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The influence of urban sprawl on farmland prices in Belgium

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Abstract.- We here study the effects of urbanization on farmland prices in Belgium. We control soil fertility (Ricardo) and adopt a Thünian's perspective: we show how urbanization influences farmland prices in the same way that it does for residential land price. We therefore estimate the same econometric equations on the two land markets (agricultural and residential) by using data aggregated at the level of all Belgian municipalities (589 communes). Results show that farmland prices decrease with distance to CBD, increase with the population of the commune, with its demographic growth as well as with households' income.

Keywords : land market, farmland, periurbanization, Belgium

JEL classification Q1, R1

1. Introduction

Since almost fifty years, most European urban regions undergo strong periurbanization process; it is intrinsically similar to suburbanization and/or « urban sprawl » in the U.S.: cities sprawl into the surrounding countryside. The mechanisms of these centre-periphery migrations have widely been studied (see e.g. Brueckner *et al*., 1999 or Burchfield *et al*., 2006) as well as their negative effects on the environment (Brueckner, 2000; European Environmental Agency, 2006). Some papers have been devoted to the consequences of periurbanization on agriculture, and more particularly on farmland prices (see e.g. Plantinga *et al.,* 2002; Cavailhès and Wavresky, 2003; Livanis *et al.,* 2006). They show that the actors on the agricultural land market anticipate capital gains from the development of farmland; these gains are capitalized into land prices, including the price of plots remaining agricultural at the time of transaction. These capital gains are larger for plots located near a city-centre, near a large city and/or when the city sprawls into its countryside. High land prices explain land intensive production systems in the close vicinity of cities (see e.g. Livanis *et al*., 2006).

This paper is in the same vein. We here study the effects of urbanization on farmland prices in Belgium, keeping in mind von Thünen's (1826) and Ricardo's (1821) original insights as well as the specificities of Belgium. We control the effects of soil fertility (Ricardo) by taking into account the Belgian agricultural zoning system, and we focus on von Thünen's perspective: we show how far urbanization influences farmland prices via Thünian determinants that explain residential land prices (see e.g. Anas *et al*., 1998) as well as farmland prices. We therefore estimate the same econometric equation on the two land markets (agricultural and residential) by means of data aggregated at the level of all 589 Belgian municipalities (communes). Results show that farmland price decreases with distance to job centres, increases with the population of the municipality and its evolution as well as with households' income.

Hence, prospects of conversion from agricultural to residential land uses are high in a dense and sprawling country like Belgium, especially as planning rules are sometimes more permissive, unlike other small and dense countries where strict zoning forbids and regulates urban sprawl (see e.g. The Netherlands). Indeed, Belgium is a small country, densely inhabited and characterized by a tight urban network. On the average, jobs are mainly located in city centers (see e.g. Riguelle *et al*., 2007) and urban sprawl largely dominates residential choice since over 40 years (see e.g. Caruso, 2002) leading to fragmented landscapes that evolve in space and time (Antrop, 2004; Thomas *et al*., 2008), but where farming still persists. At the exception of the hilly and forested Southern part of the country, urban hinterlands overlap, especially in the Northern part of the country where population density is much higher. This situation differs from large and sparsely populated countries such as the US, Canada, or France where rural landscapes cover a quite large proportion of the country. Moreover, in Belgium and especially in Wallonia (southern part) urban planning rules has often been very loose leading to a well-known "laisser-faire" (see e.g. Albrechts, 1999; Caruso, 2002).

The remainder of this paper is organised as follows: Section 2 presents the theoretical background. The Belgian urban context is described in Section 3. The econometric model and the data are developed in Section 4. Results are presented in Section 5 and further discussed in Section 6.

2. Theoretical background

Ricardo (1821) showed how the fertility differential rent is formed. Land price is the capitalisation of that rent and is given by the well-known formula: $P = R / i$, where P stands for land price, R is the differential rent and i the capitalization rate. As a forerunner of the marginalist reasoning in economics, von Thünen (1826) demonstrates the formation of the spatial differential rent, associated with the transportation cost of the agricultural products to the urban market. We here use the Ricardo's formulation to show how the prices of convertible agricultural land capitalise agricultural rent up to the moment of land conversion, and then residential land rent (after conversion)(Section 2.1). We then favour a Thünian reasoning for explaining the role played by the urban system (size of the cities, distance to CBD, etc.) in the formation of residential (Section 2.2) as well as agricultural (Section 2.3) land rents.

2.1. Farmland price

Let us consider cities growing and sprawling into the surrounding countryside. This growth generates conversion of agricultural plots into urban uses devoted to residence or any other non-agricultural land-use (industries, tertiary activities, services, transport infrastructures, etc). These land-use changes are profitable to landowners; capital gains are often quite important[1] and correspond to the capitalization of the residential rents got by the plots after conversion. Actors on the land market expect urban demographic growth and integrate these capital gains in the present farmland price.

Capozza and Hesley (1989, 1990) initiated research in this direction. They showed that farmland prices are equal to the sum of (1) the capitalization of the agricultural land rent up to the date of conversion, and (2) from that date, the capitalization of the residential land rent (that depends upon population growth or option values). These papers have been followed among others by the recent contributions of Hardie *et al*. (2001), Plantinga and Miller (2001), Plantinga *et al*. (2002), Cavailhès and Wavresky (2003), Cunningham (2006), Isgin and Forster (2006).

More precisely, Capozza and Li (1994) showed that land price P depends upon land rent R, population growth rate g and capitalization rate i

$$P = \frac{R}{i} + \frac{g}{i^2}.$$

Let t^* be the date of conversion of agricultural land (with rent R_A) into building land. Building land rent $R_H(x)$ depends on the distance x to the CBD (city centre). The price of convertible agricultural land (noted P_{AH}) is:

$$P_{AH} = \frac{R_A}{i}\left(1 - e^{-it^*}\right) + \left(\frac{R_H(x)}{i} + \frac{g}{i^2}\right)e^{-it^*}. \qquad [1]$$

The first term in equation [1] represents the capitalization of agricultural rent up to time t^*, and the second term is the capitalization of the current and future residential rents (the future

[1] Examples: « In the 1980s, the multiplier between land values for agricultural and urban uses was found to run at 50-200 (times) or even higher in the areas surrounding expanding cities in Japan and Britain, compared to 2-3 in the Netherlands (no servicing costs considered)» (Mori, 1998). Evans (1991) shows that the price of farmland around Reading (UK) was almost £2.000 high, but with a building permit it reached £500.000 up to 1 million (and hence 250 to 500 times higher). Capozza and Helsley (1989) showed that in Vancouver (Canada) in 1986, the price of recently urbanized land was 30 times as large as farmland.

residential rent depending upon population growth). When $t^* = 0$ or $t^* \to \infty$ we obtain the prices of building land P_H, and that of agricultural land located out of any urban influence P_A:

$$t^* = 0 \Rightarrow P_H = \frac{R_H(x)}{i} + \frac{g}{i^2} \qquad t^* \to \infty \Rightarrow P_A = \frac{R_A}{i}.$$

As already demonstrated by Plantinga and Miller (2001) or Cavailhès and Wavresky (2003), when $0 < t^* < \infty$ agricultural land price is higher than the capitalization of the agricultural land rent. It then incorporates the capitalization of the anticipated and actualised residential rents from time t^* and forward[2]. Let us now analyse how $R_H(x)$ is formed in equation [1].

2.2. Residential price

2.2.1. A trade-off between commuting cost and land cost

« The Isolated State » (von Thünen, 1826) was conceived for explaining the location of agricultural activities in a 19th century Prussian estate. *Mutatis mutandis*, it is at the basis of urban economics that has been developed since the 60s (Alonso, 1964; Fujita, 1989; Muth, 1969): commuting costs to the CBD now replace transportation costs of agricultural products to the central market. This theoretical framework is here shortly sketched for better understanding of the influence of urbanisation on farmland prices.

Let us consider a very simplistic space made out of a line, where the origin is occupied by a CBD represented by a point and where all non-farming jobs are located. Households are all considered as identical and have a job in the CBD; they compete with farmers on the land market. All farmers are also considered as identical. Hence, a household residing in *x* consumes a residential good $S_H(x)$ for which he/she pays a land rent $P_H(x)$ and an a-spatial composite good $Z(x)$. $Z(x)$ is composed of all other goods and is available everywhere; it is considered as the numeraire. A household maximises its utility *U*, that corresponds to a Cobb-Douglas function: $\text{Max}_{X,Z} U = \frac{1}{\alpha^\alpha \beta^\beta} S_H^\alpha Z^\beta$, (where $\frac{1}{\alpha^\alpha \beta^\beta}$ is a technical term that here simplifies further notations), under a budgetary constraint $Z + R_H S_H + \delta d = W$, where δ is the unit transportation cost, *d* is the commuting distance to the CBD and *W* is the household's income. Demand functions are obtained by the usual first order conditions. At the equilibrium, the same utility level is reached in each point *x* of the city; it is equal to the utility of the "rest of the world" noted $\overline{U}$ (« open city » model in urban economics): $U^* = \overline{U}$. The residential land rent in *x* is:

[2] We are aware that there are many other determinants of land rents. They were not considered here for different reasons. First, land prices are only made available at the aggregated level of the municipality; this means that the location of the transaction is not precisely known. Hence we cannot consider variables such as distance to amenities or to noxious facilities. Other variables were also used in the literature to explain real estate prices such as climate, pollution etc., but our objective is here to show how simple and basic urban economics variables influence land markets at the scale of one country. Moreover, the effects of farmland fertility (source of differential Ricardian rents) are considered by using the agricultural regions where the commune is located; this also conducts to ignore other agricultural determinants.

$$R_H(x) = R_A + \left(\frac{W - \delta d(x)}{\overline{U}} \right)^{\frac{1}{\beta}}. \quad [2]$$

The equilibrium is determined by a trade off between commuting cost and land cost: when a household moves closer to the city centre (hence reducing commuting cost), his/her move is associated with an increase in housing cost and a reduction of the size of the residential plot. If the effect of a reduction in commuting cost balances the increase in housing cost, there is no reason to move: household's benefits balance the losses. Conversely, the size of the housings increases with distance, and population density decreases (see a survey in Anas *et al*., 1998 and, an example for Belgium in Vanneste *et al*., 2008). This trade off between housing and transportation costs holds when periurban areas are included in the analysis because most periurban households have to commute to city centres (see e.g. Verhetsel *et al*. 2007).

2.1.2. Other determinants of land rent

First, the quality of the neighbourhood influences residential land price. Similar households take similar decisions and locate close to each other due not only to a sorting process on the land market, but also to socio-economical mechanisms leading to a socially segregated space. Heterogeneity influences land prices: better-off households are ready to pay more for their residential plot (see Zabel, 2008, for a review or Reginster and Goffette-Nagot, 2005 for a Belgian example).

Secondly, the productivity of large cities and the level of wages are also capitalized into land prices: office and housing prices are larger when cities are large. This size effect is added to that of longer commuting trips that mechanically result in pushing the limits of the cities further away from city-centre when population increases.

Finally, at the scale of a country, border effects may be observed. In Belgium, these are of different natures and scales: (*i*) the *limits of the urban areas* partition space into "job basins" each of which is polarised by a business centre (see e.g. Dujardin *et al.*, 2007 for Brussels or Dewasseige *et al*., 2001 for Belgium); (*ii*) the Belgium *linguistic* border (see e.g. Dujardin, 2001 for a review) that may generate different residential and/or employment behaviours or different policies on both sides of the border; (*iii*) *international borders* (Belgium is a small country, surrounded by four neighbouring countries), and (*iv*) last but not least, a 60km long *coastline* that is an attractive touristic amenity that is known to increase housing prices.

2.3. The price of convertible farmland

Putting [2] in [1], we obtain:

$$P_{AH} = \frac{R_A}{i}\left(1 - e^{-it^*(x)}\right) + \left(\frac{R_0 - \delta x}{i} + \frac{g}{i^2} \right) e^{-it^*(x)}, \quad [3]$$

where R_0 is the land rent at the CBD and where we consider that the conversion date t^* may depend on the distance x from the CBD.

Let us take the first derivative of [3]:

$$\frac{\partial P_{AH}(x)}{\partial x} = \left[\left(R_A - R_0 - \frac{g}{i} + \delta x \right) \frac{\partial t(x)}{\partial x} - \frac{\delta}{i} \right] e^{-it(x)}$$

The difference between the slope with distance (to the CBD) for farmland and for developable land is given by:

$$\frac{\partial P_{AH}(x)}{\partial x} - \frac{\partial P_H(x)}{\partial x} = \left[\left(R_A - R_0 - \frac{g}{i} + \delta x\right)\frac{\partial t(x)}{\partial x} - \frac{\delta}{i}\right]e^{-it(x)} - \frac{\delta}{i}$$

This difference can be positive or negative.

From [3], it is also possible to determine the date of conversion t^* anticipated by the landowner. We now consider the servicing cost *D* (conversion only occurs when urban rent is larger than agricultural rent to which the annualized servicing cost is added). We now obtain:

$$t^* = \frac{1}{i}\ln\frac{P_H - P_A}{P_{AH} + D - P_A} \qquad [4]$$

3. The Belgian urban system

3.1 Geography of Belgium

Belgium is a small and highly urbanised European country: more than 10 million inhabitants living on approximately 30 000 sq. km. Density varies from almost 30 inhabitants by sq km in rural regions to more than 20,000 in highly urbanised communes. Large density values are mainly to be found in the centre (Brussels) and in the Northern part of the country.

Belgium is administratively divided into 589 municipalities also called communes that correspond to the official European *Nust4* divisions; they are here considered as basic spatial units. Belgium is divided into three administrative regions (Flanders, Wallonia and Brussels); a linguistic border separates the country into two parts (corresponding to the Flanders/Wallonia border). Nowadays, partial political autonomy of the regions implies different land-use and housing policies.

Belgium is a quite interesting case study. Differences are observed in topography (rather flat northern part, rugged landscape in the South), in urbanisation and city networks (tight network in the North, more loose and based on coal and iron former industry in the South) as well as in housing and land-use policies (larger and older housings in the South, housings in better state in the North (Vanneste et al., 2008). Brussels, with an extended urban agglomeration counts over 1.5 million inhabitants (Dujardin *et al.*, 2007) dominates the Belgian city network.

In the urban hierarchy, Brussels is followed by Antwerp (500,000 inhabitants), Liège, Ghent, and Charleroi (between 200 and 300,000 inhabitants). Communes have been classified according their level of urbanisation, going from heavily populated agglomerations with high densities to rich and less densely populated suburbs and "commuter zones" that are re-oriented from a local economy and lifestyle to urban involvement, all the way to rural structures (see e.g. Van der Haegen *et al.*, 1996). 57% of the population live in a highly urbanized commune; this type of commune counts for 26% of the national land surface. When incorporating commuters' zones, these shares become respectively 77% (population) and 50% (territory). They reveal the importance of urban sprawl, suburbanisation and peri-urbanisation in Belgium. Living contexts are quite heterogeneous. On the average, Belgian city-centres often tend to be deprived while suburbs are appreciated by better-off populations (see e.g. Dujardin *et al.*, 2004; Goffette-Nagot *et al.*, 2000).

In 2000, agricultural production represents only 1,3 % of the Belgian GNP. Cattle's breeding represents 60% of the final production, but only 44% of the agricultural land uses are occupied by pasture (Van Hecke et al., 2010). We can sketch the Belgian agriculture as being characterized by cattle breeding and by an intensive cultivation of mainly cereals, sugar beet, flax, potatoes and green fodders (see e.g. Van Hecke *et al.*, 2010). As expected by the

profiles of urbanization, rural landscapes are quite different in the northern part of the country than in the southern part (Wallonia) (see e.g. Antrop, 2004). In opposition to Flanders, the Walloon Region still has large rural (or forested) areas, and urbanization is more concentrated; the morphology of the built-up areas traditionally follows the diversity of the rural landscapes (Thomas *et al*., 2008). Belgium is officially divided into 14 agricultural regions i.e. broad zones of similar geology, soil types, geography (relief, communal borders) and climate (DGATLP, 2001 and Appendix 1). These characteristics also influence the structure of the agriculture and the type of farms encountered in each of these regions (Van Hecke *et al*., 2010).

3.2. Urban areas and periurbanization

Since over 40 years, Belgium undergoes a strong development of its urban peripheries for residence as well as for work. This is mainly due to an increase in welfare that entails a growing mobility and changes in the residential choice criteria driven by the search of a green environment. Among others, the possibility for workers to commute by public transportation and/or with very advantageous price rates (tax deductions, employer intervention, etc.) constitute another factor that favoured large areas around the cities to become residential. The growth of urbanization was the strongest in the outer zone of the city regions called "the urban fringe" or the "periurbanization front". Up to now, it has been the most important growing zone of the cities (see Verhetsel *et al*., 2010).

The city network of the country is here summarized by 22 urban centres, which correspond to the upper levels of the urban hierarchy (Van Hecke, 1998).[3] The three cities located in a neighbouring country (Lille (F), Aachen (D) and Maastricht (NL)) were also considered as job centres because of the observed commuting patterns (Verhetsel *et al*., 2007). Hence, 25 urban centres are here taken into account. Each of the 589 communes is allocated to its closest urban centre (one of the 25 mentioned above), according to the shortest distance. Several distances were computed and compared (see Vandenbulcke, *et al*. 2009): Euclidian distance, road distance, peak and off-peak distance, gravity-type distance (population divided by square road distance). Results are little sensitive to the way of measuring distance (see also Goffette-Nagot *et al*., 2010). Hence, we here simply chose the road distance. With this criterion, urban areas were defined and a partition of the country into job-basins was obtained.

4. Model and data

4.1. The econometric model

Economic theory does not give any information about the hedonic price function because it is an envelope function (Taylor, 2008). A specification with a Box-Cox transformation is often used, given the flexibility of that method. As mentioned by Cheshire and Sheppard (1998, 360-361), « The Box Cox transformation was used as the basic for the hedonic price function. Use of this form provides for the flexibility to approximate any 'true' hedonic price function (…) If such non-linearity in prices is dictated by the observed data, it allow the identification problem discussed in Brown and Rosen (1982), and Follain and Jimenez (1985) to be overcome". This transformation is here used for the dependent variable.

[3] In the case of Brussels, 19 townships (communes) representing the urban centre are considered as a whole.

Colwell and Munneke (1997, 320-321) showed that the explained variable in the hedonic equation has to be the total price of the transaction and not the price by unit of surface which should lead to an underestimation of the slope of the rent with distance because « land prices appears to be an increasing concave function of parcel size (…) [and] parcel size increases with distance ».

The estimated equation becomes:

$$\frac{P_i^{\lambda} - 1}{\lambda} = X_i b + \varepsilon_i , \qquad [4]$$

where P_i is the sum of the prices of the properties sold during one year in commune i, X_i the matrix of covariates (including an intercept), b the vector of parameters to be estimated, and ε_i the error term. λ is the Box Cox transformation parameter. The hedonic pricing function is linear if $\lambda = 1$, logarithmic if $\lambda = 0$ and has an intermediate shape if $0 < \lambda < 1$ (Note: $\lambda > 1$ is also possible).

Hedonic methods applied to land or to housing prices often generate several well-known econometrical problems (see e.g. Sheppard, 1999 or Baranzini *et al*., 2008). Sheppard (1999) insists on the endogeneity of the covariates in the estimation of the demand parameters, i.e. in the second step of the Rosen method, which we do not consider here. Endogeneity may also appear in the first step (Epple, 1987). The instrumental method is often recommended for endogenous covariates, but it is rarely used in case of aggregated data: fair instruments (i.e. correlated to the endogenous covariates (up to several)), and satisfying exogeneity (Sargan's test) are often not available.

The hedonic method applied to housing (here: land prices) also assumes that the market is competitive and unified. The large number of buyers and sellers generally conducts to assume that competitiveness is verified even if this market is imperfect (information asymmetry, heterogeneous good, etc.). However, the market is not unified at the scale of a country, even if small. Local markets exist, at least at the regional scale. This aspect is here taken into consideration by shift variables that characterize the formerly defined urban areas. This means that we assume the market of each urban area to be unified.

Three econometric concerns are considered: heteroscedasticity of the error, spatial autocorrelation of the residuals and multicollinearity between covariates.

Heteroscedasticity often occurs with aggregated data. It is here corrected by using the Feasible Generalized Least Squares (FGLS) and the Breusch and Pagan test.

Spatial autocorrelation of the residuals can have several sources, due to spatial dependency: a direct influence of one transaction on its neighbors, omitted or poorly measured variables shared by neighboring observations, or spillover effects. Moreover, geographic data are often spatially heterogeneous, which entails spatial heterogeneity of the parameter estimates for different zones. Folowing Anselin and Lozano-Garcia (2007), these two aspects "may be addressed by means of spatial fixed-effects. This rests on the assumption that the spatial range of the unobserved heterogeneity / dependence is specific to each spatially delineated unit. In practice, there may be spatial units (such as school districts) where such a spatial fixed-effects approach is sufficient to correct for the problem". Following this method, we use a *fixed-effects* model, by transforming [4] as follow:

$$\frac{P_{ij}^{\lambda} - 1}{\lambda} = X_{ij} b + m_j + \varepsilon_{ij} \qquad [5]$$

where subscript *j* is used for the urban area *j* (m_j is a dummy variable) and subscript *ij* is used for the commune *i* pertaining to the urban area *j*. Thus $\sum_j \varepsilon_{ij} = 0$ which means that there is no correlation between the residuals of different urban areas. Nevertheless, spatial autocorrelation may also occur between the communes *i* pertaining to a same urban area *j*. A Moran's index between the neighbors' ε_{ij} is computed, its significance is tested and, if any, it is corrected by adding a term $W\hat{\varepsilon}_{ij}$ to equation [5], where $\hat{\varepsilon}_{ij}$ are the residuals estimated in a first step.[4] The final estimated equation is:

$$\Omega \frac{P_{ij}^{\lambda} - 1}{\lambda} = \Omega X_{ij} b + \Omega m_j + \Omega \rho W \hat{\varepsilon}_{ij} + \Omega \nu_{ij}, \qquad [6]$$

where Ω corrects heteroscedasticity. It is obtained in a preliminary step by regressing the absolute value of the residuals on the explanatory variables. *X* stands here for the matrix of explanatory variables (without intercept)

Multicollinearity can occur because of the centre-periphery structure that characterizes the geography of the Belgian urban areas: population and population density decrease with distance, while rural amenities and the size of the residential plots increase, etc. To avoid inefficient estimates, we limit the number of covariates. Nevertheless, multicollinearity can still subsist; it can be detected by the *condition number* based on the principal components method (cf. Greene, 2003, pp. 57–58). In this latter case, we use a second estimation procedure, the Partial Least Squares (Wold, 1985).

4.2 Data

The dependent variable is the Box Cox transformation of the total price (mean price × number of transactions) of either developable land or farmland sold in a commune during one year (source: National Institute of Statistics, SPF Économie - Direction Générale Statistiques). We here use an 11 years period (1995-2005); the database includes 11 years * 589 communes that is to say 6,479 observations (some of them are missing if no transaction is observed during one year). The Belgian official price index is used as deflator to express monetary data in 2005 euros.

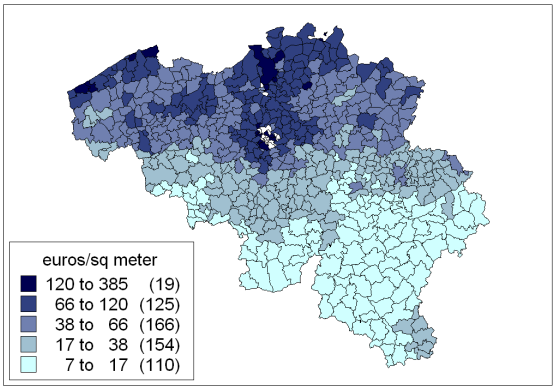

Figure 1: Residential land price per sq. meter (over the studied 11 years period, in constant 2005 euros – Source : INS/Stabel)

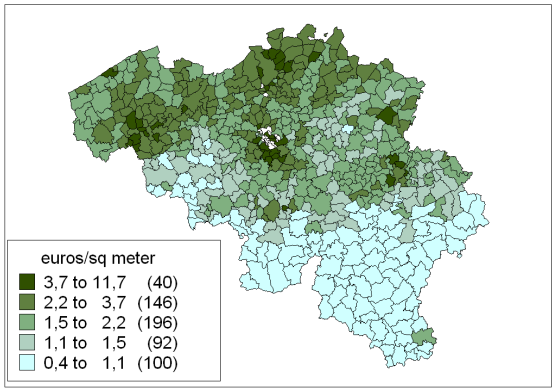

Figure 2: Farmland price per sq. meter (over the studied 11 years period, in constant 2005 euros – Source : INS/Stabel)

[4] We use a contiguity matrix *W* where communes that are less than 10 km apart are neighbors, weighted by $1/d^2$, where *d* is the distance between the commune and the centre of the urban area.

As expected, unit residential land price (Figure 1) is high in and around cities, especially large cities (Brussels, Antwerpen), and decreases with distance from city centre. There is a strong North-South difference: land is more expensive in densely populated areas especially in the Northern part of the country (see also Thomas and Vanneste, 2007; Goffette-Nagot *et al*., 2010 or Halleux, 2009 for further analyses). In the southern part of the country, land is cheaper at the exception of an area under influence of Luxembourg. Farmland price per sq. meter (Figure 2) reveals a spatial structure that looks globally like that of residential land but with some differences. There is still a North-South difference and hence more than probably an effect of the urban network, but there is also a much stronger effect of periurbanisation: farmland prices are proportionally higher in these areas. Suburban communes in the vicinity of large cities have proportionally high values for farmland. In these suburban areas, interactions of agricultural and urban market result in larger values of farmland. On the average, the coastline is less determinent in influencing farmland than residential land; this can be explained by a strong local land-use policy in order to protect the environment.

Explanatory variables used on the two models are reported in Table 1. They are exactly the same for both regressions, at the exception of the agricultural zones that are only introduced in the farmland price equation.

VARIABLE	ABBREVIATED NAME	VARIABLE	ABBREVIATED NAME
Urban area	ID-CODE	Flanders border	VL-BORDER
Surface (deciles)	SIZE	Wallonia border	W-BORDER
Log(commune mean income)	LOGINCOME	Flanders region	FLANDERS
Population (four dummies)	POP	Wallonia region	WALLONIA
Population evolution (1995-2005)	ΔPOP	Brussels region	BRUSSELS
German border	D-BORDER	Distance from the hub-city of the urban area * urban area	DIST*ID-CODE
France border	F-BORDER	year of the observation	YEAR
Luxembourg border	L-BORDER	Coastal commune * distance	COAST*DIST
The Netherlands border	NL-BORDER	Market opening	MARKET
		Agricultural regions	AGRI-ID

Table 1: Explanatory variables used in the model.

ID-CODE are dummy variables for the 25 urban areas. SIZE is the sum of the surfaces of land sold in a commune *i* during one year (average unit size × number of transactions), in deciles (Source: INS, Statbel). LOGINCOME is the logarithm of the median income declared by the households residing in commune *i* (Source: INS, Statbel). POP stands for the number of inhabitants residing in each commune (Source: National Registry of Population); it is transformed into classes of population (POP<5000, POP5-10000, POP10-20000 et POP>20000). A 1995-2005 evolution rate is computed (ΔPOP). Border effects are measured by dummy variables: linguistic border (VL- and W-BORDER when commune *i* is respectively contiguous to the Flemish or the Walloon region), boundaries with neighbouring countries (L stands for Luxemburg, NL for The Netherlands, F for France, and D for Germany). Dummy variables were also used for the administrative regions (FLANDRES, WALLONIA and BRUSSELS). The shortest road distance (computed on the real road network) between the centroïd of commune *i* and the centroïd of the closest hub-city *j* represents transportation costs. It is introduced into the regression in interaction with the dummy variable of this urban area (DIST*ID-CODE), so that the effect of distance may differ according to urban areas. COAST*DIST is the distance to the coast for the two coastal

regions (Brugge, Oostende). YEAR are dummy variables according the year of the data. The MARKET variable is the ratio of the volume of the transactions to the area of the commune, measuring the opening of the market. Finally, AGRI-ID are dummy variables for the 14 agricultural zones.

5. Results

5.1. Global comments

The parameter of the Box Cox transformation takes the value 0.09 for residential land and 0.11 for farmland. These two values are close to zero (which would correspond to a logarithmic transformation), but they are significantly different from zero. Hence, the Box Cox transformation is kept for the dependent variable.

The Breusch and Pagan test reveals that the residuals are *heteroscedastic* in the residential as well as in the farmland prices regressions. Hence, the FGLS method is used; consequently, the determination coefficient has no sense as equations are estimated without intercept. *Spatial autocorrelation* of the residuals (tested by the nullity of the Moran index) is globally observed for farmland but not for residential price. Hence, we introduce in the first case the term ρW (cf. equation [6]). Last but not least, the condition index indicates that there is no *multicollinearity* at the exception of some pairs of dummy variables identifying urban poles (ID-POLES).

Results are reported in Table 2.

Characteristics of the good and the transaction

Let us first consider the characteristics of the plots. Figure 3 shows the unit price versus the average size of the plot, for developable land (LHS) and for agricultural land (RHS). The size of developable land plots varies from 882 sq metres for the first decile to 1740 for the last one. The relationship between unit price and plot size is clearly not linear for developable land (respectively 117 and 42 €/sq m for the two before mentioned intervals) and less clearly for farmland (from 2,2 €/m² for the first interdecile interval which has an average surface of 0,5 hectare, to 1,2 €/m² for the last one which is larger than 2 hectares).

The non-linearity of the price-surface relationship is often explained by fixed costs: either transaction costs (searching for information, tax, etc.), or servicing costs (connecting to the networks, etc.) increase the unit price of very small transactions (Colwell and Munneke, 1997). However, this is probably not sufficient to explain the variations of the unit price of developable land (from 1 to more than 2), while the average plot size varies for 900 to 1,750 square meters. This unexpected result can also be due to aggregation biases.

Residential price is much larger than farmland price: if an agricultural plot of 5,100 sq meters is divided into three 1,700 sq meters plots of convertible land, the unit price is 15 times higher than farmland. The multiplier becomes 25 when we consider a plot of one hectare (=10,000 sq meters) that we divide into plots of 1,500 sq meters.

Unit prices increase regularly with time (Figure 4). The price of developable land (in constant euros) have been multiplied by more than 3 within the 11 years considered in this paper, and farmland by almost 2. The average size of the residential plots increased from 1,250 to 1,430 sq meters between 1995 and 2000 (which is a period of slight rise in prices), and then decreased to 1,080 sq meters in 2005 because of a sharp rise in prices. The average surface of a plot of farmland increased regularly from 0.9 ha in 1995 to 1.2 ha in 2005.

VARIABLE	Developable land		Farmland		VARIABLE	Developable land		Farmland	
	estimate	t	estimate	t		estimate	t	estimate	t
Ω	17.36072	27.33	27.0557	30.31	D-BORDER	0.39893	2.15	0.44328	1.38
SIZE (DECILE 1)	-4.31289	-43.67	-6.40597	-56.63	F-BORDER	-0.09888	-1.53	-0.07692	-0.84
SIZE (DECILE 2)	-2.34496	-40.2	-3.26018	-39,0	L-BORDER	0.47111	4.22	0.63051	3.41
SIZE (DECILE 3)	-1.33345	-26.31	-1.87422	-24.67	NL-BORDER	0.02719	0.35	0.22102	2.49
SIZE (DECILE 4)	-0.67285	-13.43	-0.78328	-11.88	VL-BORDER	0.45097	6.51	0.17796	1.71
SIZE (DECILE 5)	Ref.		Ref.		W-BORDER	-0.35223	-5.44	0.39942	4.54
SIZE (DECILE 6)	0.531	10.66	0.83372	12.87	COAST-BRUGGE*DIST	0.2281	13.46	-0.06954	-4.87
SIZE (DECILE 7)	1.24308	23.47	1.69306	27.1	COAST-OOSTENDE*DIST	0.11557	11.94	-0.03924	-3.66
SIZE (DECILE 8)	1.77345	33.31	2.49377	39.83	BRUSSELS	1.49366	4.69	-0.06449	-0.07
SIZE (DECILE 9)	2.73257	46.78	3.57081	51.73	FLANDERS	1.76482	16.47	0.50325	3.38
SIZE (DECILE 10)	4.27897	52.44	5.44511	57.96	LOGINCOME	3.48025	17.3	1.083	3.79
DISTANCE-ANTWERPEN	-0.02781	-3.29	0.02641	1.86	POP<5000	-2.26011	-31.03	-1.20723	-14.41
DISTANCE-MECHELEN	-0.03024	-3.57	0.01872	1.4	POP5000-1000	-1.84116	-28.04	-0.80949	-13,0
DISTANCE-TURNHOUT	-0.04284	-7.64	-0.03866	-4.87	POP10000-2000	-0.76797	-18.29	-0.41883	-7.58
DISTANCE-BRUSSEL	-0.07488	-7.69	-0.0226	-1.19	ΔPOP	5.9997	15.11	2.55157	5.05
DISTANCE-LEUVEN	-0.07402	-11.22	0.04718	4.97	YEAR1995	Ref.		Ref.	
DISTANCE-BRUGGE	-0.06529	-4.35	0.00216	0.21	YEAR1996	0.13015	2.29	-0.17264	-2.77
DISTANCE-KORTRIJK	-0.03431	-5.1	-0.05132	-4.83	YEAR1997	0.28813	5.27	-0.03753	-0.6
DISTANCE-OOSTENDE	0.00787	1.61	0.04197	3.89	YEAR1998	0.53864	9.79	0.06713	1.03
DISTANCE-ROESELARE	-0.02387	-2.96	-0.03395	-5.21	YEAR1999	0.96338	17.47	0.23855	3.75
DISTANCE-AALST	-0.05681	-9.46	-0.04745	-7.97	YEAR2000	1.13216	20.33	0.25734	3.77
DISTANCEGENT	-0.08282	-8.26	-0.04203	-4.39	YEAR2001	1.80538	26.52	0.57357	7.28
DISTANCE-SINT-NIKLAAS	-0.09129	-7.93	-0.07036	-4.42	YEAR2002	1.84001	31.48	0.77251	9.51
DISTANCE-CHARLEROI	-0.03569	-7.48	-0.02708	-4.42	YEAR2003	2.24373	36.13	0.77094	10.06
DISTANCE-MONS	-0.02216	-3.2	-0.01294	-1.32	YEAR2004	2.75891	43.81	1.00987	11.5
DISTANCE-LA LOUVIERE	0.04025	4.96	0.00273	0.29	YEAR2005	3.29626	53.33	2.08046	19.32
DISTANCE-TOURNAI	-0.03558	-3.72	-0.02176	-1.78	MARKET	0.09709	6.29	0.02328	4.13
DISTANCE-LIEGE	-0.03668	-10.94	-0.02507	-4.51	MEADOWS			2.95626	2.92
DISTANCE-VERVIERS	-0.0319	-9.1	-0.01516	-3.12	RHO			0.40594	8.47
DISTANCE-GENK	0.00811	0.87	0.00252	0.24					
DISTANCE-HASSELT	-0.03653	-6.19	-0.02608	-3.25					
DISTANCE-ARLON	-0.00731	-2.46	0.02403	4.15					
DISTANCE-NAMUR	-0.01791	-7.35	-0.02195	-5.54					
DISTANCE-AACHE	-0.09307	-2.12	-0.09797	-1.73					
DISTANCE-LILLE	-0.01706	-0.31	-0.03467	-2.19					
DISTANCE-MAASTRICHT	0.01084	0.29	-0.04309	-1.16					

Table 2: Regression results

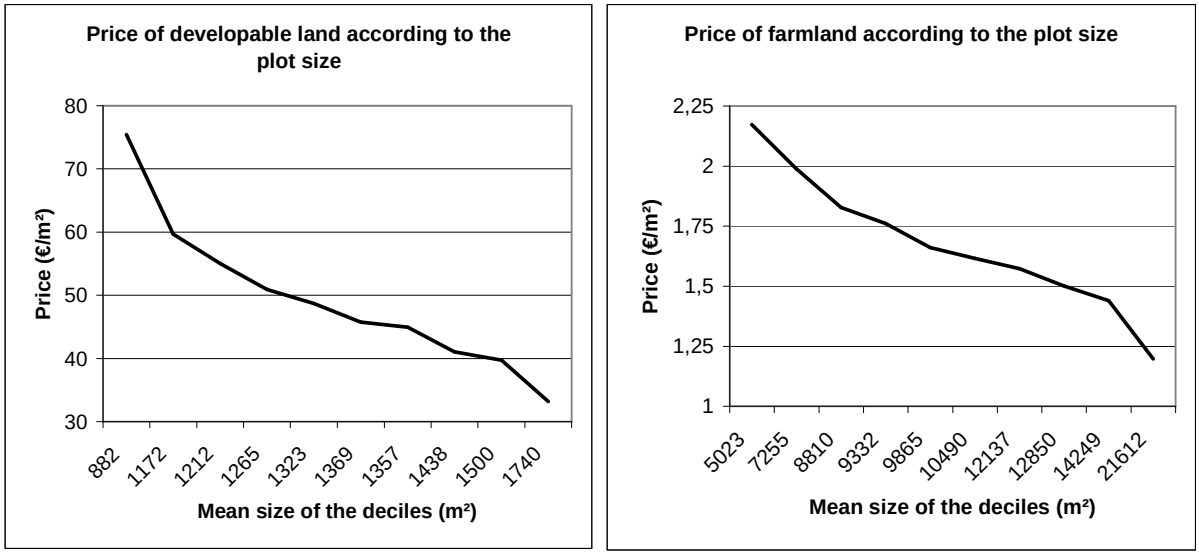

Figure 3: Unit price of developable land (LHS) and farmland (RHS) according to the plot size (price expressed in constant euros 2005 by sq meter)

Several other variables were introduced in the regressions such as those related to spatial aspects/partitioning. Variables characterizing the job basins and the agricultural zones are not all reported in Table 2. As illustrated in Appendix 1, farmland prices observed in the "polders region" or in the "sandy zone" are much higher than those observed in the "sandy-loam region" that is here considered as the reference zone (respectively +51% and +23%). Inversely, if 100 is the value of the index of reference, farmland prices is 36 in the Haute Ardenne, 41 in the Famenne, 58 in Condroz, 64 in the Jurassic region (south of the country) and in the Ardennes.

Ricardian fertility (here represented by the variables related to the agricultural zoning of Belgium) largely contributes to the explanation of farmland prices.

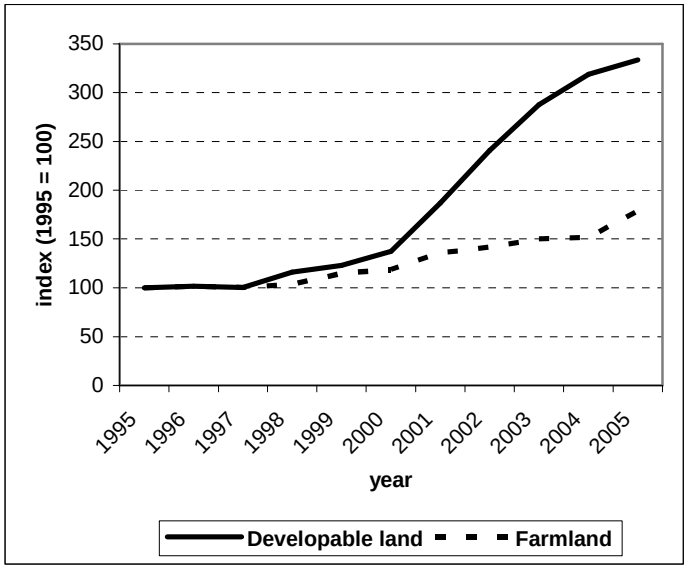

Figure 4 : Evolution with time of the unit price of land (1995-2005)

Let us now consider the spatial variables related to urban and residential economics (hereunder) and their effects on both studied land markets.

5.3. Distance to urban centres

Distance to CBD is one of the most important explanatory variables of land values in urban economics. The average slope observed for developable land in Belgium is here -3,3% by kilometre. It is lower than -7% for the urban areas of Brussels, Leuven, Aachen (Germany), Gent and Sint-Niklaas. On the opposite, it is positive and significant for the urban area of La Louvière (+4%) which is a relatively small urban area squeezed between the large areas of Brussels (North), Charleroi (East) and Mons (West). This location as well as the tight and old industrial urban structure of the built-up landscape may explain this paradoxical result. The slope is not significantly different from zero for four urban areas, among which two cities located abroad (Lille (France) and Maastricht (The Netherlands)). In ten other urban areas, the slope is close to the mean value and varies between -2.5 and -4.0%.

These rates are relatively low compared to those mentioned in other papers. MacMillen (1996) for instance obtains –14% per mile, Söderberg and Janssen (2001) –11% by km for Stockholm, Reginster and Goffette-Nagot (2005) –12% by kilometre for Namur and Charleroi (Belgium), Goffette-Nagot (2000) gets -8.6% by kilometre and Beckerich (2001) –16% by km for Lyon (France). However, Colwell and Munneke (1997) get a decreasing rate of –3% per mile; for the Dijon urban area (France), Cavailhès and Wavresky (2003) found –2,8 % by kilometre. These latter authors explain the small gradient by the existence of forest and

agricultural amenities that are more frequent when distance from city centres is large. Hence, the negative effect of distance is partly compensated by the pleasant green environment as mentioned in Brueckner *et al*. (1999).

The average slope for farmland is -1.6%, that is to say more than half that of developable land. It is less than -7% for Aachen (Germany) and Sint-Niklaas, and, on the opposite significantly positive for the urban areas of Leuven, Oostende and Arlon. It is not significantly different from zero for six urban areas. In 11 cases, it is comprised between -2 and -5%.

The theoretical model discussed in Section 2 appears to be the most plausible for explaining these negative slopes[5]: farmland in Belgium is affected by periurbanisation that leads to anticipate capital gain from farmland development; the closer the date of conversion and the closer the location of the plot to the CBD, the higher will be the gain.

This hypothesis is supported by the positive and significant correlation coefficient between the parameters of distance (distance to CBD) obtained for the 25 job centres (see Figure 5). The determination coefficient takes the value 0.18, significantly different from zero at the level of 5%.

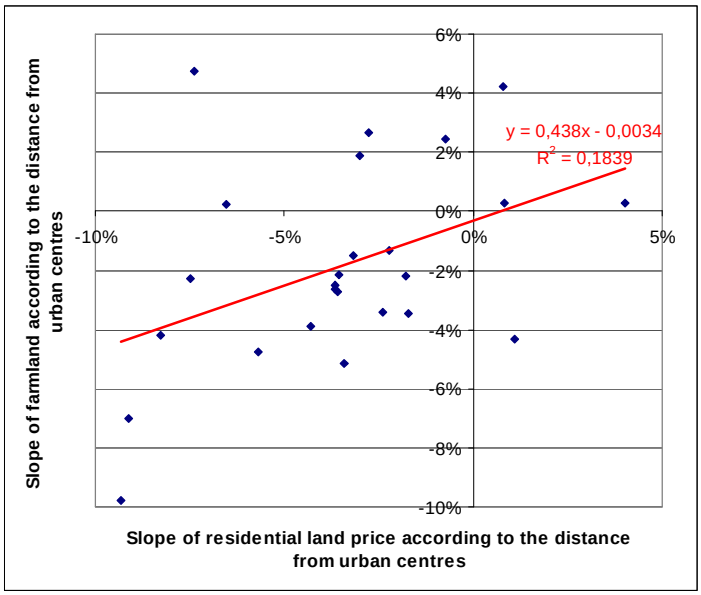

Figure 5: Parameters of distance to the 25 job centres.

5.4. Other urban economic variables

Table 3 refers to the results related to the other explanatory variables; effects are expressed in comparison to a reference (index 100). The effects of population (number of inhabitants) have the same sign on the two land markets and similar significance levels. Let us here simply give the example of developable land in the communes of less than 5,000 inhabitants that have an index 20 and farmland 47 (index 100 for the cities of more that 20,000 inhabitants). The effect of households' income is significantly positive on the two land markets: a 10% increase in income generates a change in developable land index from 100 to 130, and similarly from 100 to 107 for farmland.

[5] We do not exclude that the explanation may be associated with the Ricardian rent of soil if fertility regularly decreases when distance from employment centres increases.

	Developable Land	Farmland
Population		
POP<5000	20	47
POP5-10000	28	61
POP10-20000	59	77
POP >20000	100	100
Border effects		
NO-BORDER	100	100
D-BORDER	130	130
F-BORDER	*94**	*95**
L-BORDER	136	145
NL-BORDER	*102**	*114**
VL-BORDER	134	111
W-BORDER	79	127
COAST*DIST - BRUGGE	116	96
COAST*DIST - OOSTENDE	108	98
INCOME(+10%)	130	107

Table 3: Relative effects of other urban economic variables
(expressed in comparison to a reference)
(*: not significant at 5% level)
(see definitions of the variables in Section 4.2 and 5.4)

On both land markets, linear effects of the borders are positive; this yields for borders with Germany (respectively +30% for developable land and +30% for farmland), with Luxembourg (+36% and +45%) as well as that with Flanders (+34% and +11%, respectively). However, there is no significant effect of the border with France or with The Netherlands. On the Walloon side, there is a negative effect of the linguistic/regional border on residential land rent (-21%) while it is positive for farmland (+27%). As expected, the closeness to the sea front has a positive and important effect on the price of developable land (that is nowadays scarce and very expensive) while it is negative on the price of agricultural land (sandy soils, polders). Land-use policy intervenes here for explaining the observed differences as well as soil fertility and farm structures. The last three parameters are the only ones for which the sign is different on both land markets. At these three exceptions, it appears that the same variables explain spatial variations of both developable and agricultural land prices.

6. Conclusion and discussion

High population density and strong periurbanisation trends could explain that landowners will anticipate the conversion of farmland into developable land whatever the location of the plot in Belgium. However, developable land prices are much higher that farmland prices. These urbanisation capital gains are captured in land prices, even if these plots remain with an agricultural land-use at the time of the transaction. As expected, the agricultural land market undergoes the influence of the urban network; this is particularly high in a densely urbanized country like Belgium.

In order to test this hypothesis, we have estimated the same econometric model for developable and for agricultural land prices at the level of the 589 municipalities in Belgium. Results show that farmland prices vary according to the agricultural zone they belong to; these zones were mainly defined according to the fertility of their soils, hence generating a Ricardian differential land rent. Beyond this expected effect, it also appears that farmland prices are highly and significantly influenced by basic variables in urban economics: prices

decrease with increasing distance from CBDs (in the same way as developable land but with a smaller slope), and they increase with the size of the cities as well as with demographic growth, and they also increase with households' income. All these relationships are similar on both markets but they are weaker on the agricultural land market. More particularly, the effect of distance to the 25 employment centres is relatively similar on both markets: the slope of farmland is significantly associated to that of developable land.

Using equation [4], we can estimate the date of conversion anticipated by the landowners. This is of course a quite rough estimation because the computation depends upon the discounting rate (here: 6%), upon farmland prices observed out of any urban influence (we here consider that the probability of conversion is zero at more than 60 km of any urban centre) and the servicing cost (here set to 10 €/sq m). Results are not very sensitive to the Y-intercept (descriptive statistics show that the average developable land price in urban centres is 102 €/sq m while that of farmland is 2,7). With these assumptions in mind, the application of equation [4] leads to the conclusion that landowners think that the conversion of farmland into developable land will occur within a 20 - 30 years period: 33 years for plots close to the CBD, 20 years at 30 km and 15 years at 40 km from the CBD. The length of the period regularly decreases when distance increases. This computed date only gives a rough and discussable indication (due to the assumptions made for its computation). It however indicates that landowners reckon an urbanisation capital gain that will occur in less than one generation (this is of course not possible at an aggregated level because this would mean that agriculture will shortly disappear from the country).

It is however possible that the influence here associated to urban sprawl is in fact partly due to other factors. *First*, it is also possible that the soil fertility decreases when distance from the urban centres increases; indeed cities may have been located in areas that are more prone to feed their population, in more fertile cultivated areas. Accurate pedological data should be necessary for separating the effect of fertility from the expectation of gain from development. *Secondly*, closeness to city can also benefit to the farms as they sell fresh/dairy products to the city (this exactly corresponds to the theory von Thünen) or as they provide jobs to the other members of the household living on the farm. In-depth analyses of the farms and of the households would here be necessary to test this hypothesis. *Third*, we can also assume that non-farmer households buy farmland simply for protecting their residential plot from future urbanisation. These households are ready to pay more that a farmer would do for acquiring the land and this price may be close to developable land price. Individual data on the transaction as well as the buyer and the circumstances of the transactions are therefore necessary.

For decades, the well-known rings of dairy and intensive vegetable farming around the cities have illustrated von Thünen's model: transportation costs were the main explanation of the location of the crops. Nowadays, the dependence of the city to its cultivated hinterland has shaded because of the technical and infrastructural development of transport, but also because of the general reduction of the transportation costs and the widening of the agricultural markets (national and international). Hence, Thünian's agricultural economics (nested rings) seemed to fade. Nowadays, urban sprawl generates a new geography of farmland rent polarized by the city. It enables one to re-discover von Thünen's model that still explains today's land price structure. However, the explanation of the currently observed spatial structures is less dependent upon transportation costs than it was in the 19th century; it nowadays highly depends upon urban pressure that exerts through urbanisation expectations as well as other factors that have not been deeply studied here.

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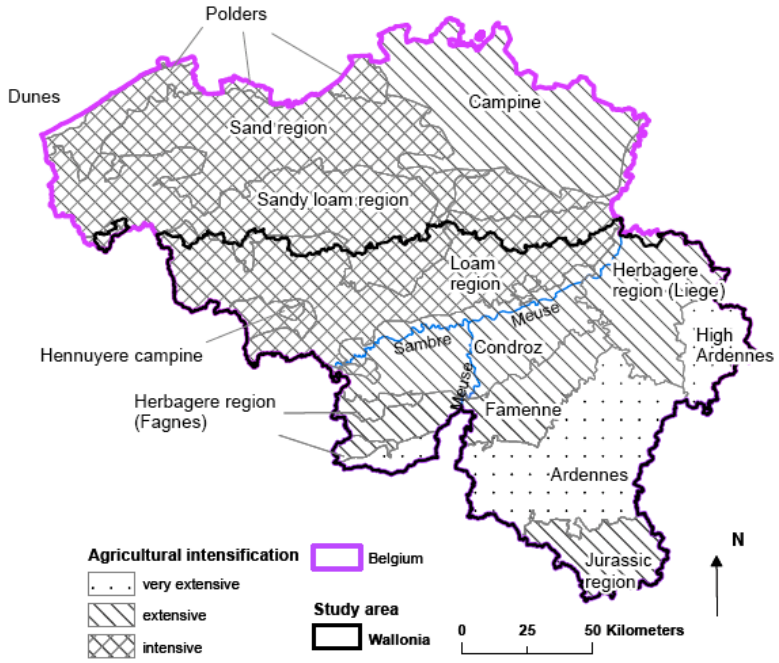
Appendix 1:
Agricultural zones and farmland price by zone

Ardennes	68
Campine	77
Condroz	58
Fagnes	63
Famenne	41
High Ardenne	36
Jurassic region	68
Loam region	91
Polders	151
Herbagère region	64
Sandy region	123
Sandy Loam region	100



Average farmland prices in euros according to the agricultural zone	Agricultural zones and soil textures (Source of map: Goidts and Van Wesemael, 2007)