Seeing and being seen: a GIS-based hedonic price valuation of landscape[1]

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Abstract

We evaluate the hedonic price of landscape seen from houses in the urban fringe of Dijon (France). The viewshed and the land cover as seen from the ground are analyzed by geographic methods from satellite images and from a digital elevation model. Then, the landscape attributes are used in an econometric model based on the sales of 2523 houses. The results show that forests and farmland in the immediate vicinity of houses have positive prices and roads a negative price when these features can be seen by an observer located on the ground, while their prices are close to zero when they cannot be seen: the view itself matters. Seeing close houses is an amenity, but being seen from nearby other houses is a nuisance. The arrangement of features in fragmented landscapes commands positive hedonic prices. Landscapes and visible features more than 100-200 m away all have non-significant hedonic prices.

Introduction

Urbanization in developed countries has been characterized for several decades now by the outward spread of cities into the countryside. This movement is in part green amenity-oriented: rural scenery, open spaces, forests, and farmland are all components of the lifestyle sought after by many of the households moving out of cities, and so are therefore the subject of increasing attention from public authorities. This paper focuses on "periurban" green landscapes that may be part of such population decentralization in France.

In France, during the 1990s, the periurban population rose by 40%.[2] In 1999, periurban communes covered a third of the territory (half as much again in 1999 as in 1990) and more than one-fifth of the French population live in such communes. This has entailed an increase in urban land use to the detriment of farmland and forests, and makes the protection of non-built areas a matter of concern for public authorities. For examples: (i) land zoning, one of the uses of which is to protect green areas, has developed over recent decades (60% of periurban communes had land use schemes in 2002, compared with just 46% in 1988); (ii) in 2004 "perimeters of protection and exploitation of agricultural and natural areas" were set up by statute; (iii) the *Conservatoire du littoral* already has purchased 73,200 ha along 861 km of coastline for the purpose of preserving its natural character and it plans to have bought one-third of the French coastline by 2020.

Taken together, these elements explain why much economic work is being carried out on the topic of urban spread into the countryside. Attempts have been made to put a value on open spaces

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[2] The periurban belts are characterized by their high proportion of commuters: the statistical threshold to be classified as a periurban *commune* is 40% of people in employment working outside of their residential *commune*, and the mean level is 72%. A *commune* is the lowest tier of local government in France (called district or *commune* afterwards).

in or near to cities and on landscapes. This paper concentrates on this last aspect of making an economic valuation of landscapes in the countryside around cities.

Of the various methods of evaluating non-market goods that of hedonic prices is adopted here for evaluating the price of rural scenery around Dijon, the capital of Burgundy (France). In this area, within a radius of some 40 km around the city, a few hundred villages and small towns are scattered over a predominantly agricultural plain and amid hills and valleys covered by forests and farmland. The novel feature of the method used here is that it analyzes a landscape as seen "from within" instead of "from above" by taking account of objects and relief which may hide the view from the ground. In this way, the view from "home" can be reconstituted in a three-dimensional space. A hedonic estimation is then used, with the instrumental variable method. The georeferenced economic data relate to 2523 houses sold between 1995 and 2002 in the study area.

The remainder of the paper is arranged into five parts. After a review of literature (section 1), the economic and geographic models are set out along with the data (section 2); then come the results (section 3) and the discussion (section 4). Section 5 concludes.

1. Landscape valuation

Basically landscape is what lies before one's eyes. This view is difficult to introduce in valuation models because of either lack of data or inadequate data. For a long time the difficulty is overcome by using photographs; then, with maps, aerial photographs, or satellite images, a fictional observer views the landscape "from above". A more recent source used in this paper is the view from ground level or "from within". These methods are briefly summarized in this section, with a precedence given to the hedonic price method that we use in our study.

Preference analysis from photographs. Photographs have long been used to analyze, by regression methods, a score attributed to landscape views by panels of people. The explanatory variables are objective attributes (objects, land use, visual arrangement, etc.), subjective attributes (mystery, atmosphere, etc.), and sometimes personal characteristics (social category, gender, age). Much of this work is old. In 1989 Gobster and Chenoweth [27] listed more than 80 references and recorded 1194 terms for describing esthetic preferences. For example, the scores for photographs in the Great Lakes region (U.S.) was explained by physical, ground cover, "informational" (order, complexity, mystery, etc.) and perceptual (open, smooth, easy to cross) variables, mystery being a good predictor of the score, which, for the authors, is a classical result [37].

Recent research has been conducted in the same vein [4], [30], [28], [33], [36], [40], [47], [49]. For example, Johnston et al. [33] use maps and photographs of alternative developments to show that households prefer fragmented "green" lots bounded by hedges. They also choose fragmented, long and narrow housing subdivisions when density is low (which maintains the esthetic and ecological quality of the whole), but opt for more clustered forms for larger subdivisions.

Economic value of landscape seen from above. Ground cover seen from satellite or aerial photographs within a perimeter around a house is extensively used for landscape valuation. In most, but not all, cases, positive hedonic prices are obtained for wooded land cover [39], particularly on the residential lot itself [17] or on adjacent lots [56] and for nearby recreational forests [57] as well as, of course, for parkland, golf courses or greenbelts. Farmland has a less clear-cut impact, some studies concluding it has a positive effect on real-estate values [51]. Nevertheless, other research reports opposite effects of forests and farmland on housing prices [22], [32], [49], [54], or non-significant effects [50]. These uncertain and unstable findings are paradoxical: if migration into the country is green-amenity oriented, why is the value of green and open spaces surrounding houses not always positive? It may be because the view "from above" introduces drawbacks into the way landscape is apprehended.

Real-estate values generally decrease in distance between housing and green areas, golf courses, forest parks [57], stretchs of water [48], [55] or wetlands [44]. This effect is sometimes non-linear, with housing that is very close to or very remote from the feature being worth less than housing at some intermediate distance [9]. In other instances contiguity has a positive value [31]. For example, Thorsnes [56] shows that housing with direct access to forests is worth 20–25% more and that this extra value vanishes if there is a road to cross to get to the forest. On the whole, the effect of nearby open spaces is substantial when the distance is short, and it falls off rapidly with distance, and cancelled out beyond a few hundred meters at most. This is a useful conclusion for modeling: the geographic scale must take into account fine features of the landscape.

The view from above also provides geometrical indices, mainly elaborated by landscape ecology, which are variables characterizing the shape or pattern of patches formed by different types of land use: synthetic indexes (diversity, fragmentation, entropy, etc.), geometric variables (fractal dimension), or statistical summaries (mean, standard deviation). Geoghegan et al. [25], who present one of the earliest examples of hedonic method using this approach, show that the presence of farmland-forest nearby (slightly) raises land values but has a negative effect when more remote. The fragmentation and diversity of landscape around housing has a negative effect on real-estate values, except where very close and very far from Washington D.C. Acharya and Bennett [1] did very similar work on a Connecticut watershed.

All in all, it should be recalled that research on landscapes seen from above often yields intuitive results; but counterintuitive signs, values close to zero, or volatile values are sometimes reported. It is hard to say whether such fragile results reflect reality or aside from the coarseness of landscape variables. Economists depend on variables supplied by geographers, which have become more precise and more accurate in recent years.

Economic value of landscape attributes seen from within. The view from the ground (“from within” as opposed to “from above”) entails integrating the third dimension, i.e. relief and the height of the objects, into the two-dimensional satellite image of land use. This view, which is the actual view, has only recently been introduced into economic valuation models, which are very few as yet, to the best of our knowledge.

Firstly, Germino et al. [26] analyzed the landscape from satellite images and a digital elevation model by using planimetric (“map-like”) and panoramic (“photograph-like”) simulations of a view. Bastian et al. [5] used such variables to evaluate the hedonic price of landscape and environmental attributes. They concluded that in the Rocky Mountains (U.S.) landscape diversity, the only landscape variable with a non-zero price, is highly appreciated.

Second, Paterson and Boyle [50] compare a rural region of Connecticut (U.S.) seen from within and from above. The sign of their results varies with the specification and in particular contrasts the view from above and the view from within and the surface area seen and the content of the field of view (built areas, forests). These results are disappointing; for example, the hedonic price of the viewshed is negative (if alone) or non-significant (with the land cover) but then forests acquire a negative price.

Lastly, Lake et al. [41] calculate the price of road nuisances, noise, and the view in the urban area of Glasgow (Scotland). The method of identifying the viewshed is burdensome (systematic visits to measure the height of the buildings), and some results are surprising: as expected, the noise from a road reduces the real-estate price, just as the view of a road does, except for the view from the backyard that has an unexplained positive effect on the home price.

To sum up, findings either from photograph analysis or landscape views both from above and from within are often counterintuitive and often contradict the hypothesis of amenity-oriented migrations into the country. This unsatisfactory state-of-the-art prompts re-investigation of the matter. This is what we do in this paper with new methods.

2. Models, sources, and data

2.1 Economic and econometric model of hedonic prices

Rosen's method. In evaluating the hedonic prices of the characteristics of houses, in particular landscape attributes, the first stage of the approach à la Rosen [52] is used. Its microeconomic foundations can be reviewed succinctly. A household *k*, with socio-economic characteristics α_k, maximizes a utility function $U = U(Z, H, \alpha_k)$ by consuming housing $H(x_1,...,x_h)$, comprising a set of intrinsic (floor space, comfort, etc.) and extrinsic (accessibility, social or environmental quality of the location, etc.) attributes, x_h, and a composite good *Z*, taken as the numéraire, under the budget constraint $W_k = P(H) + Z$, where W_k is income and *P*(*H*) the house price. The first order conditions of the usual microeconomic program give the hedonic price p_h of characteristic x_h, equal to the marginal rate of substitution of this characteristic and of the composite good:

$$\frac{\partial}{\partial x_h} P(H) = \frac{\partial U / \partial x_h}{dU / \partial Z} = p_h \qquad (1)$$

This method raises three specific major econometric issues:

First, we mention in passing the problem of identifying the demand functions for the second stage of Rosen's method, because we do not perform this stage: it assumes the provision of additional information, particularly of hedonic prices evaluated on different markets [12], which are not available for our single study area.

Second, the price of attributes does not vary linearly with their quantity: in equation (1), p_h is not a constant because of fixed transaction or building costs. This non-linearity may lead the consumer to choose both the price of housing and the quantity of certain attributes at the same time. In hedonic housing price studies, the results show that the floor space is almost always linked to the random variable. But landscape variables also may be linked with the error if the household, when selecting its location, simultaneously chooses the house price and some of its landscape features. Moreover, landscape attributes may also be endogenous. For example, in an area of high urban pressure, residential values are high and thus open spaces are scarce and small; conversely, the quantity of open space determines the residential prices through the land capitalization of amenities. Thus, simultaneity and endogeneity may entail a correlation between attributes and the error, which implies recourse to the instrumental variable method [19], [21].

Lastly, it may also be that for a spatialized good such as housing there are spatial autocorrelations. Researchs presented above generally make allowance for spatial correlations, but few studies address the issue of the simultaneous choice of the housing price and attributes ([16] is an exception) and, to the best of our knowledge, only Irwin [32] tackles both issues together. Generally, spatial correlations are controlled by introducing a spatial autoregressive variable or by modeling spatial autocorrelations between neighboring observations (depending on the distance between them or the contiguity between the administrative entities to which they belong). For example, Brasington and Hite [11] use an auto-regressive term and a spatial lag of the explanatory variables. Irwin [32] deals with the two problems of endogenous variables and of spatial autocorrelations in estimating the hedonic price of green spaces by using the instrumental variable method and eliminating the closest neighboring observations.

The model. To deal with spatial autocorrelations, we introduce, and then eliminate, a *commune* dummy variable. Communes share characteristics which are not found in the database such as fiscal and land policies (tax and zoning), local public goods (schools, etc.), and they have the same accessibility to markets for labor, goods and services, and also share miscellaneous amenities, nuisances, and externalities. To take into account these features, we begin with the equation: $\ln P_{ij} = b_0 + X_{ij}b + I_i + \varepsilon_{ij}$, where P_{ij} is the price of real-estate j in district i, X_{ij} the matrix of explanatory variables, b the vector of parameters to be estimated, I_i a dummy variable specific to district i and ε_{ij} an error term. Then, we eliminate the *commune* dummies by transforming both the explained and explanatory variables into deviations from *commune* averages:

$$\ln P_{ij} - \overline{\ln P_i} = \left(X_{ij} - \overline{X_i}\right)b + v_{ij} \qquad (2)$$

where $\overline{\ln P_i}$ is the mean of logarithms of house prices, and $\overline{X_i}$ is the matrix of means of explanatory variables in district i. The error term $v_{ij} = \varepsilon_{ij} - \overline{\varepsilon_i}$ is heteroscedastic, but this is the case where the estimator of generalized least squares is the same as the estimator of ordinary least squares [53]. Another source of heteroscedasticity is the number N_i of observations by *commune*; it is easy to check it by multiplying all the terms of (2) by $\sqrt{N_i/(N_i - 1)}$.

Statistical tests. A Box-Cox transformation, made at an explanatory preliminary stage by the maximum likelihood method, shows that the transformation parameter is close to zero, which leads to adopting the logarithmic form for prices. Equation (2), after the foregoing transformations, is estimated (without intercept). The statistical tests are as follows: Hausman's method based on the *increased regression* is used to test if a variable x is or not independent from the error, by the way of an instrumental equation using a vector Z of instruments; then, Sargan's method is used to test the validity of the instruments.[3]

In our application, the Hausman test shows that the living space of the house is endogenous. It is replaced in (2) by its projection on instruments, which are the exogenous explanatory variables of the main regression (2), the characteristics of the buyer and seller, and the toponymy of the roadways (cf. infra, section 2.3.2). The Sargan test shows that those instruments are valid. Finally, equation (2) after both substitution of the living space by its projection and heteroscedasticity control, is estimated by the two-stage least squares (2SLS) method.[4]

Discussion. Our model control omitted variables: spatial correlations between *communes* are thus avoided. Nevertheless, it also presents some drawbacks. First, it does not take into account the effects of variations of landscape attributes between *communes*. Note that, for the variables used in the regressions, inter-district standard deviations are about half the strength of intra-district standard deviations (see Table A-1 in Appendix A). Intra-district heterogeneity is therefore marked compared with the relative inter-district homogeneity, which suggests that our estimators capture a large share of variance. Second, a house is a durable good and the residential mobility of home-owners in France is low. Our estimations are based on the state of the landscape as it was at the time the satellites passed overhead; it imperfectly takes into account agents' expectations by introducing interactions variables into the model. Finally, it is well known that this framework can be used for estimating residential-use values, i.e. the value of non-market attributes capitalized in a real-estate price, but not recreational-use values or existence values.

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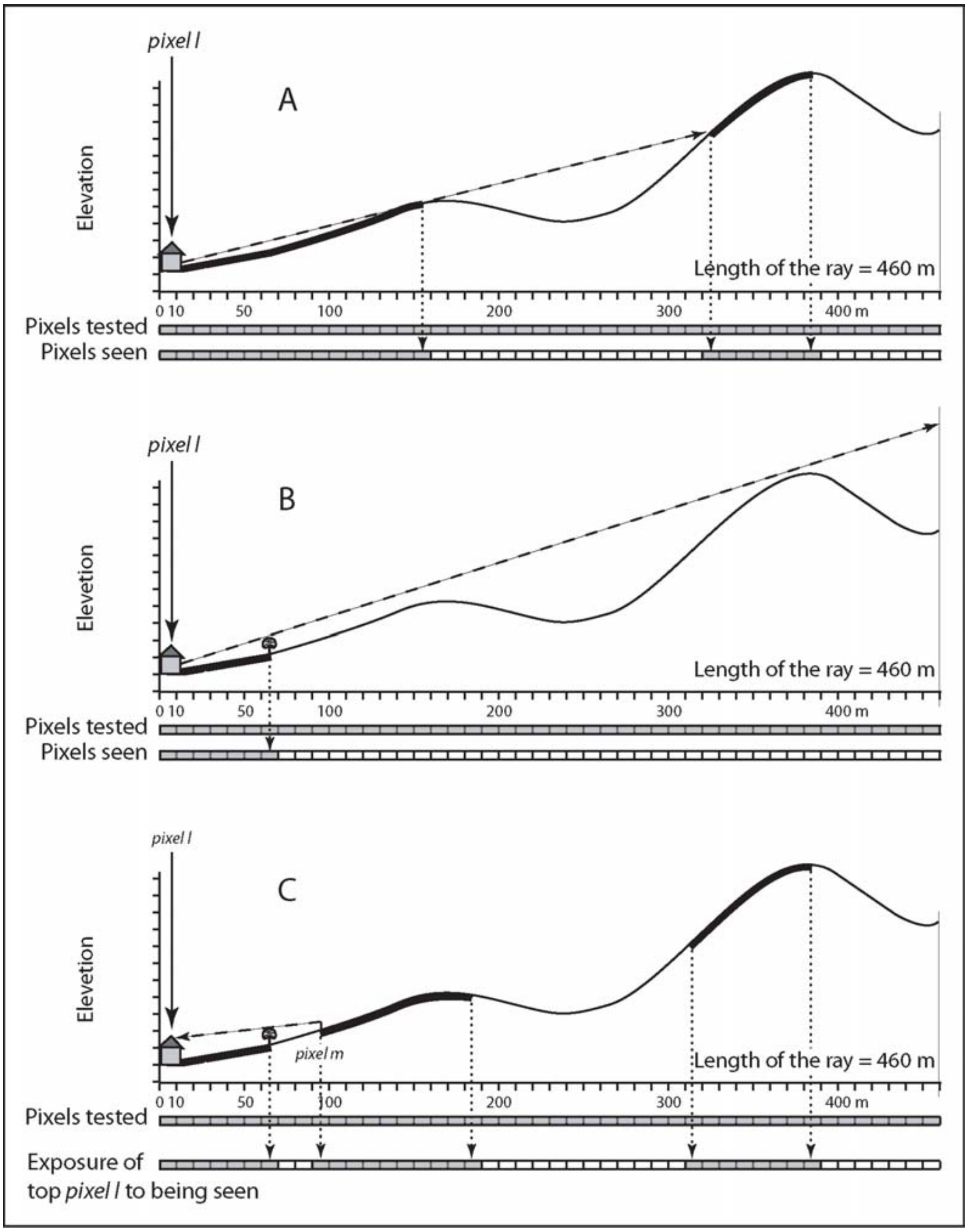
[3] The variable x that may be correlated with the error is regressed on instruments Z. The residuals are written $\hat{\eta}$. The equation of interest $Y = X\beta + \varepsilon$ is modified into an *increased regression*: $Y = X\beta + \hat{\eta}b + \varepsilon$. A Student's test is made of the coefficient b and if this is statistically non-significant, the null hypothesis is rejected: $\text{cov}(x, \varepsilon) = 0$ is accepted. The residuals of the *increased regression* are regressed on the instruments Z. Instrumental variable z ($z \in Z$) whose coefficient is statistically different from 0 is non-valid instrument. If so, it is eliminated from Z and the procedure is repeated. Sargan's test provides a statistics based on the χ^2 distribution to determine if the instruments Z taken as a whole are valid.

[4] White's test indicates that the residuals of the final estimation are homoscedastic.

2.2 Geographic model of quantitative analysis of landscape

A landscape, as said, is a portion of space before one's eyes. The overall visible area (or viewshed) is measured here by looking outward through 360 degrees. The visual quantification of landscape is based on both the extent and the content of scenery. The first factor depends both on the relief and the objects that may mask the view (depending on their height; see Figure 1) whereas the second factor depends on the diversity and type of the visible objects. To make up the landscape variables 120 rays (spaced out 3 degrees) are extended from each point in all directions and tests are conducted along the rays for each pixel encountered (a pixel is the smallest geographic object identified, here a square with 7 m sides). According to both the relief and the type of object occupying each pixel the area visible along the ray is determined (see Figure 1).

Figure 1. Viewshed and non-reflexivity of the view and exposure to be seen



In figure 1-A, the view extends up to 155 m from the observer located at pixel l, and then it is cut by a hill between 155 and 325 m. The second hill is viewed between 325 and 385 m. In Figure 1-B, the tree 65 m from the observer masks the view beyond. In Figure 1-C, a second observer at pixel m (on the slope) can catch sight of pixel l (the roof *of the house). The profile sections in bold on 1-B and 1-C underline the difference between viewshed and exposure to being seen.*

Then, the numbers of pixels of each type in this visible area are calculated. Each point is also characterized by the longitude and latitude into a French ("Lambert") system of Cartesian coordinates, and the real-estate transactions are georeferenced in this system. From the foregoing data, for each pixel, written *l*, three types of "view" are modeled:

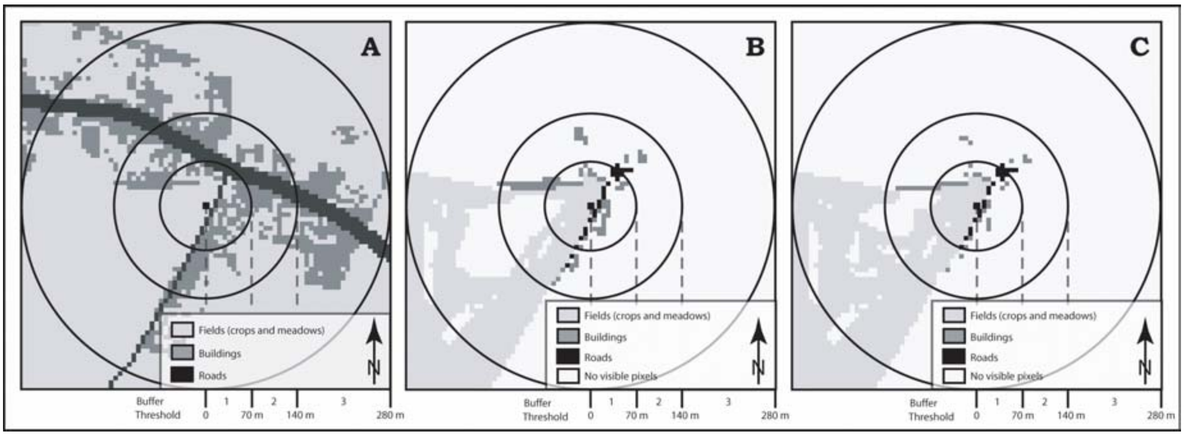
1 - Land use seen from a satellite (from above) in concentric rings around *l* (see Figure 2-A), which is the approach used by the majority of economic valuations of landscape hedonic prices.

2 - The landscape as seen by an observer at ground level (more exactly at a height of 1.80 m) with a 360 degree view out from *l*. The results show that in the study region only 18% of the pixels visible from above are seen from within (the mean is 8.9%) (Figure 2-B provides an example).

3 - Exposure to being seen by others, which is the reverse of the preceding relation, that is, all of the points from where the person at *l* can be seen. Seeing and being seen are not a reflexive relation because of the interplay of the height and layout of objects. A forest provides the best example: it can be seen from a large area, but a person under the shelter of this forest can only see a small viewshed, bounded by surrounding trees. Figure 1-B and 1-C illustrate less crude examples, and Figure2 shows the result: exposure to view (2-C) differs from the viewshed (2-B).

To the best of our knowledge, the two relations, to see and to be seen, have never before been distinguished in literature on the economic valuation of landscapes, while our results show that this matters.

Figure 2. Landscape seen from the satellite (A), from the ground (B) and exposure to view (C)



(A) (B) (C)

To analyze the three "views" of landscapes defined in this way, a land use layer, which localizes and identifies objects, is combined with a digital elevation model which models the topography and architecture of the space. First, data sources on land use, described by [35], are made up of images from two satellites: Landstat 7 ETM (30 m and 15 m spatial resolution) and IRS 1 (Indian Remote Sensing, images at 5.6 m spatial resolution). Common treatments in remote sensing science were then applied to modify the geometry of the images, merge the two satellite images and classify the pixels (See Appendix B). Finally, 12 types of land use were identified: water, conifer, deciduous tree, bush, crop, meadow, vineyard, road, built area, quarries, railroad, and trading estate. Some objects are ascribed a fixed height imposing a visual mask: 15 m from the ground for deciduous trees, 20 m for conifers, 3 m for bushes, 1 m for vineyard and 7 m for a house. Built up areas are the most frequent type of object that mask the view, because in the study area housing is clustered (the village in Figure 2 provides a good illustration of this pattern of settlement). The other types (water, roads, railroads, fields) have zero height. Second, the digital elevation model is at 50 m resolution. It is dilated to superimpose it on the 7 m resolution of the land-use image, and then the altitude of each pixel is reconstituted by interpolation. To reduce computation time, we resort to four data base of different resolution: 7, 30, 150 and 1000 m (See Appendix B).

2.3 Study region and variables

2.3.1 The study region

The study region is a belt around Dijon (France). The Dijon city (150,000 inhabitants) and its suburbs (100,000 inhabitants) have been excluded because it would be difficult to apply our method of landscape analysis because of the very variable height of buildings. The outer bound of the study region is given by access time to Dijon of less than 33 minutes or a distance by road of less than 42 km.

The study region covers 3534 km² and includes 140,703 inhabitants. It is composed of 266 *communes* with at least one transaction recorded in the data base, with a mean population of 461 inhabitants (median 229, standard deviation 733) and the average population density of 41 inhabitants per km² (median 26, standard deviation 135). Built areas cover 2.4% of the land, farmland 59%, woodland and semi-natural formations 38%. The hypotheses of both a single labor market and a single real-estate market required for the hedonic price method seem to hold up well: 74% of people in employment in this area commute to work out of the *commune* (usually in Dijon and its suburbs); in addition, from 1982 to 1999, 19,123 moved house out toward the *periurban crown* and 11,964 moved in the opposite direction.

This region covers four main geographic units. North of Dijon are limestone plateaus with large cereal farms. South of Dijon lies a series of three strips: from west to east, first a livestock farming region with its landscape of hedge-lined meadows in the valleys and woods on the higher land; second a limestone plateau dissected by dry valleys with diversified farming (fruit, cereals, livestock); finally a large floodplain with its forests and intensively farmed arable land (market gardening and arable crops). A sharp scarp separates the last two strips along which run the vineyards for which Burgundy is reputed.

2.3.2 The data and variables

The economic data come from real-estate lawyers (*notaires*), who are responsible for registering real-estate conveyances in France. The database is made up of 2757 sales of detached houses between 1995 and 2002. These are sales between private individuals for which the database records the price of the transaction and certain characteristics of the property and the economic agents involved. Some 234 observations were excluded: first, atypical observations in terms of size or their attributes and shortcomings of the data base (variables not completed or input errors) (N = 200), and second districts with just a single observation (N = 34). Evaluations were made from 2523 observations.

The characteristics of the structure were (the legend to Table 1 is in capitals in parentheses for the variables used there): living space in m² (LSPACE)[5], lot size/living space (LOT/LSPACE), average room size, i.e. living space/number of main rooms (ROOMSIZE), also included in quadratic form (ROOMSIZE²), number of stories (STORIES), year or period of construction (AGE), bathroom density, i.e. number of bathrooms/living space (BATH), presence of an attic (ATTIC), of basement (BASEMENT), of a swimming pool (POOL). The

[5] The variables correlated with the living space (lot size, number of rooms and of bathrooms) were transformed to reduce this connection.

database also includes transactions characteristics: date of conveyance[6] (DATE), property already occupied by buyer (BUYEROCC), form of transaction: between private individuals (PRIVATE) and of the previous transaction: succession (SUCC) or division of estate (DIVISION), the reference being by mutual agreement.

We introduced also location characteristics: distance to a major road, i.e. less than 100 m (<100M_ROAD) or 100-200 m (100_200M_ROAD), distance of less than 100 m from a railroad track (<100M_RAIL), land zoning of the district: mixed residential and business zones (MIXEDZONE), Zone UD of the *Plan d'Occupation des Sols* (POS), located at the periphery of villages or towns.

Some of the variables in the database were excluded from the regression. For property characteristics, these were the variables whose hedonic price was non-significant (presence of outbuildings, parking spaces, cellars, lofts, terraces or balconies) and subjective appreciation of the lawyer (good or poor state of repair). For the location characteristics, these were slope of the lot, relative altitude (height of the house related to the mean height of the viewshed), sunshine, and location in a floodable area.

This database also includes variables used as instruments. These are the gender, occupation, age, marital status, and nationality of the buyer and seller, and the road toponomy (street, lane, avenue, cul-de-sac, hamlet, etc.) for the location.[7]

The landscape variables are made up of land use, according to distance to objects. Visible areas are measured in square meters for six fields of view: less than 70 m, 70-140 m, 140-280 m, 280-1200 m, 1.2-6 km, and more than 6 km. As explained, a distinction is made between the view from within, exposure to the view of others, and the view from above.

Land uses are weighed up in number of pixels seen or pixels from which the observer may be seen (for the submission to the view), and they were tested for the six ranges of view previously defined. As before, the legend for Table 1 is in capitals in parentheses for the variables used in this table, which are as follow: view of built area (BUILT) and exposure to view from built area (EXPBUILT), forest (FOREST), which groups deciduous trees and conifers, agriculture (AGRI), made up of plow land and meadowland, road (ROAD).

We introduced three interaction variables: between the plot size and both forest (FORET*LOT/LSPACE) and agriculture (AGRI*LOT/LSPACE); the correlations between these land uses and the lot size indicate that lot sizes are larger if they are closer to forests or fields; interaction variables control for these links. An interaction between agriculture and a location in a developable area of the land zoning (AGRI*POSU) takes into account the risk of conversion from present-day agricultural use into an urban use.

Other land uses are excluded because of insufficient observations: trading estate, vineyard, railway, quarries and water. Bush land use also is excluded because it is non-significant.

All of the previous landscape features are seen from the ground. Moreover, we also estimated models with variables seen by satellite. The difference between pixels seen from above and from within, i.e. unseen pixels was also tested.

Lastly, we tested the effect of landscape indices currently used in landscape ecology, which provide information about landscape composition and shape, selecting some indices among the numerous ones present in the literature [29]. They were calculated on images of 12

[6] Continuous variable: we checked that the trend was linear by using dummy variables.
[7] The toponymy variables are non-significant when introduced into the main equation. Thus, they were used as instruments. Sargan's test shows that they are not correlated with the error: they are valid instruments.

classes of land use in the circular neighborhood of the observation points, i.e. for the view from above only.[8] The computations were applied in the same way using Fragstat software [42], [43], with a new programming routine focused on transaction points to save calculation time. These indices were tested both by each land-use class and together.

3 Results

3.1 Descriptive statistics

Table A-1 appended gives some descriptive statistics about the variables used in the model. The 2523 transactions are divided among 232 districts, averaging 10.9 (median 6). The narrowness of the viewshed should be emphasized. The median area viewed from a house is 1862 m², which is barely the average size of two residential lots. For 26.3% of the sample, the view is confined to the adjacent pixels; from the house at the third quartile of the distribution, one can see 22,020 m²; it exceeds 1 ha in 31% of cases and is 1 km² in 7.9%. The main reason for this restricted view is masking by buildings, which are numerous because housing is clustered and residential lots are small (mean 1030 m² and median 800 m²). The height attributed to a house is 7 m and, in view of the median distance to the nearest house (also 7 m), the angle between the ground and the rooftop is 45°. This makes it difficult to see beyond.

In the immediate vicinity, that is less than 70 m from a house, people almost always see other buildings (500 m² on average in this buffer), trees from 52% of them (average tree-covered area is 450 m² if non zero), and open areas, fields or meadows, from 69% in the 70 m circle (2600 m² on average) and from about the same proportion in the 280 m circle (1.22 ha on average). Roads are seen in the first 70 m from 37% of observations (900 m² on average).

3.2 Overall results

Table 1 shows the results for the variables with parameters significantly different from zero (See legend in section 2.3.2). A first regression is made without landscape variables (column 1) and column 2 integrates these variables (R^2 is 0.45 in this regression). As expected, Hausman's test shows that the living space is correlated with the error (Student's *t* by the augmented equation method is - 9.47). The Sargan test shows there are no other endogenous or simultaneous variables, in particular the landscape variables: choices of house price and landscape attributes are not affected by simultaneity or endogeneity. The parameters evaluated for non-landscape variables (column 1) are consistent with other studies in France. The introduction of landscape variables (column 2) makes little change to these results. This result makes possible to simplify Tables 2 to 4: the first group of variables (column 1) is present in the regressions for these tables, but the estimated parameters are left blank so as not to overload the tables with results similar to those of Table 1.

[8] It seems irrelevant computing such indices for the view from within, because they would mix the landscape composition effect we seek to study and a quantity effect of the viewed area. The meaning of numerous indices is not the same if the computation areas are very different.

Table 1. Global results

	Without landscape variables (1)		With landscape attributes seen from below variables (2)	
	Estimate	t	estimate	t
LSPACE (ln m²)	1.471	18.8	1.475	18.9
LOT/ LSPACE (m²)	0.0046	8.9	0.0085	9.4
ROOMSIZE (m²)	-0.02	-4.6	-0.0186	-4.3
(ROOMSIZE)² (sq m²)	0.00012	1.8	0.0001	1.5
STORIES (number)	-0.148	-9.2	-0.142	-8.9
AGE (year)	0.00066	5.7	0.0006	5.3
BATH (number/ m² floor)	21.96	8.6	22.4	8.9
ATTIC	0.096	4.0	0.098	4.1
POOL	0.067	2.1	0.063	2.0
BASEMENT	0.043	3.6	0.038	3.2
DATE (year)	0.046	16.5	0.046	16.8
PRIVATE	-0.035	-2.9	-0.041	-3.3
BUYEROCC	-0.187	-5.4	-0.199	-5.8
SUCC	-0.048	-3.2	-0.054	-3.7
DIVISON	-0.063	-2.6	-0.066	-2.8
<100M_ROAD	-0.064	-2.4	-0.044	-1.6
100-200M_ROAD	-0.091	-3.3	-0.089	-3.3
<100M_RAIL	-0.053	-1.6	-0.046	-1.4
POS-UD	-0.022	-1.8	-0.02	-1.6
MIXEDZONE	-0.045	-1.6	-0.054	-1.9
FORET < 70M (pixel)			0.0074	4.4
FORET * LOT/LSPACE			-0.00042	-4.6
AGRI 140-280M (pixel)			0.00012	4.4
AGRI * LOT/ LSPACE			-0.000049	-5.0
AGRI * POSU			-0.00007	-2.4
ROAD < 70M (pixel)			-0.00088	-2.7
BUILT_SEEN < 70M (pixel)			0.0064	2.6
EXP_BUILT < 70M (pixel)			-0.0048	-1.8
R²	0.4373		0.4529	

3.3 Attributes of the property, transaction, and situation

The living space, which averages 111 m² (median 100 m²) has a hedonic price[9] of €1461 per additional m², which is 1.4% of the house price, a value similar to values reported elsewhere in France [14], [38], [45]. One square meter of land is worth €6.1 on average.

[9] Prices in Section 3 are the means of the 2523 individual prices estimated from the Table 1 parameters.

The hedonic price of a bathroom is about €24,500, which is higher than estimations for other studies [14], [45].[10] The value of a swimming pool is €6980 (6.8% of the price), and for an attic €9735 (9.2%). The date of construction has little effect on price, since a house built one year later than the average is worth only €64 more. A house on several stories is worth less than one that is built on the level and the price of room size follows a bell-shaped curve.

Sales negotiated between private individuals are €3610 less than sales made by professionals, which is logical enough since transaction fees are lower. When the sale comes after an inheritance or a division of estate, the price is lower, which is probably because of the reduced bargaining power when there are several sellers. Lastly, when the purchaser already occupies the property, she pays less for it (about 20%).

Houses less than 100 m from a freeway or a major road are worth €4600 less than the average (€9100 for the strip 100-200 m away), and €4800 less when they are less than 100 m from a railroad tracks. Being part of a mixed land-use planning zone, that is, a zone for both housing and economic activities results in a devaluation of €5640. This result is consistent with the literature, which shows that a main objective of land zoning is to divide land into homogenous uses so as to reduce negative externalities [46]. Houses located in the periphery of the villages (zones UD of the zoning schemes) are 2.0% cheaper than the mean, probably because they are far from public goods or private services.

3.4 To see or to be seen

Looking first at the immediate proximity of houses (the first 70 m around them), columns (1) (area seen) and (2) (area from which one is exposed to view) of Table 2 show that the parameters are non-significant. The results are modified by introducing the two variables simultaneously (column 3) or the difference between view and exposure to view (column 4): the parameters are significant, being positive for the view, negative for exposure to view, and positive for the difference. As we saw, the view and exposure to view are not reflexive because of the different heights of objects. For 64% of houses, the area in view is greater than the area from where one pixel can be seen. In 37.7% of cases, the difference is of a single pixel (49 m²) and in 18% it exceeds two pixels. These differences, although small, are important: **the nearby view is an amenity and exposure to view is a nuisance**.

Beyond the first 70 m the hedonic prices of areas seen or from where one can be seen are non-significant (Table 2, columns 5-10) except for the 70-140 m range where the view seems to have a negative price. **It is as if households were short-sighted**. This is a counterintuitive result, discussed in Section 4.

3.5 To see or not to see

Table 3 differs from Table 1 by introducing unseen pixels into the regression, in the same buffers as seen pixels. Only the parameter of unseen forests is significant (apart from the interaction variables). **This shows that it is the view itself by an actual observer located on the ground and not in the air that matters, more than the surrounding, but unseen, environment of the house**. This finding is an important methodological conclusion; as we saw, reconstructing the view is a time-consuming task, but an essential one.

[10] The number of toilets is not completed in the database and the price of an extra bathroom probably encompasses that of a second toilet, which is generally goes together with the bathroom.

Table 2. Analysis of fields of view

Shared attributes: property, transaction, and location attributes

	(1)	(2)	(3)	(4)	(5)
AREA SEEN < 70M	0.000209 (1.1)		0.002131 (2.2)		0.002339 (2.3)
AREA EXP. TO VIEW < 70M		0.000071 (0.8)	-0.00097 (-2.0)		-0.00095 (-1.9)
AREA (SEEN - EXP.) 70-140M				0.0094 (2.1)	
AREA SEEN 70-140M					-0.00013 (0.8)
AREA EXP. TO VIEW 70-140M					

(CONTINUED)

Shared attributes: property, transaction, and location attributes

	(6)	(7)	(8)	(9)	(10)
AREA SEEN < 70M	0.002100 (2.1)	0.004405 (2.6)	0.004445 (2.6)	0.004430 (2.6)	0.004399 (2.6)
AREA EXP. TO VIEW < 70M	-0.00091 (-1.7)	-0.00194 (-2.4)	-0.00182 (-2.2)	-0.00183 (-2.3)	-0.00184 (-2.3)
AREA SEEN 70-140M		-0.00108 (-1.7)	-0.00149 (-2.0)	-0.00150 (-2.0)	-0.00151 (-2.0)
AREA EXP. TO VIEW 70-140M	0.00005 (0.3)	0.001031 (1.6)	0.000901 (1.1)	0.000906 (1.1)	0.000921 (1.2)
AREA SEEN 140-280M			0.000262 (1.0)	0.000258 (0.9)	0.000252 (0.9)
AREA EXP. TO VIEW 140-280M			0.0000054 (0.0)	0.000004 (0.0)	0.000003 (0.0)
FIELD OF VISION 280-600M				-0.003941 (-0.2)	
FIELD OF VISION 280-INFINITE					0.012595 (0.8)

Table 2 sets out the result of 10 regressions, which share the same attributes as in Table 1 (column 1) and differ in the field of view variables: model (1) = area seen in the first 70 m; model (2) = area in the first 70 m from which the pixel where the transaction is located can be seen; model (3) = both these variables simultaneously; model (4) = area seen in the 70-140 m range; etc. Lastly (model 10) existence of a field of view from 280 m to infinity. In parentheses: Student's t.

Table 3. Analysis of areas seen from within and unseen areas

Shared attributes: property, transaction, and location attributes	Estimate	t
FOREST SEEN from within < 70M	0.005933	3.1
FOREST SEEN from within < 70M *LOT/ LSPACE	-0.00028	-2.7
AGRI SEEN from within 140-280M	0.000141	4.5
AGRI SEEN from within < 140-280M *LOT/ LSPACE	-0.00000608	-6.0
AGRI SEEN from within < 140-280M *POSU	-0.00008	-2.5
BUILT SEEN from within < 70M	0.005854	2.3
EXP. FROM BUILT from within < 70M	-0.00443	-1.7
ROAD SEEN from within < 70M	-0.00085	-2.5
FOREST UNSEEN from within < 70M	0.000684	1.9
FOREST UNSEEN from within < 70M *LOT/ LSPACE	-0.00006	-4.3
AGRI UNSEEN from within 140-280M	0.000016	1.3
AGRI UNSEEN from within < 140-280M *LOT/ LSPACE	-0.00000161	-2,0
AGRI UNSEEN from within < 140-280M *POSU	0.000004236	0.7
BUILT UNSEEN from within < 70M	0.000109	0.9
ROAD UNSEEN from within < 70M	-0.00013	-0.5

The regression includes the variables in column 1 of Table 1. Unseen areas are equal to the difference between pixels seen from above and pixels seen from within. Unit: pixel.

Lastly, in Table 4 seen and unseen pixels are added to constitute the view from above. As expected, the results of the view from above are less significant than the findings obtained from the view from within: this is another major methodological finding that sheds light on the literature when the view from above is used: the disappointing results obtained in many cases may be explained in part by this method, which deteriorates the statistical links.

Table 4. Comparison of the view from above and from within

Shared attributes: property, transaction, and location attributes	Seen from above		Seen from within	
	Estimate	t	Estimate	t
FOREST < 70M	0.000933	3.0	0.0074	4.4
FOREST < 70M * LOT/ LSPACE	-0.00007	-6.0	-0.00042	-4.6
AGRI 140-280M	0.000033	2.8	0.00012	4.4
AGRI 140-280M * LOT/ LSPACE	-0.000003	-4.4	-0.000049	-5.0
AGRI 140-280M * POSU	-0.000000157	-0.0	-0.00007	-2.4
ROAD < 70M	-0.00046	-2.0	-0.00088	-2.7
BUILT < 70M	-0.00000694	-0.0	0.0064	2.6
EXP_BUILT < 70M			-0.0048	-1.8

Shared attributes are the same as in Table 1, 2 and 3. Unit: pixel.

3.6 Land uses

Built area. Table 1 (column 2) shows that the view of houses at less than 70 m has a positive hedonic price, which is €688 (0.6% of the house price) for an additional *are* (i.e. 100 m²) while the price of being seen from 1 *are* of built area located in the same distance range is €-518 (-0.5%). When these two variables are replaced by the difference between built areas from where one is exposed to view and the built area seen, a difference of 1 *are* has a hedonic price of €-2265 (-2.1% of the house price). It is the price of the inconvenience of having family privacy disturbed when one can be seen in one's garden. Beyond 70 m built areas have a hedonic price non-significant at the 10% level whatever the variable's modality (view, exposure, difference between exposure and view).

Forests. An additional tree-covered *are* in the first 70 m has a mean hedonic price of €800 (median €745). Houses with a view of forests see on average 7.3 *ares* within the 0-70 m range: doubling this quantity has a hedonic price of €5800. The actual view of tree-covered areas counts, whereas the parameter of their mere presence when they are not visible in the 70 m circle is less significant (the threshold is 6.2%) (Table 3). The presence of nearby, but unseen, forests has a value for recreational (walking areas), protective (against noise), and ecological (air quality, fauna and flora, etc.) functions; nevertheless, their hedonic price is a lot smaller than that of seen forests. Of course, adding seen and unseen forests gives the area of forest seen from above, which parameter is also smaller than that of the view from within (Table 4). Note that the interaction variable between the area of forest seen at less than 70 m and the lot size is significantly negative: the price of the garden is lower where a large area of forest is seen. Lastly, in fields of view beyond 70 m, all tree-covered formations have prices that are statistically non-significant, which confirms the 'myopia' of households.

Farmland. Crops or meadows seen between 140 and 280 m from houses have a positive hedonic price (Table 1) of €12 per *are* more, so for houses from where they can be seen €640 when the quantity doubles. It transpires from comparison with forests that the hedonic price of farmland seen is positive at distances somewhat greater than for trees, although confined to a radius of 300 m or so. This is consistent with other results [54], [34], which show that households pay less for housing located close or adjacent to farmland. As for the forests, the interaction parameter between lot size and the area of seen farmland is negative. Moreover, we find a negative interaction between the area of farmland seen and the location in a developable zone of the zoning scheme (POSU zones): households value the view of farmland less when they locate in a developable zone. This result is consistent with others that show that the hedonic price includes expectations about a risk of conversion [8], [54]. Note that both the parameter for unseen agriculture is non-significant (Table 3) and the parameter of agriculture seen from above is less significant than that of the view from within (Table 4).

Roads. An additional *are* of road in view at less than 70 m lowers the price of a house by €88, or €1830 for doubling the area in view. Roads within the radius of 70 m but not in view have a non-significant price (Table 3). It is therefore not the presence of the road that is a nuisance when it is not seen (although it is a source of danger, air pollution, and noise) but the actual sight of it as it is a visual obstruction. This result is consistent with that for wooded and agricultural areas: **the presence of an object counts less than whether or not it can be seen or whether one can be seen from it**. Beyond 70 m, the sight of roads no longer significantly affects house prices, indicating that such nuisances remain confined to a narrow strip.[11]

3.7 Landscape composition indices

Table 5 shows the findings obtained with and without landscape composition variables (the remainder of the equation being the same variables as in Table 1).

Table 5. Landscape composition attributes

Shared attributes: property, transaction, and location attr	Estimate	t	Estimate	t
	seen from within		seen from within	
FORET < 70M (pixel)	0.0074	4.4	0.0080	4.1
FORET * LOT/LSPACE	-0.00042	-4.6	-0.00040	-4.3
AGRI 140-280M (pixel)	0.00012	4.4	0.00013	4.6
AGRI * LOT/ LSPACE	-0.000049	-5.0	-4.75E-6	-4.9
AGRI * POSU	-0.00007	-2.4	-0.00007	-2.3
ROAD < 70M (pixel)	-0.00088	-2.7	-0.0009	-2.7
BUILT_SEEN < 70M (pixel)	0.0064	2.6	0.0048	1.9
EXP_BUILT < 70M (pixel)	-0.0048	-1.8	-0.0039	-1.5
			seen from above	
DECID_PACHES (number)			0.011	3.4
DECID_EDGE (m)			-0.00036	-3.7
COMPACT			0.226	1.8
BOUNDARY (m)			0.000037	1.8

Four indices are used: (i) the number of patches of deciduous trees within a 70 m radius has a positive price of €1190 per additional patch. (ii) The length of deciduous wood edges within a 70 m radius, which price is €-38.6 per additional meter. (iii) A compactness index ranging from 0 (compact forms) to 1 (elongate forms), whose hedonic price is €270 for 1% of additional "elongation". (iv) The total length of borders between patches of different types, whose hedonic price is €4.0 per additional meter. Many other indicators were tested, which, when examined separately, have significant hedonic prices (see Appendix C), but they were

[11] It should be remembered that the location of a house within a strip of 200 m beside a freeway or a major road is also a nuisance, which compounds that of the view.

not used because they are correlated with the previous ones. The results, for the combination used here as for other indicators taken separately, show that division, complexity, non-contiguity, landscape fragmentation, mosaic patterns, etc. have positive hedonic prices, which point to the conclusion that landscape esthetic matters.

4 Discussion

Our findings come from a single study region, the periurban area of Dijon (France). Moreover, most of them are new in regard of the literature. Thus, it is difficult to generalize the conclusions. Nevertheless, these findings either provide new hypotheses for future studies or confirm assumptions about several issues that we examine now.

4.1 Landscape prices and landscape management

The price of landscapes. By using the quality of life index method [7], hedonic prices evaluated for each landscape attribute can be used to calculate a total price of landscapes equal to the sum of the quantities weighted by prices.[12] The mean is €2850 (median: €2460). Given that the mean price of a house in the sample is €105,500, 2.5% or so of the price corresponds on average to the price of the landscape in view. Landscapes, as stylized by our geographical model, therefore represent only a small part of the real-estate value; but it is important to emphasize that this value is significantly positive.

As landscape amenities have the nature of a local public good, their Lindhal-Samuelson price is defined by the marginal rate of substitution between amenities and the numéraire (see equation (1)) times the number of households. The aggregate value is €163 million for the landscapes of the region. In comparison, the agricultural price in the study region is €3076 per hectare on average [15], giving a total value of €522 million for the farmland area in the region, or, including wooded areas set at half the value of farmland, €700 million. The total landscape value is about one-fourth or one-third of these values.

If the discount rate is 4%, the annualized value of the landscape is about €110 per household. This value is higher than most of those reported by contingent valuation method for agricultural landscapes, often €30 or so per household per year ([23], [24], [10]); other workers report higher values: up to €100–180 [6] or €230 [18] per household per year.

Agricultural and forestry subsidies. French farmers long objected to being described as “nature’s gardeners”. They now promote their role in maintaining landscape and even want to be rewarded for it. One of the reasons for this change is the World Trade Organization talks: the Europeans argue that such aid does not distort competition (it is said to be “uncoupled” from production). Our findings illuminate this public policy debate in two ways.

First, the hedonic price of an *are* of farmland seen from a house (€12 in the 140–280 m belt) is 66 times lower than that of one are of forest seen (€800 in the first 70 m disc). And yet, public aid per are of forest is €0.28 and for farmland €3.86 [3], which is almost 14 times more. Admittedly, aid for farming is not justified by its landscape conservation role alone (it is also a matter of income support for farmers and so of maintaining employment, etc.). Nevertheless, the contrast is striking.

[12] We apply the estimated unit price to the entire region, without introducing local variations, for example for the distance from Dijon. The overall price of landscapes is thus an approximation for this reason and also because our variables greatly simplify the landscape (aesthetics, shapes, etc.).

Secondly, public aid for farming and forestry is only weakly related to the location of these activities relative to housing, or even totally unrelated in most cases. The landscape function of farmland and woodland for inhabitants of periurban areas cannot be sufficient to justify public support for more than a mere fraction of these activities, because households put a positive value on their only when they are very close to housing.[13] However, local policies for enhancing villages and their immediate vicinity are justified by what we have termed "household short-sightedness". Landscaping of public areas in villages, planting within the built environment, encouraging inhabitants to landscape their private gardens, etc. are "green" goods close to housing which command higher values than more remote farmland.

Landscape shapes. The results for shape and landscape composition indices point in the same direction as the foregoing ones: over several decades, the re-parceling of farmland has formed large plots with simple geometric shapes to facilitate work with farm machinery, hedges have been torn up and tracks plowed up to enlarge production areas, crop rotations have been simplified. Forests have undergone comparable although less extensive change: same-age plantations on vast plots tend to replace coppices of different ages and woods, with the same objective of increased productivity. The resulting landscapes are more uniform and made up of large contiguous patches. Now, the composition indices we have introduced show that it is contrasted landscape forms that command high values: mosaics, small elongated patches, fragmentation and partitioning. There is a clear contrast between landscapes arising from the productive function of farming (and forestry) and landscapes valued for the non-market functions of these activities.

4.2 Consumer behavior

Periurbanization and the quest for green landscapes. Forests and farmland become more abundant with distance from Dijon and the proportion of roads declines. It is therefore logical that the total price of landscapes should increase with distance, even if our estimators are reflected by unit prices independent of distance. An OLS regression of this global price of landscape over distance shows that it increases by €44.7 when moving 1 km out from Dijon (Student's t test is 5.3). This suggests that landscape amenities go some way to explaining the households move from city into the country in the Dijon area: when landscape amenities increase with distance, the curve of land rent is flatter and the city is more extended than in a homogeneous space, as Bruekner et al. [13] show:

$$p'(x) = \frac{1}{q(x)}\left[-t + \frac{u^a}{u^e}a'(x)\right]$$

where $p'(x)$ is the derivative of the residential bid rent, $q(x)$ the housing consumption, u the utility (superscripts denote partial derivative), a and e are respectively the amenity and composite good consumption. We show that $a'(x)$, which is here the derivative of the landscape price, is positive, leading to a flatter rent than without amenities and, therefore, a larger spread of people in the countryside.

Short-sightedness. The indifference to the view of spaces beyond a few tens of meters, in particular to open views with distant ranges can be explained by the characteristics of the study zone, where distant horizons, when seen, are not formed by outstanding features, emblematic buildings, sea, or snow-capped lines of mountains, etc.; on the contrary they are

[13] By our calculations, the area within 200 meters of the built pixels represents 23,000 hectares, or some 6.8% of the 3534 km² of the study region. True, farming and forestry may have other non-market functions, especially recreational (forest walks, tourist region landscapes), ecological and cultural ones, etc.

bluish-grayish in color, making them hard to distinguish against the skyline. However, it may be thought that our results are valid more widely than for just the Dijon area, because similar commonplace rural scenery is encountered in most parts of France.

To see houses and to be seen from houses. The contrast between seeing houses (which is an amenity) and being seen from houses (which is a nuisance) is another new result in terms of consumer behavior. It is intuitive enough that exposure to being seen by others is a nuisance. That the view of houses should be an amenity is a less intuitive result. It can be explained because such views may provide both diversity or variety in the landscape, a sense of security, or even conviviality in having neighbors. Inhabitants' behavior is consistent with the above findings: often they enclose their gardens with boundary walls or hedges so they cannot be seen by their neighbors or passers-by, at the price of a loss of view of the landscape. It is as if they were protecting their patch of land from visual intrusion while enjoying the sight of the rooftops of neighboring houses above these barriers.

Consumer demand for green landscape and for residential space. The interaction variables among forests or farmland and residential lot size are both significantly negative: when large amounts of forest or farmland are visible, the unitary price of the plot area is lower. There may be a substitution relationship between green landscape and lot size (which cannot be estimated here because the consumer's demand function is unknown). Green landscapes therefore have a "land-saving" function in that they limit residential land use.

Expectations. Due to population growth and urban spread, farmland may be converted to urban uses, entailing the loss of the agricultural amenity. Conversion occurs mainly in the "U" category of the zone schemes (i.e. areas reserved for future urbanization); the interaction AGRI*POSU (Table 1) shows that the hedonic value of farmland seen is 42% lower in these zones than elsewhere. The same result does not hold for the view of wooded pixels: their price is the same whether the zone is developable or not. The difference stems from the probability of conversion, which is five times lower for forests than for farmland.[14] Households take into account this difference, expecting a risk of conversion from farmland, with a substantial effect on the price, but not from forests. With a discount rate of 5%, the mark-down of 42% signifies that households expect a conversion and the loss of the amenity in 12 years on average.

5 Conclusions

A hedonic price model has been combined here with a GIS-based geographic model to evaluate the price of landscapes seen from houses in the urban fringe of Dijon (France). The geographic model is used to identify, with a resolution of 7 m, 12 types of land use from satellite images and to measure, by trigonometry, the viewshed taking into account the relief and obstacles that may block the view (houses, trees). The view of the landscape is quantified, in terms of visible area and of the type of objects seen, as is exposure to view, which is the reverse relation (areas from which an observer can be seen). One methodological conclusion of our study is that landscapes must be analyzed as seen by from ground level and not from maps or satellite images which have fictional "from above" views entailing drawbacks.

The results show, first, that it is above all the view of the tens of meters around a house which counts; beyond that distance, few attributes still are significant up to 200-300 m, but no farther. Second, the view is an amenity and exposure to view a nuisance; in particular exposure to being seen from other houses has a negative hedonic price. Thirdly, tree-covered

[14] 1260 ha of a total 15.6 million ha of forests is annually converted for housing compared with 11,300 ha out of a total 30.1 million ha of farmland [2].

formations have positive hedonic prices, as does farmland, while roads have negative prices. Fourth, it is principally the view that influences the real-estate price and not the mere presence of certain types of land use: roads or farmland close to a house but which are not visible from it have non-significant hedonic prices, and the value of unseen tree-covered areas is far lower than seen forests. Fifth, landscape shape indexes show that households appreciate complex, fragmented shapes and mosaic patterns.

In short, the economic agent who appears from this study is shortsighted and sensitive to a few characteristics of her immediate visual environment (trees, farmland, roads). She devalues exposure to being seen by others and is insensitive to what is close by but cannot be seen. This sensitivity to landscapes may help explain migrations to mixed farmland-forest and residential spaces, which characterize the countryside close to Dijon.

However, our method is reductive because it simplifies in the extreme what a landscape is and evaluates only use values related to residential consumption. The point that in spite of these limitations it yields significant results is encouraging. However, we are aware that other methods are also required to enhance knowledge in this difficult domain of the economic valuation of landscapes.

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Appendix A: descriptive statistics

	Number of houses with the attribute	Value for houses with the attribute			
		mean	total standard deviation	between district standard deviation	within district standard deviation
Number of observations	2523				
Number of districts	232				
LSPACE (m²)		107.1	1.33	1.30	1.12
LOT (m²)		1035.7	1001.4	876.3	1035.8
ROOMSIZE (m²)		23.2	6.2	2.6	5.6
STORIES (number)		1.63	0.57	0.23	0.52
AGE (year)		1941	56.6	31.0	47.2
BATH (number)		1.23	0.40	0.14	0.37
ATTIC		0.05	0.21	0.07	0.2
POOL		0.03	0.17	0.06	0.16
BASEMENT		0.35	0.49	0.19	0.44
DATE (year)		1999	1.9	0.67	1.8
PRIVATE		0.21	0.41	0.13	0.39
BUYEROCC		0.02	0.14	0.04	0.14
SUCC		0.14	0.35	0.12	0.33
DIVISON		0.04	0.21	0.06	0.2
<100M_ROAD		0.05	0.21	0.10	0.18
100-200M_ROAD		0.04	0.20	0.09	0.18
<100M_RAIL		0.02	0.15	0.06	0.14
POS UD		0.30	0.46	0.29	0.35
MIXEDZONE		0.05	0.23	0.15	0.17
FORET < 70M (pixel)	917	7.34	5.74	3.30	5.18
AGRI 140-280M (pixel)	1744	53.6	64.0	32.2	55.0
ROAD < 70M (pixel)	942	18.5	26.1	10.8	22.5
BUILT_SEEN < 70M (pixel)	2389	10.8	5.2	2.5	4.7
EXP_BUILT < 70M (pixel)	2346	9.7	4.9	2.6	4.4
COMPACT	2523	0.61	0.04	0.016	0.038
BOUNDARY (m)	2523	1229	348	188	293
DECID_PATCH (number)	1418	4.1	3.4	2.8	2.5
DECID_EDGE (m)	1409	138.2	126.5	91.5	100.8

Appendix B: Geographical processing

The Landstat 7 ETM (30 m and 15 m spatial resolution) and IRS 1 (Indian Remote Sensing, images at 5.6 m spatial resolution) data were corrected geometrically to allow for deformations induced by the more or less oblique path of the satellite, and then combined and transformed into "color spaces" to yield a spatial resolution of 7 m. Then the multi-channel images were classified to identify land uses relevant for the economic model (ex.: precedence was given to objects liable to mask the view; maize was not distinguished from other crops, because of yearly rotation of crops, etc.). Thus, each pixel was put in the most probable class from the composite signal; 12 types of land use were identified: water, conifer, deciduous tree, bush, crop, meadow, vineyard, road, built area, quarries, railroad, and trading estate.

To reduce computation time, the 360 degree panorama was sampled by 120 rays spaced 3 degrees apart. In addition to 7 m-resolution database, three other bases were constituted at resolutions of 30 m, 150 m and 1 km (the two later images came from the database *Corine Land Cover*.). First, tests were conducted along the first segment up to a distance of 40 pixels (i.e. 280 m). A trigonometric calculation could identify the pixels seen depending on the relief and the objects encountered. Then, the same process was repeated to test the pixels between 280 m et 1200 m by the 30 m-resolution database; the 150 m base was used for testing pixels located from 1.2 km to 6 km, and finally the 1 km base was used for testing beyond that up to 40 km away. This method reduced computation time by a factor of more than 35.

In addition, this way of operating corresponds closely to the way a landscape is seen because it reflects the imperfections of the human eye. The closer an object is to the point of observation, the more of the field of view it occupies in proportion. This "visual impact" declines with distance, until distant objects may be incorporated in part or in full in the field of view and then change nature: for example, it is a forest or a village that is seen instead of a tree or a house, or even a tract of farmland if the tree or house are small.

Appendix C: Landscape composition indices

As shows the following table, the auto-adjacency and aggregation indices take relatively high values (72–82 for a theoretical maximum of 100), which may be explained by the predominance of clustered dwellings. However, mosaics are preferred to uniformity: breaks in the built environment due to other land uses have positive hedonic prices, close to €1500 for one standard deviation. Contagion, interspection and division indices are non-significant.

The indices L24, L9 and L48 are significant, from €1300-1500 for an additional standard deviation, showing that elongate and non-compact shapes are preferred to closely packed shapes. In addition, the overall contiguity index shows that partitioning is valued more highly than shape connectivity, although only slightly so (significant at 10% level).

Many small patches provide landscapes that are more highly valued than those with a few large patches. This is consistent with the positive value attributed to the length of boundaries.

fragstat code	Indice	Parameter	Descr. stat.: mean (std)	Hedonic price (+ 1 std) (€)
L114	Percentage of Like-Adjacence	-0.0017**	72.4 (7.9)	-1440
L115	Contagion index	0.00027		
L116	Aggregation index	-0.0018**	81.2 (7.9)	-1520
L117	Interspection and Juxtaposition index	0.0016		
L118	Division index	0.015		
L24	Perimeter-Area Ratio Distribution	0.036*	2.78 (0.31)	1220
L9	Landscape Shape Index	0.020**	2.44 (0.69)	1500
L30	Shape Index Distribution	0.0184		
L48	Related Circumscribing Circle Distribution	0.258**	0.61 (0.04)	1260
L54	Contiguity Index Distribution	-0.159*	0.28 (0.07)	-1100
L5	Patch number	0.0019**	20.6 (8.0)	1630
L11	Patch area mean	-0.211**	0.09 (0.06)	-1270
L7	Total edge	4^E-5**	1228 (349)	1500
L10	Largest Patch Index	1^E-6		
L130	Shannon's Evenness Index	0.038		
L131	Simpson's Evenness Index	0.022		

*Fragstat codes are by McGarigal et al. (2002). The equations comprise the variables from Table 1, column 2 plus each index introduced separately. The mean value, standard deviation and hedonic price are given only for indices significant at the 10% threshold.** and * indicate significance at the 5 and 10% levels respectively.*