Estimating a Natural Capital Account for Agricultural Land

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Introduction

The system of national accounts is an informational system that calculates statistically the economic activity of a country during a given period (Statistics Canada, 2012). It is separated into various accounts that represent different perspectives of the national economy, which can be integrated to provide a comprehensive system that portrays the whole economic activity of the country.

One weakness of the system of national accounts is its failure to take into account the evolution of the stock of natural capital of a country. To fill this gap, global initiatives, notably by the European commission and the OECD, were undertaken to create a consistent method for accounting the value of natural resources. The creation of a well-designed informational system such as a natural capital account provides two important advantages: 1) it allows for a better understanding of the evolution and the current level of the various natural capital stocks and 2) it improves the decision as to how the resources should be exploited and/or conserved. While the advantages are undeniable, some challenges still need to be addressed.

To include the agricultural land resource base as natural capital in the system of national accounts, its stock has to be considered as an asset that varies between two points in time: the opening and closing inventory, and converted to a monetary value. The conversion to a monetary value creates readily available information for policy makers to place in context the importance of its conservation and long term planning. However, this valuation exercise is a challenging task since the agricultural land base varies greatly in terms of the attributes that impact on its value, such as its soil quality, production capacity, and geographical location.

The hedonic price model can be used to calculate the value of a marketed good that is dependent on the value its attributes. It involves the analysis of the selling price of a good by breaking down its value into its multiple attributes. Every good, here land, has its own set of attribute levels, z, and the combination of their individual prices generate the overall value of the land (P). Therefore, the overall price function P(z) is determined by the price of the attribute vector z, which allows for the estimation of the implicit pricing of the attributes. This method of disaggregation generates individual markets for each attribute of agricultural land and can be used to estimate the price of agricultural land given the individual attributes and their predetermined price function.

The valuation of the attributes of agricultural land has been an important issue for agricultural economists because the value of this asset; i.e. agricultural land, represents a large part of farm value. For example, land value represents on average 80 percent of farm value in the United States (Huang et al., 2006). Also, agricultural land is an important asset for a nation because it supports the production of a large number of inputs including food. Thus, several methods have been used to evaluate this value and its source of variation. Moreover, the refinement of method and the advances in spatial econometric theory have allowed more sophisticated implicit price determination.

The System of National Accounts

The system of national accounts (SNA) is an accounting system that records economic activity with a double-entry method which reconciles the cost of the input used to produce goods and services with the revenue from the sale of these outputs. To guarantee a standardized system, the United Nations Statistical Office has been in charge of the design of its guidelines and standards (UNSO, 2008). This standardized system allows the comparison of economic performance not only through time but also between countries. This system of economic information is the corner stone of macroeconomic comparison and is a vital tool for economic analysis and policy formulation (UNSO, 2008).

The Canadian System of National Economic Accounts (CSNEA) provides information about Canadian economic activity over a given period of time. The information is compiled using statistics of the different sectors of economic activity. This system of accounts has been traditionally designed for the calculation of monetary transactions. There are four types of accounts that calculate different information but are built on similar definitions allowing their integration into one comprehensive account (Statistics Canada, 2012). Although these accounts provide useful information for understanding and projecting traditional economic activity, the central system is failing to account for some specific type of economic activity:

- The SNA does not measure the environmental and economic stock and flow information of national natural capital (Cadogan-Cowper and Comisari, 2009).

- It does not take into account non-market goods and services. For instance ecological goods and services from ecosystems is not part of the account. Therefore, the externalities related to economic activities are not taken into account.

- Expenditures for environmental disasters, such as the BP oil Spill in the Gulf of Mexico in 2010, are not included as a national costs but as positive economic activity from the removal of the oil.

Satellite Accounts

The inclusion of satellite accounts can increase the flexibility of the SNA and can fill informational gaps of the conventional central system of national accounting. The satellite accounts are linked to the central account but are distinct from the central system to avoid the distraction from the main feature. These satellite accounts can fill the informational needs of particular sectors. Hence, the environmental and resources accounts comprise information on the physical stock of natural resources of energy, mineral, timber, and land resources that are the foundation of the estimates of Canada's natural resource wealth (Statistics Canada, 2006).

Satellite accounts can be classified into two types: they can be some rearrangement of the central classification and include complementary elements or they can be based on concepts that are alternative to those of the SNA (UNSO, 2008). The first type of account could include environmental protection expenditures while the latter account for externalities between producers and consumers.

To standardize the practice for the creation of a satellite account for natural capital, the UNSO has created a guideline called Integrated Environmental and Economic Accounting (UNSO, 2003). The latest version published in 2003 provides the latest in terms of the methods and analysis to compile this set of statistical accounts. The SEEA reports identify which practices have been largely recognize and acknowledged for the progress of these practices, but it is recognized that the accounts are still under active research and investigation.

The satellite accounts also help to address the push for a 'Greener' GDP. For instance, the Report of the Commission on the Measurement of Economic Performance and Social Progress by Stiglitz, Sen and Fitoussi (2009) advocated for a national accounting system that takes into account the exploitation of natural resources. This is a shift in paradigm of calculating welfare progress instead of focusing on purely economic indicators (Martin, Diaz, and Cruz, 2011; Stiglitz, Sen and Fitoussi, 2009). This change in perspective has an important impact on policy implementation as decisions would be based on long term growth instead of short term indicators with the ability to assess the sustainability of projects.

Current treatment of agricultural land in the System of National Accounts

Currently, agricultural land value is included in the balance sheet under the agricultural sector. To evaluate the current land value, information is gathered by the Census of Agriculture (Statistics Canada, 2006) every five years. Farm operators are asked to report the estimated fair market value of their owned assets. Although these figures are useful for estimating agricultural asset value, it is not consistent with the standards for natural resource accounting as prescribed by the SEEA because it implicitly includes values of buildings on the land and the value reported is based on the knowledge of the respondents who are not always fully aware of the market value of their assets. In addition, these estimates do not account for the depletion of the land over time and do not include the value of publicly owned land that is also part of a nation's natural capital.

The construction of a land satellite account

The land account is a combination of physical inventory and the value of the different types of land. The physical inventory is constructed by four layers of geographical information: physical foundation, land cover, land use, and land potential (Statistics Canada, 2006). Table 1 provides an overview of the information contained in the different layers. With the development of geographical information system (GIS) and satellite mapping, the precision of the estimation and the capability of processing large amount of geographical information have increased tremendously.

One important aspect of the land account that is currently under investigation is the methodology to generate appropriate estimates for the agricultural land value layer. Currently, the data source is the farm real estate values declared in the Census of Agriculture (Statistics Canada, 2006). While this information represents a good foundation for land valuation, two important shortcomings are acknowledged: first, the value of agricultural activity is not segregated from the overall value that can include some speculative value from alternative use such as urban or commercial purpose; and second, it does not capture the environmental cost and benefits from agricultural activities (Statistics Canada, 2006). The hedonic price model will attempt to value each attribute that impacts the price of agricultural land using market transactions. The isolated value of each attribute can then be used to simulate the value of the land inventory in the province of Quebec.

Table 1: Layers necessary for the construction of the wealth account:

Layers	Description
Physical foundation	Land and water areas for Canada are calculated using a modified version of the digital map Terrestrial Ecozones and Ecoregions for Canada 1995 (Ecological Stratification Working Group, 1995)
Land cover	Natural Resources Canada and Forestry Canada have compiled a composite land-cover picture for all of Canada (Natural Resources Canada and Forestry Canada, 1994).
Land use	Agricultural land use: Agricultural census Forestland use: Canada Vegetation Cover-Digital Satellite Image and CANFI91 Urban-Rural land use: Statistics Canada Digital Enumeration Area Polygon file
Land potential	Land capabilities based on Canada land Inventory (CLI)
Land value	Census of Agriculture (once every four years)

Other methods have been used to refine the estimation of agricultural land value in Canada is through the net returns from agricultural operation (McAuley, 1996). This method is based on the theory that the value of an asset should be consistent with the stream of net rent expected from the operation of this factor of production. Although the method is consistent with the Capital Asset Pricing Model, the method revealed some important weaknesses that are difficult to address. The hedonic pricing method presented here would supply a new method for statisticians to estimates agricultural land values. For example, it is possible to evaluate the implicit price of urban proximity on agricultural land value. If the information about the type of ecological goods and services are known, it could also be possible to generate estimates from such attributes.

Agricultural Land Improvement and Degradation

Quality of agricultural land evolves over time. Especially in the province of Quebec, land is usable for agriculture only after the clearance of forests. After deforestation, land is often further improved by surface drainage, liming, and underground drainage. Such improvements can have a drastic impact on the return from agricultural land.

However, agricultural land can also degrade. Some types of degradation are permanent, such as the conversion of agricultural land into urban purpose or due to major soil erosion while other are reversible such as abandoned land or minor erosion. In order to track changes of the land degradation, current land quality must be precisely assessed and a means of calculating potential degradation must be established (Gretton and Salma, 1996). For instance, the Australian Bureau of statistics estimated that soil depletion from erosion will cost $14.3 billion over a range of 50 years (Cadogan-Cowper and Comisari, 2009).

This paper will focus mainly on the value of agricultural land in the province of Quebec based on market prices from 2009. Research was conducted to evaluate the effect of more localized improvements, such as drained land, but this information is generally contained in regional datasets which is beyond the scope of this atudy.

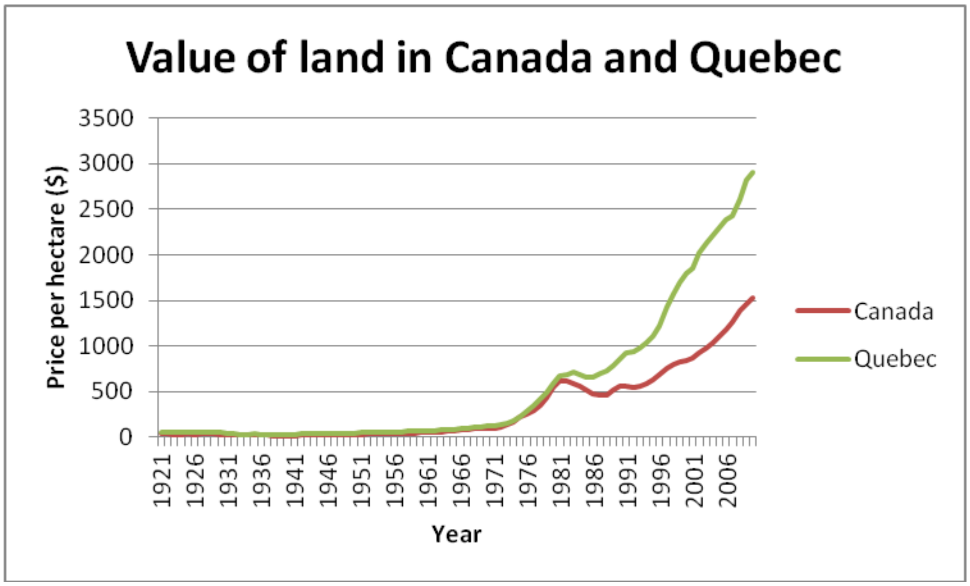
Historical perspective of the agricultural land inventory in Quebec

The total value of an inventory depends on both the quantity and quality of land available. Therefore, it is important to evaluate the changes in the quality of land in the national inventory as some qualities such as land capability or drainage have positive impact on the value of the land asset.

The Evolution of Agricultural Land value in Quebec

One interesting observation about farmland prices over the last forty years is its large increase. As illustrated in Figure 1, this noticeable change started in the 1970s and, apart from a slight dip in mid 1980s, has continued to the present. This upward trend in agricultural land value is observed throughout the province. Since 1990 alone, the average price has increased by 3.5 times (Groupe Ageco, 2010). The increase in price has been contributed to different factors such as changes in farmland return (Alston, 1986) or changes in risk (Reinsel and Reinsel, 1984). According to Just and Miranowski (1993), the main factors that drive the increases in values are land price expectation, inflation and opportunity cost of capital.

Figure 1 Evolution of agricultural land in Quebec and Canada.



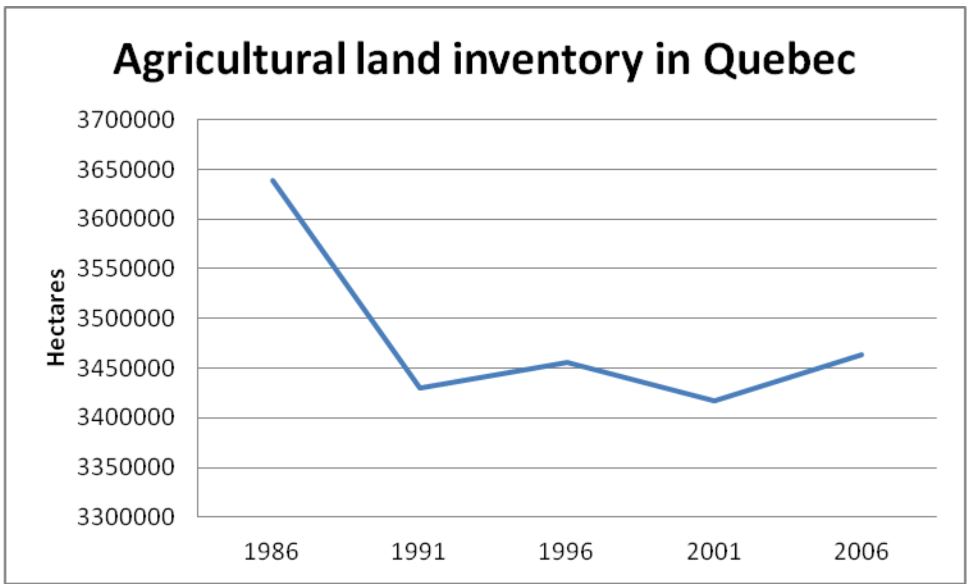
Source: Statistics Canada, Series V52231010

There is great variability in land values between regions reflecting their differences in attribute characteristics. For instance, in 2009, the average agricultural land price was $2,155 per hectare in the Bas St-Laurent region as compared to $12,387 per hectare in the Montérégie-Est (Groupe Ageco, 2010). Due to geographical differences, several attributes such as the variation in soil capability and the weather can explain the high variance in agricultural land value as the expected rent from agricultural land varies greatly between one location to the other.

The Evolution of the Agricultural Land Inventory in Quebec

Based on the data from Statistics Canada (Figure 2), the agricultural land inventory in Quebec has experienced a substantial decrease of about 6% of its total quantity between 1986 and 1991. This is the only noticeable changes in the quantity of the land in the last 20 years. However, considering the decrease in the number of farms over the period, the average size farm has increased.

Figure 2 Evolution of agricultural land area in Quebec.



Source: Statistics Canada (2008)

To evaluate the agricultural land disaggregated by soil index, the Circa land cover vector (Natural Resource Canada, 2009) was used. Table 2 provides the number of hectares cultivated in every soil class. The area considered cultivated are the polygons coded as “Grassland”, “Cultivated Agricultural Land”, “Annual Cropland”, and “Perennial Cropland and Pasture”. It can be observed that highest quality soil is rare in Quebec.

Table 2 Total land inventory in the province of Quebec (Hectares)

Soil capability index	Area (hectares)	Cultivated area (Ha)
1	16,452	10,158
2	771,496	443,592
3	1,063,224	480,818
4	2,613,285	916,986
5	1,712,137	237,190
6	81	51
7	19,016,328	615,120
0[1]	837,912	44,557
Total	26,030,915	2,748,502

[1] Soil capability index of "0" represents organic soils.

Method for land valuation

There are three main methods used to evaluate the value of agricultural land as natural capital. The first method is the real estate value. It uses the appraised market value of agricultural land. The data is gathered by the Census of Agriculture and provides an estimate of the total value of the land account. In the context of the Census of Agriculture, the estimation of market value is done by the owner of the property (Statistics Canada, 2006). One drawback with this method is that it includes the value of alternative use of the land and cannot assess any estimation of the environmental goods and services from agricultural activities. Also, the method does not provide quantitative estimates about the factors influencing the land value.

A second method developed to calculate land value is the estimation of economic rent (Statistics Canada, 1996). To evaluate the economic rent of a factor of production such as agricultural land, one has to calculate the stream of profit from the use of this factor of production. An attempt to evaluate this method was made by McAuley (1996) for New Brunswick. The present value of the estimated economic rent was much smaller than the real estate value from the Census of Agriculture. This large gap fails to reconcile the methods as a robust method to calculate land value.

The third method, the hedonic valuation, uses agricultural land transactions and breaks down the market value of the goods traded into their different attributes. This method allows for greater flexibility in estimation and can be used on a larger scale than mean market value. However, since the calculation is based on an econometric method employing statistical estimation and assumptions, the estimation generated must be used parsimoniously. However, two advantages of this method is its capacity for benefit transfer (Statistics Canada, 2006) and the possibility of simulating the impact of various policy scenarios (UNSO, 2003).

Following the advice of SEAA, the calculation of land value as natural capital must be refined to exclude the value pertaining to other uses such as residential. As explained previously, the CAPM model is a framework that explains the price of an asset from the expected flow of income from this asset. Since land value is derived from a competitive market, the value of agricultural land is traded at an equilibrium price which should represent the highest expected flow of income from the asset and thus represent the most precise expected rent from natural capital.

Factors influencing farmland price

Land is a factor input that is highly substitutable and is therefore used for most human activity such as residential and industrial purpose. The price of agricultural land is dependant of factors that are not only related to agricultural activity but also to non-agricultural factors such as proximity from residential development or urban agglomerations. Given this, capital asset pricing theory predicts that the value of land will reflect the discounted present value of the future stream of returns (Henneberry and Barrows, 1990). Therefore, if the predicted return is higher than the one from agricultural use, the value of agricultural land will be traded above the expected flow of income from agricultural activity. Based on the considerations that alternative uses can have a major impact on its value, the proximity of agricultural land to urban areas must be considered.

Huang et al. (2006) undertook a large study of Illinois farmland value using the transactions from the Illinois Land Registry. They used panel data of traded agricultural land value to evaluate a number of attributes: land productivity, parcel size, improvements, and distance to large cities, urban-rural index, regional livestock density measure, income and inflation. This study had a large number of observations but cannot be fully applied to the Canadian situation because the legislative background between the two countries is different. For example, agricultural land in Quebec is protected by legislation that restricts the use of protected agricultural land to agricultural activity (Loi de la protection du territoire agricole). According to Henneberry and Barrows (1990), exclusive agricultural zoning has a negative effect on price because it excludes alternative uses such as residential or industrial use.

Amenities for residential purpose are also recognized to have an effect on agricultural land price. Wasson et al. (2010) has concluded that amenities have a positive effect on prices. The researchers noticed that residential development in the intermountain West region of the United States would influence agricultural land price based on environmental attributes such as protected ecosystem services, accessing recreational sites or scenic view as oppose to urban fringe that would have a more traditional set of attributes such as access to health care, employment and education facilities. Indeed, they concluded that environmental amenities should be considered when evaluating the value of rural residential areas. This provides information about the increased importance of environmental amenities when the distance from cities increases.

The research of Goodwin and Ortalo-Magné (1992) relates the effect of agricultural subsidies on land price. They concluded that subsidies are capitalized into the agricultural land price. They observed that countries where the subsidies are higher were found to have higher agricultural land prices thus imputing the effect of capitalization of subsidies into agricultural land price.

The impact of environmental goods and services has been evaluated through hedonic pricing by Palmquist and Danielson (1989). Based on their study, they value the effect of US farmland improvement such as drainage and erosion reduction method. They found a positive effect of both drainage (by 34%) and erosion reduction method ($6.19 per acre per year reduction in potential soil loss) on the price of land.

The competition for land is an obvious factor for the variation of land prices. In some regions of the province of Quebec, where important vertically integrated agricultural businesses are located, the pressure for acquiring agricultural land is high because this land is close to their operation and they are bound by legislative constraint to own a sufficient land base to dispose of animal waste. This creates pressure on land prices in these regions.

The effect of recreational activity on agricultural land price has been evaluated by Guiling, Brorsen and Doye (2007). They used linear regression to evaluate this effect and found an increasing recreational use has a positive impact on farmland prices in Oklahoma.

Method

Econometric estimation

With the advances in geospatial technologies, the hedonic pricing method is able to obtain a greater level of precision. ArcMap software was used to generate the vector of information for every lot transacted that is then used in a regression model. To generate the information, the dataset of transactions was included as a geographical layer of information and was joined with the other layers of information. The first part of this section will provide details on the hedonic price method and its design and the second part will explain how it can be applied to land accounting.

The hedonic pricing model is based on the work by Lancaster (1966) that assumes that a consumer derives their utility from the set of attributes that constitute a good, as oppose to consumer theory where the good is viewed as indivisible in term of its characteristics. Lancaster's consumer theory is based on the assumption that the attributes of the good and not the good itself produces utility for the consumer. As a result, a good can be described as a combination of attributes and various levels of the same attribute can create a completely different good.

Extending Lancaster's theory, it is possible to generate a model where the price of a good p(V) is a function of the combination of the quality and quantity of the set of attributes k that constitute this good (Rosen, 1974):

$$p(V) = \sum_{k=1}^{K} v_k$$

Using this approach to construct the price function, it is possible to estimate the contribution of each attributes on the value of the good by calculating their respective implicit prices: $\frac{\partial p(V)}{\partial p(v_k)}$ (Rosen, 1974; Ladd and Martin, 1976). This marginal rate of substitution of the attributes is the equilibrium value between the consumer utility maximization problem and the land owner profit maximization problem. This implicit price is therefore the equilibrium of the various attributes on the market that take into consideration not only budget constraints but also expected rent from the land asset.

One important feature of hedonic model is that the implicit price of the attributes are determined in the market place and thus at an equilibrium point between buyers and sellers (Rosen, 1974). This market situation creates a robust basis to evaluate aggregate value and also permits the isolation of the factors pertaining to factors of production from potential alternative uses that are of a speculative nature. This isolation of the relevant attributes into the agricultural land valuation model is a consistent methodology for the calculation of the national accounts (Statistics Canada, 2006).

One advantage of the hedonic price model over alternative non-market valuation methods, such as stated preference methods, is that the choice is made in the context of a budget constraint which reveals the true value for the attributes (Lancaster, 1966; Rosen, 1974). In addition, this also reveals the relative scarcity of every attributes in the context of the market where land is a factor of production and its characteristics will have an effect on its future expected rent (UNSO, 2003). Based on these features, the hedonic price model is a valid instrument for estimating the implicit price of the attributes of agricultural land from the market.

Data source and treatment

Although land transactions are publicly disclosed in the Quebec land registry, detailed data concerning land transactions are not easy to gather. One reason is that the transaction of land usually includes the transaction of the buildings and their share of the price is not always explicit. In addition, the context of the transaction is not always fully exposed in the contract. For example, the price of a transaction can diverge from the fair market price when the transaction involves an intergenerational transfer. Often in intergenerational transfers of farms, the assets are traded below their fair market price to allow the continuation of the family business. Therefore, these transactions do not represent the real value of the land traded since other factors are taken into consideration. In order to have a representative market price, the transaction must be surveyed to identify who is involved in the transaction and if the price is fully disclosed in the transaction.

The land transaction dataset used for this research was provided by la Financière Agricole du Québec. The dataset consisted of arms-length transaction of agricultural land over the last 10 years, collected across the province of Quebec and includes approximately 2,600 transactions. For this paper, the data from 2009 was used and included 576 observations. This dataset had the advantage of providing land value separately from the value of the whole property transaction. The dataset has also the advantage of including only arm's length transactions that are considered to reflect the fair market value of the asset. The information used in the analysis is the price of the transaction, the size of the land traded, the municipality where the land is located and the date of the transaction.

For the preparation of the data, the values of the transactions were aggregated at the municipal level which was the smallest identified geographic area available. The main reason for this aggregation is the lack of more precise geographical information in the dataset: the cadastral identification was either not available or impossible to tract due to the cadastral renovation that is currently in process in the province of Quebec. In addition, the spatial weighted matrix that must be constructed to correct for autocorrelation would have been difficult to manage due to its size. However, this aggregation comes with a computational cost: as explained by Orcutt et al. (1968) aggregation generates less efficient parameter estimates, decreases sample biases and thus reduces the likelihood of detecting misspecification due to information losses.

The information from the transactions was linked with other geographical attributes using the ArcMap software using the spatial join tool and other tools in the software. If more than one level was encountered in the polygon, the dominant attribute was chosen. The superposition of the different layers of geographic information was then converted to a Stata (StataCorp) database and analysed with this software.

Variables	Definition	No. Obs.	Mean	Std. Dev.
lnlandval	Natural logarithm of weighted average sales price per hectare, in 2009 dollars	576	8.52	0.9254
lnegdd	Natural logarithm of the number of growth degree days units for agricultural crops;	576	7.37	0.1460
class_q	Soil capability index, from 1 to 8 where 1 is excellent and 8 is not usable for agricultural purpose	576	4.80	2.0963
organic	Dummy variable, 1 for organic land	576	0.036	0.1876
lnpop	Natural Logarithm of the population density of the municipality in 2010, calculated in individuals per square kilometer.	576	2.93	1.4144
lnsup	Natural logarithm of the area of the land transacted expressed in hectares.	576	3.68	0.8250

distmtl	Inverse of the Euclidian distance from Montreal calculated in degrees	576	0.87	0.9157
distqc	Inverse of the Euclidian distance from Quebec calculated in degrees	576	0.78	0.8528

Model Specification

Taken the context of the land transaction, the variables included in the model are those considered significant in the literature and available in the dataset. Therefore, the empirical model has been constructed to capture the effect of the different attributes that are considered to have an effect on land value in the province.

Economic theory does not propose one specific functional form for a hedonic price model. Therefore, the choice is directed toward the goodness of fit and other ad hoc considerations (Kim et al., 2001). A box-cox test was performed to determine which functional form provided the best fit for the data. The test rejected the null hypothesis that the right-hand-side transformation would not significantly add to the regression (Stata, 2009). Similarly, the test rejected the null hypothesis that a left-hand-side transformation, except for the dummy variable *organic*, would not significantly add to the regression (Stata, 2009). The linear model had a better fit than log-linear and the linear dependent variable is better than the log of the dependent variable. Because the implicit prices are the partial derivatives of the coefficients, the derivatives are interpreted as elasticity. Therefore, the model used to estimate the implicit prices is a spatial-autocorrelation corrected regression log-log form. The model will follow the model of Huang et al. (2006) with the exception of the serial correlation. The model has the following form:

$$\ln P_i = \beta_0 + \beta_1 lnegdd_i + \beta_2 lnClass_i + \beta_3 Organic_i + \beta_4 lnpop_i + \beta_5 lnsup_i + \beta_6 sqclass_i + \beta_6 distmtl_i + \beta_7 distqc_i + u_i$$

Where: $u_i = \lambda u_{i,t-1} + v_{it}$ and $v_{it} \sim N(0, \sigma^2)$, $E[u_{it} u'_{is}] = \sigma_v^2 \Omega(\lambda)$, t ≠ s

With the covariance matrix has this form:

$$\Omega(\lambda) = \mathrm{I_N} \otimes \left\{ \frac{1}{1-\lambda^2} \begin{bmatrix} 1 & \lambda & \lambda^2 & \cdots & \lambda^{T-1} \\ \lambda & 1 & \lambda & \cdots & \lambda^{T-2} \\ \lambda^2 & \lambda & 1 & \cdots & \lambda^{T-3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \lambda^{T-1} & \lambda^{T-2} & \lambda^{T-3} & \cdots & 1 \end{bmatrix} \right\}$$

lnP_i = Average sales price per hectare of agricultural land at the municipal level;

$lnegdd_i$ = Number of growth units for agricultural crops, calculated in growth units;

$lnClass_i$ = Soil Capability index, from 1 to 8 where 1 is excellent and 8 is not usable for agricultural purpose;

organic_i=Dummy variable, 1 for organic land;

lnpop_i = Population density of the municipality in 2010, calculated in individuals per square kilometer.

$lnsup_i$ = Natural logarithm of the area of the land transacted expressed in hectares.

$sqclass_i$ =Square of the soil capability index;

$distmtl_i$ =Inverse of the Euclidian distance from Montreal calculated in degrees;

distqc_i = Inverse of the Euclidian distance from Quebec calculated in degrees;

W = row standardized spatial weight matrix, based on queen adjacency relations among municipalities;

I_N = identity matrix with dimension N (number of municipalities);

$\otimes$ = Kronecker product;

i = subscript index for municipality.

The variables used in the regression represent the two main groups of variables that have an impact on land values: the variables related to productivity and human factors. The productivity factors are expressed by the *lnegdd*, *organic*, *class* and *sqclass*. The average vegetative heat unit per year is an important factor to determine the returns from the land because increased vegetative heat units increases crop yields. The *Class* variable is an index that represents soil capability. Land that is of excellent quality will require less corrective measures, such as drainage, liming or rock removal, and will have higher return. Land categorized below class five is considered marginal land for agricultural purpose (Patterson, 1997). Because the effect of class on land value can have an impact at an increasing rate, the square of land class called *sqclass* was included in the model. Organic soils (*organic*) must be treated as a different group because it is difficult to compare to mineral soils due to its specificity and its use. Organic soils are used mainly for vegetable production. This soil type has the capability of generating high income but requires drainage and special conservation techniques that imply a separate treatment in terms of its price effect.

The variables that are related to human factors are generally related to the pressure on the land market. As population increases in a region, the pressures for alternative use increases and leads to an increase in agricultural land value. Thus, the population density (*lnpopDens*) of the municipality will be related to pressure on the available land. The proximity of the two main cities in the province, Quebec and Montreal, is also expected to have an impact on the value of agricultural land due to the important demand for land nearby metropolitan areas but also because the agricultural production from these lands can be more profitable. Indeed, the possibility of selling directly to consumers or using the land for more recreational activities, such as horseback riding, can increase the expected revenue from the land. Finally, the size of the land sold is an importance factor because the law forbids the fragmentation of land into smaller lots. Thus small lots can be bought for hobby farming but it will not be the case for land of large size. Therefore, it is expected that land sold in smaller lots will have higher value.

Spatial Autocorrelation detection and correction

One important assumption in the regression analysis is the homoscedasticity, where variance of the parameters is stable over the whole range of values. When treating spatial relationships, several empirical studies have been found to have autocorrelation, thus violating the homoscedasticity assumption (Anselin, 1990). Similarly to time series data, models were built to generate consistent estimates for modelling in the presence of autocorrelation. The model takes into consideration the relative distance from each observation and calculates the correlation based on these relative distances, a technique developed by Cliff and Ord (1973). This model uses an endogenous “Weight” matrix to account for the calculated correlation.

Autocorrelated disturbance can have a strong negative impact on the data because it generates biased and inconsistent estimators (Greene, 2004). The test designed for autocorrelation is the Moran I test. When performing this test on the data collected, the conclusion was the rejection of no autocorrelation. Therefore, the appropriate correction was necessary.

The spatial weight matrix is created from spatial distance of the various observations based on the principle of Tobler’s first law of geography: “everything is related to everything else, but near things are more related than distant things” (Tobler, 1970). Based on this principle, the autocorrelation is assumed to be related to distance of each observations. Thus, the spatial weight matrices M and W are endogenous variables based on some knowledge of the spatial interactions. Imposing the correlation matrix leads to potentially deficient parameters but is less damaging than leaving the autocorrelation untreated (Greene, 2004).

The calculation of distance takes two different forms: contiguity or inverse of the Euclidian distance. In the context of the present model, land transactions were not recorded from each municipality which created “islands” instead of a mapping with all observations contiguous to a set area. Therefore, the use of inverse distance was more appropriate in the context of this analysis.

Two methods are available for parameter estimation: Maximum-likelihood (ML) and generalized spatial two-stage least squares (GS2SLS). However, ML estimation does not appear to be efficient in the presence of non-spherical disturbance (Lee, 2004) and thus GS2SLS will be preferred over ML model.

To correct spatial models from spatial-autoregressive disturbance, the creation of a spatial weight matrix is necessary (Drukker et al., 2011).

$$y = \lambda W y + X\beta + u$$

$$u = \rho M u + \epsilon$$

Where

y is the vector of dependent variable of size n X 1;

W and M are spatial-weighting matrices of size n X n (with zero diagonal elements);

The Wy and Mu are the spatial lags of size n X 1 with λ and ρ being the scalar spatial-autoregressive parameters;

X is the matrix of observations on k right hand side exogenous variables of size n X k and β the parameter vector of size k X 1;

ϵ is the vector of innovations of size n X 1.

Thus, this spatial autoregressive model with spatial-autoregressive disturbance uses spatial lags to account for the spatial interactions. The spatial interaction modelled by the spatial weight matrix is taken into account in the value of the dependent variable, the explanatory variable and the error term.

Heteroscedasticity

Although heteroscedasticity does not bias the estimator, it can invalidate statistical test of significance and thus leading to wrong conclusions. The Breusch-Pagan Test for heteroscedasticity was performed to evaluate the presence of heterogeneity of the error term. The test provided strong evidence of heterogeneity and thus was corrected in the regression using Generalized Method of Moment (GMM) estimator.

Results

Hedonic Price Model

The following table summarizes the results from the spatial weighted regression performed. Spatial autocorrelation was tested with Moran's I test and rejected the null hypothesis of no spatial autocorrelation; therefore the spatial weight matrix was included in the regression analysis to generate unbiased and efficient estimators (Greene, 2004). The inverse distance of polygon centroid was the most appropriate method for distance calculation since the contiguity analysis was impossible due to several discontinuities between polygons. To generate the estimator, the computational software Stata was used and the spatial weighted matrix was generated using the *spmat* and *spreg* commands.

Two specifications of the model generated two sets of results. Model 1 provided results using ordinary least square corrected for heteroscedasticity but not for spatial lag. The second model generated results using 2SGLS parameter estimation and used the spatial weight matrix. The parameters from Model 1 have greater magnitude than Model 2. These bigger numbers with OLS are observed empirically (Huang et al., 2006) and expected theoretically (Greene, 2004; LeSage and Pace, 2009). The spatial lag coefficient, represented by λ, in Model 2 is statistically significant and is consistent with the conclusion from the Moran I test.

The results from Model 2 confirmed that agricultural land value declined with the size of the transacted area (*sup*) and land class (*class*). In term of magnitude, a 1% increase in area transacted leads to a 0.11% decrease in value, similarly a decrease in land quality from class 1 to class 2 leads to a decrease in value of 3%. On the other hand, agricultural land value increases when the land is in a region with more favorable weather (*egdd*), and when population density increases. The parameters *distmtl* and *distqc* that are distance from the two major cities in the province must be interpreted carefully because they are expressed as the inverse of the Euclidian distance from the city calculated in degrees. Thus, the positive coefficient means that as the distance increases from the city, the value of farmland value decreases.

Most of the parameters showed a priori expected relationship. One interesting coefficient is the soil class (*class*) that is significant and has a negative impact on land value. As the quality of land decreases as the value increases in the index, a negative relationship with land value was observed as expected. The parameter coefficient for the *organic* variable was not expected. A positive coefficient was expected because the crops that are produced on organic land are more profitable. Organic soil is dispersed throughout the province and its agricultural quality varies greatly. For example, organic soils in the South-East region of Quebec have desirable quality for agricultural production while organic soils from North-West region of Quebec have poorer quality. In addition, new regulations protecting wetlands in Quebec restraint the conversion of this type of land to agricultural purpose which reduces its value. The low number of observations that involve organic soil restricts further analysis to generate more conclusive results.

Table 3: Hedonic Regression Results

	Dependent Variables: ln (price per hectare)	
Variable	Model 1: OLS	Model 2: 2SGLS (Spatial Lags)
ln (egdd)	3.094364***	1.997824***
	(.2187576)	(.2376636)
Class	-.0383139***	-.034735***
	(.0134055)	(.0124581)
organic	-.4630341***	-.3699262***
	(.1342881)	(.1251711)
ln (pop)	.0661774***	.0714792***
	(.0190802)	(.0177325)
ln (sup)	-.1633718***	-.117617***
	(.0283925)	(.0268692)
distmtl	.208359***	.1179501***
	(.0363142)	(.0352283)
Distqc	.1784697***	.0806344***
	(.02907)	(.0291558)
intercept	-13.99955***	-6.80447***
	(1.622703)	(1.710578)
Λ		.1513844***
		(.0170191)
Adjusted R2	0.42	

Asterisks (*, **,***) are significance level of null hypothesis at 10%, at 5%, at 1% respectively. Standard errors are given in parenthesis.

The Wealth Account

The wealth account was calculated using the coefficients from the regression of the hedonic price model. By identifying the cultivated polygons from the soil coverage map, the set of attributes for every polygon was identified and used to estimate the value of the land. The following table presents the values from each land class. For consistency purpose, all the variables that were considered having an impact on land value were included to avoid omitted variable bias. The contribution of land size to land value is estimated at the average area transacted of 39.75 ha.

Table 4: Total and average value of agricultural land in the province of Quebec Dollars

Soil capability index	Value($)	Value ($/ha)
1	85,012,780	8,399.01
2	3,426,506,951	7,727.87
3	2,471,854,594	5,140.94
4	4,197,485,329	4,577.48
5	866,285,227	3,652.29
6	277,255	3,419.93
7	2,058,404,448	3,346.35
0	233,007,632	2,365.54
Total	13,338,834,215	4,760.11

Conclusion

This study provided estimates of the different factors that influence agricultural land value in the province of Quebec. The model also shows that spatial relationships are present and demonstrates the importance of correcting for such correlation. In the model presented here, avoiding this necessary step would lead to biased estimates. The expected results were observed for most of the coefficient estimated: the value of agricultural land had a positive relationship with soil quality (*class* and *sqclass*), effective growing degree days (*egdd*), and population density. On the other hand, agricultural land value had a negative relationship with increasing distance with Quebec and Montreal, increasing size of the area traded and the presence of organic soil.

The question raised about the effect of organic soil on agricultural land value is not fully understood and should be further investigated. The relationship between organic soil and its long term depletion is a subject that would necessitate more investigation to be more conclusive. In addition, the inclusion of maintenance cost or some form of index could help the analysis.

Although temporal correlation was irrelevant in the context of this study (observations were taken from 2009 only), a more elaborate estimation involving the presence of temporal autocorrelation can be designed using the 10 years of data that are available in the dataset. This can provide interesting estimates for longer term prediction and evaluate the relative importance of the various attributes over time. In the context of policy decision making, these estimates can help to better understand the impact of policy on the agricultural land inventory.

References

Alston, J. M. 1986. “An analysis of growth of U.S. farmland prices, 1963-82.” *American Journal of Economics* 68(1):1-9.

Anselin, L., F.G.M. Florax, and S.J. Rey, Eds. 2004. *Advances in Spatial Econometrics*. Berlin, Germany: Springer-Verlag.

Anselin, L. 1990. “Spatial dependence and spatial structural instability in applied regression analysis.” *Journal of Regional Science* 30:185-207.

Cadogan-Cowper, A., and A. P. Comisari. 2009. Recording Land in the National Balance Sheet. Paper presented at the 15th Meeting of the London Group on Environmental Accounting, Eiesbaden, Germany, December 4.

Cliff, A.D. and J.K. Ord. 1973. *Spatial Autocorrelation*. London: Pion.

Deaton, B.J. and R. J. Vyn. 2010. “The effect of strict agricultural zoning on agricultural land values: The case of Ontario’s greenbelt.” *American Journal of Agricultural Economics* 92(4): 941-955.

Drukker, D.M., I.R. Prucha, and R. Raciborski. 2011. *Maximum-Likelihood and Generalized Spatial Two-Stage Least-Squares Estimators for Spatial-Autoregressive Model with Spatial-Autoregressive Disturbances.* College Station, Texas: Stata Corporation.

Farm Credit Canada. 2011. Spring 2011 Farmland Value Report. http://www.fcc-fac.ca/en/Products/Property/FLV/Spring2011/index.asp (Accessed May 10, 2011).

Groupe AGECO. 2010. Valeur des terres agricoles dans les régions du Québec. http://www.groupeageco.ca (accessed March 15, 2011).

Goodwin, B.K., and F. Ortalo-Magné. 1992. "The capitalization of wheat subsidies into agricultural land values." *Canadian Journal of Agricultural Economics* 40: 37-54.

Greene, W.H. 2004. *Econometric Analysis 3rd. ed*. Upper Saddle River, NJ: Prentice-Hall.

Gretton, P. and U. Salma. 1997. "Land degradation: Links to agricultural output and profitability." *The Australian Journal of Agricultural and Resource Economics*. 41(2): 209-225.

Guiling, P., B.W. Brorsen and D. Doye. 2007. "How much influence does recreational land value?" Paper presented at the Southern Agricultural Economics Association Annual Meeting, Mobile, Alabama, 4-7 February.

Henneberry, D.M., and R.L. Barrows. 1990. "Capitalization of exclusive agricultural zoning into farmland prices." *Land Economics* 66: 249-258.

Huang, H., G.Y. Miller, B.J. Sherrick, and M.I. Gomez. 2006. "Factor influencing Illinois farmland values." *American Journal of Agricultural Economics* 88(2):458-470.

Just, R.E. and J.A. Miranowski. 1993. "Understanding farmland price changes." *American Journal of Agricultural Economics*. 75(1): 156-168.

Kim, C. W., T. T. Phipps, and L. Anselin, 2003. "Measuring the benefit of air quality improvement: A spatial hedonic approach." *Journal of Environmental Economic and Management* 45:24-39.

Ladd, G. W. and M. B. Martin. 1976. "Prices and demands for input characteristics." *American Journal of Agricultural Economics* 58: 21-30.

Lajoie, P.G., 1975. "Agricultural Lands in Southern Quebec: Distribution Extent and Quality." Soil Research Institute, Research Branch, Agriculture Canada.

Lancaster, K.J. 1966. "New approach to consumer theory." *Journal of Political Economy* 74(2): 132-157.

Lee, L-F. 2003. "Best spatial two-stage least squares estimators for a spatial autoregressive model with autoregressive disturbances." *Econometric Reviews* 22(4): 307-335.

LeSage, J.P., and R.K. Pace. 2009. *Introduction to Spatial Econometrics*. Florida, United States: Chapman & Hall/CRC.

Martin, F.G., R.F. Diaz, and I.L.Cruz. 2011. "Economic and Environmental Accounting and Green Growth." Instituto Nacional de estadistica y Geografia, Mexico.

McAuley, J. 1996. "Agricultural Land Valuation in Canada Environmental Perspectives 3: Studies and Statistics." Statistics Canada, Catalogue No. 11-528E-XPE, No.3, Ottawa.

Natural Resource Canada, 2009. “Land Cover, circa 2000-Vector.” Map. Center for Topographic Information Earth Science Sector, Natural Resource Canada, Sherbrooke (Quebec), Canada.

Orcutt, G.H, H.W. Watts, and J.B. Edwards. 1968. “Data aggregation and information loss.” *American Economic Review* 58(4): 773-787.

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

Patterson, K.L. 1997. “Wealth Accounts for Agricultural Land: A Hedonic Pricing Approach.” MSc Thesis. McGill University.

Reinsel, R. D., and E. I. Reinsel. 1984. “The economics of asset value and current income in farming.” *American Journal of Agricultural Economics* 66: 422-429.

Rosen, S. 1974. “Hedonic prices and implicit markets: Product differentiation in pure competition.” *The Journal of Political Economy* 82(1): 34-55.

StataCorp. 2009. *Stata Base Reference Manual, Release 11*. College Station, TX: StataCorp LP.

Statistics Canada. 1996. Environmental perspective, studies and statistics. Catalogue no.11-528-XPE, No.3, 114 p. Ottawa, Ontario.

Statistics Canada, 2006. Concept, Sources and Method of the Canadian System of Environmental and Resource Account. Catalogue no.16-505-GIE, 157 p.Ottawa, Ontario.

Statistics Canada. 2006. *2006 Census of Agriculture*. Survey. Agriculture Division, Statistics Canada, Ottawa, Ontario.

Statistics Canada, 2008. Total farm area, land tenure and land in crops, by province (Census of Agriculture, 1986 to 2006, Quebec). http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/agrc25f-eng.htm (Accessed November 20, 2011).

Statistics Canada. 2012. Canada's system of national economic accounts: an overview. http://www.statcan.gc.ca/nea-cen/about-apropos/index-eng.htm#satellite (Accessed October 12, 2011).

Stiglitz, J.E., A. Sen, and J.P.Fitoussi. 2009. Report by the commission on the measurement of economic performance and social progress. Commission on the measurement of economic performance and social progress, France.

Tobler, W. R. 1970. "A computer movie simulating urban growth in the Detroit region." *Economic Geography* 46: 234-240.

United Nations Statistical Office. 2003. *Integrated Environmental and Economic Accounting.* New York.

United Nations Statistical Office. 2008. *System of National Accounts.* New York.

Wasson, J., D.M. Mcleod, C.T. Bastian, and B.S. Rashford. 2010. The Effect of scenic and environmental amenities on agricultural land values. Paper presented at the Agricultural and Applied Economics Association`s 2010 AAEA, CAES & WAEA Joint Annual Meeting, Denver, Colorado, July 25-27, 2010.