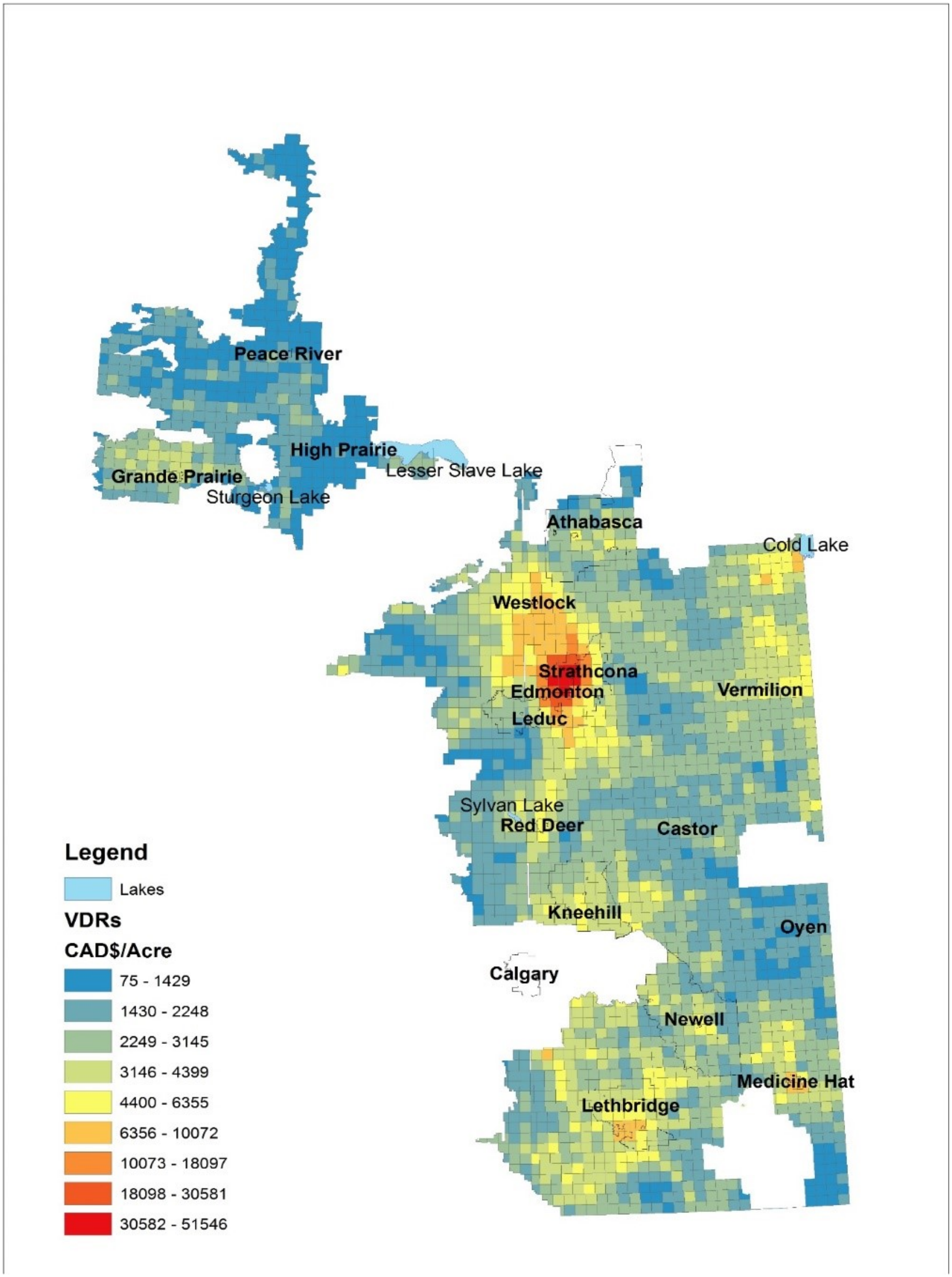
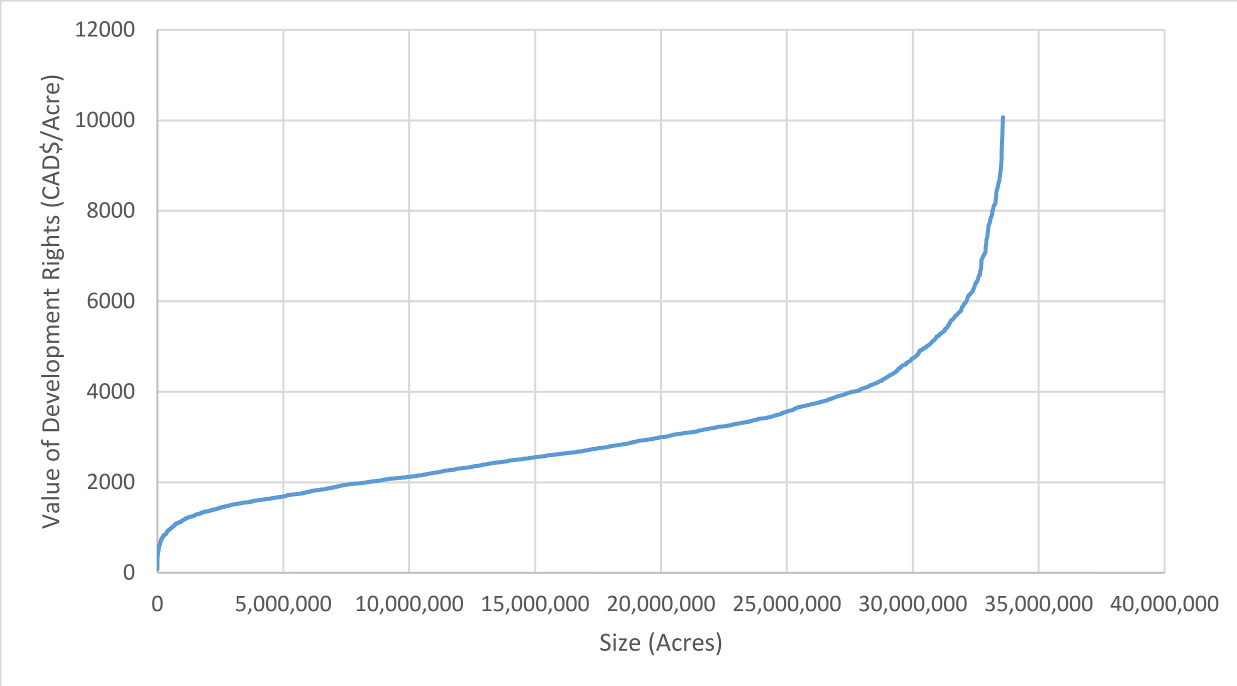


Figure 3-10: Farmland Supply Curve



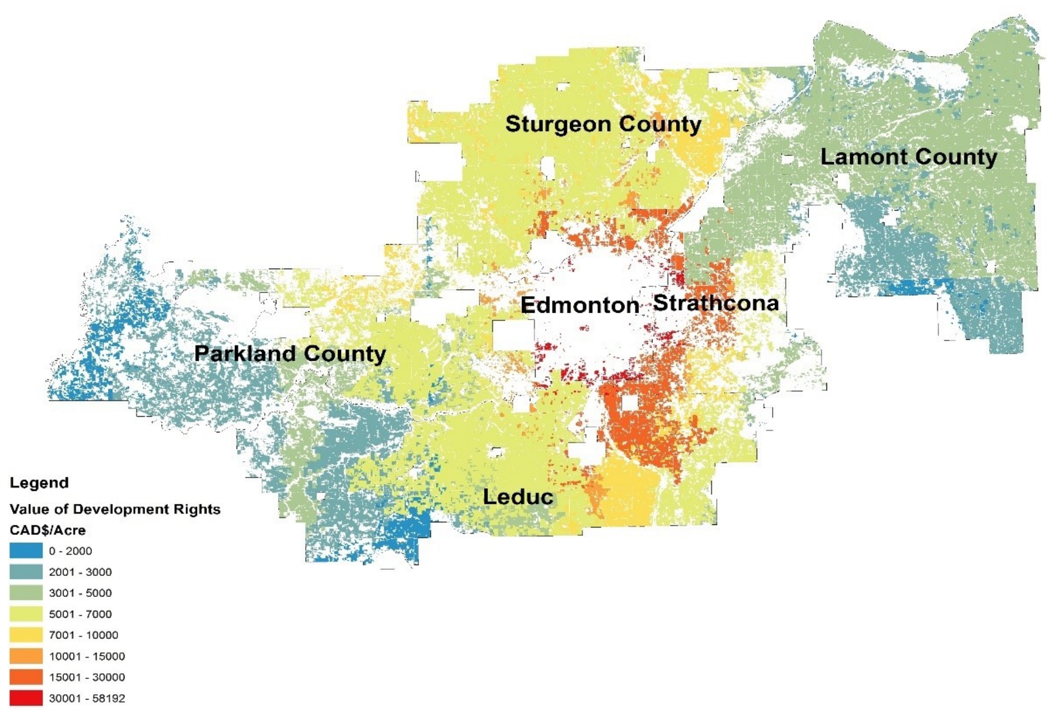
5. Implications

Implications from our results are as follows. First, our results can be used for the exploration of a farmland conservation program in the province. If the provincial government wants to create a provincial farmland conservation program in the future, our results can be used to forecast a major component of the potential costs.

Second, our results have implications for the farmland conservation strategies that could be used by local municipalities. For example, if it is unaffordable for the local government to directly purchase development rights, market-based conservation tools such as Transfer of Development Credits could be easier to adopt because the costs are transferred to developers or landowners. Strict agricultural land zoning is also affordable from the perspective of government, but should be carefully taken with due consideration of the lost development opportunities and participants' willingness. Figure 3-11 shows how our results can be applied to the Alberta Capital Region. As discussed in Chapter 1, the Modernized Municipal Government Act (currently in draft) requires collaborative Growth Management Boards in Edmonton and Calgary regions to cope with the increasing agricultural land conversion. Our estimated farmland conservation costs might provide useful information for the new boards.

Third, the results have implications for conservation priorities when we have scarce conservation funds. For example, if there was a conservation fund of 10 million dollars, how could it be efficiently allocated? Some relevant studies on conservation priority are Myers et al. (2000), Ando et al. (1998), and Newburn et al. (2006), which focus on the allocation efficiency in biodiversity conservation, and Duke et al. (2014) and Wang and Swallow (in press), which focus on the optimal selection of farmlands for conservation. According to these studies, there are three overall conservation strategies: 1), a cost targeting strategy, which is to minimize the cost so that the conserved area will be largest; 2), a benefit targeting strategy, which is to maximize the total benefits by selecting the prior payment areas; and 3) benefit-cost targeting, which is to maximize the net benefits. Our results show that if we employed a cost targeting strategy to conserve farmlands in Alberta, we can start purchasing farmlands from the one with the lowest VDRs to the one with the highest VDRs. In other words, farmland with the lowest value of development rights such as those around Oyen and Caster will be given priority when making conservation payment under a cost targeting strategy.

Figure 3-11: VDRs for Agricultural Lands in Alberta Capital Region



6. References

Alberta Government, 2016. Environmental Tools. http://aep.alberta.ca/about-us/environmental-tools-guide/for-tool-developers/overview-of-environmental-tools-fact-sheets/documents/Purchase_of_Development_Rights.pdf. Accessed on 7th July,2016.

Alberta Stewardship Act, 2009. http://www.qp.alberta.ca/1266.cfm?page=A26P8.cfm&leg_type=Acts&isbncln=9780779758579 . Accessed on 6th July,2016.

Ando, A., Camm, J., Polasky, S., & Solow, A., 1998. Species distributions, land values, and efficient conservation. *Science*, *279*(5359), 2126-2128

Arc Map, 2016. Retrieved from http://desktop.arcgis.com/en/arcmap/latest/extensions/geostatistical-analyst/how-inverse-distance-weighted-interpolation-works.htm.

Capozza, D. R., & Helsley, R. W., 1989. The fundamentals of land prices and urban growth. *Journal of urban economics*, *26*(3), 295-306.

City of Cold Lake, 2016. http://www.coldlake.com/content/recreation. Accessed on 10th July, 2016.

County of Vermillion River, 2016. http://www.vermilion-river.com/about_us.html. Accessed on 10th July,2016.

Bartier, P. M., & Keller, C. P., 1996. Multivariate interpolation to incorporate thematic surface data using inverse distance weighting (IDW). *Computers & Geosciences*, *22*(7), 795-799.

Lawley, C., & Towe, C., 2014. Capitalized costs of habitat conservation easements. *American Journal of Agricultural Economics*, *96*(3), 657-672.

Chiasson, C., Good, K., Greenaway G., & Unger J., 2012. "Conservation Easement for Agriculture in Alberta".

Chicoine, D. L., 1981. Farmland values at the urban fringe: an analysis of sale prices. *Land Economics*, *57*(3), 353-362.

Chiles, J. P., & Delfiner, P., 2009. *Geostatistics: modeling spatial uncertainty*(Vol. 497). John Wiley & Sons.

Conservation Easement in Alberta, 2016. http://www.ce-alberta.ca/question/16/. Accessed on 7th, July, 2016

Ducks Unlimited, 2016a. http://www.ducks.ca/resources/landowners/revolving-land-conservation-program/. Accessed on 20th April, 2016

Ducks Unlimited, 2016b: http://www.ducks.ca/resources/landowners/revolving-land-conservation-program/. Accessed on 7th July, 2016.

Duke, J. M., & Aull-Hyde, R., 2002. Identifying public preferences for land preservation using the analytic hierarchy process. *Ecological Economics*,*42*(1), 131-145.

Duke, J. M., Dundas, S. J., & Messer, K. D., 2013. Cost-effective conservation planning: Lessons from economics. *Journal of environmental management*, *125*, 126-133.

Efficient Use of Land Implementation Tools Compendium, 2014. https://landuse.alberta.ca/LandUse%20Documents/LUF%20EUL%20Implementation%20Tools%20Compendium%20_2014-07.pdf. Accessed on 1st July, 2016

Environmental Protection and Enhancement Act, 2000. http://www.qp.alberta.ca/documents/Acts/E12.pdf. Accessed on 6th July,2016.

Federation of Canadian Municipalities, 2016. Retrieved from http://www.fcm.ca/home/programs/partners-for-climate-protection/alternative-financing-mechanisms/revolving-funds.htm.

Greenaway G., Good K., 2008. " Transfer of Development Credits in Alberta: A Feasibility Review. " http://www.rockies.ca/project_info/TDCFeasibilityReviewMiistakis.pdf. Accessed on 3rd May.

Hengl, T., Heuvelink, G. B., & Stein, A., 2004. A generic framework for spatial prediction of soil variables based on regression-kriging. *Geoderma*,*120*(1), 75-93.

Holcombe, R. G., 1992. Revolving fund finance: The case of wastewater treatment. *Public Budgeting & Finance*, *12*(3), 50-65.

Isaaks, E. H., 1989. *Applied geostatistics* (No. 551.72 I86). Oxford University Press.

Lu, G. Y., & Wong, D. W. (2008). An adaptive inverse-distance weighting spatial interpolation technique. *Computers & Geosciences*, *34*(9), 1044-1055.

Miller G. and Krieger D.,2004. Purchase of Development Rights: Preserving Farmland and Open Space. http://plannersweb.com/2004/01/purchase-of-development-rights-preserving-farmland-and-open-space/. Assessed on May 1st, 2016.

Modernized Municipal Act, 2016.
http://www.assembly.ab.ca/ISYS/LADDAR_files/docs/bills/bill/legislature_29/session_2/20160308_bill-021.pdf. Accessed on 18th July, 2016.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J., 2000. Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772), 853-858.

Naidoo, R., Balmford, A., Ferraro, P. J., Polasky, S., Ricketts, T. H., & Rouget, M., 2006. Integrating economic costs into conservation planning. *Trends in ecology & evolution*, *21*(12), 681-687.

Machado, E. A., Stoms, D. M., Davis, F. W., & Kreitler, J., 2006. Prioritizing farmland preservation cost-effectively for multiple objectives. *Journal of soil and water conservation*, *61*(5), 250-258.

Odeh, I. O., McBratney, A. B., & Chittleborough, D. J., 1995. Further results on prediction of soil properties from terrain attributes: heterotopic cokriging and regression-kriging. *Geoderma*, *67*(3), 215-226.

Overview of Environmental Tools Fact Sheets, 2015. http://aep.alberta.ca/about-us/environmental-tools-guide/for-tool-developers/overview-of-environmental-tools-fact-sheets/documents/Transfer_of_Development_Rights.pdf. Accessed on 7th July,2016.

Palmquist, R. B., & Danielson, L. E., 1989. A hedonic study of the effects of erosion control and drainage on farmland values. *American Journal of Agricultural Economics*, *71*(1), 55-62.

Plantinga, A. J., & Miller, D. J., 2001. Agricultural land values and the value of rights to future land development. *Land Economics*, *77*(1), 56-67.

Pond, D., 2009. Ontario's Greenbelt: Growth management, farmland protection, and regime change in southern Ontario. *Canadian Public Policy*,*35*(4), 413-432.

Pruetz, R., & Pruetz, E., 2007. Transfer of development rights turns 40. *Planning & Environmental Law*, *59*(6), 3-11.

Quebec Government, 1999. The Act to Preserve Agricultural Land and Agricultural Activities ,1999. http://www.cptaq.gouv.qc.ca/fileadmin/en/publications/guides/Summary.pdf. Accessed on 19th July, 2016.

Rouhani, S., & Hall, T. J., 1989. Space-time kriging of groundwater data. In *Geostatistics* (pp. 639-650). Springer Netherlands.

State Revolving Fund and Wetlands Documents, 2015.

https://www.epa.gov/sites/production/files/2015-10/documents/2004_10_25_wetlands_state_rev_fund.pdf. Accessed on 7th July, 2016.

Vaillancourt, F., & Monty, L., 1985. The effect of agricultural zoning on land prices, Quebec, 1975-1981. *Land Economics*, *61*(1), 36-42.

Wang, H. & Swallow, B.M. (in press). "Optimizing expenditures for agricultural land conservation: spatially-explicit estimation of benefits, budgets, costs and targets." Land Use Policy.

Ware, C., Knight, W., & Wells, D., 1991. Memory intensive statistical algorithms for multibeam bathymetric data. *Computers & Geosciences*, *17*(7), 985-993.

Chapter 4 - Conclusions

1. Conclusions and Implications

This thesis aims to empirically examine the determinants of farmland values and estimate the cost of farmland conservation for the white zone of Alberta. A Spatial Hedonic Price Model is estimated to identify and quantify the influential factors of farmland values in Alberta. Our results provide further evidence that agricultural value, residential value, recreational value and development potential (option value) are principal components of total farmland value so that farmland value can be decomposed into four parts. After reviewing the existing conservation tools, we find out that value of development rights is the main cost under all ways of farmland conservation. We predict the VDRs for the white zone in the province of Alberta by utilising the Co-Kriging interpolation approach. The following are the main findings and policy implications of this thesis.

Chapter 2 provides both empirical and descriptive results of farmland value in Alberta. Our results show that development potential such as distance to the metropolitan districts, road density in the township and population in the census subdivision all play an important role in farmland value. Besides, it is noticeable that Surface Lease Revenue has an insignificant negative impact on the farmland price in the Spatial Error Model. The negative impact of Surface Lease Revenue suggests that landowners might not be receiving enough compensation for their losses from leased surface.

For agriculture suitability, soil quality is not significant and our results (Table 2-5) interestingly show that the better the soil quality is, the lower the farmland price is. Soil quality is expected to be considered by purchasers who want to continue farming the land. However, our data doesn't support this hypothesis. One possible explanation is that the farmland is not primarily purchased for farming, but for investing, so that soil quality becomes insignificant. For example, in the northeast of Edmonton, the majority of landowners are developers and land investors (such as Walton International), but not the farmers themselves (Smythe, 2015). Also, we have some observations in our data in which owners specifically ask for high prices because of the expected impending annexation by Edmonton of a section of Leduc County[16]. This phenomenon has been described as a Canadian version of "land grabbing", which is the acquisition of large amount of farmlands, re-renting the land to the farmers, and waiting for a speculation opportunity such as re-zoning and annexation approval (Smythe, 2015). Land grabbing might threaten food security and significantly change land use in the future (Margulis et al., 2013). Authorities are advised to pay attention to the farmland investment behavior in their land use planning.

In Chapter 3, we estimate the cost of farmland conservation in Alberta using Co-Kriging Interpolation. It is better to use Co-Kriging for this study instead of the conventional prediction by observable variables. This is because we are not able to collect all the necessary attributes for every parcel of farmlands in Alberta. For example, it is impossible to observe the residence on the farmlands. Attributes like the surface lease income is also reported by landowners.

Results show that Edmonton and the Edmonton-Calgary Corridor (ECC) have the highest VDRs in the province, which means they are the most expensive areas to conserve in Alberta. Meanwhile, the farmlands in the Corridor have good agriculture suitability (Appendix C, Figure C-4). Therefore, conserving farmland in the ECC areas might be characterized by high costs and high benefits at the same time. Although it might be of great interest to the public to conserve these high quality farmlands, the local government would find it expensive to directly purchase the development rights. Voluntary conservation easements, transfer of development credits and agricultural land zoning could be explored by local governments.

Additionally, we derive the supply curve of farmland conservation from our estimated VDRs (Figure 3-10). For a potential provincial conservation program, we show how much budget the authorities would need to allocate and how many farmlands could be conserved. Figure 3-10 shows that the supply curve is concave first and then convex, which means that the marginal conservation cost decelerates first and then accelerates with the increasing scale of conserved farmlands.

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[16] More details about the annexation in Leduc County can be found: http://www.leduc-county.com/local-government/annexation.

2. Limitations

This research is useful for the interested third parties such as farmland investors, farmland value assessors, policy makers and land conservation organizations. However, the results are somewhat limited by the data. As we mentioned, the price in our data is the list or asking price. Asking price is usually higher than the sales price and our assumption of the linear relationship between sold price and asking price might not be necessarily true. Second, due to the relatively small amount of farmland transaction records, we have only 615 observations for the province and very few observations especially for the Calgary region. Relatively smaller sample size causes larger estimation errors when we predicted the VDRs. We tried to solve the problem by adding the second variable (road density) using Co-Kriging. Third, we tried to approximate the attributes of the farmlands. But missing information and measurement errors still could happen.

We recognize that our conclusions might be influenced by the possible problems of endogeneity and market extent. In terms of market extent, we assumed a single land market for the rural agricultural areas of Alberta. Land Class might be an important driver of farmland price in rural areas while it is not important in urban areas. Significance of Land Class would be dependent on the market extent. However, our data don't support the analysis of a small single market as we have very limited observations. As an example of possible endogeneity, high development values or residential values may cause a landowner to apply to the local municipalities for subdivision. In Alberta, each municipality has slightly different rules and procedures regarding subdivision. As a result, endogeneity may exist in our study and induce bias. Currently, we have no better ways to solve this problem partly due to the lack of information on each observation. We do not have variables that allow us to use either the Instrumental Variable or Simultaneous Equation Model approach.

3. Future Directions

Finally, the benefits of farmland conservation in the province of Alberta need to be further explored. As argued by some scholars such as Newburn et al. (2006), Wang and Swallow (in press) and Duke et al. (2013), benefit-cost targeting strategy is more efficient in funding allocation, compared to benefit only and cost only strategy. Ando et al., (1998) also empirically proved that considering both benefits and costs is more efficient than benefits only. However, we have limited data on the benefits of conserving farmland across the province. The study by Wang and Swallow (2016) focuses on the Alberta Capital Region, but not the rest of the province. Thus we cannot use his data as the benefit of farmland conservation in Alberta. Soil quality data is available in the province level. But it is improper to use the soil quality as the benefits of farmland protection. The benefits of farmland conservation are more than the food concerns and should include the non-market values such as open space and countryside lifestyle. Therefore, in this stage, we are not able to compare the efficiency of each conservation strategy. Further study on the non-market benefits of protecting farmlands in Alberta is necessary to help design a complete conservation program.

4. References:

Ando, A., Camm, J., Polasky, S., & Solow, A., 1998. Species distributions, land values, and efficient conservation. *Science*, *279*(5359), 2126-2128.

Duke, J. M., Dundas, S. J., & Messer, K. D., 2013. Cost-effective conservation planning: Lessons from economics. *Journal of environmental management*, *125*, 126-133.

Margulis, M. E., McKeon, N., & Borras Jr, S. M., 2013. Land grabbing and global governance: critical perspectives. *Globalizations*, *10*(1), 1-23.

Newburn, D. A., Berck, P., & Merenlender, A. M., 2006. Habitat and open space at risk of land-use conversion: targeting strategies for land conservation. *American Journal of Agricultural Economics*, *88*(1), 28-42.

Smythe, E. A., 2015. Local food, farmland, and urban development: A case of land grabbing North *American style. Canadian Food Studies/La Revue canadienne des études sur l'alimentation, 2(1), 48-74.*

Wang, H. & Swallow, B.M. (in press). Optimizing expenditures for agricultural land conservation: spatially-explicit estimation of benefits, budgets, costs and targets. *Land Use Policy.*

References:

Agricultural Real Estate Transfer, 2014. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sdd1504. Accessed on 20th April, 2016.

Agriculture Land Commission, 2016. Provincial Agricultural Land Commission Annual Report 2015-2016. http://www.alc.gov.bc.ca/assets/alc/assets/library/commission-reports/annual_report_2015-2016.pdf. Accessed on July 1st,2016.

Agriculture Master Plan, 2016. http://www.strathcona.ca/files/files/at-tas-agriculture-master-plan-2015.pdf. Accessed on 21st April, 2016.

Agriculture Profile of Rocky View County, 2004: http://www.rockyview.ca/Portals/0/Files/Business/Invest/RVC-Agriculture-Profile.pdf. Accessed on 1st July, 2016.

Alberta Government, 2016. Municipal Census and Population List. http://www.municipalaffairs.alberta.ca/mc_official_populations. Accessed 15th July, 2016.

Alberta Government, 2016. Environmental Tools. http://aep.alberta.ca/about-us/environmental-tools-guide/for-tool-developers/overview-of-environmental-tools-fact-sheets/documents/Purchase_of_Development_Rights.pdf. Accessed on 7th July,2016.

Alberta Government, 2016a. http://www.alberta.ca/release.cfm?xID=4185154FA551C-A8F9-F963-537250BD1AE2EBEF. Accessed on 14th July, 2016.

Alberta Government, 2016b. http://mgareview.alberta.ca/whats-changing/plan-for-growth/. Accessed on 15th July, 2016.

Alberta Stewardship Act, 2009. http://www.qp.alberta.ca/1266.cfm?page=A26P8.cfm&leg_type=Acts&isbncln=9780779758579 . Accessed on 6th July,2016.

Ando, A., Camm, J., Polasky, S., & Solow, A., 1998. Species distributions, land values, and efficient conservation. *Science*, *279*(5359), 2126-2128

Ando, A., Camm, J., Polasky, S., & Solow, A., 1998. Species distributions, land values, and efficient conservation. *Science*, *279*(5359), 2126-2128.

Anselin, L., 2004. Exploring spatial data with GeoDaTM: a workbook. *Urbana*, *51*, 61801.

Arc Map, 2016. http://desktop.arcgis.com/en/arcmap/latest/extensions/geostatistical-analyst/how-inverse-distance-weighted-interpolation-works.htm.

Bailey, T. C., & Gatrell, A. C., 1995. *Interactive spatial data analysis* (Vol. 413). Essex: Longman Scientific & Technical.

Bartier, P. M., & Keller, C. P., 1996. Multivariate interpolation to incorporate thematic surface data using inverse distance weighting (IDW). *Computers & Geosciences*, *22*(7), 795-799.

Bartik, T. J., 1987. The estimation of demand parameters in hedonic price models. *Journal of political Economy*, *95*(1), 81-88.

Bastian, C. T., McLeod, D. M., Germino, M. J., Reiners, W. A., & Blasko, B. J., 2002. Environmental amenities and agricultural land values: a hedonic model using geographic information systems data. *Ecological Economics*,*40*(3), 337-349.

Borchers, A., Ifft, J., & Kuethe, T., 2014. Linking the price of agricultural land to use values and amenities. *American Journal of Agricultural Economics*,*96*(5), 1307-1320.

Boxall, P. C., Chan, W. H., & McMillan, M. L., 2005. The impact of oil and natural gas facilities on rural residential property values: a spatial hedonic analysis. *Resource and energy economics*, *27*(3), 248-269.

Bunce, M., 1998. Thirty years of farmland preservation in North America: discourses and ideologies of a movement. *Journal of Rural Studies*, *14*(2), 233-247.

Burger, A., 2001. Agricultural development and land concentration in a central European country: a case study of Hungary. *Land Use Policy*, *18*(3), 259-268.

Campbell, B. A., 2014. Aggregate Resource Extraction: Examining Environmental Impacts on Optimal Extraction and Reclamation Strategies. (Master dissertation). Retrieved from https://era.library.ualberta.ca/downloads/cz30pt96v.

Capital Region Board, 2016. Understanding the Land Use Framework. http://capitalregionboard.ab.ca/-/toolkit/module1-understandingthelanduseframework.pdf.

Capozza, D. R., & Helsley, R. W., 1989. The fundamentals of land prices and urban growth. *Journal of urban economics*, *26*(3), 295-306.

Chiasson, C., Good, K., Greenaway G., & Unger J., 2012. "Conservation Easement for Agriculture in Alberta".

Chicoine, D. L., 1981. Farmland values at the urban fringe: an analysis of sale prices. *Land Economics*, *57*(3), 353-362.

Chiles, J. P., & Delfiner, P., 2009. *Geostatistics: modeling spatial uncertainty*(Vol. 497). John Wiley & Sons.

City of Cold Lake, 2016. http://www.coldlake.com/content/recreation. Accessed on 10th July, 2016.

Conservation Easement for Agriculture in Alberta., 2012. https://landuse.alberta.ca/LandUse%20Documents/Conservation%20Easements%20for%20Agriculture%20in%20Alberta%20-%202012-03.pdf.

Conservation Easement in Alberta, 2016. http://www.ce-alberta.ca/question/16/. Accessed on 7th, July, 2016

Coulson, E. N., 2008. Hedonic Methods and Housing Markets, Chapter 2. Retrieved from: http://grizzly.la.psu.edu/~ecoulson/hedonicmonograph/chapter2.pdf.

County of Lethbridge, 2013. 2013-2015 Budget. Retrieved from: http://www.lethcounty.ca/home/showdocument?id=982.

County of Vermillion River, 2016. http://www.vermilion-river.com/about_us.html. Accessed on 10th July,2016.

CR-FAIR, 2012. Regional Farmland Conservation and Access Program. http://www.communitycouncil.ca/sites/default/files/CRFAIR-Farmland_Access_and_Conservation_Policy_Discussion_Paper_0.pdf. Accessed on 21st, May, 2016.

Daniel, G. A., 1987. Spatial Autocorrelation: A Primer. In *Association of American Geographers*.

Daniels, T. L., 1991. The purchase of development rights: preserving agricultural land and open space. *Journal of the American Planning Association*, *57*(4), 421-431.

Deaton, B. J., & Vyn, R. J., 2010. The effect of strict agricultural zoning on agricultural land values: The case of Ontario's greenbelt. *American Journal of Agricultural Economics*, aap022.

Dong, Z., Guan, H., & Ming, Y., 2010. "Real Estate Price Influencing Factors: An Empirical Study of China's provinces and cities based on panel data." *China University of Geosciences: Social Sciences* 10.2: 98-103.

Ducks Unlimited, 2016a. http://www.ducks.ca/resources/landowners/revolving-land-conservation-program/. Accessed on 20th April, 2016

Ducks Unlimited, 2016b: http://www.ducks.ca/resources/landowners/revolving-land-conservation-program/. Accessed on 7th July, 2016.

Duke, J. M., & Aull-Hyde, R., 2002. Identifying public preferences for land preservation using the analytic hierarchy process. *Ecological Economics*,*42*(1), 131-145.

Duke, J. M., Dundas, S. J., & Messer, K. D., 2013. Cost-effective conservation planning: Lessons from economics. *Journal of environmental management*, *125*, 126-133.

Duke, J. M., Dundas, S. J., & Messer, K. D., 2013. Cost-effective conservation planning: Lessons from economics. *Journal of environmental management*, *125*, 126-133.

Eagle, A. J., Eagle, D. E., Stobbe, T. E., & van Kooten, G. C., 2015. Farmland Protection and Agricultural Land Values at the Urban-Rural Fringe: British Columbia's Agricultural Land Reserve. *American Journal of Agricultural Economics*, *97*(1), 282-298.

Efficient Use of Land Implementation Tools Compendium, 2014. https://landuse.alberta.ca/LandUse%20Documents/LUF%20EUL%20Implementation%20Tools%20Compendium%20_2014-07.pdf. Accessed on 1st July, 2016

Environment and Climate Change Canada, 2010.

Environmental Protection and Enhancement Act, 2000. http://www.qp.alberta.ca/documents/Acts/E12.pdf. Accessed on 6th July,2016.

Farm Credit Canada, 2015. Farmland Value Explained: https://www.fcc-fac.ca/fcc/about-fcc/corporate-profile/reports/ag-economist/ag-economics-farmland-values-explained-summer-2015.pdf. Accessed on 5th July, 2016.

Federation of Canadian Municipalities, 2016. Retrieved from http://www.fcm.ca/home/programs/partners-for-climate-protection/alternative-financing-mechanisms/revolving-funds.htm.

Garrod, G., & Willis, K., 1992. The Environmental economic impact of woodland: A two-stage hedonic price model of the amenity value of forestry in Britain. *Applied economics*, *24*(7), 715-728.

Gloy, B., Boehlje, M. D., Dobbins, C. L., Hurt, C., & Baker, T. G., 2011. Are economic fundamentals driving farmland values ?. *Choices*, 26(2).

Goodman, A. C., 1978. Hedonic prices, price indices and housing markets. *Journal of Urban Economics*, *5*(4), 471-484.

Greenaway G., Good K., 2008. " Transfer of Development Credits in Alberta: A Feasibility Review. " http://www.rockies.ca/project_info/TDCFeasibilityReviewMiistakis.pdf. Accessed on 3rd May.

Greene, W. H., 2003. *Econometric analysis*. Pearson Education India.

Guiling, P., Brorsen, B. W., & Doye, D., 2009. Effect of urban proximity on agricultural land values. *Land Economics*, *85*(2), 252-264.

Guiling, P., Brorsen, B. W., & Doye, D., 2009. Effect of urban proximity on agricultural land values. *Land Economics*, *85*(2), 252-264.

Haarsma, D., & Qiu, F., 2015. Assessing neighbor and population growth influences on agricultural land conversion. *Applied Spatial Analysis and Policy*, 1-21.

Haarsma, D., 2014. "Spatial analysis of land conversion and its associated drivers in Alberta" (Master dissertation). Retrieved from: https://era.library.ualberta.ca/downloads/5138jg191.

Halvorsen, R., & Palmquist, R., 1980. The interpretation of dummy variables in semilogarithmic equations. *American economic review*, *70*(3), 474-75.

Hengl, T., Heuvelink, G. B., & Stein, A., 2004. A generic framework for spatial prediction of soil variables based on regression-kriging. *Geoderma*,*120*(1), 75-93.

Holcombe, R. G., 1992. Revolving fund finance: The case of wastewater treatment. *Public Budgeting & Finance*, *12*(3), 50-65.

Huang, H., Miller, G. Y., Sherrick, B. J., & Gomez, M. I., 2006. Factors influencing Illinois farmland values. *American journal of agricultural economics*, *88*(2), 458-470.

Isaaks, E. H., 1989. *Applied geostatistics* (No. 551.72 I86). Oxford University Press.

Kline, J. D., 2005. Forest and farmland conservation effects of Oregon's (USA) land-use planning program. *Environmental Management*, *35*(4), 368-380.

Kong, F., Yin, H., & Nakagoshi, N., 2007. Using GIS and landscape metrics in the hedonic price modeling of the amenity value of urban green space: A case study in Jinan City, China. *Landscape and Urban Planning*, *79*(3), 240-252.

Land-use Framework, 2008. https://www.landuse.alberta.ca/Documents/LUF_Land-use_Framework_Report-2008-12.pdf. Accessed on 14th July, 2016.

Lawley, C., & Towe, C., 2014. Capitalized costs of habitat conservation easements. *American Journal of Agricultural Economics*, *96*(3), 657-672.

Legendre, P., 1993. Spatial autocorrelation: trouble or new paradigm?.*Ecology*, *74*(6), 1659-1673. Lynch, L., & Carpenter, J. (2003). Is there evidence of a critical mass in the Mid-Atlantic agriculture sector between 1949 and 1997?. *Agricultural and Resource Economics Review*, *32*(1), 116-128.

Lu, G. Y., & Wong, D. W. (2008). An adaptive inverse-distance weighting spatial interpolation technique. *Computers & Geosciences*, *34*(9), 1044-1055.

Machado, E. A., Stoms, D. M., Davis, F. W., & Kreitler, J., 2006. Prioritizing farmland preservation cost-effectively for multiple objectives. *Journal of soil and water conservation*, *61*(5), 250-258.

Malpezzi, S., 2003. Hedonic pricing models: a selective and applied review.*Section in Housing Economics and Public Policy: Essays in Honor of Duncan Maclennan*, 67-74.

Marchildon, G. P., 2007. Institutional adaptation to drought and the special areas of Alberta, 1909–1939. In *Prairie Forum* (Vol. 32, No. 2, pp. 251-272).

Margulis, M. E., McKeon, N., & Borras Jr, S. M., 2013. Land grabbing and global governance: critical perspectives. *Globalizations*, *10*(1), 1-23.

Miller G. and Krieger D.,2004. Purchase of Development Rights: Preserving Farmland and Open Space. http://plannersweb.com/2004/01/purchase-of-development-rights-preserving-farmland-and-open-space/. Assessed on May 1st, 2016.

Miranowski, J. A., & Hammes, B. D., 1984. Implicit prices of soil characteristics for farmland in Iowa. *American Journal of Agricultural Economics*, *66*(5), 745-749.

Modernized Municipal Act, 2016. http://www.assembly.ab.ca/ISYS/LADDAR_files/docs/bills/bill/legislature_29/session_2/20160308_bill-021.pdf. Accessed on 18th July, 2016.

Mok, H. M., Chan, P. P., & Cho, Y. S., 1995. A hedonic price model for private properties in Hong Kong. *The Journal of Real Estate Finance and Economics*, *10*(1), 37-48.

Mostafavi, S. M., Roohbakhsh, S. S., & Behname, M., 2013. Hedonic price function estimation for mobile phone in Iran. *International Journal of Economics and Financial Issues*, *3*(1), 202.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J., 2000. Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772), 853-858.

Naidoo, R., Balmford, A., Ferraro, P. J., Polasky, S., Ricketts, T. H., & Rouget, M., 2006. Integrating economic costs into conservation planning. *Trends in ecology & evolution*, *21*(12), 681-687.

Nelson, A. C., Pruetz, R., & Woodruff, D., 2013. *The TDR handbook: Designing and implementing transfer of development rights programs*. Island Press.

Newburn, D. A., Berck, P., & Merenlender, A. M., 2006. Habitat and open space at risk of land-use conversion: targeting strategies for land conservation. *American Journal of Agricultural Economics*, *88*(1), 28-42.

Odeh, I. O., McBratney, A. B., & Chittleborough, D. J., 1995. Further results on prediction of soil properties from terrain attributes: heterotopic cokriging and regression-kriging. *Geoderma*, *67*(3), 215-226.

Overview of Environmental Tools Fact Sheets, 2015. http://aep.alberta.ca/about-us/environmental-tools-guide/for-tool-developers/overview-of-environmental-tools-fact-sheets/documents/Transfer_of_Development_Rights.pdf. Accessed on 7th July,2016.

Packman, K., Weber, M., and Boxall, P.,2013. Poster presented at Canadian Agricultural Innovation and Regulation Framework: http://www.ag-innovation.usask.ca/policyconference/pdfs/2013/PDFposters/LEARN%20Poster%20Packman.pdf. Accessed on 15th June, 2016.

Palmquist, R. B., & Danielson, L. E., 1989. A hedonic study of the effects of erosion control and drainage on farmland values. *American Journal of Agricultural Economics*, *71*(1), 55-62.

Plantinga, A. J., & Miller, D. J., 2001. Agricultural land values and the value of rights to future land development. *Land Economics*, *77*(1), 56-67.

Plantinga, A. J., Lubowski, R. N., & Stavins, R. N., 2002. The effects of potential land development on agricultural land prices. *Journal of Urban Economics*, *52*(3), 561-581.

Pond, D., 2009. Ontario's Greenbelt: Growth management, farmland protection, and regime change in southern Ontario. *Canadian Public Policy*,*35*(4), 413-432.

Pruetz, R., & Pruetz, E., 2007. Transfer of development rights turns 40. *Planning & Environmental Law*, *59*(6), 3-11.

Qiu, F., Laliberté, L., Swallow, B., & Jeffrey, S., 2015. Impacts of fragmentation and neighbor influences on farmland conversion: A case study of the Edmonton-Calgary Corridor, Canada. *Land Use Policy*, *48*, 482-494.

Quebec Government, 1999. The Act to Preserve Agricultural Land and Agricultural Activities ,1999. http://www.cptaq.gouv.qc.ca/fileadmin/en/publications/guides/Summary.pdf. Accessed on 19th July, 2016.

Rashford, B. S., Bastian, C. T., & Cole, J. G., 2011. Agricultural Land-Use Change in Prairie Canada: Implications for Wetland and Waterfowl Habitat Conservation. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, *59*(2), 185-205.

Roertson, M. S., 2012. A Spatial Model of Agricultural Land Use with Climate Change for the Canadian Prairies. (Phd Thesis) Retrieved from: https://era.library.ualberta.ca/downloads/p5547s23c.

Rosen, S., 1974. Hedonic prices and implicit markets: product differentiation in pure competition. *Journal of political economy*, *82*(1), 34-55.

Rouhani, S., & Hall, T. J., 1989. Space-time kriging of groundwater data. In *Geostatistics* (pp. 639-650). Springer Netherlands.

Ruan, X., Qiu, F., & Dyck, M., 2016. The effects of environmental and socioeconomic factors on land-use changes: a study of Alberta, Canada.*Environmental Monitoring and Assessment*, *188*(8), 1-31.

Serecon, 2014. Economic Impact of Agriculture in Lethbridge County: http://www.lethcounty.ca/home/showdocument?id=2246. Accessed on 1st July, 2016.

Serecon, 2015. Farmland Values: Bargain or Bubble: http://aaea.ualberta.ca/Portals/50/Documents/Conferences/2015/2015Visions_2_David_Weber_Farm_Land_Values.pdf?ver=2015-07-27-144801-253. Accessed on 4th July, 2016.

Shultz, S. D., & King, D. A., 2001. The use of census data for hedonic price estimates of open-space amenities and land use. *The Journal of Real Estate Finance and Economics*, *22*(2-3), 239-252.

Smythe, E. A., 2015. Local food, farmland, and urban development: A case of land grabbing North American style. *Canadian Food Studies/La Revue canadienne des études sur l'alimentation*, *2*(1), 48-74.

State Revolving Fund and Wetlands Documents, 2015. https://www.epa.gov/sites/production/files/2015-10/documents/2004_10_25_wetlands_state_rev_fund.pdf.Accessed on 7th July, 2016.

Statistics Canada, 2011. 2011 Census Profile: https://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/download-telecharger/comprehensive/comp-csv-tab-dwnld-tlchrgr.cfm?Lang=E#tabs2011. Accessed on 3rd July, 2016.

Statistics Canada, 2014. Human Activity and the Environment. http://www.statcan.gc.ca/pub/16-201-x/16-201-x2014000-eng.pdf. Accessed on 15th July, 2016.

Statistics Canada,2013. Farm Financial Survey, Canadian and Regional Agricultural Balance Sheet: http://www5.statcan.gc.ca/cansim/pick-choisir. Accessed on 5th July,2016. Accessed on 3rd July, 2016.

Strathcona County, 2016. In *Wikipedia, The Free Encyclopedia*. http://www.ec.gc.ca/pde-egp/default.asp?lang=En&n=3B7034EA-1. Accessed on July 1st, 2016. https://en.wikipedia.org/w/index.php?title=Strathcona_County&oldid=723911687. Accessed on 15th July, 2016.

Strathcona Statistics and Facts, 2016: http://www.strathcona.ca/files/files/at-comc-factsandstats2016.pdf: 3-5. Accessed on 1st July, 2016.

Suparman, Y., Folmer, H., & Oud, J. H., 2014. Hedonic price models with omitted variables and measurement errors: a constrained autoregression–structural equation modeling approach with application to urban Indonesia.*Journal of Geographical Systems*, *16*(1), 49-70.

TDC in Alberta, 2016. http://www.tdc-alberta.ca/. Accessed on 28th June, 2016.

The Canadian Encyclopedia, 2015. http://www.thecanadianencyclopedia.ca/en/article/lethbridge/. Accessed on 3rd, August, 2016.

USDA, 2016: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/. Accessed on July 1st, 2016.

Vaillancourt, F., & Monty, L., 1985. The effect of agricultural zoning on land prices, Quebec, 1975-1981. *Land Economics*, *61*(1), 36-42.

Vercammen, J. (2014). A Welfare Analysis of Conservation Easement Tax Credits.

Vyn, R. J., 2012. Examining for evidence of the leapfrog effect in the context of strict agricultural zoning. *Land Economics*, *88*(3), 457-477.

Wang, H. & Swallow, B.M. (in press). Optimizing expenditures for agricultural land conservation: spatially-explicit estimation of benefits, budgets, costs and targets. *Land Use Policy*.

Wang, H., 2015. "Analyzing nonmarket values of agricultural land conservation in the Alberta capital region, Canada"(Master dissertation). https://era.library.ualberta.ca/files/1r66j351v#.Vr4cqpMrLVo.Accessed on 18th July, 2016.

Wang, H., Qiu, F., & Ruan, X., 2016. Loss or gain: A spatial regression analysis of switching land conversions between agriculture and natural land.*Agriculture, Ecosystems & Environment*, *221*, 222-234.

Ware, C., Knight, W., & Wells, D., 1991. Memory intensive statistical algorithms for multibeam bathymetric data. *Computers & Geosciences*, *17*(7), 985-993.

Weersink, A., Clark, S., Turvey, C. G., & Sarker, R., 1999. The effect of agricultural policy on farmland values. *Land Economics*, 425-439.

Weisbrod, B. A., 1964. Collective-consumption services of individual-consumption goods. *The Quarterly Journal of Economics*, *78*(3), 471-477.

Wheeler, D. C., Páez, A., Spinney, J., & Waller, L. A., 2014. A Bayesian approach to hedonic price analysis. *Papers in Regional Science*, *93*(3), 663-683.

Witte, A. D., Sumka, H. J., & Erekson, H., 1979. An estimate of a structural hedonic price model of the housing market: an application of Rosen's theory of implicit markets. *Econometrica: Journal of the Econometric Society*, 1151-1173.

Yim, E. S., Lee, S., & Kim, W. G., 2014. Determinants of a restaurant average meal price: An application of the hedonic pricing model. *International Journal of Hospitality Management*, *39*, 11-20.

Young, J. E., Sánchez-Azofeifa, G. A., Hannon, S. J., & Chapman, R., 2006. Trends in land cover change and isolation of protected areas at the interface of the southern boreal mixedwood and aspen parkland in Alberta, Canada.*Forest Ecology and Management*, *230*(1), 151-161.

Appendix A: Correlation Coefficients Table

Table A-1:Correlation Matrix

	lnp	Size	avr_p rep	avr_d ays	subdi v	SLR	room s	popul ation	DTE	Land class
lnp	1.00									
Size	-0.18	1.00								
avr_p rep	0.05	-0.04	1.00							
avr_d ays	0.23	0.08	-0.13	1.00						
subdi v	0.39	-0.08	0.03	0.02	1.00					
SLR	-0.06	0.05	0.08	-0.03	-0.04	1.00				
room s	0.15	0.21	0.07	-0.02	-0.15	0.09	1.00			
popul ation	0.24	-0.04	-0.01	0.07	0.03	-0.03	0.05	1.00		
DTE	-0.31	0.13	0.10	-0.21	-0.05	0.07	-0.16	-0.31	1.00	
landc lass	-0.09	0.06	0.20	-0.16	-0.02	0.09	0.04	0.04	0.03	1.00
Road ensi	0.43	-0.07	-0.12	0.29	0.04	-0.03	-0.02	0.37	-0.11	-0.17
DisN ear	-0.34	0.02	0.15	-0.22	-0.05	0.04	-0.02	-0.08	0.08	0.19
healt hpoin t	0.36	-0.05	-0.09	0.19	0.08	-0.05	0.01	0.13	-0.01	-0.13

lakearea	0.10	-0.04	0.14	-0.06	-0.03	0.07	0.03	-0.04	-0.09	-0.01
developing	0.40	-0.05	-0.05	0.15	0.41	-0.04	-0.13	0.13	-0.14	-0.05
livestock	0.20	-0.04	0.03	0.04	-0.06	-0.02	0.17	-0.02	-0.01	0.01
pastures	-0.31	0.07	0.09	-0.08	-0.21	0.10	0.07	-0.04	0.11	0.05
ruralproperty	0.33	-0.08	0.03	0.03	0.14	-0.04	0.19	0.06	-0.16	0.01
vacantlot	-0.18	-0.05	-0.01	-0.09	-0.05	-0.04	-0.24	-0.02	0.00	0.10
Highway(km)	-0.26	0.02	-0.12	-0.14	-0.07	0.03	0.09	-0.13	0.31	0.20
VDR	0.74	-0.10	0.00	0.10	0.38	-0.07	-0.06	0.36	-0.24	-0.05

	Roadensi	DisNear	healthpoint	lakearea	developing	livestock	pastures	ruralproperty	vacantlot	highway	VDR
Roadensi	1.00										
DisNear	-0.41	1.00									
healthpoint	0.58	-0.50	1.00								
lakearea	-0.05	-0.04	-0.01	1.00							
developing	0.20	-0.13	0.19	0.00	1.00						
livestock	-0.02	0.01	-0.02	0.03	-0.06	1.00					

pastures	-0.14	0.03	-0.06	-0.02	-0.20	-0.13	1.00				
rural property	0.08	-0.07	0.07	0.04	-0.12	-0.08	-0.26	1.00			
vacantlot	-0.07	0.16	-0.12	0.03	-0.14	-0.10	-0.31	-0.18	1.00		
Highway(km)	-0.24	0.24	-0.08	-0.15	-0.11	0.03	0.11	-0.11	0.03	1.00	
VDR	0.41	-0.20	0.31	0.08	0.43	0.07	-0.23	0.17	-0.03	-0.20	1.00

Table A-2: VIF Table

Variable	**VIF**	**1/VIF**
Roaddensi	1.98	0.504899
Healthpoints	1.79	0.558224
pastures	1.56	0.640366
developing	1.51	0.660603
Disnear	1.51	0.662108
Bare	1.49	0.669581
Ruralproperty	1.46	0.685585
Highway	1.34	0.744573
Subdiv	1.33	0.750744
DTE	1.29	0.777918

Rooms	1.27	0.789623
Population	1.23	0.81443
Avr_gs5	1.2	0.834715
Avr_prep	1.18	0.846531
Landclass	1.16	0.862036
Livestock	1.16	0.863693
Acre	1.11	0.903403
Lakearea	1.07	0.934012
SLR	1.05	0.955646
Mean VIF	1.35	

Table A-3:Robust Test for Radial Distance Weights

	5km	10km	15km	20km	25km	30km
Variable	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)
CONSTANT	46113.42*** (9434.43)	47699.02*** (8609.67)	47939.25*** (8205.48)	48224.00*** (9670.66)	50079.13*** (10451.00)	52948.37*** (11142.72)
acre	-1.97*** (0.40)	-1.93*** (0.41)	-1.91*** (0.41)	-2.01*** (0.40)	-2.00*** (0.39)	-1.96*** (0.39)
avr_prep	12.73* (5.94)	12.11** (5.50)	12.34** (5.33)	11.95* (6.11)	11.13* (6.48)	11.22 (6.84)
avr_gs5	178.37*** (49.88)	169.87*** (45.86)	167.04*** (43.75)	168.99*** (51.34)	162.40*** (55.57)	145.92** (58.96562)
subdiv	6822.01*** (967.22)	7103.84*** (991.92)	7088.65*** (988.02)	6641.95*** (972.75)	6619.29*** (957.61)	6944.98*** (946.04)
SLR	-0.06 (0.08)	-0.08 (0.08)	-0.07 (0.08)	-0.07 (0.08)	-0.07 (0.08)	-0.07 (0.08)
rooms	719.02*** (92.23)	699.84*** (93.47)	677.24*** (93.66)	740.60*** (92.65)	730.37*** (91.81)	724.87*** (91.02)
population	8.65* (4.24)	9.03* (4.25)	9.24** (4.30)	8.0752* (4.15)	8.52** (4.14)	8.30** (4.09)
DTE	-5.27*** (1.78)	-5.63*** (1.63)	-5.43*** (1.57)	-5.14*** (1.83)	-5.24*** (1.98)	-5.06** (2.17)
landclass	98.48 (231.61)	126.19 (234.70)	67.13 (233.43)	91.96 (231.66)	110.61 (229.03)	142.87 (227.20)
Roaddensi	20.09*** (4.15)	20.71*** (4.17)	22.02*** (4.24)	19.65*** (4.10)	18.63*** (4.05)	18.94*** (4.05)
Disnear	-107.58*** (29.36)	-108.41*** (27.86)	-108.65*** (27.18)	-110.75*** (29.58)	-110.94*** (30.27)	-114.31*** (30.51)
Healthpoints	99.06* (56.13)	126.72** (57.01)	140.82** (57.22)	94.84* (55.59)	88.62 (54.54)	77.34 (54.19)
Lakearea	2420.02** (1033.67)	2640.38*** (997.55)	2604.76*** (978.14)	2324.76** (1023.25)	2254.03** (1030.45)	2288.16** (1001.85)
developing	10182.29*** (1309.52)	9664.55*** (1323.70)	9744.91*** (1333.54)	10420.68*** (1312.34)	10263.50*** (1294.30)	10088.58*** (1286.80)
livestock	11903.11*** (1618.02)	11642.62*** (1638.01)	11919.28*** (1642.04)	11869.22*** (1627.97)	11692.99*** (1610.75)	11463.39*** (1599.40)
pastures	-2137.50*** (788.58)	-2342.19*** (807.31)	-2269.62*** (805.30)	-2212.11*** (790.45)	-2228.99*** (775.44)	-2293.80*** (773.87)
ruralprope	6771.92*** (1039.64)	6657.52*** (1056.36)	6669.63*** (1057.63)	6722.05*** (1046.65)	6659.50*** (1037.07)	6497.36*** (1023.84)
bare	-408.15 (930.33)	-803.79 (949.65)	-857.61 (940.03)	-193.08 (934.96)	-218.44 (924.82)	93.31 (920.98)
Highway	-21.09* (11.83)	-17.37 (10.90)	-17.37* (10.64)	-21.02* (12.08)	-25.26* (13.22)	-29.36** (14.01)
kijiji	3159.98*** (781.03)	3200.188*** (795.13)	3159.07*** (799.79)	3092.81*** (787.55)	3058.16*** (778.40)	2977.37*** (772.23)

Appendix B: Examples of Custom Rent Survey

Figure B-1: Cropland Lease and Rental Survey 2014

CROPLAND LEASE AND RENTAL SURVEY 2014

Region	County	Soil Type	Irrigated? (Yes or No)	--Lease-- Form	Term	Years Left	-- Acres In Lease -- Crop	Hay	Pasture	Other	Total Acres Paid On	Cash ($/acre)	Crop Share	Rent Due	Notes
S	Cypress	BR	N	V	1				420		420		1/2;1/2	F	LL pays land taxes
S	Lethbridge	BR	Y	W	1	1	150				150	$150.00		S,F	LL pays land taxes and irrigation levies; T pays irrigation equipment, weed control, seeding, fertilizer and crop insurance
S	Newell Co 4	BR	Y	W	1	Open	400				400	$125.00		F	LL pays land taxes, irrigation equipment and levies; T pays weed control, seeding, fertilizer, and crop insurance
S	Newell Co 4	BR	Y	V	1	Open	130				130	$150.00		S	LL pays land taxes, irrigation equipment and levies; T pays weed control, seeding, fertilizer, and crop insurance
S	Taber MD	BR	Y	W	5	1	300			20	320	$80.00		S,F	LL pays land taxes; T pays irrigation equipment and levies, weed control, seeding, fertilizer and crop insurance
S	Willow Creek MD26	DB	N	V	1	1	320				320		1/3;2/3	O	LL pays land taxes, 1/3 weed control, 1/3 seeding, and 1/3 fertilizer; T pays 2/3 weed control, 2/3 seeding, and 2/3 fertilizer
S	Willow Creek MD26	DB	N	V	1	1	480				480		1/3;2/3	O	LL pays land taxes, 1/3 weed control, 1/3 seeding, and 1/3 fertilizer; T pays 2/3 weed control, 2/3 seeding, and 2/3 fertilizer
C	City of Calgary	DB	N	V	1		773				773		1/2;1/2	F	LL pays land taxes, 1/2 weed control, 1/2 seeding, 1/2 fertilizer and 1/2 crop insurance; T pays 1/2 weed control, 1/2 seeding, 1/2 fertilizer and 1/2 crop insurance

LEGEND: Region: S-South C-Central NE-North East NW-North West P-Peace Soil Type: BR-Brown DB-Dark Brown TB-Thin Black BL-Black GW-Grey Wooded Y-Yes N-No
Lease Form: W-Written V-Verbal LT-Long Term Crop Share: bu - bushel Rent Due: S-Spring F-Fall O-Other Notes: LL-Landlord T-Tenant

Figure B-2: Pastureland Lease and Rental Survey 2014

PASTURELAND LEASE AND RENTAL SURVEY 2014

Region	County	Soil Type	--Lease-- Form	--Lease-- Years	Lease Years Left	Native Grass	Cultivated Tame	Native Grass with Weed & Brush Control	Wetland -Bush	Cows with Calves	Dry Cows & Yearlings	Other	Total Payment	No. of Acres Paid On	Months Grazed	Land Owner	Notes
S	Cypress	BR	V	1		420				42	2	2 bulls	$30.00/aum bulls, $1.00/aum cow/calf		5.5	PR	LL for new fencing
S	Wheatland	DB	W	3	2		290						$30.00/aum		6	PR	LL pays land taxes and new fencing; T pays fence repairs
C	Clearwater	GW	W	10						128			$165.00/season		3	CR	T pays land taxes, weed control, seeding, re-seeding, fertilizer and fence repairs
C	Clearwater	GW	V									60	$2,000/season		4	PR	LL pays land taxes; T pays weed control, seeding, re-seeding, fertilizer, and fence repairs
C	Clearwater	GW	V	3	3		350	50	400	89		4 bulls	$20.00/aum		5	PR	LL pays land taxes, weed control, seeding, re-seeding, fertilizer, 1/2 new fencing and 1/2 fence repairs; T pays 1/2 new fencing and 1/2 fence repairs
C	Clearwater	GW	W	10	7	10			190	11			$200.00/season		2	CR	T pays land taxes, weed control, seeding, fertilizer, new fencing and fence repairs
C	Clearwater	BL	V	5	1	40	280				170		$21.00/aum		3.5	PR	LL pays land taxes, seeding and new fencing; T pays weed control and fence repairs

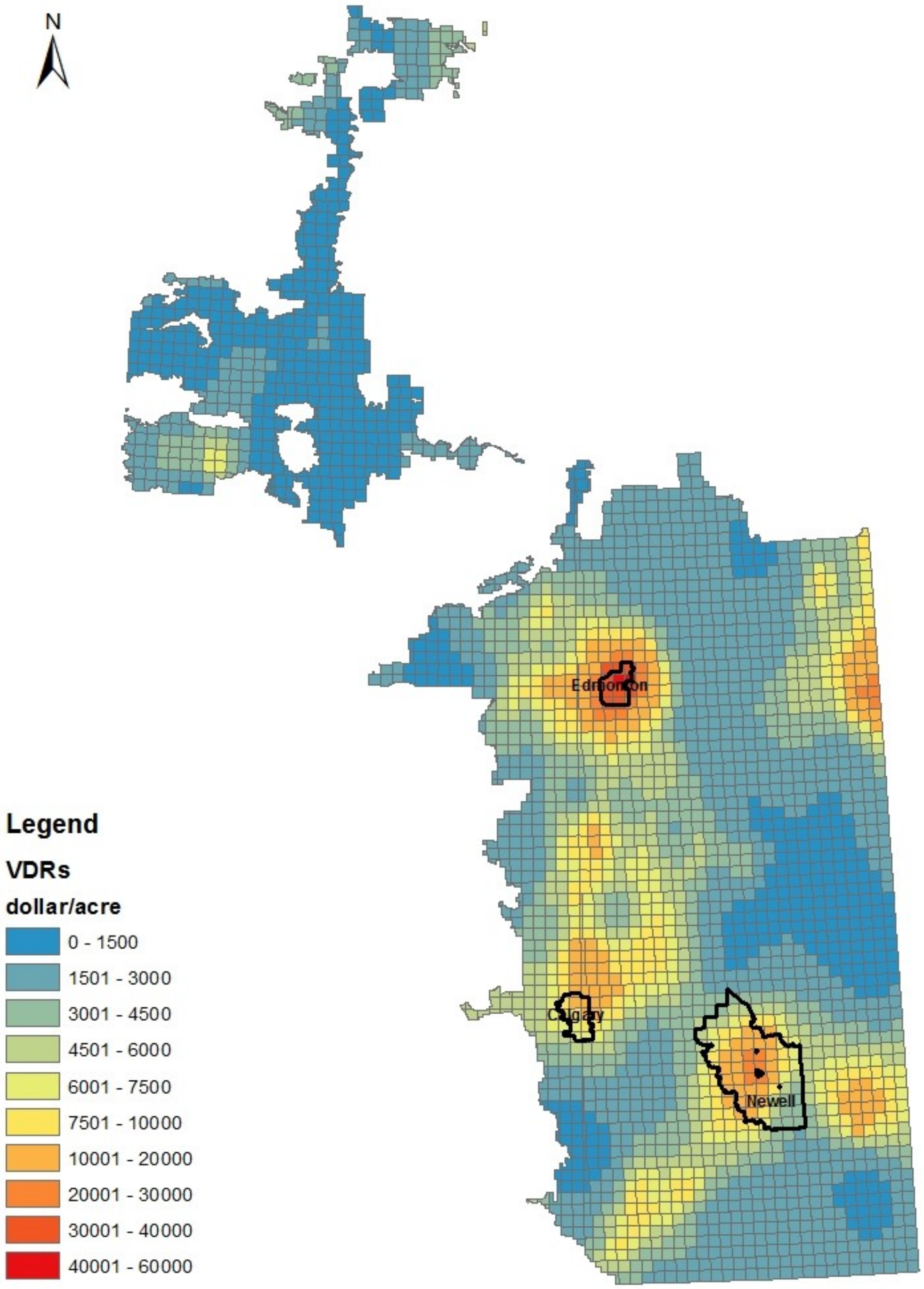
LEGEND: Region: S-South C-Central NE-North East NW-North West P-Peace Soil Type: BR-Brown DB-Dark Brown TB-Thin Black BL-Black GW-Grey Wooded Lease Form: W-Written V-Verbal LT-Long Term Total Payment: aum-animal unit month (one cow-calf pair for one month) Land Owner: PR-Private CP-Community Pasture CR-Crown land Notes: LL-Landlord T-Tenant lb(s)-pound(s)

Table B-1: Matching Records for Missing Municipalities

Matching Municipalities	**Missing Municipalities**	**Matching Municipalities**	**Missing Municipalities**
Big Lakes	Lesser Slave Lake	Saddle Hills	Spirit River
Northlights	Mackenzie County	Kneehill	Starland
Peace River	Northern Sunrise	Lethbridge	Taber
Willow Creek	Rachland	Minburn	Two Hills
Grande Prairie	Smoky River	Yellowhead	Woodlands
Newell	Special Area No. 2 (3)	Thorhild	Smoky Lake

Appendix C: Interpolation

Figure C-1: VDRs Estimation in Alberta by Univariate Interpolation



The pattern in this figure is problematic because it shows that farmland in Calgary is cheaper than the lands in the north of Calgary. It is also cheaper than the farmland in Newell. The unrealistic result is probably due to insufficient data points around Calgary.

Figure C-2: Entropy Voronoi Map

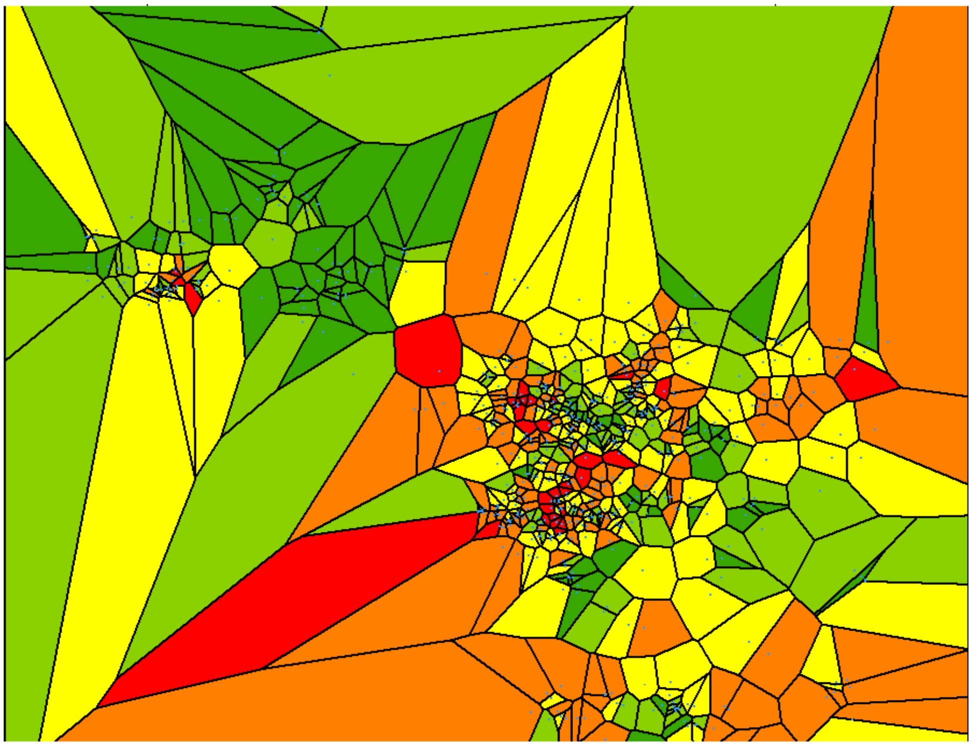


Figure C-3: Global Trend Analysis

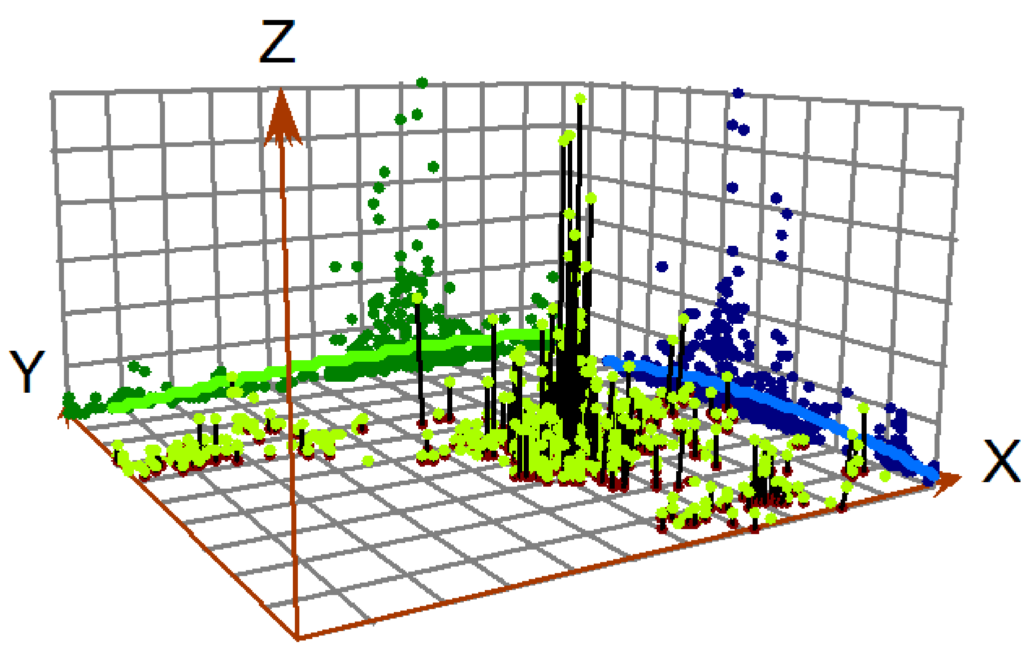


Figure C-4: Class One Farmland in Alberta

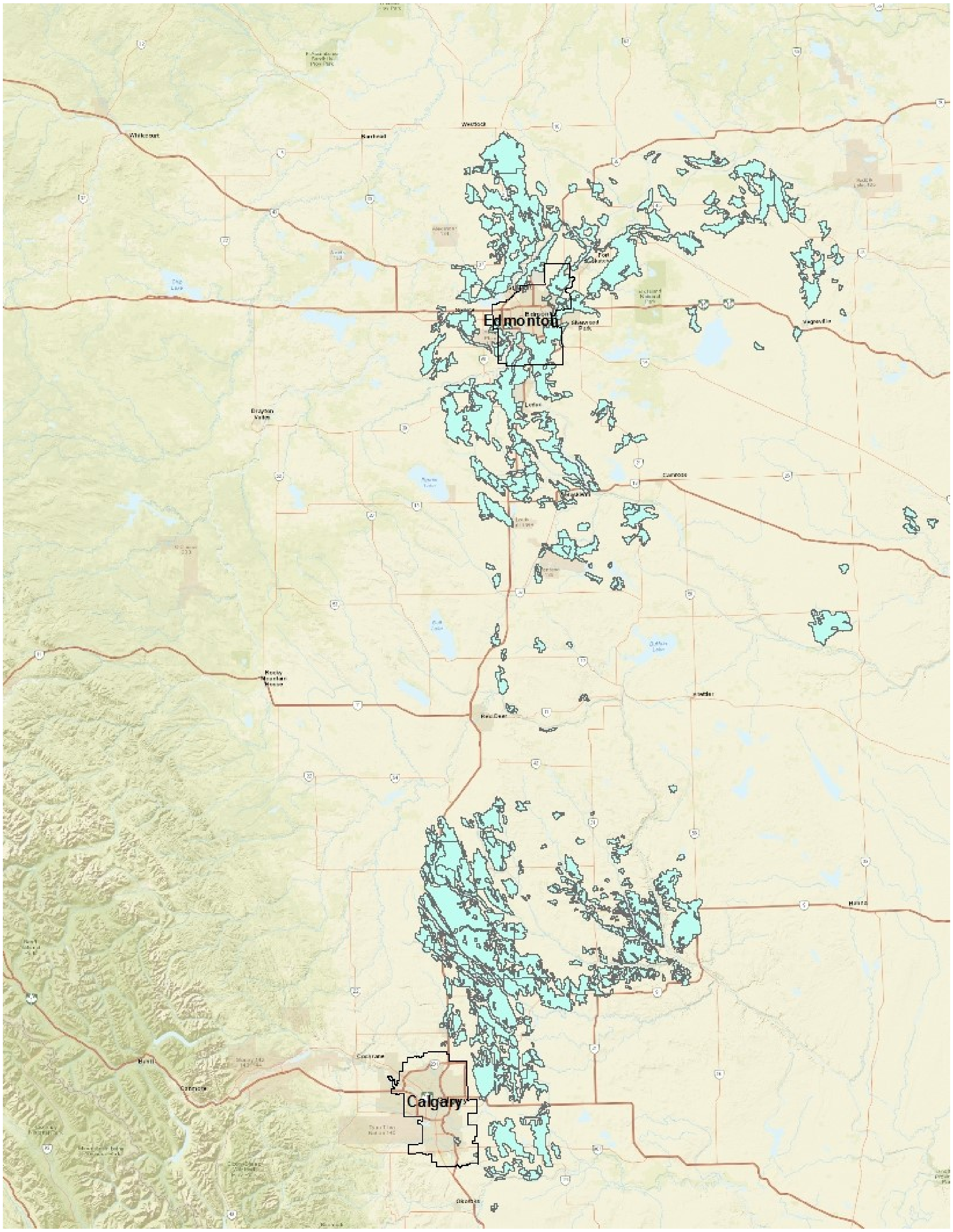


Figure C-5: Edmonton Calgary Corridor

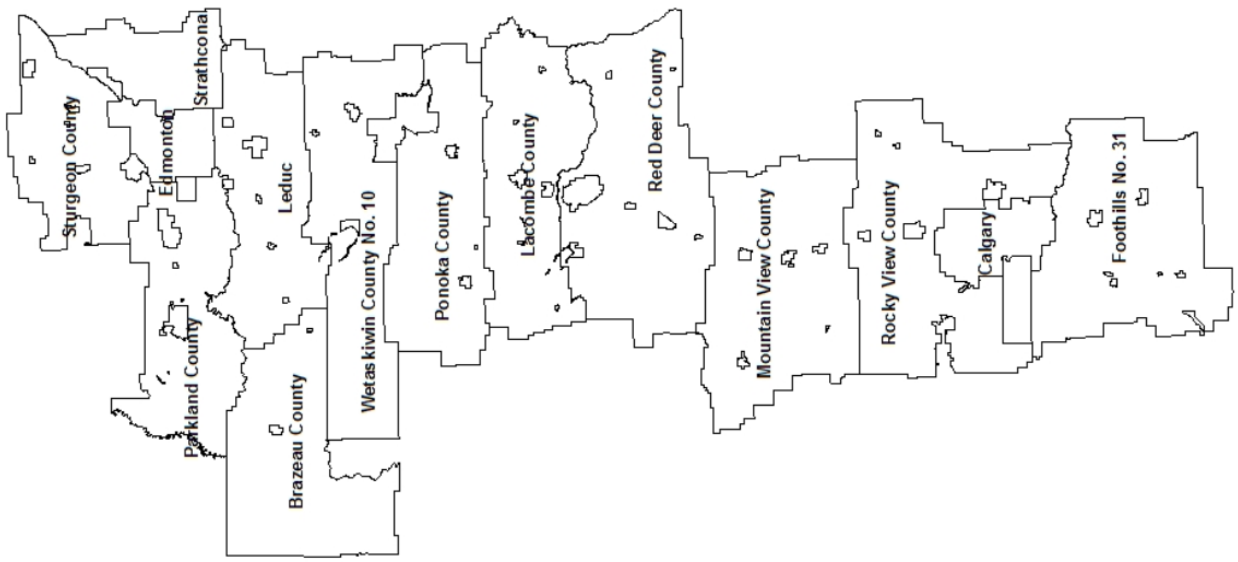


Figure C-6: Alberta Capital Region