Analysis of Factors Influencing Urban Growth Patterns on Small Towns

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Abstract: - Urban structure conditions to a great extent the future evolution of cities and towns. In this paper urban growth patterns of a small town are analyzed using landscape metrics, and subsequently the possible variables influencing the dynamics that have generated the urban patterns are studied, by using logistic regression techniques in order to unveil the processes through which urban structure is generated.

Key-Words: - Urban growth patterns, logistic regression, landscape metrics

1 Introduction

By the end of the 50's decade, as a consequence of the sociopolitical development produced after the II World War, cities underwent a process of urban growth [1] that has continued until nowadays. This process has generated several problems derived from the generated urban patterns [2]. These problems led to the necessity of studying urban growth processes and their derived inconveniences in a scientific way.

The target of this work is to study urban growth dynamics in the region of Galicia (North West of Spain). Galicia has a very dispersed population; about the 30% of Spanish towns are located in this region. This contributed to the sprawl of large urban areas over rural zones creating a rururban structure which spans over the administrative boundaries of cities. This forms a continuum originating a lot of problems like the difficulties to provide services to the population, the increase of private car trips which generates pollution and congestion problems in city centers, administrative, planning and management problems derived from the confrontation between the municipalities over which the city spans, etc.

There are already studies on similar urban structures like "desakota" regions in southeastern Asia [3]. However Galician rururban structures arose from different dynamics, which were generated by the specific historic and sociocultural context of this region.

In the present work, an analysis of the urban growth processes and patterns of a small Galician village called Ribadeo is carried out. This study at such detailed scale will allow to extrapolate results to other parts of the region with similar urban growth patterns. Besides, most of the previous urban growth studies have focused on large cities [4][5][6][7][8], so only few works deal with the dynamics of small urban areas.

In this paper, after explaining how the data were obtained and the methodology used in the analysis, a description of the study area is made. Afterwards, the results of the analysis with landscape metrics are presented so as to know the urban growth patterns in the study area. Then, the variables influencing urban growth are examined using logistic regression. The aim is to know the variables involved in the urban growth processes which generate the urban growth patterns of Ribadeo.

2 Methodology

The study area comprises 5 parishes of Ribadeo municipality; Ribadeo, Piñeira, Vilaselán, Vilaframil and Obe. Ribadeo municipality is on the northeastern coast of Galicia (Fig. 1), in the border between this region and Asturias region. It is divided in two well defined zones. Firstly, a coastal flat area where the urban core of Ribadeo is located, surrounded by a constellation of small villages spread along the main road. This road communicates the northeastern Galician shore with the interior of this region and with the neighbouring region of Asturias. Secondly, an interior mountainous zone, less populated, dedicated to dairy farming. Most of the urban growth in the region takes place along the coastal flat area, using as a frame the main road and the net of small roads that communicate the small villages.

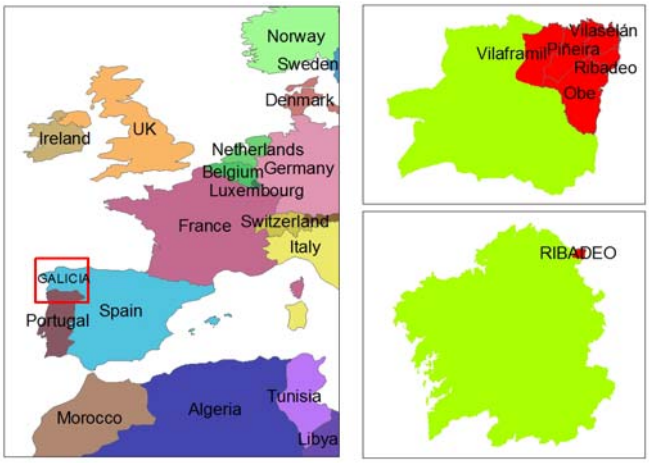

Fig. 1. Location of Ribadeo and the study area.

Due to its location, in the crossroad between two regions, the main economic activity in the town is commerce and services which provide the surrounding towns. That is the reason why Ribadeo is the main town in the area.

2.1 Data

Data were obtained from a land use map of the year 1995, an orthophoto of the year 2003, a cadastral parcels and road map of 1995, a digital terrain model (DTM) and the data of the Spanish Local Infraestructure and Equipments Survey for the years 2000 and 2005.

With this information two road maps for the years 1995 and 2003 and two land use maps for the years 1995 and 2003 were elaborated, considering the following land uses: residential, commercial warehouses, industrial warehouses, institutional (public buildings), forest (woods and thicket), agriculture (meadows and farmland), green areas (parks and gardens) and roads. These maps were rasterized to a cell resolution of 35x35m. The DTM and the variables obtained from the cadastral parcel map have also been rasterized to this resolution.

2.2 Landscape Metrics

Landscape metrics were developed in the field of landscape ecology to study changes in landscape and its heterogeneity. These metrics were also applied to study urban growth [9][10][6][8].

Landscape metrics were calculated using the software Fragstats [11]. The used metrics are described as follows. The class area (CA), which measures the total area of each land use in hectares. The number of patches (NP), which measures the number of patches of each land use. The largest patch index (LPI) that is the percentage of the landscape that occupies the largest patch. The mean area (AREA_MN), which refers to the area of the patches of each land use. The area weighted mean fractal index (FRAC_AM) that takes values between 1 and 2 and measures the complexity of the patches of a class. It takes a value of 1 if the patch has as simple perimeter like that of a square. Besides, the higher the complexity, the closer is the index to 2. This index is weighted by the area of the patch which means that larger patches contribute more to the mean value than smaller ones. This is due to the fact that the shape of small patches depends largely on the resolution of the rasterized map. The contagion index (CONTAG) that takes values between 0 and 100 and indicates the complexity of a landscape. The larger the number and smaller size of patches, the closer the index will be to 0 and the lower the number and larger size of patches, the closer the index will be to 1.

All the metrics were calculated for commercial, industrial and residential patches of the land use maps for the years 1995 and 2003, with the exception of the contagion index, which was only calculated for the total landscape, considering only the urban and non urban uses. The urban land use was obtained merging the following land uses: residential, commercial, industrial, institutional and green areas. The other indexes were also calculated for the urban patches.

2.3 Logistic Regression

Once the urban growth patterns were studied through the landscape metrics, the dynamics that generated these patterns were explained by analyzing the factors involved in this process.

The method used for this task was logistic regressions, which has been used in other studies to analyze the variables that participate in urban growth processes [12]. Logistic regressions (1) relate the probability of change of a dependent binary variable (for example, non urban to commercial) with some independent variables (the variables which are supposed to explain urban growth). The relation between dependent and independent variables is determined adjusting equation (1), where P is the probability of change, x_k are the independent variables, b_k are the coefficients estimated with the regression and *error* is an error term.

(1) $$Ln(P/(1-P)) = b_0 * x_0 + b_1 * x_1 + b_2 * x_2 + ... + b_k * x_k + error$$

Once the equation is adjusted, the coefficients will explain how each variable contributes to the probability of change. There are other statistical indicators that can be extracted from the regression models like the significance level of each variable

(Pr(>|z|). The higher the value, the more significant the variable will be when explaining urban growth.

2.1.1 Considered Variables

The variables considered in the logistic regression analysis where: distance to main roads, distance to secondary roads, distance to other roads, distance to bypass roads, distance to railways, elevation, slope, distance to the shore, distance to commercial land uses, distance to industrial land uses, distance to residential land uses, distance to institutional land uses, distance to green areas, distance to villages, distance to Ribadeo, distance to forests, distance to Ribadeo port, distance to train station, cadastral parcels with access to roads, cadastral parcels area, shape index (equation 2) of the cadastral parcels, neighborhood (number of urban cells in a circular neighborhood of 300 m, where each cell was weighted by its distance to the central cell) and viewsheds from which the sea can be seen.

$$(2)\ Shape\ Index = \frac{perimeter}{4 * \sqrt{area}}$$

The correlation between these variables was analyzed with the Sperman coefficient. It was considered that variables with a coefficient greater than 0.6 where correlated. According to this, distance to railways was very correlated with distance to the shore and elevation; distance to green areas, distance to the port and distance to villages were correlated with distance to Ribadeo. So these variables were eliminated from the logistic regression analysis.

Before applying the logistic regressions, variables with a skewed distribution (median>>mean) were corrected with a logarithmic curve to avoid bias in the results.

So as to compare how different variables contribute to land use change, they are normalized between 0 and 1.

The influence of each remaining variable on the land use changes (non urban to residential, non urban to commercial and non urban to industrial) was analyzed using logistic regressions and Pr(>|z|). The variables with the lowest significance levels were not considered in further analysis.

Finally, logistic regressions were used to analyze how each variable contributed to the processes of residential, commercial and industrial growth.

3 Results

The analysis of the land developed between the years 1995 and 2003 (Fig.2) shows that, except for Ribadeo parish, residential development is located mainly in Vilaselán and Obe, where there are small villages, close to the urban core, that attract this kind of growth. Commercial development is located only in Ribadeo and Piñeira. Piñeira is a parish next to Ribadeo and the main road passes through it, so it can be deduced that commercial land prefers well communicated locations close to the town. Industrial growth takes place mainly in the parishes through which the main road passes. In this case, the proximity to the town center does not play an important role while this land use prefers well communicated parcels which are close to urban areas.

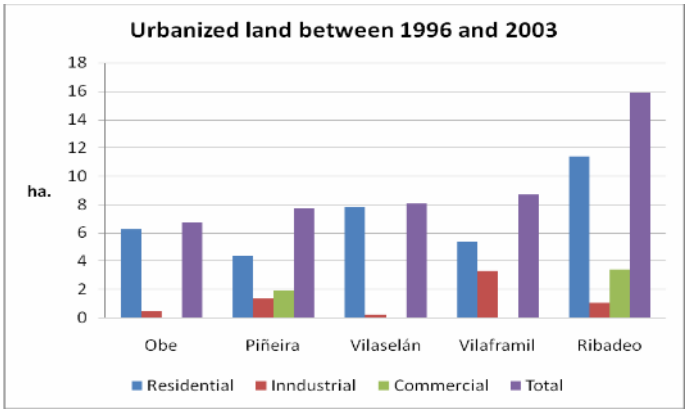

Fig. 2. Developed land in hectares of the main urban land uses in each parish.

3.1 Landscape metrics

The results of the landscape metrics (Table 1) show that, as it would be expected, all land uses increased their area in the period between 1995 and 2003, but the number of patches has not increased for the residential use. The values of LPI, AREA_MN and FRAC_AM indexes have increased, indicating that all the residential growth took place in already existing patches which increased their size and complexity.

All the indexes calculated for commercial land use increased, with the exception of the FRAC_AM index, which remained stable. This may be due to the building of a big shopping center in Ribadeo outskirts. Besides, only commercial warehouses were classified as commercial, so the new patches are large and dispersed. On the other hand, new industrial patches are small and dispersed, that is why the AREA_MN index has decreased and the FRAC_AM index has remained stable.

Table 1. Values of the landscape metrics for each land use

Land use	CA	NP	LPI	AREA_MN	FRAC_AM
Res95	128	223	0.42	0.57	1.11
Res03	159	223	0.78	0.71	1.16
Com95	3	7	0.01	0.38	1.05
Com03	8	11	0.06	0.77	1.05
Ind95	30	29	0.14	1.05	1.08
Ind03	40	42	0.15	0.94	1.08

The analysis of the results for the urban patches (Table 2) shows that the NP index has not increased too much and LPI and AREA_MN indexes have increased a lot indicating that the growth was mainly in existing urban patches. CONTAG index descends corroborating that the patches are bigger and less fragmented. However, FRAC_AM index has increased which indicates that patches are more complex.

Table 2. Values of the landscape metrics for urban patches

YEAR	CA	NP	LPI	AREA_MN	FRAC_AM	CONTAG
1995	5633	295	0.42	0.61	1.1	65.08
2003	5666	307	0.78	0.75	1.13	61.8

3.2 Logistic regression analysis

After interpreting the landscape metrics, several logistic regression analysis were made to determine which variables influence the process of land use change from non urban to commercial, industrial and residential land uses. This was done by considering the significance of each variable, so variables with a higher Pr(>|z|) value were selected to be used in further analysis.

Variables which showed to be more influencing on the transitions to residential land use were: parcels adjacent to roads, distance to main roads, distance to secondary roads, elevation, distance to the shore, distance to commercial, distance to industrial, distance to residential, distance to forests, slope, neighborhood, distance to bypass roads, distance to Ribadeo, distance to institutional, viewsheds, and area of the parcels.

In the case of commercial land use, these variables were: distance to main roads, distance to commercial, slope, distance to industrial, distance to bypass roads, distance to forests, distance to institutional, distance to Ribadeo, distance to other roads, viewsheds, shape index of the parcels, distance to residential, neighborhood and elevation.

And finally for industrial land use: distance to main roads, distance to commercial, distance to industrial, slopes, elevation, distance to institutional, distance to forests, parcels adjacent to roads, neighborhood, distance to bypass roads and distance to residential.

The aforementioned variables were used in logistic regression analysis to determine their role in processes of residential, commercial and industrial land use development. As a result, the most determinant variables to explain the transitions from non urban to urban were (Table. 3): distance to Ribadeo, cadastral parcels adjacent to roads, distance to bypass roads, viewsheds, elevation, distance to forests, distance to secondary roads, cadastral parcels area and distance to secondary roads.

Table 3. Result of the logistic regression for non urban to residential land use change

Variable	**Coefficient**	**Pr(>|z|)**
(Residual)	-4.10923	1.03e-12***
Adjacent parcels	0.88016	3.49e-07 ***
Dist. Secondary roads	-1.40920	0.02433 *
Elevation	-3.52834	0.00625 **
Dist. To commercial	-2.37594	0.04154 *
Dist. To forest	0.23086	0.02252 *
Dist. To bypass rds.	-4.76149	1.03e-05***
Dist to Ribadeo	6.59074	6.77e-11***
Viewshed	-0.40231	0.00311 **
Parcels area	-1.79032	0.01099 *

Due to the correction of the distribution of the variables with the logarithmic curve, the sign of the coefficients is inverted. In fact, if the coefficient of distance to roads is negative, it indicates that if the distance to the road increases the probability of change decreases. Bearing this in mind, the negative influence of the distance to Ribadeo may indicate that the urban core is in an expansion process, so a lot of land is being developed in the outskirts. That is the reason why the bypass road attracts growth. The parcels with direct access to roads are preferred for being developed as well as small parcels. Maybe small parcels have a higher probability of development because agriculture land in the study

area has been involved in a land consolidation process, so parcels near Ribadeo are smaller than those in rural areas. The vicinity of main roads exerts a negative influence on residential growth, while secondary roads exert a positive influence. Commercial and residential uses attract residential use but industrial uses repel it. The closeness to the shore does not have a positive influence, this is because of the coast protection law.

Commercial land uses (Table 4) prefer regular parcels, close to Ribadeo and placed near the main road. Other commercial uses exert a positive influence but residential and industrial do not. This is due to the fact that commercial warehouses need large amounts of terrain to settle in, which is difficult to find inside urban areas, that is why parcels near urban areas are preferred.

Table 4. Result of the logistic regression for non urban to commercial land use change

Variables	**Coefficient**	**Pr(>|z|)**
(Residual)	-3.871e+15	<2e-16 ***
Dist. Main roads	-1.198e+14	<2e-16 ***
Dist. Other roads	6.201e+13	<2e-16 ***
Elevation	-9.366e+14	<2e-16 ***
Dist. Commercial	-4.651e+14	<2e-16 ***
Dist. Industrial	2.245e+13	<2e-16 ***
Dist. Residential	4.473e+14	<2e-16 ***
Dist. Forest	3.268e+13	<2e-16 ***
Slope	1.100e+14	<2e-16 ***
Neighbourhood	2.017e+13	<2e-16 ***
Dist. Bypass road	1.614e+15	<2e-16 ***
Dist Ribadeo	-1.211e+15	<2e-16 ***
Dist. Institutional	2.696e+13	<2e-16 ***
Viewshed	-3.177e+13	<2e-16 ***
Parcel SI	3.110e+15	<2e-16 ***

Industrial uses are preferably placed near other industrial uses and main roads. Residential uses exert a negative influence and commercial uses a positive one (Table 5) .

4 Conclusion

It has been proven that the analyses using landscape metrics and logistic regressions constitute useful tools to study urban growth patterns and relate them with certain dynamics and variables.

The present work has made possible the acquisition of a deepest knowledge of the expansion processes in a small town, which can be extrapolated to other regions with similar patterns.

The landscape metrics show that urban growth in the study area is produced mostly by the expansion of existing urban areas which spread out in an irregular and dispersed way.

The logistic regression analysis facilitated the identification of the main factors that conditioned urban expansion in the analyzed time period. It has been proven that the preferred parcels for residential development are those adjacent to roads but not those which support a lot of transit like main roads. Shore proximity has a negative influence on residential uses, which is due to the shore protection law. As well as in big cities, the proximity to industrial uses exerts a negative influence on residential uses.

The construction of the shopping center was an important factor in the changes in commercial land use patterns and attracted other commercial land uses to the area. It has been shown the great importance of the closeness to the main road and the bypass road in commercial development.

In the case of industrial land uses, the two variables which determine in a greater extent the location of this kind of land use are the closeness to the main road and other industrial land uses. The development of new urban patches is produced mainly by this land use. The reason of this could be the municipal planning of 1978 which only establishes a zoning for the parish of Ribadeo; the industrial land in the zoning was occupied by commercial land uses and industrial ones had to look for parcels outside Ribadeo parish, which were not regulated by the municipal planning.

In general, Ribadeo land use dynamics are not too different from those of big cities, where the proximity to roads and neighbourhoods are the main factors that determine the urban structure. Although urban growth patterns may look disperse, they take advantage of the existing urban settlements, so the town growths by the expansion of existing urban patterns.

Variable	Coefficient	Pr(>|z|)
(Residual)	-3.22187	0.000246 ***
Dist. Main roads	-7.04442	0.000875 ***
Dist. Industrial	-10.63125	1.17e-05 ***
Dist. Residential	2.37653	0.049522 *
Neighbourhood	-0.04756	0.047923 *
Adjacent parcels	0.77130	0 .048326 *
Dist. Commercial	-1.50851	0.222350

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